AKENTEN APPIAH-MENKA UNIVERSITY OF SKILLS TRAINING AND ENTREPRENEURIAL DEVELOPMENT

MAMPONG- ASHANTI

EFFECT OF DIFFERENT RATES OF NPK FERTILIZER AND SUPERGRO ON GROWTH AND YIELD OF TWO VARIETIES OF GROUNDNUT (*Arachis hypogaea* L.)

SIMON KWASI AYER

MASTER OF PHILOSOPHY CROP SCIENCE

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BY

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A THESIS IN THE DEPARTMENT OF CROP AND SOIL SCIENCES EDUCATION, FACULTY OF AGRICULTURE EDUCATION, SUBMITTED TO THE SCHOOL OF GRADUATE STUDIES, IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF DEGREE OF MASTER OF PHILOSOPHY CROP SCIENCE (AGRONOMY)

JUNE 2025

DECLARATION

Candidate's Declaration

I hereby declare that, except for references to other people's work, which have been cited and duly acknowledged, this research is the result of my own original work and that no part or whole of it has been presented for another degree in this university or elsewhere.

Simon Kwasi Ayer

Signature……………………………… Date………………………….………

Supervisors' Declaration

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

Prof. (Mrs.) Margaret Esi Essilfie (Principal Supervisor)

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

Rev. Kwame Nkrumah Hope (Co-Supervisor)

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

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DEDICATION

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LIST OF ABBREVIATIONS

SG	SuperGro
PM	Poultry manure
Fr	Fertilizer rates
°C	Degrees Celsius
SGFF	SuperGro foliar fertilizer
DAT	Days after transplanting
NS	Not significant
kg/ha	Kilogram per hectare
t/ha	Tonnes per hectare
HSD	Honest Significant Difference
NPK	Nitrogen, Phosphorus, Potassium
G	Grams
CV	Coefficient of variation
Kg	Kilogram
ANOVA	Analysis of Variance

ABSTRACT

Two field experiments were carried out at the Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development (AAMUSTED)-Mampong campus research field during the 2023 major rainy season (May to August) and minor rainy season (September to December) to evaluate the effect of varying fertilizer and SuperGro application rates on groundnut productivity. The experimental design used for the study was a 2×5 factorial experiment arrangement in a Randomized Complete Block Design with ten treatments, each replicated four times. The factors were: (A) groundnut varieties ((i) Yenyawoso and (ii) Dehyee) and (B) fertilizer rates ((i) no fertilizer, (ii) 50 kg/ha NPK, (iii) 150 kg/ha NPK, (iv) 250 kg/ha NPK, and (v) 10 ml SuperGro per 10 L of water). The results showed that percentage crop establishment was significantly affected ($P \leq 0.05$) by variety, fertilizer rates, and their interaction across both seasons. Yenyawoso consistently recorded higher crop establishment percentages compared to Dehyee, with the highest values observed at 150 kg/ha NPK. Days to 50% flowering, pegging, podding, and maturity were generally earlier in Yenyawoso, particularly under 50–150 kg/ha NPK, than in Dehyee, mostly in the minor season. Growth parameters such as plant height, canopy spread, number of branches, stem girth, and biomass accumulation were influenced by variety, fertilizer rate, and their interactions across different growth stages. Dehyee had taller plants and wider canopies in the major season, while Yenyawoso showed superior growth in the minor season. Across both seasons, Dehyee grown on 50 kg/ha NPK produced the greatest number of pods per plant, pod weight per plot, and pod yield, while Yenyawoso treated with 150 kg/ha NPK achieved the highest seed yield compared to its control. Farmers are encouraged to grow Dehyee with 50 kg/ha NPK and Yenyawoso with 150 kg/ha NPK for higher yield and yield component.

CHAPTER ONE: INTRODUCTION

1.1 Background to the Study

Groundnut or peanut (*Arachis hypogaea* L.), is an exceptionally nourishing oilseed and legume that is cultivated in over a hundred countries across the globe's tropical and subtropical regions. Presently, more than 28.5 million hectares worldwide are devoted to the cultivation of this particular crop, which produced 45.95 million tonnes of pods in 2018 (FAOSTAT, 2018). It is a member of the *Fabaceae* family and the *Papilionaceae* subfamily (Tanko *et al*., 2022). It is additionally referred to as *goober, earthnut, and monkey nut*. Originating in South America and Brazil, groundnut subsequently was disseminated to other parts of the globe. It is also cultivated in Asia, Africa, Australia, and the Caribbean, and recognized as a valuable crop.

In Ghana, the residue that remains after oil extraction is molded into various forms before being fried and used as pastries. Haulms are a valuable source of livestock fodder, especially during the dry season, and the kernel is excellent source of protein for humans. As a result, it is a significant contributor to the fight against malnutrition and the promotion of food security in Ghana. Furthermore, groundnut holds significant importance as a component in countless delectable preparations and commercial products (Mondal *et al*., 2018). China is the global leader in production. Nigeria is the third largest producer globally and the leading producer of groundnuts in West Africa (FAO, 2022). Monyo and Varshney (2016) found that groundnut productivity varies from 3500 kg/ha in the United States to 2500 kg/ha in South America, 1600 kg/ha in Asia, and below 800 kg/ha in Africa (Seetha *et al*.,2018).

Drought and excessive temperature stress are the primary determinants of crop productivity limitation in Africa. Prior to flowering, and reproductive stages are, especially susceptible to these stresses and nutrient deficiencies, which result in substantial yield losses in groundnut production. Alongside groundnut, various cereal and root crops are intercropped, including yam, cassava, sorghum, pearl millet, and maize which additionally serves as a revenue stream for numerous smallholder farmers in sub-Saharan Africa. It also promotes soil fertility in marginal lands, sustainability of farming systems, and weed suppression through the provision of ground cover and nitrogen fixation.

In contrast to many other commodities, the grain yield of groundnut is relatively meager at approximately 225 kg/ha, despite its immense significance. Even though the Northern Savanna Zone of Ghana produces approximately 500,000 metric tonnes of groundnuts annually, average farm yields are low at 0.9 t/ha, which is significantly lower than the achievable 2.5 t/ha (Fixen, 2020). Genetic, climatic, and cultural practices all exert impact on groundnut yield (Awal & Lija, 2015). Besides, the two most crucial factors are soil enhancement and the plant's immune system. Research has shown that adhering to the prescribed fertilizer application rate results in enhanced crop yields (Chukwu *et al.*, 2022). Despite the symbiotic nitrogen fixation by groundnuts, plants reliant on such nitrogen may experience transient nitrogen deficiency during seedling development once the reserves in the cotyledon are depleted (Osuna *et al.*, 2015).

Phosphorus is essential for groundnuts due to its significant impact on the oil content of the seeds. Consequently, a phosphorus deficiency can lead to a reduction in the oil percentage of peanuts that are intended for human consumption and oil production. This reduction in oil percentage has adverse effects on the nutritional quality and economic value of the biological yield.

Chukwu *et al.*, (2022) in their study observed notable variations in growth, yield, and yield components between two groundnut cultivars grown in reclaimed loamy sand soil treated with various combinations of NPK fertilizer. A balanced and sufficient nutrient supply influences groundnut yield and nutritional content directly.

The growth of crops can be limited, flower and pod formation can be diminished, and ultimately, lower yields can result from inadequate nutrient availability (Fixen, 2020). Bio liquid fertilizer, SuperGro is formulated from poultry manure and guano (Alamene and Hawells., 2022). SuperGro liquid organic fertilizer contains *Ethoxylated Alkyl phenol Polysiloxane* and the product is effective, economical and versatile. SuperGro application to the soil help reduce water surface tension, increases soil penetration, and reduces water loss due to runoff and evaporation (SuperGro Liquid Fertilizer label). A significant challenge encountered by groundnut producers is the exorbitant production expenses resulting from the application of inorganic fertilizers (Noble & Smith, 2015). The availability of nutrients significantly impacts plant growth and development, with nitrogen, phosphorus, and potassium constituting the primary constraints in agricultural production (Murphy *et al*., 2017). The administration of fertilizers has the potential to increase nutrient levels in the soil, thereby facilitating favourable crop growth, yield and seed quality.

1.2 Problem Statement and Justification

Groundnut (*Arachis hypogaea* L), is a vital legume crop in Ghana, providing a significant source of protein, oil and income to smallholder farmers. The haulm is also utilized as livestock forage. However, its productivity is often constrained by inadequate soil fertility. Majority of agricultural lands in Ghana are impacted by population pressure and land use systems. Farmers are compelled to continue cultivating the same pieces of land for extended periods of time, resulting in soil resources depletion, which in turn reduces the yield of groundnut cultivation.

Utilization of NPK and SuperGro liquid fertilizers is widespread in contemporary agriculture as a means to meet nutrient requirements of the soil and increase crop yield, seed and nutritional quality. The impact of SuperGro, a liquid adjuvant, on groundnut productivity and NPK use efficiency is not well understood by most farmers. Thus, sufficient understanding regarding the proper utilization of NPK and Super Gro rates is required to enhance the development and productivity of groundnut in the forest-savannah transition zone of Ghana. Majority of studies have examined the impact of NPK on groundnuts; however, literature is scarce regarding the efficacy of groundnuts in response to various rates of NPK and SuperGro foliar fertilizer.

Understanding the effects of varying rates of fertilizer administration on groundnut growth is essential for optimizing its cultivation. Also, by incorporating SuperGro organic fertilizer into groundnut production, the effect of the product can be evaluated in conjunction with various NPK fertilizer rates. NPK fertilizer and SuperGro organic fertilizer applications are efficient management tools for maximizing crop yield by optimizing soil resource utilization such as light, nutrients, and water and minimizing soil surface evaporation through plant population (Naim *et al*., 2022). The response of groundnut to NPK has been investigated in many areas of the world but, such information need to be well-studied. Being a cover crop, they protect the soil from soil degradation, and suppressing of weeds (Akobundu *et al*, 2017). The application of NPK fertilizer at a rate of 250 kg ha^{-1} substantially increased the number of pods per hill, according to Chukwu *et al.*, (2022).

Elrys *et al*. (2023) observed that in arid soils, a mild application of nitrogen fertilizer consisting of 50 kg ha^{-1} of sulphate of ammonia, which is equivalent to approximately 10 kg ha^{-1} N, would provide a favourable initial environment for germination of seedlings prior to the establishment of a substantial root system required for nodulation.

In addition, most research has focused on the impact of NPK on groundnuts, whereas the literature regarding the effects of SuperGro on groundnut varieties is scarce. Therefore, the study aims to investigate groundnut varietal response and productivity to different rates of NPK fertilizer and SuperGro.

1.3 Objectives of the Study

1.3.1 Main Objective

The main objective of the study was to improve growth and yield of groundnut through proper soil amendment.

1.3.2 Specific Objectives

The specific objectives of the study were to;

1. Determine the effect of different NPK fertilizer rates and SuperGro on soil physical and chemical properties.
2. Assess the effect of NPK and SuperGro foliar fertilizer on phenology and growth of two groundnut varieties.
3. Assess the interactive effect of NPK fertilizer and SuperGro foliar fertilizers on yield and yield components of groundnut.
4. Determine the economic benefit analysis on the yield productivity of two groundnut varieties as affected by different rates of NPK and SuperGro.

CHAPTER TWO: LITERATURE REVIEW

2.1 Origin and Distribution

Archaeological evidence places the cultivation of groundnut (*Arachis hypogaea* L.) in coastal Peru between 1200 and 1500 BC, making it a primordial crop of the New World (Hammons *et al*., 2016). Presently, cultivation occurs in regions situated between 40 degrees south and 40 degrees north of the equator, characterized by mean daily temperatures exceeding 20 ^{o}C and average precipitation ranging from 500 to 1200 mm (Adazebra, 2019). On an estimated 22.2 million hectares, groundnuts are cultivated in 108 nations, with 13.69 million hectares in Asia, 7.39 million ha in Sub-Saharan Africa, and 0.7 million ha in Central and South America (Nigeria Export Promotion Council, 2022).

There was a marginal rise in average pod yields worldwide from 1.08 Mt ha^{-1} during the 1980s to 1.15 Mt ha^{-1} during the 1990s, with a total global production of 29 million tonnes of pods. The leading producers and growers of groundnuts worldwide are India, China, and the United States (Adazebra, 2019). The Virginia variety was likely introduced to Mexico and the Philippines by the Spanish in the sixteenth century; the Portuguese subsequently introduced it to Africa, India, and Brazil. Slaves transported Virginians to the Southeast United States via the slave trade. Additionally, Dew-Becker *et al.* (2017) observed considerable secondary diversity in Asia and Africa. The discovered varieties and their respective locations provided support for the diverse hypotheses pertaining to dispersal. Groundnuts are a crucial staple food that are cultivated in every tropical region (Otieno *et al*., 2019).

2.2 Botany

Groundnut is classified under the *Fabaceae* family *(Leguminoseae*) and *Papilionaceae* subfamilies, specifically under the *Arachis* genus and the *Hypogaea* species (Shinde *et* *al*., 2019). The genus *Arachis* derives its name from the Greek word ‘a-rachis’, which means ‘without spine,’ which refers to the lack of upright branches. The genus name ‘*hypogaea*’ originated from the Greek word ‘hupo-gè,’ which translates to ‘below earth.’ This name refers to the *gynophore*, which is a flower stalk or peg that descends into the ground, facilitating the development of the embryo underground (Yusuf *et al*., 2024).

It is remarkable that *Arachis hypogaea* in its natural form is unknown. The primary criteria for sub-specific and varietal classifications are flower placement on the plant, reproductive node patterns on branches, *trichome* count, and pod morphology (Reddy and Jabean, 2016). In addition, groundnut exhibits *allotetraploid* characteristics (Alix *et al*., 2017), which can be attributed to natural chromosome duplication subsequent to the hybridization of two feral species.

It is important to note that *Arachis hypogaea* comprises two significant subspecies, which primarily differ in their branching pattern (Zhang *et al*., 2017). The *hypogaea* species are characterized by alternate branching, whereas subspecies *fastigiatais* exhibit sequential branching. Moreover, two botanical varieties comprise the *hypogaea* sp: var. *hypogaea* (runner and Virginia varieties) and var. *hirsuta* (Peruvian humpback and Chinese dragon). Furthermore, *fastigiatais* subspecies are subdivided into *vulgaris* (the Spanish variety) and *fastigiata* (the Valencia type) botanical varieties (Mohammed *et al*., 2024).

Table 2. 1: Subspecies of Groundnut and their Characteristics

Subspecies	Site of flowering and pod production	Growth Habit	Botanical variety and market type	Seed Dormancy	Maturation Time
Fastigiata Valencia Fastigiata	Main stem	Erect	Fastigiata Valencia	Low or Absent Low or Absent	Short 90-120 days
Hypogea	Lateral Branches	Spreading	Hypogea Runner	Present	Long 145-165 days
		Bunching	Hypogea Virginia Hirsuta	Present	

Source: Gangurde., (2019)

Height variation is characteristic of groundnut stems, which are typically herbaceous and differ by cultivar and growing environment. The cylindrical stem is frequently adorned with nodes from which leaves and branches protrude. It provides support for all aboveground components, including developed pods, flowers, and foliage. Furthermore, the stem facilitates water movement and assimilate translocation occurring within the plant. Additionally, adventitious roots may form at nodes of the stem in order to enhance stability and potentially augment the absorption of soil resources (Varshney *et al*, 2019). Anthocyanin pigments of various hues; dark red, light red, or green are produced in the epidermal cells of groundnut stems (Xue *et al*., 2023). The stem is comprised of elongated shoots and glandular filaments that have bulbous bases.

The roots of groundnuts are dicotyledonous in nature. The root architecture is determined by the quantity and development of various variety of roots, including adventitious, primary, lateral, and seminal roots (Bianco & Kepinski, 2018). Furthermore, root phenes of groundnut influence the root architecture, morphology, anatomy or physiology and distribution, including the length, number, branching and elongation of lateral roots, and the development of root filaments (Burridge *et al*., 2020). Conversely, the taproot undergoes lateral root development to facilitate the absorption of water and nutrients. The development of these lateral roots commences shortly after the seed germinates. To begin with, juvenile seedlings already possess well-developed lateral root primordial that extend from the primary root, positioned 20 mm from the root tip. There are two to three xylem and phloem poles with root nodules on these lateral roots. This species develops nodules in response to particular nitrogen-fixing bacteria, *Rhizobia* in particular.

Undoubtedly, the mechanism by which biological nitrogen fixation supplies the essential nutrients required for protein synthesis and overall plant well-being to groundnut plants is indispensable (Clúa *et al*., 2018). Research findings suggest that the release of metabolites from groundnut roots served to enhance root colonization, inhibit fungal proliferation, stimulate plant development, and augment the secretion of defense-related proteins within the roots (Ankati *et al.,* 2019).

Groundnut plants demonstrate an indeterminate growth phase that is critical for the processes of self-pollination and pod formation. Groundnut flowers have a yellow hue and resemble peas; they consist of sepals, stamens, and pistils. Additionally, yield is highly reliant on the availability of fundamental reproductive units. Conversely, flowering commences 25 days subsequent to sowing depending of variety and exhibits a consistent and gradual increase in formation for approximately 40 days, following which sporadic flowering commences (Song *et al.,* 2020). As a consequence, considerable quantity of flowers that emerge early develop into pods; furthermore, flowers that manifest 70 days subsequent to blossoming fail to pod, leading to a reduction in overall yield (Vinothini *and* Umaruni.., 2018). In addition, it takes approximately eight weeks for groundnut pods to mature from the moment of blossoming; thus, only the initial three weeks of flowering can be deemed productive.

One of the primary constraints associated with low production in groundnut cultivation is the protracted flowering period and the variability in seed sizes.

Peanut plants bear both underground fruits and aerial flowers. *Gynophores,* are the developmental stage of fertilized ovaries of above-ground flowers that typically occur subsequent to successful pollination and flowering. The positively geotropic stalk-like structure known as the peg is composed of elongating cells, the basal tissue of which is situated at its apex. Pegging is an essential phase in the development of groundnuts, as it directly impacts the formation of pods and the potential yield. Pod anchorage and protection during pod maturity, elongation and penetration of stakes into the soil are critical. According to Quamruzzaman *et al*. (2018), the application of boron in combination with NPK resulted in a greater quantity of pods in groundnuts. Additionally, the authors noted that light significantly influenced both the vegetative and reproductive development of groundnuts.

Drought is regarded as the most severe constraint on peanut seed yield due to its detrimental effects on plant development, growth, and overall crop productivity. A substantial decline in crop production results from drought during the pegging stage (Vadez *et al*., 2023). Pods are elliptical in shape and comprise two or more seeds, with each half encased in a hull. Critical nutrients for germination and early seedling development are stored in the seeds' two cotyledons (Kumar *et al*, 2021).

2.3 Varieties

Varieties of groundnut have been introduced in Ghana by CSIR-SARI and CSIR-CRI which are high yielding commercial varieties and are cultivated throughout the country. (Danso-Abbeam *et al.*, 2017)

2.4 Nutritional Value and Uses

Modern societies cultivate groundnuts primarily for their kernels and consumable oils. In numerous African villages, groundnut-based dishes, including groundnut cake (Desire *et al*., 2021) and the vegetative residue, are extremely popular. In addition to protein and oil, groundnut kernels contain approximately 10–15 percent carbohydrates and are rich in vitamins B and E (Koushki *et al*., 2015). Groundnut seed comprises 44 to 56% oil and 22 to 30% protein. Moreover, it is an abundant source of vitamins (E, K, and B group) and minerals (P, Ca, Mg, and K) (Monika *et al.*, 2024). Peanut protein is gaining significance as a feed and food source, contributing to food security, particularly in developing nations where the majority of the population lack access to animal-derived proteins. As whole seeds are processed into peanut butter, oil, soups, stews, and other products, the seed has numerous applications. There are numerous uses of the cake in infant and nutrition formulations (Hauser, 2018).

Groundnuts find application in diverse forms. Among all vegetable oils, groundnut oil is the most cost-effective and is widely utilized as a culinary oil, margarine producer, and salad ingredient in numerous countries (Hashempour-Baltork *et al*., 2016). In addition, groundnut paste finds application in the preparation of delectable African dishes, including stews, curries, and sauces, where it imparts richness and flavour. Its most prevalent use is as a thickener in soups (Ting Meng *et al.,* 2019).

The shells are the dry pericarp of the mature pods and contain such chemicals as cellulose, carbohydrates, proteins, minerals, and lipids (Figueroa *et al.*, 2020). The shells have been utilized in a variety of applications such as a source of activated carbon (Jain *et al*, 2016). Groundnut shells are used as fuel when pelletized and made as smokeless briquettes (Balraj *et al.*, 2021). It is also used as a soil conditioner, filler in fertilizer and feed formulation, processed as a substitute for cork and hardboard, and composting with lignin composting bacteria (Malliga *et al*., 2020). The foliage of groundnut crops (haulm) also serves as silage and forage in livestock production, especially during the dry seasons (Kebede, 2020). Premalatha *et al*., (2022) categorized the shell ash with about 8.66% calcium oxide (CaO), 1.93% Iron oxide (Fe_2O_3), 6.12% magnesium oxide (MgO), 15.92% silicon oxide (SiO_2), and 6.73% Aluminum Oxide (Al_2O_3). This composition makes it suitable for application in concrete as a partial replacement for cement with a measure of success achieved in developed countries.

2.5 Production Estimate

According to Amoah *et al.,* (2016), the global groundnut production area spanned 23.91 million hectares in 2017. The estimated unshelled production was 37.95 million tonnes, and the average yield per hectare was 1.58 tonnes. Prominent global producers of groundnuts include Sudan, China, India, Nigeria, the United States, and Indonesia. Worldwide, the cultivation area for this particular commodity amounts to 26.4 million hectares, yielding a total of 37.1 million metric tonnes at an average productivity of 1400 kg ha^{-1}. From 2017 to 2018, the yearly worldwide export of groundnuts amounted to two million metric tonnes and was valued at 2,600 million US dollars. India is positioned first in terms of acreage, and second in terms of production and productivity. It has an annual all-season coverage of approximately 70 hectares, which yielded 85 metric tonnes of groundnuts in 2017-18, which was sufficient to cover the country's oil deficit. With a 20–25% share of global markets, India competes closely with Argentina, the United States, and China as one of the largest exporters in the world. India was responsible for 2.7% of global oilseed production and 19% of oilseed area (Parthiban., 2019).

On the contrary, smallholder producers in Africa typically produce inadequate yields of groundnuts (Bilali *et al.*, 2024). As an illustration, the global average groundnut yield in 2010 was recorded at 1580.7 kg ha^{-1}. In Africa, the production reached 902.1 kg ha^{-1}, whereas in the Americas, it was 3086.2 kg ha^{-1} (Amoah *et al.*, 2016). In contrast, according to Amoah *et al.*, (2016), the global groundnut harvested area was 23.4 million hectares in 2010, resulting in a cumulative output of 34.9 million metric tonnes. In comparison to 2000, the aggregate harvested area witnessed a growth of 3.7 million ha^{-1} in 2010, whereas production exhibited an increase of 11.7 million. In 2010, the global average productivity was approximately 1490 kg ha^{-1}. It is cultivated in over ninety countries across the globe. Nearly all agricultural communities in the forest savanna transition zone and Guinea savanna zone in Ghana cultivate groundnut. More than 70% of cultivators in the three northern regions of Ghana, according to Owusu-Adjei *et al*. (2017), cultivate groundnuts, which account for more than 85% of the national output. According to Desire *et al.,* (2021), groundnuts and legumes are high-value commodities that have the capacity to significantly boost the economies of the regions in which they are grown, consequently elevating the living conditions of the impoverished rural population, particularly women. Ojiewo *et al*., (2015) stated that groundnuts and their by-products aid in ensuring food security and satisfying the nutritional requirements of rural residents.

2.6 Climatic and Soil Requirements

2.6.1 Climatic Requirements

Groundnut yield variation can be ascribed to fluctuations in water availability, specifically the quantity and distribution of precipitation. Primarily, the efficacy of precipitation in facilitating crop production is contingent upon the timing of sowing. Moreover, during the critical period of pod set, the quantity and distribution of precipitation during the season, when water deficit is a significant constrain ton groundnut production, are crucial. Concurrently, flowering may persist until the plant dies, 30–55 days after sowing (Bitarafan & Andreasen, 2019). However, fruit production is stimulated by short day lengths and relatively high night temperatures, whereas leaf production is enhanced by short day lengths. According to the findings of Cocetta *et al*. (2017), fruit-set in groundnuts is adversely affected by high light intensity and temperature.

This is because the light disrupts the physiology of the reproductive organ. Although productivity is minimal below 16º C and above 32º C, the ideal temperature range is from 20º C to 30º C (Asseng *et al*., 2015). During the reproductive period, nighttime temperatures varied between 22.4°C and 25.3°C, while maximum temperatures spanned from 32.7 °C to 34.5°C. To ensure an optimal yield of 1450 kg per hectare under rain-fed conditions, groundnut requires an even distribution of 294 mm of precipitation from pod development to maturity (Prathima *et al*., 2022). The progression of plant development is influenced by the accumulation of particular amounts of heat; therefore, the utilization of growing degree days enables the prediction of developmental events in groundnut, irrespective of fluctuations in temperature throughout the growing season (Piao *et al*., 2019).

Conversely, the cultivation of the crop is feasible in areas that receive precipitation varying from 200 to 1000 mm (Qutbudin *et al*., 2019). According to Boote *et al*. (2018), groundnut production is affected by both day duration and light intensity; however, for optimal results, the crop prefers sunny days with ample daylight. In addition, the temperature regulates the flowering period of this day-neutral plant. Post-flowering assimilation and reproductive efficiency are both significantly influenced by photoperiod. Furthermore, extended daylight hours facilitate vegetative development while impeding reproductive progress. Nonetheless, reproductive development is inhibited during the post-flowering period when the photoperiod lengthens from 13 to 16 hours. Moreover, prolonged daylight and elevated temperatures have been found to reduce reproductive efficiency (Mani *et al*., 2021). Additionally, specific cultivars exhibit sensitivity to photoperiod due to the fact that photoperiod affects flowering (Durner, 2015). In groundnut production, Ajeigbe *et al*. (2015) concluded that low temperatures at sowing delay germination and increase seed and seedling diseases.

2.6.2 Soil Requirements

Soils which fall into the orders Alfisols, Entisols, Inceptisols, and Ultisols, have a granular texture (Kefas *et al*., 2022). However, Kotu *et al*. (2022) noted that the groundnut seedling's emergence from the majority of surface crusts was ensured by its relatively large stem diameter. However, it is crucial that the subsurface soil remains flexible and porous, as even minor reductions in porosity can have a profound impact on plant growth. According to the findings of Nanduri Dakheel (2015), despite the pegs' ability to exert significant force, penetration and pod development could be negatively impacted by a surface crust of 1.5 cm. However, according to Janila & Mula (2015), light-textured soils are also more resistant to waterlogging, a condition that can harm groundnut seedlings within a single day. Waterlogging inhibits the development of rhizobia in immature plants when nitrogen is in high demand, according to Allito *et al*. (2020). Although groundnuts can grow in both acidic and alkaline environments, optimal soil pH for cultivation is between 6 and 7. Additionally, it flourishes in sandy loam soils with good drainage, the pegs are more easily able to penetrate the soil during growth and harvesting. In addition, establishment and sowing are facilitated by light-textured soils (Phogat *et al*., 2020).

Diallo *et al*. (2019), on the other hand, discovered that certain groundnuts can be effectively cultivated in heavier soils, despite typically in raised beds. Harvesting is impeded in heavy clay soils due to the reduction in yields caused by peg fracture and the potential staining of pods by adhering clay (Abubakari *et al*., 2019). It is imperative to mention that the subsurface soil should possess loose and porous consistency, as even minute reductions in porosity can have a profound impact on the growth and development of groundnut. Moreover, soils that are loose and friable facilitate peg development and penetration, as well as pod hoisting. Groundnut, according to Dash and Chimmad (2019), is exceptionally tolerant of mild temperate and tropical conditions, and its growth is severely stunted when subjected to stresses associated with extremely low or high temperatures. In addition, 95% of seeds germinate in soil temperatures between 18 and 30 degrees Celsius and can tolerate both acidic and alkaline conditions; however, optimal productivity occurs at a pH between 6 and 7.

2.7 Crop Propagation

According to Patel *et al.* (2016), the application of fungicides like *Fernasan D, Apron Plus, or Apron Star* at a rate of 1 sachet per 5 kg of seeds can prevent pests such as squirrels, mice, rats, lizards, termites, and birds from destroying or removing the seeds from the soil after sowing. This will also guarantee a complete establishment of the crop after germination. Kotu *et al*., (2020) and Ansa (2016) suggested crop spacing of 30 cm × 15 cm and 30 cm × 30 cm, respectively, on flat or elevated beds. Rees *et al*., (2016) suggested a spacing of 60 cm x 10 cm for cluster varieties and 90 cm× 20 cm for spreading varieties. Bugilla (2023) also suggested 40 cm× 20 cm for intercropping in Ghana. The optimal period for groundnut cultivation in Ghana is determined by the prevailing season and agro-ecological zones.

Rainfall is the most variables that will determine the precise sowing date. It is not advisable to plant in September after the initial rainfall (Son *et al*., 2023). Planted seeds encounter soil temperatures below 18°C, which have the effect of inhibiting germination. Wetting the soil immediately following planting induces a cooling effect. Therefore, groundnuts ought to be sown in the earliest stages of the growing season, when the likelihood of severe cold has already diminished (Jones, 2016). Groundnuts that are planted lately in a season generally yield less and require more foliar disease management (Ajeigbe *et al*., 2015).

2.8 Agronomic practices

2.8.1 Weed control

Weeds are plants that are deemed undesirable in a specific context, usually due to their proliferation in areas where they are not intended to be and their ability to obstruct crop growth. Weeds are undesirable plants that proliferate on cultivated farms and engage in competition with crops for vital resources, including nutrients and sunlight. Additionally, they serve as reservoirs for pests and diseases and impede the process of crop harvesting (Harding & Raizada, 2015). Groundnut cultivation necessitated regular weed control measures in order to achieve greater seed production, owing to the plant's physiological attributes such as pegging and podding tendency, vulnerability to weed infestation, and initial sluggish growth rate.

Unmanaged weeds have a detrimental impact on groundnut yield, decreasing it by 54 to 71%, particularly in the early stages of crop development and growth. Weed surges, in contrast to other crops, causes challenge during cultivation, planting, pod development, harvesting and competition for vital soil resources with crops. Four to eight weeks after sowing was identified as the critical period of vegetation competition. Hence, it is imperative to conclude weeding prior to the pegging phase in groundnut cultivation (Vora *et al*., 2019). While the necessity of weeding is acknowledged by all small-scale farmers, for the most part, it does not occupy a prominent position among the contending priorities of these farmers. Hence, it becomes imperative to implement control measures only when the crop is nearly enveloped in vegetation (Tippe *et al*., 2017).

A hidden cause of loss among groundnut farmers is untimely weeding, which stems from the traditional cropping system in which all forms of hand-weeding are postponed until the groundnut is completely covered by weeds. According to Taylor (2015), early weed interference affects all commodities. In the case of groundnuts, weeds must be eliminated within the initial two to three weeks after planting in order to assist it in weed suppression.

2.8.2 Fertilizer Application

Similar to other plant species, groundnut cultivation necessitates a considerable quantity of fertilizer to support its growth, development, and yield enhancement. Asante *et al*. (2020) documented that groundnuts exhibit phosphorus responses due to its impact on the nitrogen fixation rate. In addition, Elrys *et al*. (2018) determine that single superphosphate at a rate of 50-100 kg ha^{-1} produces superior results compared to other types of phosphate fertilizers due to its high calcium and sulphur content, both of which are essential for groundnut production. The findings of Karthikeyan *et al*. (2023) demonstrated that the growth, yield, and nutrient uptake of groundnut were all substantially enhanced through the application of potassium fertilizer. Groundnuts exhibit enhanced nutrient uptake when potassium was applied at a rate of 100 kg K_2O ha^{-1}. Consequently, small-holder farmers could resolve nutrient deficiencies, promote optimal growth, increase yield potential, and improve the quality of their economic yield by applying fertilizer to groundnut crops.

2.8.3 Pests and Diseases Control

In the semiarid tropics, white grubs, termites, millipedes, wireworms, and earwigs are known to incisively bore openings in developing groundnut pods, according to Tarig *et al*., 2019). White grubs and termites also cause root injury. On the other hand, *Spodoptera litura* and *Aproaerema modicella,* which are groundnut leaf miner species native to Asia, are examples of aboveground parasites. The bud necrosis disease vector, *Schultzei* (Trybom), is a significant concern in Asia, the southern United States of America, and Australia. As alternatives to insecticides, which are frequently available but prohibitively expensive, natural control and the exploitation of host plant resistance are considered viable options for pest management. Groundnut rosette disease, leaf spot (early and late leaf spot), stem rot, seed rots, pre-emergence rots, mycotoxin infection, leaf rust, pod rot, southern blight, seedling diseases, and rust are among the groundnut diseases identified by Jayalakshmi *et al*., (2020).

Utilizing resistant cultivars, deep ploughing to remove plant debris from the soil surface, crop rotation to prevent disease accumulation in the soil, early planting, removal of volunteer plants and weeds that serve as alternate hosts, improved drainage to reduce disease spread in the soil, burning affected plants, and seed dressing with appropriate fungicides are all recommended methods of disease and pest control (Panth *et al*., 2020). Groundnut is susceptible to infestation by an extensive group of insect and parasite populations. As stated by Flint (2018), leaf-feeding caterpillars, thrips, leaf-eating ants, bean and flea beetles, aphids, and leaf miners are the primary insects that cause damage to groundnut.

2.8.4 SuperGro

A systemic liquid organic fertilizer, which contains active ingredient *Ethoxylated Alkyl phenol Polysiloxane*. SuperGro contains other ingredients such as Iron (Fe), Iodine (I), Marine salt (MS) and Zinc (Zn) and improve fertilizer uptake by plant and foliar application effectiveness. The formulation reduces water surface tension, increases soil penetrance and reduces water loss due to runoff and evaporation (SuperGro container label, NeoLife Distributors). The solution is formulated to be easily absorbed by plants, thereby promoting faster and more robust growth. Emede *et al*. (2018) observed that total fruit weight and yield of cucumber treated with Super Gro alone amounted 3.15 kg and 3.80 t/ha, was comparable to that of inorganic fertilizer (NPK) alone 3.30 kg and 3.90 t/ha respectively, therefore concluded that SuperGro alone is economical and could be a good substitute for NPK.

Okeke *et al*. (2019) also reported that applying 5 ml SuperGro resulted in higher yields and improved fruit quality of vegetables. A discernible change in plant vigour and reduced incidence of diseases, suggesting that SuperGro may also enhance plant resilience, promote beneficial microbial symbiotic and fungi activity in the soil, which aids in nutrient availability and uptake (Azawei *et al*, 2022). Application of SuperGro at 0.5, 1.0 and 1.5 L ha^{-1} increased plant height, leaf area index, foliage yield and seed yield. However, foliage yield was highest with application of 1 L ha^{-1} of SuperGro where 75,556 kg ha^{-1} was obtained in 2019 and 86,632 kg ha^{-1} in 2022 (Luka *et al*., 2023). SuperGro is applied to leaves of plants in ratio of 1ml: 1L of water, 5 ml: 5 L of water, and 100 ml: 100 L of water for 1 week or 2 weeks interval before flowering of crops (SuperGro Container label, NeoLife Distributors).

2.8.5 Harvesting

Crops are harvested in accordance with maturity signs such as leaf yellowing, senescencing of stem, leaf shedding, pod hardening, and soil surface cracking. The aforementioned are considered to be critical physiological maturity indicators in groundnut production. Hand pulling method is employed to harvest the bunch and semi-spreading varieties, whereas ploughing or bullock-drawn harrows are utilized to harvest the spreading variety (Ajeigbe *et al*., 2015). When physiological maturity signs are absent, caution must be exercised when selecting pods for maturity testing (Lavkor & Var, 2017).

When the leaves begin to yellow and fall, the hulls become dense and dark on the inside, and the seeds are easily detachable, groundnuts are practically ready for harvest (Singh *et al*., 2020). Furthermore, during the physiological phase of groundnut cultivation, harvest timing is of the utmost importance; an early harvest results in diminished yield and quality of the crop, whereas a delayed harvest allows for loose legumes to remain in the soil, which are susceptible to diseases that cause post-harvest losses. Generally, harvesting in Ghana involves either hand pulling method or excavating it with small machinery or animal-drawn equipment. In general, harvested crop is dehydrated in the field (Shamshir *et al*., 2022).With the pods elevated, crops dry more uniformly and expeditiously. Pods may be left on the field for two to three days, with consideration given to climatic conditions. Finally, pods are primarily detached by hand from the apex of the plant's pegs subsequent to the dehydrating process (Paulsen *et al*., 2015).

2.9 Effect of Inorganic Fertilizers on Growth and Yield of Groundnut.

A successful harvest would be contingent on the timing and quantity of fertilization. Soil fertility is a significant determinant of crop production in tropical regions;

inadequacies of nutrients including nitrogen, phosphorus, and potassium, for instance, impede soil productivity. Phosphorus is a critical nutrient in groundnut production due to its significant impact on the oil content of the seeds. However an overabundance or deficiency of phosphorus can lead to a reduction in the oil percentage of the crop's seeds. In addition, the administration of 20 kg N, 26 kg P, and 26 kg K of NPK fertilizer led to an expansion of the crop canopy, consequently promoting greater rates of growth (0rji *et al*., 2022). A study identified notable variations in the growth, yield, and yield components of two groundnut cultivars grown in recently reclaimed loamy soil using different combinations of NPK fertilizer. Specifically, the application was 100 kg ha^{-1} NPK and 150 kg ha^{-1} NPK resulted in the maximum weight of fresh pods per hill and the greatest number of seeds per hill, respectively (Deepa *et al*., 2022).

According to the findings of Orji *et al.*, (2022), groundnut is an acid-tolerant plant that flourishes in a light sandy loam with adequate drainage. A substantial variation in the overall fresh weight of biomass was observed when 150 kg ha^{-1} of NPK 15:15:15 fertilizer was applied, according to the authors. From 50 kg ha^{-1} to 150 kg ha^{-1}, the biological yield exhibited a discernible upward trend; however, beyond this threshold, the total fresh weight of biomass began to decline. Orji *et al*., (2022) found that the total fresh weight of biomass from groundnut was substantially impacted by the application of NPK fertilizer, with 150 kg ha^{-1} producing the greatest total fresh weight of biomass per hill. Similar results were observed when 250 kg ha^{-1} of NPK fertilizer was applied; this resulted in a substantial increase in the number of legumes per hill. However, the rate did not significantly affect the total fresh weight of pods/hill, number of seeds/hills, 100 seed weight/hill, and harvest index.

2.10 Effect of SuperGro on growth and yield of groundnuts

Research conducted at the greenhouse in Nigeria to assess the effectiveness of Super Gro in promoting the growth and yield of flute pumpkin shows that SuperGro had statistically significant impact on all assessed parameters, particularly at the 15 ml administration in week 8 compared to the control (Fidel, 2024). Plant height, number of branches, vine diameter, fruit size and quality of the crop found to be substantially impacted by SuperGro (Alamene & Howells, 2022). According to Ekeoma & Adessoji (2018), their investigation into the cucumber and the comparison of SuperGro (SG), NPK, and poultry manure (PM) revealed that the yield and total fruit weight of SuperGro (3.15 kg and 3.80 t/ha) were similar to those of NPK (3.30 kg and 3.90 t/ha) when used in isolation. Total fruit weight and fruit yield for the control were recorded as 1.54 kg and 1.80 t/ha, respectively. Thus, given the expensive cost of inorganic fertilizers, PM + SG is a viable option in organic agriculture. Furthermore, SuperGro is inexpensive on its own and may serve as a suitable replacement for NPK fertilizer. SuperGro special formula is believed to have contain *Ethoxylated Alkyl phenol Polysiloxane*, reduces water surface tension, water loss due to runoff and evaporation and increase soil penetration. The product is said to allow plants to make use of water, by allowing penetration into the root system. The manufacturer suggested other uses as a wetting agent and soil penetrant and that suitable for use on all indoor and outdoor vegetation (SuperGro container label, NeoLife Distributors).

CHAPTER THREE: MATERIALS AND METHODS

3.1 Description of Experimental Locations / Sites

Two field trials were conducted at the AAMUSTED-Mampong campus research field from May to August, 2023 in the major rainy season and September to December, 2023 in the minor rainy season. The area is situated in the forest-savannah transition zone of Ghana (Geodatos, 2020). Ashanti-Mampong is situated at a latitude of 07^0 04 N and a longitude of $01^0$24 W of the equator and at an attitude of 457 m above sea level. The area has an average daily temperature of 25 ^{0}C to 37^0 C (Mamudu, 2022). Ashanti-Mampong has bimodal rainfall pattern characterized by a mean annual rainfall of about 1,270 mm. The major rainy season is between April and July, whereas the minor season spans from September to December, with a dry period occurs in August, but the main dry season begins in December and ends in March.

3.2 Soil Type and Vegetation at the Experimental Site

The soil at the experimental site is derived from the Voltaian Sandstone of Afram plains. It belongs to the Savannah Ochrosol class and is characterized by deep sandy loam; free from pebbles. It is well drained and contains moderate organic matter. The soil has a good water-holding capacity. It has been classified by FAO/UNESCO (2008) legend as Chromic Luvisol and locally as Bediesi series. The soil pH is between 6.5 and 7. In addition, the experimental site was utilized for the cultivation of numerous crops, including corn, soybean, groundnut, and cowpea. It promotes the growth of tuber, cereal, and legume crops. Grasses such as nut grass (*Cyperus rotundus*), giant star grass (*Cynodon plectostachus*), guinea grass (*Panicum maximum*) and elephant grass *(Pennisetum purpureumthe*), are most dominant grass species. Other weeds such as *Chlomolaena odorata* and *Aspillia africana* are also part of the vegetation.

3.3 Experimental Design and Treatments

The experimental design used was a 2×5 factorial experiment arranged in randomized complete block design (RCBD) , with each replicated four (4) times. There were two factors (A) groundnut varieties ((i) Yenyawoso and (ii) Dehyee) and (B) fertilizer rates ((i) no fertilizer,(II) 50 kg ha^{-1} NPK, (iii)150 kg ha^{-1} NPK, (iv)250 kg ha^{-1} NPK and (v) Super Gro 10ml per 10L water.

The total number of treatment combinations is presented in Table 3.1

Table 3. 1: Treatment Combinations

Treatment	Varieties	Fertilizer rates
T1	Yenyawoso	No fertilizer (control)
T2	Yenyawoso	50 kg ha $^{-1}$
T3	Yenyawoso	150 kg ha $^{-1}$
T4	Yenyawoso	250 kg ha $^{-1}$
T5	Yenyawoso	SuperGro 10 ml : 10 L water
T6	Dehyee	No fertilizer (control)
T7	Dehyee	50 kg ha $^{-1}$
T8	Dehyee	150 kg ha $^{-1}$
T9	Dehyee	250 kg ha $^{-1}$
T10	Dehyee	SuperGro 10 ml : 10 L water

A field size of 35 m × 22 m was demarcated (770 m^2) ploughed, harrowed, leveled, lined and pegged and ridges were created. Each experimental plot measured 4 m x 3 m. A 2.0 m was left between blocks and 0.5 m between plots. Each block contains 10 plots given a total of 40 plots for the experiment. Each plot contained 6 rows of ridges with 0.5 m in between ridges.

3.4 Planting Material

The planting materials used for the experiment were obtained from the Crops Research Institute of CSIR, located in Fumesua near Kumasi. The groundnuts varieties were Yenyawoso and Dehyee. Both were utilized due to their characteristics: Yenyawoso variety has semi-erect growth habit, matures early (90 days) and has pod yield potential of (2.7 t/ha). Dehyee variety also has semi-erect growth habit, matures early 85-90 days and has pod yield potential of 2.9 t/ha (Danso-Abbeam *et al.*, 2017).

3.5 Land Preparation and Planting

The experimental site was ploughed, harrowed, leveled, pegged and ridges prepared on May 14, 2023. The purpose for ridge preparation was to facilitate root and peg penetration and for easy harvest of pods. After preparing the ridges, the seeds were sown on May 16, 2023 for the major season. In the minor season, ridges were prepared on September 12, 2023 and seeds sown on September 14, 2023. The seeds were sown in rows at an approximate depth of 5 centimeters. Two seeds were sown per hill, and seedlings were thinned to one per hill at 50 cm by 20 cm spacing on each plot. There were six rows per plot with twenty (20) plants per row, making 120 plants per plot. Germination began approximately five (5) days after sowing, and supplying was done seven days after germination in plots that contained vacant holes.

3.6 Agronomic Practices

3.6.1 Weed control

Weeds were controlled three times by hand hoeing. Initial weed control was done two weeks following the emergence of the seedlings, and the areas between the groundnut plants hoed and hand-pulling method for the second and third weeding during the stages of pegging and podding. This was done to prevent weeds from interfering during harvesting and to compete with the crops for space, light, nutrients, and water. Subsequently, earthing up of ridges was done after weeding. This was done to prevent the pods been exposed to the detriment of rodents and other pest.

3.6.2 Pest and Disease Control

Periodically, pest and disease incidences were monitored by conducting frequent inspections at the experimental site for termites, white grubs, nematodes, and aphid larvae. An insecticide ATAKA SUPER 19.2g/l EC, *(Emmanectin Benzoate)* at a rate of 30 ml per 15L knapsack was applied at 35 days after planting (DAP). No severe disease was detected in the field during the experimental periods.

3.6.3 Inorganic NPK Fertilizer Application

The NPK fertilizer (20:10:10) was applied to each plot once. The different inorganic fertilizers application was done 21 DAP at the rate of 0.80 g (50 $kgha^{-1}$ NPK), 2.40 g (150 $kgha^{-1}$ NPK), and 4.0 g (250 $kgha^{-1}$ NPK) per plant according to treatment. This was done to meet moderate root establishment for nutrient utilization in the soil. The application rate was calculated based on the field size (770 m^2) as well as plot size. The fertilizer was directly applied to the crop using the side placement method and worked into the soil using the dibber.

3.6.4 Spraying of SuperGro

A 10 L of water per 10 ml of SuperGro *(Ethoxylated Alkyl phenol Polysiloxane)* solution was applied early in the morning on the leaves of the plants, at 21 DAP and was repeated at one-week interval for three times using knapsack sprayer. This was done to meet moderate canopy spread for translocation of the water plus SuperGro mixture in the plants vascular tissues.

3.7 Data Collected

3.7.1 Soil Chemical and Physical analysis

Soil chemical and physical analysis was done to determine total Nitrogen, Organic Carbon, Organic matter, Available P, particle size distribution (sand, clay, silt), exchangeable cations (Ca, K, Mg, Na) was carried out at Soil Science Laboratory at CSIR –Soil Research Institute (CSIR-SRI).

3.8 Phenology

3.8.1 Percentage crop establishment

The percentage crop establishment were determined by counting the number of crops that had established at twenty-one (21) days after sowing groundnut seed and estimated as a percentage of the number of the plants that had established within the four harvestable central rows.

3.8.2 Days to 50% flowering

Days to 50% flowering were determined as the number of days when 50% of the plant within the four harvestable central rows had flowered from the day of sowing of seeds.

3.8.3 Days to 50% pegging

Days to 50% pegging were determined when 50 % of plants within the four harvestable central rows had pegged from the day of sowing of seeds.

3.8.4 Days to 50% podding

Days to 50% podding were determined when 50 % of plants within the four harvestable central rows had form pods from the day of sowing of seeds.

3.8.5 Days to 100% maturity

Days to 100% maturity were determined when all plants within the four harvestable central rows had matured from the day of sowing of seeds.

3.9 Growth Data

3.9.1 Plant height

The plant height was measured on five (5) tagged plants from the four harvestable central rows from the base of the plant to the apical leaf using a meter rule at 21 days after planting (DAP) and at every two weeks intervals and the mean estimated.

3.9.2 Number of branches per plant

The total number of branches per plant was counted for each of the five (5) tagged plants randomly selected from the four harvestable middle rows per plot at 21 days after planting (DAP) and at every two weeks intervals and the mean estimated.

3.9.3 Canopy width

The canopy width of five (5) randomly selected plants from the four harvestable middle rows per plot was measured from the widest leaf canopy using meter rule at 21 days after planting (DAP) and at two weeks interval and the mean computed.

3.9.4 Stem girth

The stem girth of five (5) randomly selected plants from the four harvestable middle rows per plot was measured at 21 DAP in cm from the surface of the soil and at the widest part of the stem using a digital Vernier caliper and at two weeks interval and the mean computed.

3.9.5 Dry matter accumulation (g)

Three (3) plants were uprooted from the border and separated into root and shoot. The fresh root and shoot weight were determined using electronic weighing scale and then oven dry at 70 ^{o}C to constant weight. This was done at 21 days after planting (DAP) and at two (2) weeks interval and the mean estimated.

3.10 Physiological Growth Data

3.10.1 Crop growth rate

Crop growth rate is the gain in dry matter produced by the crop per unit of land area per unit of time; $CGR=1/P\times (W2-W1)/T_2-T_1$

Where, P = Ground area.

W1= Dry weight gain of plant/m^2 recorded at time t_1.

W2= Dry weight gain of plant/m^2 recorded at time t_2.

T= time

3.10.2 Relative growth rate

Relative growth rate is the measure of the rate of biomass increase compared to the initial biomass size of a crop.

$RGR= (InW2-InW1)/t_2-t_1.$

Where, In = Natural log.

W1= Dry weight of plant/m^2 recorded at $t_{1.}$

W2= Dry weight of plant/m^2recorded at t_2

T = Time

3.11 Yield and Yield Components

3.11.1 Number of plants harvested

The total number of plants harvested from the four harvestable central rows was counted and the mean computed.

3.11.2 Number of pods per plant

The total number of pods per plant from the five (5) randomly selected tagged plant from the four harvestable middle rows per plot was counted after harvest and the mean estimated.

3.11.3 Number of filled and unfilled pods per plant

The total number of filled and unfilled pods per plant was counted from the five (5) randomly selected tagged plants from the four harvestable middle rows after harvest and the mean estimated.

3.11.4 Pod Weight per Plot

Pod weight per plot was taken from four harvestable middle rows after harvest of pods including the five (5) randomly selected tagged plants, weighed using electronic weighing scale and the mean estimated.

3.11.5 Seed weight per plot

After shelling, all seeds from the four central rows of each treatment plot were weighed using and electronic weighing scale and the mean weight was recorded in grams (g).

3.11.6 100-Seed weight

Hundred seed weight (100-Seed weight) were randomly sampled from each treatment plot and weighed using an electronic weighing scale. The mean weight was recorded in grams.

3.11.7 Haulm weight at harvest

At harvest, the shoot of all plants from the four harvestable middle rows and the five (5) selected tagged plants was weighed and the mean computed.

3.11.8 Shelling percentage

This was achieved by taking a known weight of dried, unshelled groundnut pods. After weighing, the pods were shelled carefully to separate the seeds from the shells. Then, the weight of seeds was obtained after shelling. The shelling percentage was subsequently calculated by dividing the weight of the kernels by the original weight of the unshelled pods, and then multiplying the result by 100 to express it as a percentage. Mathematically,

$$Shelling\ percentage = \frac{Seed\ weight\ (kg)}{Pod\ weight\ (kg)}\ x\ 100\%$$

3.11.9 Harvest index

Harvest index was determined by dividing the grain yield by the total biomass yield.

$$Harvest\ index = \frac{Grain\ yield\ (kg)}{Total\ biomass\ yield\ (kg)}$$

3.11.10 Pod yield

Pod weight per plot was taken from the four harvestable rows after harvest of pods including the five (5) randomly selected tagged plants, weighed using electronic weighing scale and the mean estimated. The estimated mean was then used to estimate pod yield in kg/ha using the formular below;

$$Pod\ yield\ (kg/ha) = \frac{Pod\ yield\ per\ plot\ (kg)}{Harvestable\ area\ (m^2)}\ x\ 10,000\ m^2$$

3.11.11 Grain yield

Seed weight recorded form the harvestable rows of each treatment plot was used to determine grain yield (t/ha) using the formula below: -

$$Grain\ yield\ (t/ha) = \frac{Seed\ weight\ per\ plot\ (kg)}{Harvestable\ area\ (m^2)}\ x\ \frac{10,000\ m^2}{1000}$$

3.12 Statistical Analysis

The data collected were analyzed by Analysis of Variance (ANOVA) using Genstat Release 18.5 statistical package. Significant differences between treatment means were separated and compared using Tukey's HSD at a 5% level of probability. Correlation analysis was carried out between vegetative, yield and yield components of groundnut.

CHAPTER FOUR: RESULTS

4.1 Soil Analysis

4.1.1 Initial Soil Characteristics of the Study Area

Initial soil analysis conducted prior to ploughing of the land and treatment application showed that the study area predominantly exhibited a sandy loam texture in the major and minor seasons, providing favourable conditions for groundnut cultivation due to its good drainage properties (Table 4.1). The soil pH ranged from 5.56 during the major season to 6.69 in the minor season, falling within the slightly acidic range optimal for groundnut growth (preferred range: 5.5-6.5).

Available phosphorus (5.75-6.26 mg/kg) was below the optimal threshold for vigorous root development and nodulation in groundnut, which typically requires 10-20 mg/kg. Similarly, organic matter levels (1.79-1.91%) were marginally inadequate for sustaining biological nitrogen fixation processes, with groundnut generally benefiting from organic matter content above 2%.

Exchangeable calcium levels (1.25-1.34 cmol/kg) were suboptimal compared to the ideal 2-4 cmol/kg necessary for effective pod formation. Exchangeable potassium (0.365-0.381 cmol/kg) also fell slightly below the preferred range (0.4-0.6 cmol/kg) for groundnut production. However, magnesium levels (1.28-1.69 cmol/kg) were satisfactory, supporting physiological functions such as photosynthesis and enzyme activation.

Total nitrogen content ranged between 0.093% and 0.101%, which, although low, aligns with expectations for leguminous crops that derive a significant portion of their nitrogen through symbiotic fixation.

Overall, the soil fertility status was characterized as low to moderate, necessitating nutrient amendment interventions to optimize groundnut growth and yield performance.

Table 4. 1: Initial Soil Chemical and Physical Properties of the Study Area Prior to Treatment Application

Parameter	Major Season	Minor Season
pH (H_2O)(1:2.5 H_2O)	5.56	6.69
EC (µS/cm)	97.6	72.0
Available P (mg/kg)	5.75	6.26
Total Nitrogen (%)	0.093	0.101
Organic Carbon (%)	0.349	0.361
Organic Matter (%)	1.79	1.91
Exchangeable K (cmol/kg)	0.365	0.381
Exchangeable Ca (cmol/kg)	1.34	1.25
Exchangeable Mg (cmol/kg)	1.28	1.69
Exchangeable Na (cmol/kg)	0.252	0.260
Sand (%)	62.00	59.30
Silt (%)	24.00	27.08
Clay (%)	14.00	16.40
Textural Class	Sandy loam	Sandy loam

4.1.2 Treatments Effects on Final Soil Chemical Properties during 2023 major and minor cropping seasons

The application of varying fertilizer rates, particularly NPK (50, 150, and 250 kg/ha) had notable impacts on the chemical properties of the soil during both major and minor cropping seasons. These changes reflect how nutrient amendments influenced soil fertility dynamics in sandy loam soils under tropical rainfall conditions.

Soil pH remained relatively stable across all fertilizer treatments, showing no significant trend with increasing NPK rates. However, a slight acidifying effect was observed with higher NPK applications, where pH values in the major season declined marginally from 5.56 in the control to 5.40 under 250 kg/ha NPK, and similarly in the minor season from 6.69 to 6.50. SuperGro maintained the highest pH values (5.60-6.70), suggesting its minimal impact on soil acidity.

Electrical conductivity (EC) exhibited a consistent upward trend with increasing NPK levels. In the major season, EC increased from 94.7 µS/cm (control) to 124.6 µS/cm (250 kg/ha NPK), while in the minor season, it ranged from 71.8 to 99.3 µS/cm across the same treatments. This reflects elevated ionic concentrations due to the mineral dissolution of added fertilizers. Conversely, the EC under SuperGro remained low (89.6-69.8 µS/cm), supporting its limited contribution to salt buildup (Table 4.2).

Available phosphorus (P) improved significantly with rising NPK levels, indicating effective phosphate release and retention in the soil. Major season values rose from 4.5 mg/kg in the control to 9.0 mg/kg under 250 kg/ha NPK. A similar trend was noted in the minor season, ranging from 4.2 to 8.5 mg/kg. SuperGro contributed modestly to available P, with values of 5.0 and 5.1 mg/kg across the two seasons, respectively.

Unexpectedly, total nitrogen (% N) decreased with NPK application. Control plots recorded the highest values (0.15% major; 0.12% minor), whereas fertilized plots ranged between 0.10% and 0.12%. This decline may be attributed to increased leaching losses of nitrate under high rainfall, a known risk in sandy loam soils with poor nutrient retention.

Potassium (K) content rose consistently with fertilizer rate, from 0.28 cmol/kg in the control to 0.48 cmol/kg in the 250 kg/ha NPK treatment during the major season, and from 0.36 to 0.50 cmol/kg in the minor season. This highlights the strong contribution of NPK to exchangeable K levels. SuperGro treatments recorded intermediate K levels (0.37-0.38 cmol/kg) (Table 4.2).

Calcium (Ca) and magnesium (Mg) also responded to fertilizer treatments, although trends were more variable. Ca ranged from 1.25-1.40 cmol/kg in the major season and

1.15-1.30 cmol/kg in the minor season, with 50 kg/ha NPK producing the highest values. Mg showed incremental increases with NPK levels, peaking at 1.45 cmol/kg in 250 kg/ha NPK plots during the major season and 1.85 cmol/kg in the minor season. Sodium (Na) levels remained relatively unchanged across treatments, fluctuating minimally between 0.25-0.26 cmol/kg. This stability indicates that fertilizer treatments did not introduce salinity hazards from sodium accumulation (Table 4.2).

Organic carbon (OC) and organic matter (OM) levels were modestly enhanced by all fertilizer rates, particularly under SuperGro. Organic carbon ranged from 0.34–0.36%, while organic matter varied between 1.79-1.95%. These increases suggest improved organic residue decomposition and microbial activity, especially with organic foliar amendments like SuperGro (Table 4.2).

The increasing NPK fertilizer rates substantially improved EC, available P, and exchangeable K and Mg, but led to a reduction in total N, likely due to leaching. Super Gro had a stabilizing effect on pH and organic matter without significantly altering macro-nutrient levels. These findings emphasize the need for balanced nutrient management to avoid nutrient losses while enhancing soil fertility in rain-fed groundnut systems.

Table 4. 2: Initial and Final Soil chemical Properties and Fertilizer Rates during 2023 Major Cropping Season

Fertilizer rates	P^H (H_2O) (1:2.5 H_2O)	% TOTAL N	Avail. P mg/kg	Exch. Base (cmol/kg) Ca	Mg	Na	K	%Org. C	%Org, M	EC **µS/cm**
2023 major cropping season										
No fertilizer	5.56	0.15	4.50	1.34	1.28	0.25	0.28	0.35	1.79	94.70
50 kg ha^{-1} NPK	5.50	0.10	6.00	1.40	1.38	0.26	0.38	0.34	1.85	104.90
150 kg ha^{-1} NPK	5.45	0.11	7.50	1.30	1.40	0.25	0.43	0.36	1.82	114.80
250 kg ha^{-1} NPK	5.40	0.12	9.00	1.25	1.45	0.26	0.48	0.36	1.80	124.60
10 ml SuperGro	5.60	0.14	5.00	1.30	1.30	0.25	0.37	0.36	1.83	89.60
2023 minor cropping season										
No fertilizer	6.69	0.12	4.20	1.25	1.69	0.26	0.36	0.36	1.91	71.80
50 kg ha^{-1} NPK	6.60	0.10	5.50	1.30	1.75	0.26	0.40	0.34	1.95	79.60
150 kg ha^{-1} NPK	6.55	0.11	7.00	1.20	1.80	0.26	0.45	0.36	1.90	89.90
250 kg ha^{-1} NPK	6.50	0.12	8.50	1.15	1.85	0.26	0.50	0.35	1.88	99.30
10 ml SuperGro	6.70	0.11	5.10	1.20	1.70	0.26	0.38	0.36	1.92	69.80

*Abbreviations: EC = Electrical Conductivity; Avail. P = Available Phosphorus; Total N = Total Nitrogen; OC = Organic Carbon; OM = Organic Matter. NS = Not Significant. ** And * denote significance at $P \leq 0.01$ and $P \leq 0.05$, respectively*

4.2 Climatic conditions at the experimental sites

Appendix 2 provides detailed information on the climatic conditions at the experimental site during the 2023 major cropping season. From March 2023 to July 2023, the site recorded a total monthly rainfall of 784 mm, with the highest rainfall occurring in April (258.8 mm) and July (198.9 mm). The mean monthly relative humidity was 90.4% at 6:00 hours and 63% at 15:00 hours, with an overall range from 55% to 92%. During the same period, the mean monthly minimum and maximum temperatures varied from 22.76°C to 31.72°C.

During 2023 minor cropping season, a total monthly rainfall of 786.90 mm was recorded from August 2023 to December 2023 with the October and August recording the highest amount of rainfall of 286.4 mm and 213.40 mm respectively. The mean monthly relative humidity for 6:00 hours was 88% whereas 61.60% was recorded for 15:00 hours respectively. Generally, the relative humidity ranged from 44% to 93%. The mean monthly minimum and maximum temperature ranged from 22.4 °C to 34.5 °C within the period of August 2023 to December 2023 (Appendix 3).

4.3 Phenology of groundnut

4.3.1 Percentage crop establishment

From Table 4.3, the variety, fertilizer rates and the seasons significantly influenced percentage crop establishment in both seasons. Percentage crop establishment ranged from 59.50% - 84% and 53% - 73.75% in 2023 major and 2023 minor cropping seasons, respectively. Yenyawoso recorded the highest (80.35% and 67.80%) percentage crop establishment and was significantly ($P \leq 0.05$) different from Dehyee with the least (73.10% and 60.90%) across both cropping seasons (Table 4.3). Groundnut plants that received 150 kg/ha NPK produced the highest percentage crop establishment and differed insignificantly ($P \geq 0.05$) from all the amended plot but was significantly ($P \leq 0.05$) different from groundnut grown on unamended plot across both cropping seasons (Table 4.3). Yenyawoso that received 50 kg/ha NPK produced significantly ($P \leq 0.05$) higher number of established plants than Dehyee grown on unamended plot which produced the least percentage of established crops in both cropping seasons. Significantly greater number of established plants was recorded in 2023 major cropping season than 2023 minor cropping season. The interaction between season and variety, fertilizer rates and variety, fertilizer rates and season as well as the interaction between season and fertilizer rates and variety did not significantly influence percentage crop establishment.

4.3.2 Days to 50% flowering

The variety, fertilizer rates and their interaction did not significantly influence number of days to 50% flowering in 2023 major cropping season (Table 4.3).

In 2023 minor cropping season, there were significant ($P \leq 0.05$) differences between variety, fertilizer rates and their interaction on number of days to 50% flowering. Yenyawoso recorded significantly lower (28.05 days) number of days to 50% flowering than Dehyee with 28.80 days. Groundnut plants that received 10 ml SuperGro and groundnut plants grown on unamended plot had the same number of days (28.00 days) to 50% flowering and differed significantly ($P \leq 0.05$) from groundnut plants that received 50 kg/ha NPK (29.00 days) that flowered a day later. Yenyawoso grown on 150 kg/ha NPK recorded the least number (27.75 days) to 50% flowering and significantly emerged 2 days earlier than Dehyee grown on 200 kg/ha NPK that recorded the highest (30.00 days) number of days to 50% flowering. Significantly lower number of days to 50% flowering was recorded in 2023 major cropping season than 2023 minor cropping season. The interaction between season and variety, fertilizer rates and variety, fertilizer rates and season as well as the interaction between season and fertilizer rates and variety did not significantly influence percentage crop establishment (Table 4.3).

Table 4. 3: Effect of variety and fertilizer rates on percentage crop establishment and days to 50% flowering during 2023 major and 2023 minor cropping seasons

Treatment	% crop establishment		Days to 50% flowering	
	Major season	Minor season	Major season	Minor season
Variety (V)				
Yenyawoso (Yenya.)	80.35a	67.80a	27.35	28.05b
Dehyee (Dehy.)	73.10b	60.90b	27.90	28.80a
HSD (P ≤ 0.05)	**5.60**	**4.96**	**NS**	**0.34**
Fertilizer Rates (FR)				
No fertilizer (Control)	61.25b	56.00b	27.65	28.00b
50 kg/ha NPK	76.13a	67.88a	28.50	29.00a
150 kg/ha NPK	79.25a	68.38a	26.50	28.75ab
250 kg/ha NPK	73.00a	64.00a	27.38	28.38ab
10 ml SuperGro	71.50a	65.50a	28.13	28.00b
HSD (P ≤ 0.05)	**8.45**	**7.85**	**NS**	**0.79**
Interaction (V X FR)				
Yenya. x No fertilizer (Control)	63.00cd	59.00cd	27.50	28.00bc
Yenya. x 50 kg/ha NPK	84.00a	73.75a	27.75	29.00ab
Yenya. x 150 kg/ha NPK	83.25a	72.25ab	26.75	27.50c
Yenya. x 250 kg/ha NPK	73.75abc	64.50abc	27.25	27.75bc
Yenya. x 10 ml SuperGro	77.75ab	69.50abc	27.50	28.00bc
Dehy. x No fertilizer (Control)	59.50d	53.00d	27.75	28.00bc
Dehy. x 50 kg/ha NPK	68.25bcd	62.00bcd	29.25	29.00ab
Dehy. x 150 kg/ha NPK	75.25abc	64.50abc	26.25	30.00a
Dehy. x 250 kg/ha NPK	72.25abc	63.50abcd	27.50	29.00ab
Dehy. x 10 ml SuperGro	65.25bcd	61.50bcd	28.75	28.00bc
HSD (P ≤ 0.05)	**12.52**	**11.10**	**NS**	**1.26**
CV (%)	**11.94**	**11.88**	**7.22**	**1.83**

		% crop establishment	Days to 50% flowering
Variety (V)	=	3.65**	0.65**
Fertilizer Rates (Fr.)	=	5.77**	NS
Season (S)	=	3.65**	0.65**
S x V	=	NS	NS
Fr. x V	=	NS	NS
Fr. x S	=	NS	NS
S x Fr. x V	=	NS	NS

Means bearing the same letters within a column are not significantly different at 5% level of significance.

4.3.3 Days to 50% pegging

The variety had no significant influence on number of days to 50% pegging in 2023 major cropping season. The fertilizer rates and the interaction between variety and fertilizer rates significantly influenced number of days to 50% pegging in 2023 major cropping season (Table 4.4). Groundnut plants that received 50 kg/ha NPK recorded the least number of days (34.63 days) to 50% pegging and differed significantly ($P \leq 0.05$) from groundnut plants that received 150 kg/ha NPK (36.25 days). Yenyawoso plants that received 50 kg/ha NPK recorded the least number of days (34.50 days) to 50% pegging and differed significantly from the Dehyee plants that received 150 kg/ha NPK (37.00 days) season (Table 4.4).

In 2023 minor cropping season, the variety had no significant influence on number of days to 50% pegging in 2023. The fertilizer rates and the interaction between variety and fertilizer rates significantly influenced number of days to 50% pegging in 2023 minor cropping season (Table 4.4). Groundnut plants that received 50 kg/ha NPK pegged almost four days (45.13 days) earlier than groundnut plants that received 200 kg/ha NPK (48.75 days). Dehyee plants that received 50 kg/ha NPK pegged almost five days (44.75 days) earlier than Dehyee plants that received 250 kg/ha NPK (49.50 days). Significantly lower number of days to 50% flowering was recorded in 2023 major cropping season than 2023 minor cropping season. The interaction between season and variety, fertilizer rates and variety, fertilizer rates and season as well as the interaction between season and fertilizer rates and variety did not significantly influence percentage crop establishment (Table 4.4).

4.3.4 Days to 50% podding

The variety had significant influence on number of days to 50% podding in the major season. Dehyee podded almost a day (42.25 days) earlier than Yenyawoso (42.65 days). In minor season, the variety had significant influence on number of days to 50% podding. Yenyawoso podded almost three days (79.85 days) earlier than Dehyee (76.10 days). The fertilizer rates did not significantly influence number of days to 50% podding in both seasons (Table 4.4). Significantly lower number of days to 50% podding was recorded in major season than minor season. The interaction between season and variety was significant. However, the interaction between fertilizer rates and variety, fertilizer rates and season as well as the interaction between season and fertilizer rates and variety did not significantly influenced days to maturity (Table 4.4).

Table 4. 4: Effect of variety and fertilizer rates on days to 50% pegging and podding during 2023 major and 2023 minor cropping seasons

Treatment	Days to 50% pegging		Days to 50 % podding	
	Major season	Minor season	Major season	Minor season
Variety (V)				
Yenyawoso (Yenya.)	35.10	46.45	42.65a	76.10b
Dehyee (Dehy.)	35.30	47.20	42.25b	79.85a
HSD (P ≤ 0.05)	**NS**	**NS**	**0.36**	**3.58**
Fertilizer Rates (FR)				
No fertilizer (Control)	35.00b	45.75b	42.38	78.00
50 kg/ha NPK	34.63b	45.13b	42.25	75.63
150 kg/ha NPK	36.25a	47.25ab	42.75	78.00
250 kg/ha NPK	35.13b	48.75a	42.38	78.50
10 ml SuperGro	35.00b	47.25ab	42.50	78.00
HSD (P ≤ 0.05)	**0.75**	**2.85**	**NS**	**NS**
Interaction (V X FR)				
Yenya. x No fertilizer (Control)	35.00b	46.00ab	42.75	78.50
Yenya. x 50 kg/ha NPK	34.50b	45.50ab	42.25	72.75
Yenya. x 150 kg/ha NPK	35.50b	45.50ab	42.75	76.25
Yenya. x 250 kg/ha NPK	35.50b	48.00ab	42.50	75.75
Yenya. x 10 ml SuperGro	35.00b	47.25ab	43.00	77.25
Dehy. x No fertilizer (Control)	35.00b	45.50ab	42.00	77.50
Dehy. x 50 kg/ha NPK	34.75b	44.75b	42.25	78.50
Dehy. x 150 kg/ha NPK	37.00a	49.00ab	42.75	79.75
Dehy. x 250 kg/ha NPK	34.75b	49.50a	42.25	81.25
Dehy. x 10 ml SuperGro	35.00b	47.25ab	42.00	82.25
HSD (P ≤ 0.05)	**1.25**	**4.74**	**NS**	**NS**
CV (%)	**1.46**	**4.16**	**1.30**	**7.09**

	Days to 50% pegging	Days to 50 % podding
Variety (V)	= NS	NS
Fertilizer Rates (Fr.)	= 1.01**	NS
Season (S)	= 0.64**	1.87**
S x V	= NS	2.64**
Fr. x V	= 1.43**	NS
Fr. x S	= 1.43**	NS
S x Fr. x V	= NS	NS

Means bearing the same letters within a column are not significantly different at 5% level of significance

4.3.5 Days to maturity

In 2023 minor cropping season, there were significant (P≤0.05) differences between variety and the interaction of variety and fertilizer rates on number of days to maturity. However, fertilizer rates had no significant effect on days to maturity. For the varieties, Yenyawoso recorded the least number of days (90.90 days) to maturity and differed significantly from Dehyee that recorded the highest days (93.12 days) to maturity. Yenyawoso matured two (2) days earlier than Dehyee (Table 4.5). Yenyawoso that received 150 kg/ha NPK and 250 kg/ha NPK had the least number of days (90.50 days) to maturity and differed significantly (P≤0.05) from Dehyee that received 150 kg/ha NPK (93.75 days) that flowered two (2) days later.

The variety, fertilizer rates and their interaction did not significantly influence number of days to maturity in minor cropping season. Significantly lower number of days to maturity was recorded in major season than minor season (Table 4.5). The interaction between season and variety was significant. However, the interaction between fertilizer rates and variety, fertilizer rates and season as well as the interaction between season and fertilizer rates and variety did not significantly influenced days to maturity (Table 4.5).

Table 4. 5: Effect of variety and fertilizer rates on days to maturity during 2023 major and 2023 minor cropping seasons

Treatment	Days to maturity	
	Major season	Minor season
Variety (V)		
Yenyawoso (Yenya.)	90.90b	96.80
Dehyee (Dehy.)	93.12a	97.50
HSD (P ≤ 0.05)	**0.76**	**NS**
Fertilizer Rates (FR)		
No fertilizer (Control)	92.13	96.63
50 kg/ha NPK	91.88	96.63
150 kg/ha NPK	92.38	97.00
250 kg/ha NPK	91.88	97.63
10 ml SuperGro	91.88	97.88
HSD (P ≤ 0.05)	**NS**	**NS**
CV (%)	**1.28**	**2.00**

Variety (V)	=	1.72
Fertilizer Rates (Fr.)	=	NS
Season (S)	=	1.72**
S x V	=	1.01**
Fr. x V	=	NS
Fr. x S	=	NS
S x Fr. x V	=	NS

Means bearing the same letters within a column are not significantly different at 5% level of significance.

4.4 Vegetative growth of Groundnut

4.4.1 Plant height

The results on plant height as influenced by variety and fertilizer rates during major and minor seasons are presented in (Figure 4.1). In the major season, the tallest plant was recorded in Dehyee and was significantly different from Yenyawoso from 21 to 77 DAP. Fertilizer rates had no significant effect on plant height from 21 to 77 DAP (Figure 4.1). Dehyee that received 10 ml SuperGro and 50kg/ha NPK produced significantly taller plants than Yenyawoso that received the same amendment from 21 to 77 DAP.

In the minor season, variety, fertilizer rates and their interaction had no significant effect on plant height at 21 DAP. Yenyawoso produced the tallest plant and differed significantly from Dehyee from 35 to 49 DAP. Varieties had no significant effect on plant height from 63 to 77 DAP. Fertilizer rates had no significant effect on plant height at 35 DAP (Figure 4.1). Yenyawoso that received 50 kg/ha NPK produced significantly taller plants than Dehyee grown on amended plot at 35 DAP. Groundnut plants that received 50 kg/ha NPK and Yenyawoso that received 50 kg/ha NPK produced significantly taller plants than groundnut plants grown on unamended plot and Dehyee grown on unamended plots respectively from 49 to 77 DAP (Figure 4.1).

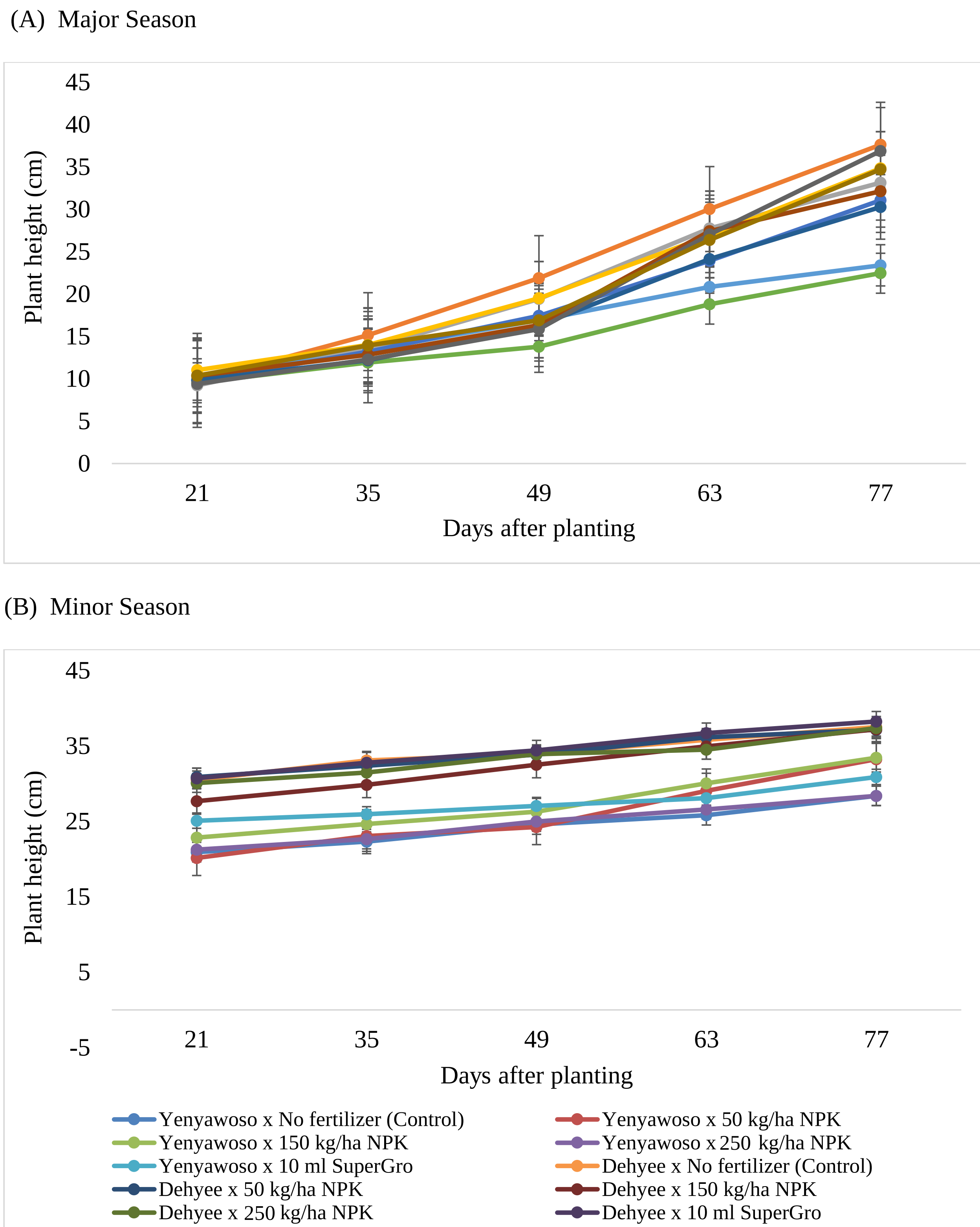


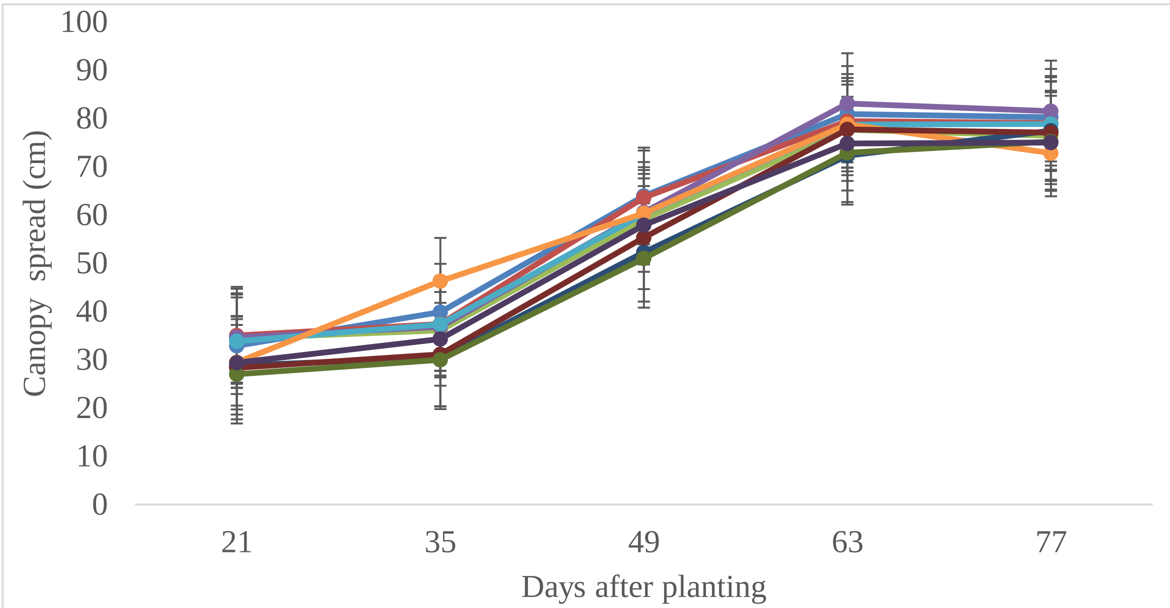
Figure 4. 1: Effect of variety and fertilizer rates on plant height

4.4.2 Canopy spread

The results on canopy spread during 2023 major and minor seasons are presented in (Figure 4.2). In the major season, Dehyee recorded significantly wider canopy spread than Yenyawoso across the entire growing period. Fertilizer rates had no significant effect on canopy spread from 21 to 77 DAP. Dehyee grown on unamended plot recorded the widest canopy spread and was significantly different from Yenyawoso grown on unamended plot at from 21 to 77 DAP except 35 DAP where no significant differences occurred between the interactive effects (Figure 4.2).

In the minor season, Yenyawoso produced the widest canopy spread and was significantly different from Dehyee from 21 to 77 DAP except at 35 DAP where there was no significant difference between variety. Generally, the fertilizer rates had no significant influence on canopy spread from 21 to 35 DAP and 63 to 77 DAP. However, at 49 DAP the unamended plot recorded the greatest canopy spread that differed significantly from groundnut that received 150 kg/ha NPK (Figure 4.2). The interaction between variety and fertilizer rates was significant from 21 to 77 DAP in canopy spread. At 21 DAP and 35 DAP Yenyawoso that received 50 kg/ha NPK and Dehyee grown on unamended plot produced significantly wider canopy spread than Dehyee that received 200 kg/ha NPK and Dehyee that received 150 kg/ha NPK respectively. However, at 49 DAP, the widest canopy spread was recorded by Yenyawoso that received 50 kg/ha NPK. From 63 to 77 DAP, Yenyawoso that received 200 kg/ha NPK recorded significantly wider canopy spread than the interaction between Dehyee x 50 kg/ha NPK and Dehyee x No fertilizer respectively.

(A) Major Season



(B) Minor Season

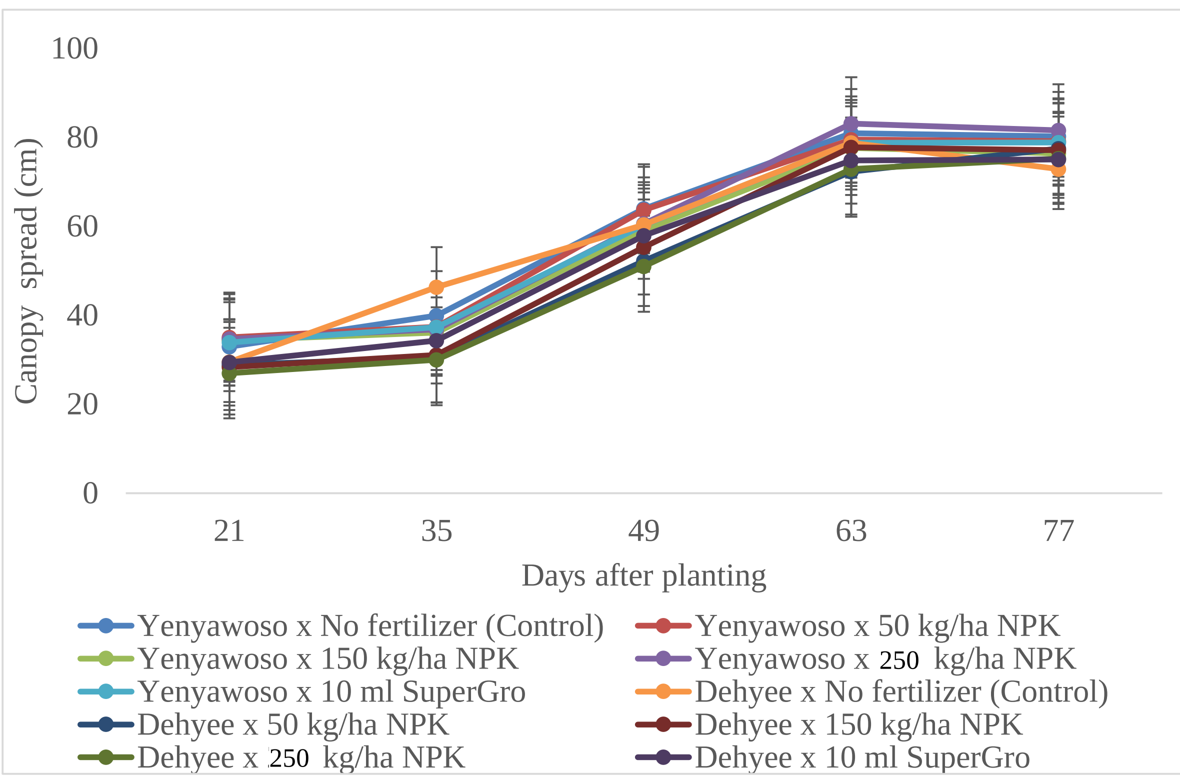


Figure 4. 2: Effect of variety and fertilizer rate on canopy spread

4.4.3 Number of branches per plant

The results on number of branches per plant as influenced by groundnut variety during 2023 major and 2023 minor cropping seasons is presented in (Figure 4.1a and b). Dehyee recorded significantly higher number of branches per plant than Yenyawoso from 21 to 77 DAP across both cropping seasons (Figure 4.1a and b). In the major season, groundnut plants that received 10 ml SuperGro produced significantly higher number of branches per plant than groundnut plants grown on unamended plot at 21 and 77 DAP. However, there were no significant ($P \geq 0.05$) differences between fertilizer rates in number of branches per plant from 35 to 63 DAP (Figure 4.2c). At 21 DAP, Yenyawoso and Dehyee that received 10 ml Super Gro recorded the same mean (4.00) and differed significantly from Yenyawoso grown on unamended plot with the least mean of 2.75 (Figure 4.3d). At 35 DAP, Yenyawoso grown on 200 kg/ha NPK recorded significantly higher number of branches per plant than Yenyawoso grown on unamended plot. From 49 to 77 DAP, Dehyee plants grown on 150 kg/ha NPK recorded significantly higher number of branches per plant than both varieties grown on unamended plot (Figure 4.3d).

In the minor season, groundnut plants that received 150 kg/ha NPK produced significantly higher number of branches than plants grown on the unamended plots from 21 to 77 DAP except from 35 to 49 DAP where no fertilizer rates had no significant ($P \geq 0.05$) effect on number of branches per plant. The interaction between variety and fertilizer rates significantly influenced number of branches per plant (Figure 4.3c). Dehyee grown on 50 kg/ha NPK recorded significantly higher number of branches per plant than both varieties grown on unamended plot from 21 to 77 DAP (Figure 4.3d).

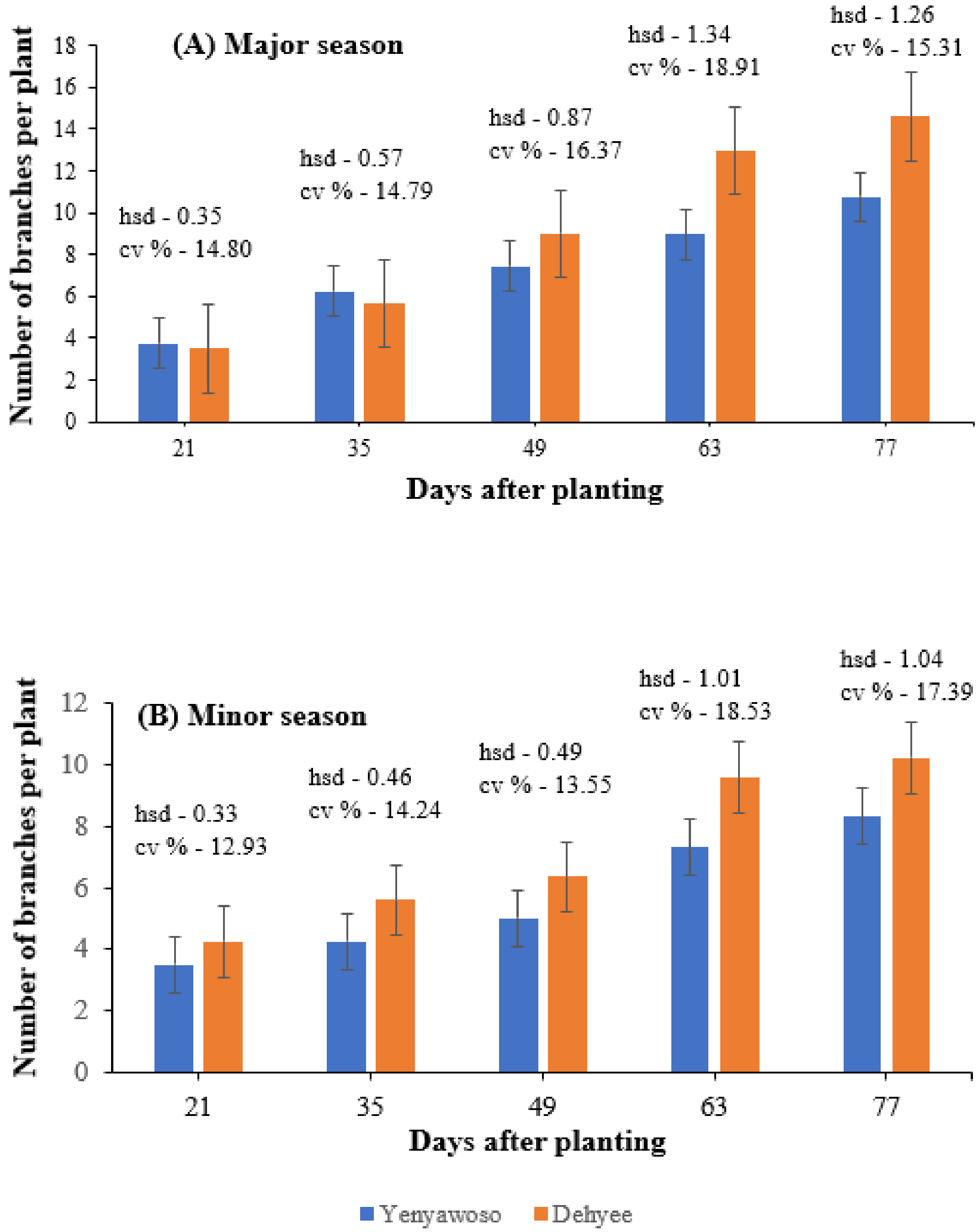
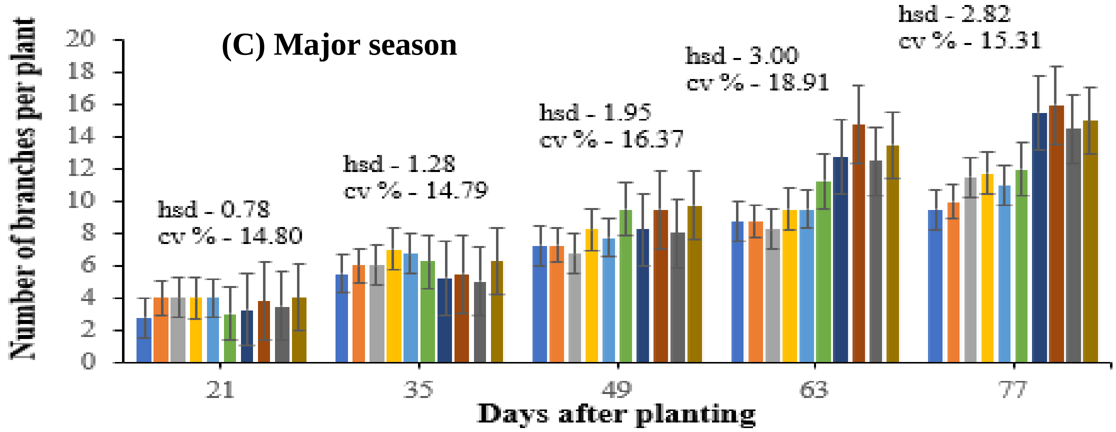


Figure 4. 3: Varietal effect on number of branches per plant during 2023 major and minor cropping seasons



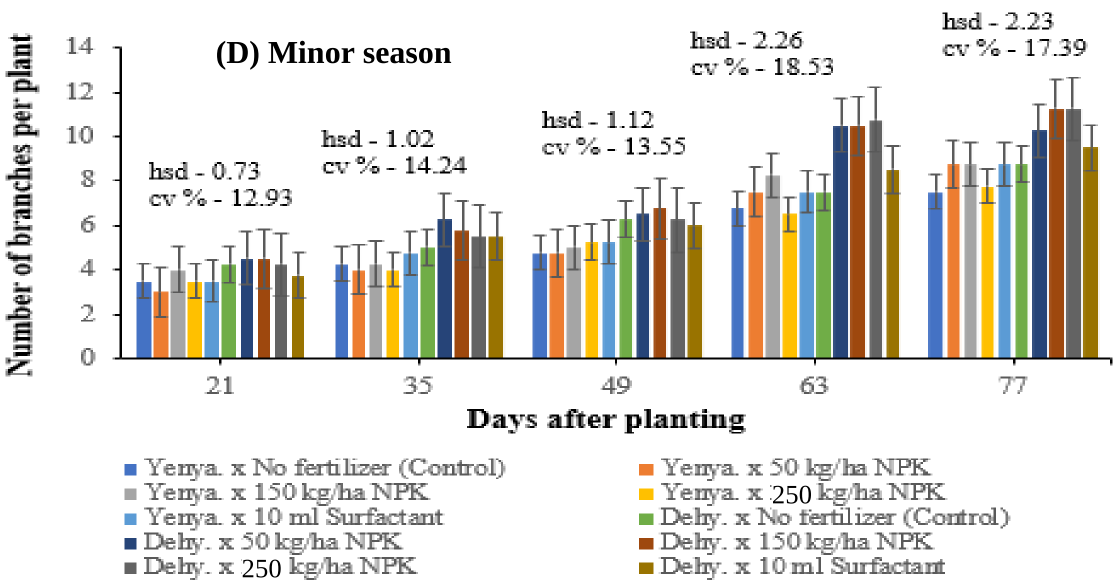


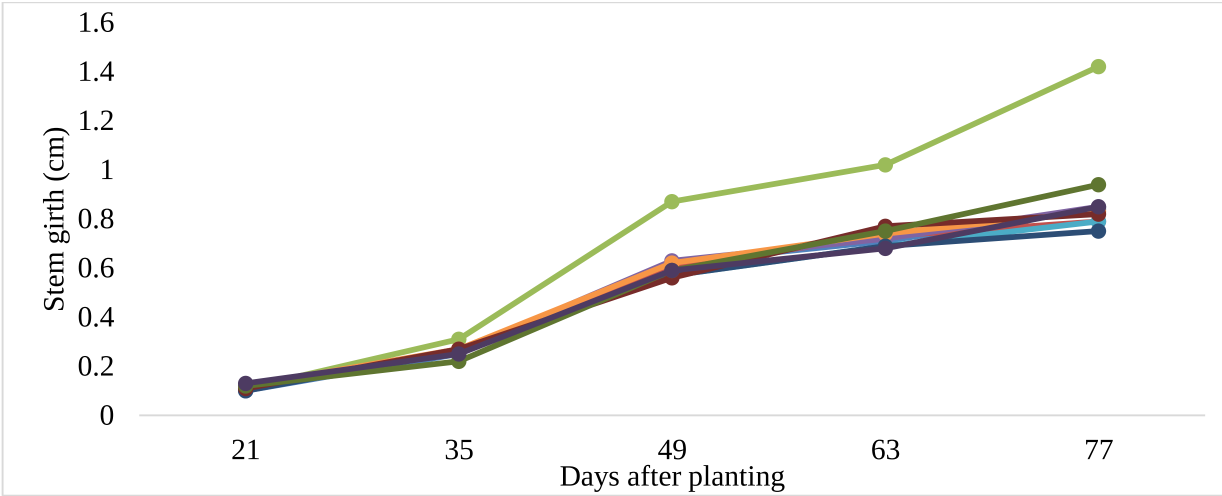
Figure 4. 4: Interactive effect on number of branches per plant during 2023 major and minor cropping seasons

4.4.4 Stem girth

Variety had no significant (P≥0.05) effect on stem girth of groundnut plants from 21 to 77 DAP during the major season (Figure 4.5). At 21 DAP, groundnut plants that received 10 ml SuperGro recorded significantly wider stem diameter than plants grown on unamended plot. However, from 35 to 77 DAP there were no significant (P≥0.05) differences between fertilizer rates in stem girth except at 63 DAP where groundnut plants that received 250 kg/ha NPK recorded significantly wider stem girth than plants that received 10 ml Super Gro. There interaction between variety and fertilizer rates was not significant on stem girth at 21 and 77 DAP. However, Yenyawoso grown on 150 kg/ha NPK recorded significantly wider stem girth than Dehyee grown on 250 kg/ha NPK from 35 to 63 DAP.

In the minor season, Dehyee recorded significantly wider stem girth than Yenyawoso from 21 to 49 DAP. Variety had no significant effect on stem girth from 63 to 77 DAP (Figure 4.3). Fertilizer rates had significant influence on stem girth from 21 to 63 DAP. Groundnut plants that received 150 kg/ha NPK and 50 kg/ha NPK recorded significantly wider stem girth at 21 and 35 DAP respectively than the unamended plot. Again, groundnut plants that received 50 kg/ha NPK and 150 kg/ha NPK recorded significantly wider stem girth at 49 and 63 DAP respectively than the unamended. Dehyee grown on 50 kg/ha NPK recorded significantly wider stem girth than Yenyawoso grown on unamended plot from 21 to 63 DAP (Figure 4.5).

(A) Major Season



(B) Minor Season

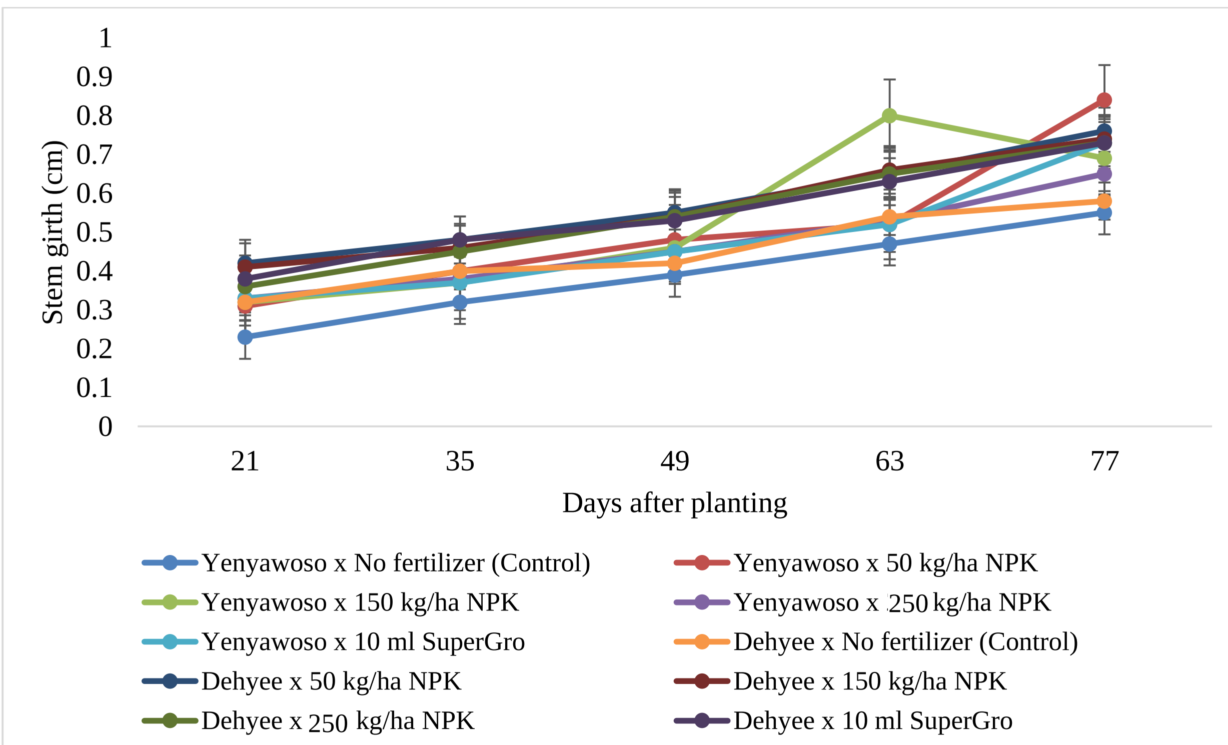


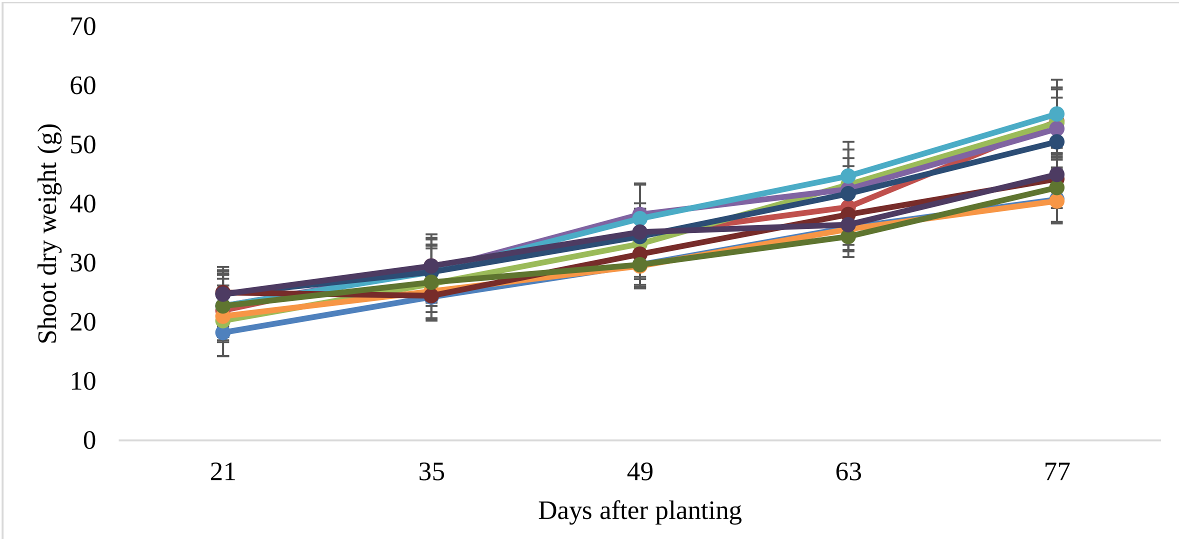
Figure 4. 5: Effect of variety and fertilizer rates on stem girth during 2023 major and minor seasons.

4.4.5 Shoot dry weight per plant

The results on shoot dry weight per plant as influenced by variety and fertilizer rates during 2023 major and minor seasons are presented in (Figure 4.6). Varieties had no significant influence on shoot dry weight per plant from 21 to 49 DAP during the major season. However, Yenyawoso recorded significantly higher shoot dry weight per plant than Dehyee from 63 to 77 DAP during the 2023 major season. There were no significant ($P \geq 0.05$) differences between fertilizer rates in shoot dry weight per plant from 21 to 35 DAP and at 63 DAP. However, groundnut plants that received 10 ml SuperGro recorded the highest shoot dry weight per plant at 49 and 77 DAP and differed significantly from groundnut plants grown on unamended plot. There were no significant ($P \geq 0.05$) differences between variety and fertilizer rates interaction in shoot dry weight per plant from 21 to 49 DAP. Yenyawoso grown on 10 ml SuperGro recorded the highest shoot dry weight per plant from 63 to 77 DAP and differed significantly from Yenyawoso and Dehyee grown on unamended plot (Figure 4.6a).

In the minor season, varieties had no significant influence on shoot dry weight per plant from 21 to 77 DAP (Figure 4.6b). For fertilizer rates, groundnut plants that received 50 kg/ha NPK recorded significantly heavier shoot dry weight per plant than groundnut grown on unamended plot from 21 to 35 DAP. There were no significant ($P \geq 0.05$) differences between fertilizer rates in shoot dry weight per plant from 49 to 77 DAP. Yenyawoso plants grown on 50 kg/ha NPK recorded significantly higher shoot dry weight per plant than Dehyee grown on unamended plot with the least mean value of 11.50 g at 21 DAP. There were no significance ($P \geq 0.05$) differences between variety and fertilizer rates interaction in shoot dry weight per plant from 35 to 77 DAP.

(A) Major Season



(B) Minor Season

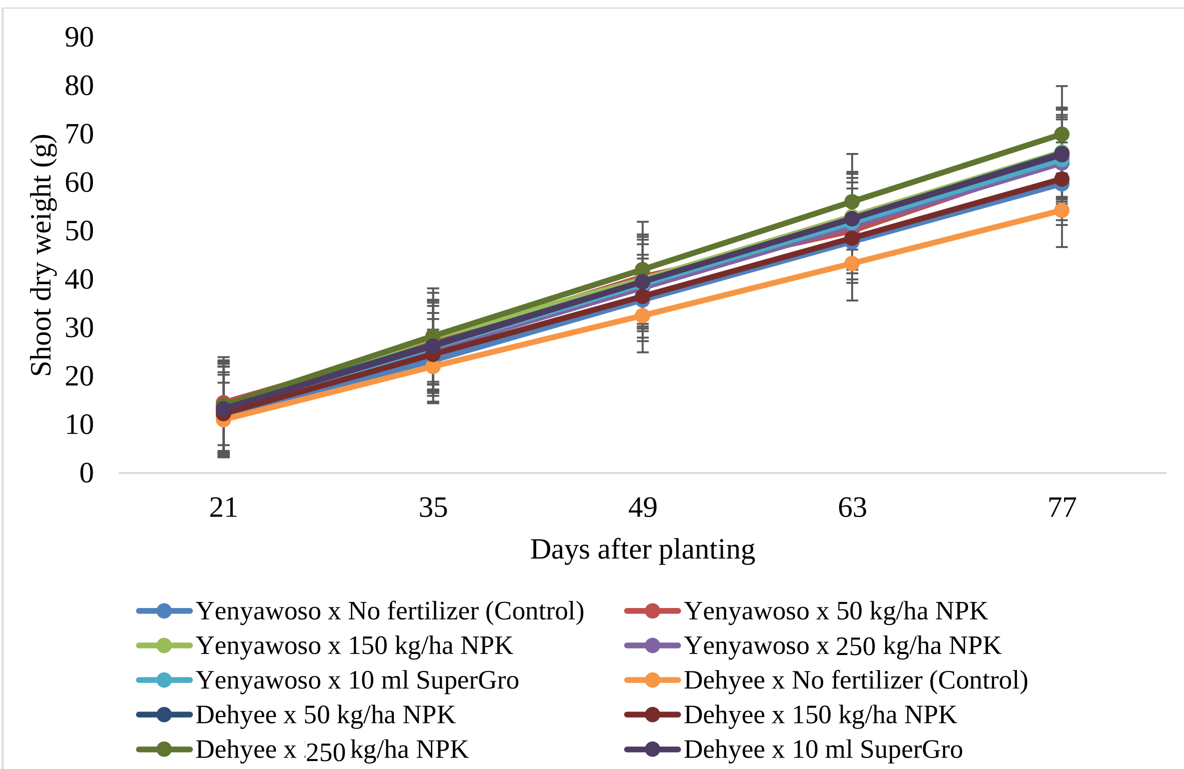
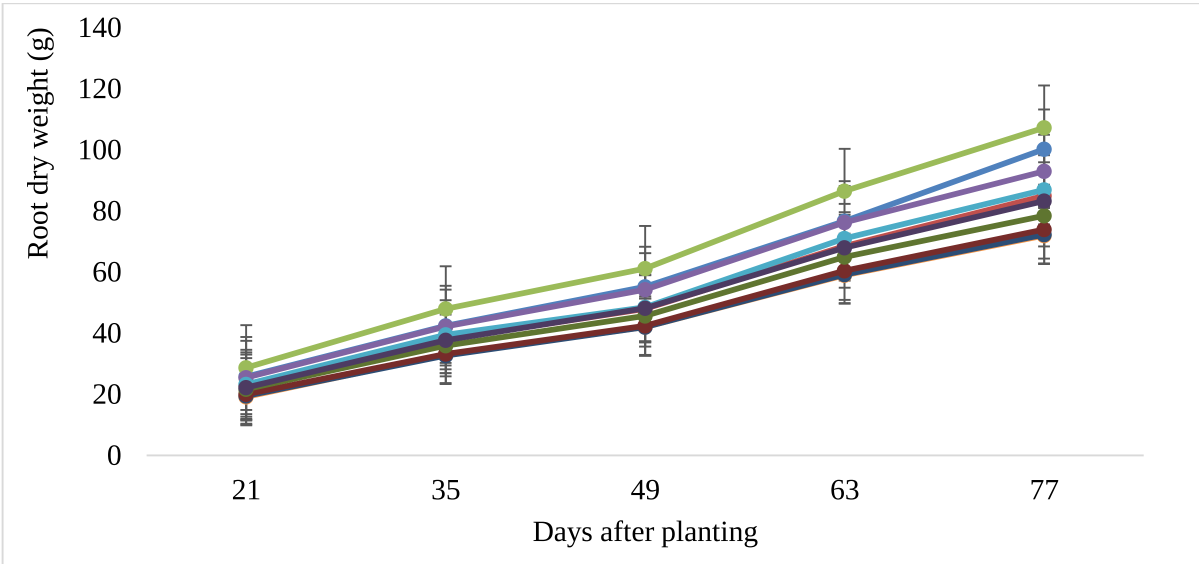


Figure 4. 6: Effect of variety and fertilizer rates on shoot dry weight during 2023 major and minor seasons.

4.4.6 Root dry weight per plant

The results on root dry weight per plant as influenced by variety and fertilizer rates during 2023 major and minor seasons are presented in (Figure 4.7). In the major season, Yenyawoso recorded significantly higher root dry weight per plant than Dehyee from 21 to 77 DAP. Fertilizer rates had no significant influence on root dry weight per plant throughout the entire growing period. The interaction between variety and fertilizer rates significantly influence root dry weight per plant from 21 to 77 DAP. Generally, Yenyawoso grown on 50 kg/ha NPK recorded significantly heavier root dry weight throughout the entire growing period (21 to 77 DAP) than Dehyee grown on unamended plot. Dehyee plants grown on unamended plot recorded the least root dry weight per plant from 21 to 77 DAP (Figure 4.7a). In the minor season, variety, fertilizer rates and the interaction between variety and fertilizer rates did not significantly influence root dry weight per plant from 21 to 77 DAP(Figure 4.7b).

(A) Major Season



(B) Minor Season

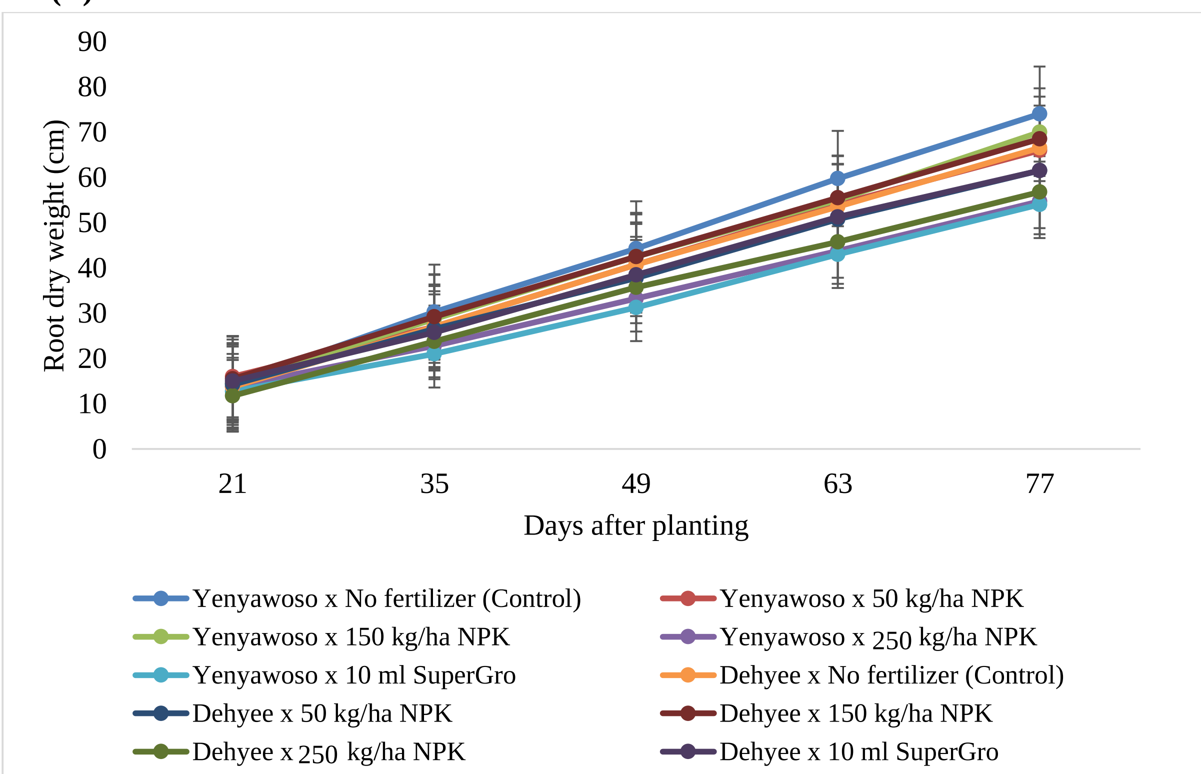


Figure 4. 7: Effect of variety and fertilizer rates on root dry weight during 2023 major and minor seasons.

4.5 Physiological growth parameters

4.5.1 Crop growth rate

The results on crop growth rate (CGR) during the two seasons are presented in (Tables 4.6 and Table 4.7). During the major season, Yenyawoso recorded significantly higher (17.21 g m^{-2} day^{-1}) CGR than Dehyee (14.07 g m^{-2} day^{-1}) at 0-21 DAP (Tables 4.16). There were no significant ($P \geq 0.05$) differences between variety in CGR from 21-35 DAP to 77 DAP to harvest. Groundnut plants that received 10 ml SuperGro recorded significantly higher CGR than groundnut plants grown on unamended plots from 0-21 DAP to 49-63 DAP. There were no significant ($P \geq 0.05$) differences between fertilizer rates in CGR from 63-77 DAP to 77 DAP to harvest. Yenyawoso plants that received 10 ml Super Gro produced the highest CGR than the same variety grown on unamended plot from 0-21 DAP to 63- 77 DAP. Variety and fertilizer rates interaction had no significant influence in CGR at 77 DAP to harvest (Table 4.6).

In 2023 minor season, variety and fertilizer rates and variety by fertilizer interaction did not significantly influence CGR from 0-21 DAP to 77 DAP to harvest (Tables 4.7).

Table 4. 6: Effect of variety and fertilizer rates on crop growth rate during 2023 major cropping season

Treatment	Crop growth rate (g m^{-2} day^{-1})					
	0-21 DAP	21-35 DAP	35-49 DAP	49-63 DAP	63 -77 DAP	77 DAP to harvest
Variety (V)						
Yenyawoso	17.21a	26.77	34.41	44.47	37.44	19.29
Dehyee	14.07b	24.13	35.01	44.57	38.15	20.59
HSD (P ≤ 0.05)	**2.84**	**NS**	**NS**	**NS**	**NS**	**NS**
Fertilizer Rates (FR)						
No fertilizer (Control)	14.07b	21.43b	28.82b	40.72b	33.36	19.75
50 kg/ha NPK	14.40b	26.06ab	34.09a	45.13ab	39.11	19.57
150 kg/ha NPK	16.28ab	26.26ab	36.31a	44.99ab	38.97	20.28
250 kg/ha NPK	15.99ab	25.03ab	35.52a	44.20ab	38.09	19.89
10 ml Super Gro	17.45a	28.45a	38.82a	47.55a	39.43	20.22
HSD (P ≤ 0.05)	**2.84**	**4.95**	**5.06**	**5.99**	**NS**	**NS**
Interaction (V X FR)						
Yenya. x No fertilizer (Control)	13.85c	23.06bc	30.34bc	39.50b	30.14b	18.10
Yenya. x 50 kg/ha NPK	16.33abc	26.23abc	33.54abc	47.64ab	40.68a	19.14
Yenya. x 150 kg/ha NPK	19.00a	26.86ab	35.85ab	44.72ab	39.30ab	16.66
Yenya. x 250 kg/ha NPK	18.07ab	26.74abc	34.44abc	43.56ab	35.68ab	20.49
Yenya. x 10 ml Super Gro	18.80a	30.96a	39.74a	48.17a	42.40a	19.09
Dehy. x No fertilizer (Control)	14.29bc	19.80c	27.31c	41.94ab	36.58ab	21.41
Dehy. x 50 kg/ha NPK	12.47c	25.89abc	34.64ab	42.62ab	35.83ab	20.01
Dehy. x 150 kg/ha NPK	15.91abc	25.67abc	36.76ab	45.27ab	39.65a	20.90
Dehy. x 250 kg/ha NPK	13.92c	23.33bc	36.60ab	44.84ab	40.49a	19.29
Dehy. x 10 ml Super Gro	13.75c	25.95abc	37.90a	46.93ab	38.18ab	21.35
HSD (P ≤ 0.05)	**4.01**	**6.99**	**7.16**	**8.47**	**8.63**	**NS**
CV (%)	**17.69**	**18.96**	**14.22**	**13.11**	**15.74**	**16.12**

Means bearing the same letters within a column are not significantly different at 5% level of significance; x = interaction; V = Varieties; FR = Fertilizer Rates; ml = Milliliters; HSD= Highest significant difference; CV = Coefficient of variation; Yenya. = Yenyawoso; Dehy. = Dehyee; DAP = Days after planting.

Table 4. 7: Effect of variety and fertilizer rates on crop growth rate during 2023 minor cropping season

Treatment	Crop growth rate (g m^{-2} day^{-1})					
	0-21 DAP	21-35 DAP	35-49 DAP	49-63 DAP	63 -77 DAP	77 DAP to harvest
Variety (V)						
Yenyawoso	13.14	22.08	27.89	33.04	22.18	15.47
Dehyee	12.71	21.74	28.97	34.07	20.86	14.33
HSD (P ≤ 0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Fertilizer Rates (FR)						
No fertilizer (Control)	12.28	18.26	24.67	29.96	19.59	14.29
50 kg/ha NPK	13.80	23.35	30.76	34.73	21.71	15.67
150 kg/ha NPK	13.33	23.80	29.76	35.91	22.21	15.44
250 kg/ha NPK	12.44	21.07	27.31	33.09	20.02	13.96
10 ml SuperGro	12.78	23.05	29.65	34.08	24.08	15.12
HSD (P ≤ 0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
CV (%)	**17.34**	**26.09**	**20.50**	**16.54**	**15.12**	**22.54**

Means bearing the same letters within a column are not significantly different at 5% level of significance; x = interaction; V = Varieties; FR = Fertilizer Rates; ml = Milliliters; HSD= Highest significant difference; CV = Coefficient of variation; Yenya. = Yenyawoso; Dehy. = Dehyee; DAP = Days after planting.

4.5.2 Relative growth rate

The results on relative growth rate (RGR) the two seasons are presented in (Tables 4.8 and 4.9). In the major season, there were no significant (P≥ 0.05) differences between varieties in RGR (Table 4.8). From 0-21 DAP to 21-35 DAP, groundnut plants that received 50 kg/ha NPK produced the highest RGR and differed significantly from the unamended plot with the least RGR during the same period. Again from 35-49 DAP to 49-63 DAP, groundnut plants that received 10 ml SuperGro recorded significantly higher RGR than the control whereas the highest RGR at 63-77 DAP was recorded by 50 kg/ha NPK with the control recording the least. Dehyee x 50 kg/ha NPK interaction recorded significantly higher RGR than both groundnut varieties grown on the unamended plots from 0-21 DAP to 21-35 DAP. Dehyee plants that received 10 ml SuperGro produced significantly higher RGR than both groundnut varieties grown on the unamended plots from 35-49 DAP to 49-63 DAP whereas at 63-77

DAP Yenyawoso groundnut variety grown on 10 ml SuperGro recorded the highest RGR (Table 4.8).

In the minor season, variety and fertilizer rates did not significantly influence RGR from 0-21 DAP to 77 DAP to harvest except from 63 -77 DAP where Yenyawoso produced significantly higher crop growth rate than Dehyee (Tables 4.9).

Table 4. 8: Effect of variety and fertilizer rates on relative growth rate during 2023 major cropping season

Treatment	Relative growth rate (g g $^{-1}$ day^{-1})					
	0-21 DAP	21-35 DAP	35-49 DAP	49-63 DAP	63 -77 DAP	77 DAP to harvest
Variety (V)						
Yenyawoso	0.72	0.58	0.48	0.38	0.29	0.18
Dehyee	0.76	0.60	0.49	0.40	0.28	0.16
HSD (P ≤ 0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Fertilizer Rates (FR)						
No fertilizer (Control)	0.59c	0.48c	0.35c	0.26c	0.18c	0.13
50 kg/ha NPK	0.81a	0.69a	0.55ab	0.43ab	0.36a	0.18
150 kg/ha NPK	0.7bab	0.54c	0.48b	0.38b	0.28b	0.15
250 kg/ha NPK	0.80ab	0.58bc	0.48b	0.42ab	0.29b	0.19
10 ml Super Gro	0.76ab	0.67ab	0.57a	0.46a	0.34ab	0.19
HSD (P ≤ 0.05)	**0.09**	**0.11**	**0.08**	**0.07**	**0..07**	**NS**
Interaction (V X FR)						
Yenya. x No fertilizer (Control)	0.62de	0.49cd	0.38cd	0.28c	0.17d	0.14
Yenya. x 50 kg/ha NPK	0.76abc	0.66ab	0.53ab	0.42b	0.35a	0.20
Yenya. x 150 kg/ha NPK	0.69cd	0.56abcd	0.50abc	0.38b	0.31ab	0.18
Yenya. x 250 kg/ha NPK	0.75abc	0.54bcd	0.48bc	0.42b	0.28abc	0.18
Yenya. x 10 ml Super Gro	0.75abc	0.64abc	0.53ab	0.40b	0.35a	0.19
Dehy. x No fertilizer (Control)	0.56e	0.46d	0.32d	0.25c	0.19cd	0.12
Dehy. x 50 kg/ha NPK	0.87a	0.72a	0.56ab	0.44ab	0.19cd	0.16
Dehy. x 150 kg/ha NPK	0.73bcd	0.51bcd	0.45bc	0.37b	0.25bcd	0.13
Dehy. x 250 kg/ha NPK	0.85ab	0.61abcd	0.49abc	0.43ab	0.30ab	0.21
Dehy. x 10 ml Super Gro	0.77abc	0.70a	0.61a	0.51a	0.32ab	0.19
HSD (P ≤ 0.05)	**0.13**	**0.16**	**0.12**	**0.09**	**0.10**	**NS**
CV (%)	**11.92**	**18.12**	**16.93**	**16.69**	**22.99**	**34.75**

Means bearing the same letters within a column are not significantly different at 5% level of significance; x = interaction; V = Varieties; FR = Fertilizer Rates; ml = Milliliters; HSD= Highest significant difference; CV = Coefficient of variation; Yenya. = Yenyawoso; Dehy. = Dehyee; DAP = Days after planting.

Table 4. 9: Effect of variety and fertilizer rates on relative growth rate during 2023 minor cropping season

Treatment	Relative growth rate (g g $^{-1}$ day^{-1})					
	0-21 DAP	21-35 DAP	35-49 DAP	49-63 DAP	63 -77 DAP	77 DAP to harvest
Variety (V)						
Yenyawoso	0.72	0.49	0.41	0.32	0.13a	0.09
Dehyee	0.67	0.49	0.42	0.28	0.11b	0.09
HSD (P ≤ 0.05)	**NS**	**NS**	**NS**	**NS**	**0.02**	**NS**
Fertilizer Rates (FR)						
No fertilizer (Control)	0.66	0.47	0.38	0.29	0.11	0.09
50 kg/ha NPK	0.74	0.50	0.42	0.32	0.12	0.09
150 kg/ha NPK	0.68	0.50	0.43	0.31	0.11	0.08
250 kg/ha NPK	0.69	0.49	0.42	0.31	0.13	0.09
10 ml SuperGro	0.70	0.50	0.42	0.27	0.13	0.09
HSD (P ≤ 0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
CV (%)	**9.71**	**17.36**	**15.84**	**27.39**	**27.54**	**24.66**

Means bearing the same letters within a column are not significantly different at 5% level of significance.

4.6 Yield and yield components

4.6.1 Number of plants harvested

From Table 4.10, variety, fertilizer rates and the interaction between variety and fertilizer rates significantly influenced number of plants harvested in both seasons. In the major season, Dehyee had the greatest number of plants harvested (49.55) that differed significantly (P≤0.05) from Yenyawoso (44.15). Groundnut plants that received 10 ml SuperGro produced the greatest (52.50) number of plants harvested that was not significantly (P≥0.05) different from groundnut plants that received 50 kg/ha NPK (51.50), but significantly (P≤0.05) different from the unamended plot (39.83). Yenyawoso plants that received 10 ml SuperGro produced the greatest number of plants harvested (53.50) that was significantly (P≤0.05) different from same variety grown on unamended plot (33.75).

In the minor season, Dehyee had the greatest number of plants harvested (33.75) that differed significantly (P≤0.05) from Yenyawoso (30.05). Groundnut plants that received 10 ml SuperGro produced the greatest (34.63) number of plants harvested and differed significantly (P≤0.05) groundnut plants grown on unamended plot (23.25). Dehyee plants that received 50 kg/ha NPK produced greatest number of plants harvested (44.50) that was significantly (P≤0.05) different from Yenyawoso grown on unamended plot (22.75). The interaction between season and fertilizer rates and variety did not significantly influenced number of plants harvested (Table 4.10). Season had significant effect on number of plants harvested.

Table 4. 10**:** Effect of variety and fertilizer rates on number of plants harvested during 2023 major and 2023 minor cropping seasons

Fertilizer	Number of plants harvested					
	Major season			Minor season		
	Yenyawoso	Dehyee	**Mean**	Yenyawoso	Dehyee	**Mean**
No fertilizer (Control)	33.75	45.00	**39.38**	22.75	24.25	**23.50**
50 kg/ha NPK	50.25	52.75	**51.50**	31.50	37.50	**34.50**
150 kg/ha NPK	45.00	48.75	**46.88**	30.25	38.75	**34.50**
250 kg/ha NPK	38.25	49.75	**44.00**	32.50	32.25	**32.38**
10 ml SuperGro	53.50	51.50	**52.50**	33.25	36.00	**34.63**
Mean	**44.15**	**49.55**		**30.05**	**33.75**	
CV (%)	13.70			16.40		
Variety (V)	HSD (0.05) = 4.16			HSD (0.05) = 3.39		
Fertilizer (F)	HSD (0.05) = 6.58			HSD (0.05) = 5.37		
V x F	HSD (0.05) = 9.31			HSD (0.05) = 7.59		
Season	HSD (0.05) = 2.79			HSD (0.05) = 2.79		

4.6.2 Number of pods per plant

Table 4.11 shows number of pods per plant as influenced by NPK and Super Gro foliar fertilizer during 2023 major and 2023 minor cropping seasons. During the major season, Dehyee recorded significantly greatest number of pods (41.35) per plant than Yenyawoso (34.55). Groundnut plants that received 50 kg/ha NPK produced the greatest number of pods (41.50) per plant and was significantly different from the groundnut plants grown on unamended plots (29.25). Dehyee plants that received 50 kg/ha NPK produced significantly greatest number (44.50) of pods per plant than Yenyawoso grown on unamended plot (26.00). In the minor season, Dehyee recorded significantly greatest number of pods (23.75) per plant than Yenyawoso (19.65). Groundnut plants that received 10 ml SuperGro produced the greatest number of pods (24.00) per plant and differed was significantly from the groundnut plants grown on unamended plots (16.75). Dehyee plants that received 10 ml SuperGro produced significantly higher number (26.50) of pods per plant than Yenyawoso grown on unamended plot (14.75) with the least mean number. Significantly lower number of pods per plant was recorded in the major season than in the minor season.

Table 4. 11: Effect of variety and fertilizer rates on number of pods per plant during 2023 major and 2023 minor cropping seasons

Fertilizer	Number of pods per plant					
	Major season			Minor season		
	Yenyawoso	Dehyee	Mean	Yenyawoso	Dehyee	Mean
No fertilizer (Control)	26.00	32.50	29.25	14.75	18.75	16.75
50 kg/ha NPK	38.50	44.50	41.50	21.50	24.00	22.75
150 kg/ha NPK	37.50	43.00	40.25	21.25	25.25	23.25
250 kg/ha NPK	37.50	41.75	39.63	19.25	24.25	21.75
10 ml SuperGro	33.25	41.75	39.13	21.50	26.50	24.00
Mean	34.55	41.35		19.65	23.75	
CV (%)	14.56			18.39		
Variety (V)	HSD (0.05) = 3.59			HSD (0.05) = 2.59		
Fertilizer (F)	HSD (0.05) = 5.67			HSD (0.05) = 4.09		
V x F	HSD (0.05) = 8.02			HSD (0.05) = 5.79		
Season (S)	HSD (0.05) = 2.28			HSD (0.05) = 2.28		

4.6.3 Pod weight per plot

There was significant difference between variety, fertilizer rates and their interaction in pod weight per plot in both cropping seasons. In major season, Dehyee produced significantly heavier pod weight per plot (6.33 kg) than Yenyawoso (4.37 kg). Groundnut plants that received 10 ml SuperGro produced the heavier pod weight per plot (7.03 kg) and was significantly ($P \leq 0.05$) different from groundnut plants grown on unamended plot (2.44 kg). Dehyee plants that received 50 kg/ha NPK produced significantly heavier pod weight per plot (8.17 kg) than Yenyawoso plants grown on unamended plot with the least pod weight per plot (1.61 kg) (Table 4.13).

In the minor season, Yenyawoso produced significantly heavier pod weight per plot (0.87 kg) than Dehyee (0.63 kg). Groundnut plants that received 150 kg/ha NPK produced the heaviest pod weight per plot (0.89 kg) and was significantly ($P \leq 0.05$) different from groundnut plants that received 10 ml SuperGro (0.62 kg). Yenyawoso plants that received 150 kg/ha NPK produced significantly heavier pod weight per plot (1.02 kg) than Dehyee plants that received that received 10 ml SuperGro (0.43 kg) with the least mean value (Table 4.22). Significantly heavier pod weight per plot was recorded in the major than in the minor season (Table 4.13).

Table 4. 12: Effect of variety and fertilizer rates on pod weight per plot during 2023 major and 2023 minor cropping seasons

Fertilizer	Pods weight per plot (kg)					
	2023 major season			2023 minor season		
	Yenyawoso	Dehyee	Mean	Yenyawoso	Dehyee	Mean
No fertilizer (Control)	1.61	3.26	2.44	0.94	0.80	0.87
50 kg/ha NPK	4.21	8.17	6.19	0.97	0.54	0.75
150 kg/ha NPK	4.88	6.81	5.84	1.02	0.75	0.89
250 kg/ha NPK	3.72	6.80	5..26	0.63	0.63	0.63
10 ml SuperGro	7.45	6.62	7.03	0.81	0.43	0.62
Mean	4.37	6.33		0.89	0.63	
CV (%)	24.27			30.45		
Variety (V)	HSD (0.05) = 1.19			HSD (0.05) = 0.16		
Fertilizer (F)	HSD (0.05) = 1.88			HSD (0.05) = 0.25		
V x F	HSD (0.05) = 2.66			HSD (0.05) =0.35		
Season (S)	HSD (0.05) = 0.59			HSD (0.05) =0.59		

4.6.4 Seed yield

The results on seed yield as influenced by NPK and SuperGro foliar fertilizer in the 2023 major and minor season are presented in Table 4.14. During the major season, variety had no significant influence on seed yield. Groundnut plants that received 10 ml SuperGro produced the heaviest seed yield (779.17 kg/ha) and was significantly ($P \leq 0.05$) different from groundnut plants grown on unamended plot (330.21 kg/ha) with the least mean value. Dehyee plants that received 50 kg/ha NPK produced significantly heavier seed yield (883.34 kg/ha) than Yenyawoso plants grown on unamended plot with the least seed weight per plot (310.41 kg/ha).

In the minor season, Yenyawoso produced significantly heavier seed yield (357.58 kg/ha) than Dehyee (242.22 kg/ha). Fertilizer rates had no significant influence on seed yield. Yenyawoso plants that received 50 kg/ha NPK produced significantly heavier pod weight per plot (491.67 kg/ha) than Dehyee plants that received 10 ml SuperGro with the least mean value (198.86 kg/ha) (Table 4.14). Significantly heavier seed yield was recorded in the major cropping season than the minor cropping season. The interaction between season and variety as well as fertilizer rates and season significantly influence seed yield.

Table 4. 13: Effect of variety and fertilizer rates on seed weight per plot during 2023 major and 2023 minor cropping seasons

Fertilizer	Seed yield (kg/ha)					
	Major season			Minor season		
	Yenyawoso	Dehyee	Mean	Yenyawoso	Dehyee	Mean
No fertilizer (Control)	310.42	350.01	330.22	344.11	228.90	286.51
50 kg/ha NPK	600.00	883.34	741.67	491.67	257.65	374.66
150 kg/ha NPK	656.25	689.60	672.93	378.69	250.73	314.71
250 kg/ha NPK	704.18	714.59	709.39	302.61	274.94	288.78
10 ml SuperGro	841.67	716.67	779.17	354.48	198.86	276.67
Mean	622.49	670.86		357.58	242.22	
CV (%)	25.31			25.61		
Variety (V)	HSD (0.05) = NS			HSD (0.05) = 90.56		
Fertilizer (F)	HSD (0.05) = 167.92			HSD (0.05) = NS		
V x F	HSD (0.05) = 237.47			HSD (0.05) = 134.25		
Season (S)	HSD (0.05) = 78.34			HSD (0.05) = 78.34		

4.6.5 100- Seed weight

The results on 100-seed weight as influence by NPK and SuperGro foliar fertilizer in both seasons are presented in Table 4.15. During the major cropping season, Yenyawoso produced significantly heavier 100-seed weight (42.99 g) than Dehyee (40.00 g). For fertilizer rates, groundnut plants that received 50 kg/ha NPK produced the heaviest 100-seed weight (44.06 g) and was significantly ($P \leq 0.05$) different from groundnut plants grown on unamended plot with the least mean value of 35.84 g. Yenyawoso plants that received 50 kg/ha NPK produced the heaviest 100-seed weight (44.69 g) and was significantly different from both Yenyawoso and Dehyee grown on unamended plot with the least 100-seed weight (39.23 g and 32.44 g). In the minor season, Dehyee produced significantly heavier 100-seed weight (40.20 g) than Yenyawoso (37.81 g). Fertilizer rates had no significant influence on 100-seed weight. Dehyee plants that received 150 kg/ha NPK produced the heaviest 100-seed weight (42.10 g) and was significantly (P≤0.05) different from Yenyawoso plants that received that received 150 kg/ha NPK with the least mean value (36.42 g) (Table 4.15). Significantly heavier 100-seed weight was recorded in the major cropping season than the minor season. The interaction between season and variety as well as fertilizer rates and season significantly influence 100-seed weight.

Table 4. 14: Effect of variety and fertilizer rates on 100-seed weight during 2023 major and 2023 minor cropping seasons

Fertilizer	100-seed weight (g)					
	Major season			Minor season		
	Yenyawoso	Dehyee	Mean	Yenyawoso	Dehyee	Mean
No fertilizer (Control)	39.23	32.44	35.84	36.99	38.87	37.93
50 kg/ha NPK	44.69	42.43	43.56	39.49	39.85	39.67
150 kg/ha NPK	43.99	44.12	44.06	36.42	42.10	39.26
250 kg/ha NPK	43.31	39.62	41.64	37.10	40.67	38.89
10 ml SuperGro	43.72	41.02	42.37	39.05	39.50	39.28
Mean	42.99	40.00		37.81	40.20	
CV (%)	8.56			7.15		
Variety (V)	HSD (0.05) = 2.31			HSD (0.05) = 1.81		
Fertilizer (F)	HSD (0.05) = 3.65			HSD (0.05) = NS		
V x F	HSD (0.05) = 5.15			HSD (0.05) = 4.05		
Season (S)	HSD (0.05) = 1.41			HSD (0.05) = 1.41		

4.6.6 Haulm weight per plot

Haulm weight per plot as influenced by NPK and SuperGro foliar fertilizer in both seasons are presented in Table 4.16. During the major season, Dehyee produced significantly heavier haulm weight per plot (5.41 kg) than Yenyawoso (3.83 kg). For fertilizer rates, Groundnut plants that received 10 ml SuperGro produced the heaviest haulm weight per plot (5.68 kg) and was significantly (P≤0.05) different from groundnut plants grown on unamended plot with the least mean value (2.93 kg). Dehyee plants that received 10 ml SuperGro produced the heaviest haulm weight per plot (7.14 kg) and was significantly different from Yenyawoso grown on unamended plot with the least haulm weight per plot (2.81 kg).

In the minor season, variety had no significant effect on haulm weight per plot.

Groundnut plants that received 50 kg/ha NPK produced the heaviest haulm weight per plot (2.43 kg) and was significantly ($P \leq 0.05$) different from groundnut plants grown on unamended plot (1.34 kg). Dehyee plants that received 200 kg/ha NPK produced the heaviest haulm weight per plot (2.72 kg) and was significantly ($P \leq 0.05$) different from same variety grown on unamended plot with the least mean value (1.26 kg). Significantly heavier haulm weight per plot was recorded in the major season than the minor season (Table 4.16).

Table 4. 15: Effect of variety and fertilizer rates on haulm weight per plot during 2023 major and 2023 minor cropping seasons

Fertilizer	Haulm weight per plot (kg)					
	Major season			Minor season		
	Yenyawoso	Dehyee	**Mean**	Yenyawoso	Dehyee	**Mean**
No fertilizer (Control)	2.81	3.06	**2.93**	1.42	1.26	**1.34**
50 kg/ha NPK	4.17	5.61	**4.89**	2.27	2.60	**2.43**
150 kg/ha NPK	4.13	5.18	**4.66**	2.09	2.44	**2.26**
250 kg/ha NPK	3.80	6.08	**4.94**	2.07	2.72	**2.40**
10 ml SuperGro	4.21	7.14	**5.68**	2.59	1.81	**2.20**
Mean	**3.83**	**5.41**		**2.09**	**2.17**	
CV (%)	20.09			25.46		
Variety (V)	HSD (0.05) = 0.90			HSD (0.05) = NS		
Fertilizer (F)	HSD (0.05) = 1.43			HSD (0.05) = 0.56		
V x F	HSD (0.05) = 2.02			HSD (0.05) = 0.79		
Season (S)	HSD (0.05) = 0.48			HSD (0.05) = 0.48		

4.6.7 Shelling percentage

From Table 4.17, variety had no significant effect on harvest index in the major season. For fertilizer rates, Groundnut plants that received 50 kg/ha NPK recorded the highest shelling percentage (76.04%) and was significantly (P≤0.05) different from groundnut plants grown on unamended plot (57.17%). Dehyee plants that received 50 kg/ha NPK recorded the highest shelling percentage (80.15%) and was significantly different from Dehyee grown on unamended plot with the least mean (54.52%).

In minor season, Yenyawoso recorded significantly higher (61.87%) shelling percentage than Dehyee (57.00%). Fertilizer rates had no significant effect on shelling percentage (Table 4.17). Yenyawoso plants that received 150 kg/ha NPK produced the highest shelling percentage (65.91%) and was significantly different from Dehyee that received 150 kg/ha NPK with the least mean (52.23%). Season and the interaction between season and variety were significant.

Table 4. 16: Effect of variety and fertilizer rates on shelling percentage during 2023 major and 2023 minor cropping seasons

Fertilizer	Shelling percentage (%)					
	Major season			Minor season		
	Yenyawoso	Dehyee	**Mean**	Yenyawoso	Dehyee	**Mean**
No fertilizer (Control)	59.81	54.52	**57.17**	55.78	56.36	**56.07**
50 kg/ha NPK	71.94	80.15	**76.04**	61.70	58.29	**59.95**
150 kg/ha NPK	68.19	67.69	**67.94**	65.91	52.23	**59.07**
250 kg/ha NPK	58.32	70.09	**64.20**	61.47	60.46	**60.97**
10 ml SuperGro	61.78	77.72	**69.75**	64.147	57.76	**61.11**
Mean	**64.01**	**70.03**		**61.87**	**57.00**	
CV (%)	15.35			12.07		
Variety (V)	HSD (0.05) = NS			HSD (0.05) = 4.65		
Fertilizer (F)	HSD (0.05) = 10.55			HSD (0.05) = NS		
V x F	HSD (0.05) = 14.92			HSD (0.05) = 10.41		
Season (S)	HSD (0.05) = 3.88			HSD (0.05) = 3.88		

4.6.8 Harvest index

Table 4.18 shows the results on harvest index as influenced by NPK and SuperGro foliar fertilizer in 2023 major and minor seasons. During the major season, variety had no significant effect on harvest index. For fertilizer rates, groundnut plants that received 10 ml SuperGro produced the highest harvest index (0.79) and was significantly ($P \leq 0.05$) different from groundnut plants grown on unamended plot with the least mean value (0.49). Yenyawoso plants that received 10 ml SuperGro produced the highest harvest index (0.87) and was significantly different from Dehyee grown on unamended plot with the least mean (0.42).

In the minor season, variety and fertilizer rates had no significant effect on harvest index (Table 4.18). Yenyawoso plants that received 10 ml SuperGro produced the highest harvest index (0.28) and was significantly different from Dehyee grown on unamended plot with the least mean (0.13). Dehyee plants that received 10 ml SuperGro and Dehyee plants grown on unamended plots had the same harvest index of 0.13. Significantly higher harvest index was recorded in 2023 major cropping season than 2023 minor cropping season.

Table 4. 17: Effect of variety and fertilizer rates on harvest index during 2023 major and 2023 minor cropping seasons

Fertilizer	Harvest index					
	Major season			Minor season		
	Yenyawoso	Dehyee	Mean	Yenyawoso	Dehyee	Mean
No fertilizer (Control)	0.56	0.42	0.49	0.14	0.13	0.14
50 kg/ha NPK	0.67	0.70	0.68	0.18	0.23	0.21
150 kg/ha NPK	0.56	0.48	0.52	0.21	0.20	0.20
250 kg/ha NPK	0.74	0.63	0.69	0.25	0.16	0.20
10 ml SuperGro	0.87	0.71	0.79	0.28	0.13	0.20
Mean	0.68	0.59		0.21	0.17	
CV (%)	22.84			28.44		
Variety (V)	HSD (0.05) = NS			HSD (0.05) = NS		
Fertilizer (F)	HSD (0.05) = 0.27			HSD (0.05) = NS		
V x F	HSD (0.05) = 0.39			HSD (0.05) = 0.13		
Season (S)	HSD (0.05) = 0.09			HSD (0.05) = 0.09		
V x F x S	HSD (0.05) = NS			HSD (0.05) = NS		

4.6.9 Pod yield

Pod yield as influenced by NPK and SuperGro foliar fertilizer in both seasons are presented in Table 4.19. During the major season, variety had no significant effect on pod yield. For fertilizer rates, Groundnut plants that received 50 kg/ha NPK produced the heaviest pod yield (2446.20 kg/ha) and was significantly (P≤0.05) different from groundnut plants grown on unamended plot with the least mean value (1651.50 kg/ha). Dehyee plants that received 50 kg/ha NPK produced the heaviest pod yield (24.72 kg/ha) and was significantly different from Yenyawoso grown on unamended plot with the least mean (1655.30 kg/ha).

In the minor season, Yenyawoso produced significantly higher pod yield (1176.70 kg/ha) than Dehyee (848.30 kg/ha). Groundnut plants that received 150 kg/ha NPK produced the highest pod yield (1229.20 kg/ha) and was significantly (P≤0.05) different from groundnut plants grown on unamended plot with the least mean value (674.9 kg/ha). Yenyawoso plants that received 150 kg/ha NPK produced the highest pod yield (14.13 kg/ha) and was significantly (P≤0.05) different from Dehyee variety grown on unamended plot with the least mean value

(579.10 kg) (Table 4.19). Significantly heavier pod yield was recorded in the major season than in the minor season.

Table 4. 18: Effect of variety and fertilizer rates on pod yield during 2023 major and 2023 minor cropping seasons

Fertilizer	Pod yield (kg/ha)					
	Major season			Minor season		
	Yenyawoso	Dehyee	Mean	Yenyawoso	Dehyee	Mean
No fertilizer (Control)	1655.30	1647.80	1651.50	770.80	579.10	674.90
50 kg/ha NPK	2420.10	2472.20	2446.20	1395.80	919.60	1157.70
150 kg/ha NPK	2395.90	2317.20	2356.50	1413.20	1045.10	1229.20
250 kg/ha NPK	2173.70	2263.80	2218.70	1145.80	878.50	1012.20
10 ml SuperGro	2402.80	2062.50	2232.60	1157.90	819.30	988.60
Mean	2209.50	2152.70		1176.70	848.30	
CV (%)	14.73			23.57		
Variety (V)	HSD (0.05) = NS			HSD (0.05) = 220.53		
Fertilizer (F)	HSD (0.05) = 329.67			HSD (0.05) = 348.69		
V x F	HSD (0.05) = 466.22			HSD (0.05) = 493.12		
Season (S)	HSD (0.05) = 0.09			HSD (0.05) = 0.09		

4.6.10 Grain yield

Grain yield as affected by NPK and SuperGro foliar fertilizer application during the 2023 major and minor cropping seasons are shown in Table 4.20. In the major season, there was no significant difference in grain yield between the two groundnut varieties. However, fertilizer application had a significant effect ($P \leq 0.05$), with the highest grain yield (2.14 t/ha) recorded under the 50 kg/ha NPK treatment and the lowest yield (1.34 t/ha) obtained from the control plots without fertilizer. Among the varieties, Dehyee fertilized with 50 kg/ha NPK produced the highest yield (2.16 t/ha), which was significantly greater than the yield from both varieties grown on unamended plots (1.32 t/ha) (Table 4.20).

During the minor season, the Yenyawoso variety produced a significantly higher grain yield (1.08 t/ha) compared to Dehyee (0.77 t/ha). Groundnut plants fertilized with 150 kg/ha NPK recorded the highest grain yield (1.13 t/ha), which was significantly ($P \leq 0.05$) greater than that of the unfertilized control (0.60 t/ha). Yenyawoso plants treated with 150 kg/ha NPK achieved the highest grain yield (1.30 t/ha), significantly outperforming Dehyee grown on the control plot, which recorded the lowest yield (0.50 t/ha). Overall, significantly higher grain yields were observed in the major season compared to the minor season (Table 4.20).

Table 4. 19: Effect of variety and fertilizer rates on grain yield during 2023 major and 2023 minor cropping seasons

Fertilizer	Grain yield (t/ha)					
	Major season			Minor season		
	Yenyawoso	Dehyee	Mean	Yenyawoso	Dehyee	Mean
No fertilizer (Control)	1.32	1.32	1.34	0.70	0.50	0.60
50 kg/ha NPK	2.11	2.16	2.14	1.30	0.84	1.07
150 kg/ha NPK	2.11	2.03	2.07	1.30	0.97	1.13
250 kg/ha NPK	1.86	1.98	1.92	1.04	0.80	0.92
10 ml SuperGro	2.12	1.78	1.95	1.08	0.74	0.91
Mean	1.90	1.86		1.08	0.77	
CV (%)	16.61			26.90		
Variety (V)	HSD (0.05) = NS			HSD (0.05) = 0.22		
Fertilizer (F)	HSD (0.05) = 0.32			HSD (0.05) = 0.35		
V x F	HSD (0.05) = 0.45			HSD (0.05) = 0.50		
Season (S)	HSD (0.05) = 0.15			HSD (0.05) = 0.15		

4.7 Correlation matrix analysis

Tables 4.21 and 4.22 show correlation matrix between vegetative and yield and yield components of groundnut during 2023 major and minor seasons respectively. During the major season, there was a strong and positive correlation between about 18% of the variables correlated (Table 4.33). The strong and positive correlation was observed between number of pods per plot and pod yield (0.67***), 100-seed weight and pod yield (0.57***), number of branches per plant and haulm weight per plot (0.56***), plant height and canopy spread (0.56***) and number of pods per plot and haulm weight per plot (0.50***). Plant height and number of branches per plant yield (0.42**) showed a moderate and positive correlation. There was no significant correlation between about 68% of the variables correlated.

During the minor season, there was a strong and positive correlation between about 15% of the variables correlated (Table 4.34). The strong and positive correlation was observed between number of pods per plot and pod yield (0.56***), number of pods per plot and haulm weight (0.49***), haulm weight per plot and pod yield (0.43**), 100-seed weight and haulm weight per plot (0.43***). Plant height and grain yield (0.44**) showed a moderate and positive correlation. There was no significant correlation between about 68% of the variables correlated whereas number of branches per plant 100-seed weight showed low and positive correlation.

Table 4. 20: Correlation matrix among vegetative and yield and yield components parameters of Groundnut during, 2023 major cropping season

	1	2	3	4	5	6	7	8
1. Plant height	1	0.56***	0.42**	0.37*	-0.39ns	0.21ns	-0.02ns	-0.01ns
2. Canopy spread		1	0.15ns	0.29ns	-0.22ns	0.05ns	-0.01ns	-0.02ns
3. Number of branches per plant			1	0.30*	-0.03ns	0.56***	0.06ns	0.08ns
4. Number of pods per plot				1	0.33*	0.50***	0.67***	0.67***
5. 100-seed weight					1	0.16ns	0.57***	0.56***
6. Haulm weight per plot						1	0.17ns	0.19ns
7. Pod yield							1	0.98***
8. Grain yield								1

Numbers against the parameters in columns correspond with variables in rows; NS – Not significant ***** = *Significant at P≤0.05* ****** *= Significant at P≤0.01*
******* *= Significant at P≤0.001*

Table 4. 21: Correlation Matrix among vegetative and yield and yield components parameters of Groundnut during, 2023 minor cropping season

	1	2	3	4	5	6	7	8
1. Plant height	1	-0.03ns	-0.08ns	0.23ns	0.09ns	0.29ns	0.44**	0.43**
2. Canopy spread		1	-0.55ns	0.17ns	-0.06ns	-0.10ns	0.06ns	0.05ns
3. Number of branches per plant			1	-0.14ns	0.34*	0.28ns	-0.28ns	-0.28n
4. Number of pods per plot				1	0.01ns	0.49***	0.56***	0.54**
5. 100-seed weight					1	0.43***	0.02ns	0.03ns
6. Haulm weight per plot						1	0.43***	0.42**
7. Pod yield							1	0.99**
8. Grain yield								1

Numbers against the parameters in columns correspond with variables in rows; NS – Not significant **(***P≥ 0.05***;**
***** *= Significant at P≤0.05***; **** *= Significant at P≤0.01***;**
******* *= Significant at P≤0.001*

4.8 Economic Analysis of Groundnut Varieties under Fertilizer Treatments

The economic performance of different fertilizer applications across the two groundnut varieties was evaluated using grain yield, net return, and benefit-cost ratio (BCR) metric during both seasons (Table 4.23). Grain yield and financial returns varied significantly across treatments, varieties, and seasons, with statistically significant differences observed in yield based on HSD at 5% probability level.

In the major season, the highest grain yield was recorded by Dehyee × 50 kg/ha NPK (2,010.0 kg/ha) and Yenyawoso × 50 kg/ha NPK (2,260.0 kg/ha), both significantly outperforming the control.

These treatments also yielded the highest net returns of GH₵11710.00/ha and GH₵13210.00/ha respectively. Notably, the application of 10 ml Super Gro to Yenyawoso resulted in a grain yield of 2110.0 kg/ha and the highest BCR (867.31) due to the minimal fertilizer cost of GH₵14.58/ha. This indicates that SuperGro was exceptionally cost-effective under favorable climatic conditions in the major season.

In the minor season, grain yields declined across all treatments, yet Yenyawoso consistently outperformed Dehyee. The combination of Yenyawoso × 150 kg/ha NPK produced the highest grain yield (1,790.0 kg/ha), while Yenyawoso × 10 ml SuperGro and Dehyee × 10 ml Super Gro achieved the highest BCRs of 344.68 and 398.18, respectively. Despite lower yields, these Super Gro treatments, maintained profitability due to their low input costs.

Across both seasons, applying 50-150 kg/ha NPK or 10 ml SuperGro to Yenyawoso proved economically superior to the control and all other combinations. These findings highlight the potential for input optimization in groundnut production, particularly under variable seasonal conditions.

Table 4. 22: Economic Analysis of Variety and Fertilizer Rate Interactions during the 2023 Major and Minor Cropping Seasons

	Major Season					Minor Season				
Treatment	**Grain yield (kg/ha)**	**Variable cost (GH₵/ha)**	**Gross revenue (GH₵/ha)**	**Net return (GH₵/ha)**	**BCR**	**Grain yield (GH₵/ha)**	**Variable cost (GH₵/ha)**	**Gross revenue (GH₵/ha)**	**Net return (GH₵/ha)**	**BCR**
No fertilizer	1,550.0	0.00	9,300.00	9,300.00	0.00	900.0	0.00	5400.00	5,400.00	0.00
50 kg/ha NPK	2,260.0	350.00	13,560.00	13210.00	37.74	1,280.0	350.00	7,680.00	7,330.00	20.94
150 kg/ha NPK	2,140.0	1,050.00	12,840.00	11,790.00	11.23	1,790.0	1,050.00	10,740.00	9,690.00	9.23
250 kg/ha NPK	2,060.0	1,750.00	12,360.00	10,610.00	6.06	1,290.0	1,750.00	7,740.00	5,990.00	3.42
10 ml SuperGro	2,110.0	14.58	12,660.00	12,645.42	867.31	840.0	14.58	5,040.00	5,025.00	344.68
No fertilizer	1,850.0	0.00	11,100.00	11,100.00	0.00	640.0	0.00	3,840.00	3,840.00	0.00
50 kg/ha NPK	2,010.0	350.00	12,060.00	11,710.00	33.46	990.0	350.00	5,940.00	5,590.00	15.97
150 kg/ha NPK	2,150.0	1,050.00	12,900.00	11,850.00	11.29	1,140.0	1,050.00	6,840.00	5,790.00	5.51
250 kg/ha NPK	1,810.0	1,750.00	10860.00	9110.00	5.21	1,100.0	1,750.00	6,600.00	4,850.00,	2.77
10 ml SuperGro	1,860.0	14.58	11,160.00	11,145.42	764.43	970.0	14.58	5,820.00	5,805.24	398.18

Superscript letters indicate significant differences in pod yield means according to the HSD test ($P \leq 0.05$). Means sharing the same letter(s) are not significantly different. Fertilizer costs were estimated at GH₵ 7.00/kg for NPK and GH₵ 14.58/ha for Super Gro, applied at 5 ml per 12 m² plot (equivalent to 416.67 ml/ha) at a market price of GH₵ 35 per litre.

CHAPTER FIVE: DISCUSSION

5.1 Initial and Final Soil Characteristics

The experimental sites' sandy loam soil, characterized by low initial organic matter (1.79-1.91%) and moderate acidity (pH 5.56-6.70), reflects typical tropical agroecosystems where nutrient leaching and organic carbon depletion are prevalent (Bationo *et al.*, 2018). The initial soil analysis revealed inherently low cation exchange capacity (CEC), a common trait of sandy loam soils, which exacerbates nutrient losses under high rainfall (Fageria & Moreira, 2016).

The application of NPK fertilizers significantly altered soil chemical properties. Increasing NPK rates (50-200 kg/ha) elevated electrical conductivity (EC) by 11-39% in the major season, consistent with findings by Theresa *et al.,* (2020), who attributed such increases to soluble salt accumulation from mineral fertilizers.

Available phosphorus (Avail. P) rose by 33-100% under NPK regimes, mirroring observations by Nkebiwe *et al.*, (2016) in groundnut systems, where P fixation in acidic soils was mitigated by phosphate fertilizers. However, the decline in total nitrogen (% Total N) at higher NPK rates (0.10-0.12% vs. 0.15% in controls) underscores the vulnerability of NO_3^--N to leaching in sandy soils, as reported by Chivenge *et al.* (2015). This leaching risk is amplified in high-rainfall regimes (784-787 mm/season), where excessive N mobility reduces fertilizer-use efficiency (Dobermann *et al*., 2022).

SuperGro, a foliar organic input, showed limited impact on macronutrients (e.g., Avail. P, K) but marginally improved organic carbon (0.34-0.37%) and organic matter (1.83-1.95%). Similar modest gains were reported by Mayindo and Rufas., (2023) in sandy soils amended with organic foliar, where rapid mineralization under tropical temperatures limited long-term organic matter accumulation. The inability of SuperGro to significantly enhance N or P aligns with studies showing that non-root organic inputs minimally affect soil nutrient pools unless combined with soil-incorporated amendments (Raja *et al*., 2017).

Yenyawoso exhibited higher total nitrogen (0.15% vs. 0.14% in Dehyee) but lower Avail. P (4.5 vs. 5.0 mg/kg), suggesting varietal differences in rhizosphere processes. This aligns with Muscolo *et al.* (2022), who found that legume varieties modulate root exudates, influencing P solubility and N fixation. Yenyawoso's superior N retention may reflect symbiotic rhizobia efficiency, a trait critical for N-scarce soils.

The minor season's higher pH (6.50-6.70 vs. 5.40-5.65) and lower EC (67.8-99.3 vs. 87.9-129.3 µS/cm) likely resulted from reduced leaching intensity and residual base cation accumulation, as observed in West African savanna soils by Adam *et al,* (2021). Seasonal stability in organic matter (1.79-1.95%) contrasts with findings by Manzoni & Cotrufo, (2024), who reported tropical organic matter fluctuations; this inconsistency may stem from the experimental site's low initial organic carbon, limiting further decomposition.

The rapid leaching of applied N and the modest organic carbon gains highlight the need for integrated nutrient management (INM) in sandy loam soils. Split NPK applications, as advocated by Manickam *et al*., (2020), could mitigate N losses, while combining SuperGro with compost or biochar may enhance organic matter retention (Lehmann *et al.*, 2015). Additionally, varietal selection (e.g., Yenyawoso for N fixation) offers a low-cost strategy to optimize nutrient-use efficiency.

5.2 Effect of NPK and SuperGro Foliar Fertilizer on Phenology of Groundnut

The significantly greatest number of established plants produced by Yenyawoso compared to Dehyee across both cropping seasons could be due to inherent genetic potential of Yenyawoso. This might have been more efficient in nutrient uptake, its utilization and seed vigour during the early growth stages. That could have contributed to its better establishment. The highest number of established plants produced by groundnut plants that received NPK fertilizer (150 kg/ha) and Yenyawoso grown on 50 kg/ha NPK across both cropping seasons could be that NPK fertilizer might have provided sufficient nutrients to support the growth and establishment of groundnut plant. Murrel *et al.* (2021) asserted that adequate nutrient availability, especially nitrogen, phosphorus, and potassium in NPK fertilizer is crucial for seed germination, seedling vigour, and early growth.

Varieties, fertilizer rates and their interactions did not significantly affect days to 50% flowering in 2023 major cropping season. Yenyawoso flowered a day earlier than Dehyee in 2023 minor cropping season. This could likely be due to inherent genetic differences between the two groundnuts variety. Yenyawoso may possess genetic factors that promote earlier flowering compared to Dehyee, such as variations in genes regulating the transition from the vegetative to the reproductive phase. Groundnut plants treated with SuperGro foliar fertilizer (10 ml SuperGro) reached 50% flowering stage earlier than those treated with 50 kg/ha NPK fertilizer. Probably due to the fact that, SuperGro applied directly to the leaves, allows for quicker nutrient absorption through the plant's stomata and subsequently within the leaf's vascular system (xylem and phloem), leading to faster physiological responses such as flowering. This agrees with El-Ramady *et al.* (2016) that foliar application enhances the rate of photosynthesis, leading to improved nutrient transfer from the leaves to the developing roots. The least days to 50% flowering produced by Yenyawoso that received 150 kg/ha NPK compared to Dehyee grown on the same treatment could be attributed to variations in their genetic makeup and growth habits (Umadevi *et al.*, 2025).

Varieties had no significant influence on days to 50% pegging across both cropping seasons. Groundnut plants that received 50 kg/ha NPK as well as Yenyawoso and Dehyee grown on 50 kg/ha NPK were the earliest to peg across both cropping seasons. This indicates that the application of 50 kg/ha NPK was optimal for promoting earlier pegging in groundnut, while higher rates of 150 kg/ha and 250 kg/ha NPK did not provide additional benefits and may have even delayed pegging.

The earlier podding in Dehyee than Yenyawoso during 2023 major cropping season and vice versa in 2023 minor cropping season might be due to the differences in the genetic makeup of the two groundnut varieties.. Fertilizer rates and the interaction between variety and fertilizer rate did not significantly affected number of days to podding across both cropping seasons.

The least number of days to maturity by Yenyawoso compared to Dehyee in 2023 major cropping season could be attributed to the differences in the inherent genetic potential of the two varieties. This confirms the findings of Njoki *et al.* (2024) who recorded differences in days to maturity among groundnut varieties. Fertilizer rates did not significantly affected number of days to maturity in 2023 major cropping season. The least number of days to maturity recorded by Yenyawoso that received 50 kg/ha NPK than Dehyee with 150 kg/ha NPK in 2023 major cropping season could be due to the higher rate of the NPK fertilizer supplied in the rightful quantities which promoted higher growth and development hence least days to maturity (Seadh *et al.,* 2017).

5.3 Effect of NPK and SuperGro Foliar Fertilizer on Vegetative Growth of Groundnut

During the 2023 minor season, Yenyawoso plants treated with 50 kg/ha NPK produced significantly taller plants, while Dehyee plants treated with the same fertilizer rate exhibited wider stem girth throughout the entire growing period than the unamended plot. This may be attributed to the sufficient supply of essential nutrients provided by the NPK fertilizer, particularly nitrogen, which promotes vegetative growth and elongation in the plants, leading to increased plant height. Phosphorus and potassium play key roles in strengthening plant structures and supporting cell division, contributing to the wider stem girth observed in Dehyee (Rashid *et al.*, 2020). These nutrients optimize growth by improving nutrient absorption and utilization, allowing both varieties to reach their potential for height and stem development. The interaction between variety and fertilizer rates did not significantly affect shoot dry weight per plant, shoot dry weight per plant and root dry weight per plant during the 2023 minor cropping season.

Dehyee recorded significantly taller plants, wider canopy spread and greater number of branches per plant than Yenyawoso during most of the periods of data collection during 2023 major cropping season whereas Yenyawoso recorded significantly heavier root dry weight per plant than Dehyee from 21 to 77 DAP during the major cropping season. In 2023 minor cropping season, Dehyee recorded significantly higher number of branches per plant, and wider stem girth than Yenyawoso whereas Yenyawoso recorded the widest canopy spread than Dehyee. The differences between Dehyee and Yenyawoso in vegetative growth parameters might be due to the differences in genetic make-up and their response to soil nutrients. Also, it could be due to how the two groundnut varieties respond to SuperGro foliar fertilizer that reduces the surface tension of water, allowing for better infiltration and distribution of water and nutrients in the soil, which enhances root absorption for effective growth and development. This was in agreement with Essilfie *et al.* (2023) who asserted that differences between Obatanpa and Omankwa maize varieties in vegetative growth was due to the genetic variability between the two varieties and their ability to leverage environmental factors such as soil moisture, temperature, and nutrients. The varieties did not significantly affect stem girth and shoot dry weight per plant in 2023 major cropping season. In 2023 minor cropping season, plant height, shoot dry weight per plant and root dry weight per plant were not significantly affected by varieties.

The lack of significant differences in plant height, canopy spread, and root dry weight per plant across the different fertilizer rates in both cropping seasons could be explained in the fact that the nutrients provided by the fertilizers were adequate across all treatments, satisfying the plants basic nutrient requirements for vegetative growth. According to Mohammed (2020), plant growth is often limited by factors other than nutrient availability, such as water, light, or genetic potential, which could explain the uniformity in growth parameters despite varying fertilizer rates. However, the significantly taller plants observed in groundnut plants that received 50 kg/ha NPK, compared to the unamended plots from 49 to 77 DAP during the minor cropping season, could be attributed to improved nutrient availability, particularly nitrogen, phosphorus, and potassium. This aligns with findings by Jideani & Jideani (2021), who noted that balanced fertilization enhances groundnut growth and productivity, particularly during key vegetative growth stages.

The significantly higher number of branches per plant and wider stem girth and heavier shoot fresh weight per plant observed in groundnut plants that received150 kg/ha NPK from 49 to 77 days after planting (DAP) across both cropping seasons, compared to those in unamended plots, can be attributed to the enhanced nutrient availability provided by the fertilizer. NPK, particularly nitrogen, plays a crucial role in promoting vegetative growth, which includes the development of branches. According to Sardans & Peñuelas (2021), phosphorus aids in energy transfer and root development, while potassium helps regulate physiological processes like water uptake, all contributing to more robust branching. In contrast, the unamended plots likely experienced nutrient limitations, which restricted the plant's ability to allocate resources for branching and dry matter accumulation. This aligns with studies like those by Jideani &

Jideani (2021), where balanced fertilization led to improved growth and branching in legumes.

The significantly heavier shoot dry weight per plant in groundnut plants that received 10 ml of SuperGro during the 2023 major cropping season, at 49 and 77 DAP, compared to the unamended plot, and could be that SuperGro reduces the surface tension of water, allowing for better infiltration and distribution of water and nutrients in the soil, which enhances root absorption. This improved nutrient and water availability likely led to increased photosynthesis and biomass accumulation, contributing to the heavier shoot dry weight. According to El-Ramady *et al*. (2023), SuperGro can enhance plant growth by optimizing the soil-water-plant interaction, leading to better nutrient utilization and overall plant vigour. The significantly heavier shoot dry weight per plant in groundnut plants treated with 50 kg/ha NPK during the 2023 minor cropping season from 21 to 35 days after planting (DAP) compared to the unamended plot could be due to the immediate availability of essential nutrients, particularly nitrogen, phosphorus, and potassium. These combined effects likely resulted in more vigorous early-stage growth, contributing to increased shoot biomass.

The interaction between Dehyee and 10 ml of SuperGro significantly enhanced plant height during the 2023 major cropping season compared to other treatment combinations. This improvement can be attributed to the SuperGro ability to enhance water infiltration and nutrient absorption, facilitating better root development and overall plant growth. Additionally, Yenyawoso plants treated with 10 ml of SuperGro demonstrated significantly higher shoot dry weight per plant compared to both varieties grown in unamended plots. This suggests that the SuperGro effectively promoted biomass accumulation by optimizing soil-water-plant interactions, leading to increased photosynthesis and nutrient uptake. Almaz *et al.* (2023) reported that an increase in soil organic matter and nutrient availability for plants utilization after SuperGro application.

Dehyee plants that received with 150 kg/ha of NPK demonstrated a significantly higher number of branches per plant and throughout the entire growing period in both cropping seasons compared to those grown in unamended plots. Similarly, Yenyawoso plants that received the same NPK treatment exhibited significantly wider stem girth and increased root dry weight per plant during the major cropping season. These enhancements can be attributed to the ample supply of essential nutrients provided by the NPK fertilizer, which supports various physiological processes in plants. This optimal nutrient supply allows the plants to maximize their growth potential, resulting in improved structural characteristics and biomass accumulation (Fageria & Moreira, 2016). The significantly wider canopy spread recorded by Dehyee that received 50 kg/ha NPK and Yenyawoso that received 50 kg/ha NPK during the major and minor cropping seasons respectively as compared to both varieties grown on the unamended plot could be due to the presence of adequate supply of essential plant nutrients by the NPK fertilizers and inability of the unamended soil to provide adequate nutrients for plant growth and development.

5.4 Effect of NPK and SuperGro Foliar Fertilizer on Physiological Growth Parameters of Groundnut

Generally, the different varieties of groundnut had no significant effect on crop growth rate (CGR) and relative growth rate (RGR) across both cropping seasons. Similarly, Essilfie *et al.* (2023) also observed no significant differences in CGR and RGR between two maize varieties namely Obatanpa and Omankwa. Overall, the crop growth rate was slower whereas the RGR was higher during the early stages of development, increased as the crop grew and matured, and then declined as the crop neared physiological maturity. This initial phase is characterized by the establishment of the plant's root system and the development of foundational structures, such as leaves and stems where the plant's energy is primarily focused on building a strong base for future growth, leading to lower CGR (Majumdar *et al.*, 2016). As the crop progresses and enters the phase of active growth, the rate of growth significantly increases. This surge in growth continues as the plant moves toward maturity, with the accumulation of biomass peaking. According to Majumdar *et al*., (2016) as crop approaches physiological maturity the stage where the plant's development is complete and it begins transitioning to reproductive or senescence phases, the growth rate naturally declines. At this point, the plant shifts its energy from vegetative growth to reproductive processes, such as flowering and seed formation, leading to a reduction in overall CGR and RGR as the plant reaches the end of its life cycle (Ibrahim *et al.*, 2021).

5.5 Effect of NPK and SuperGro Foliar Fertilizer on Yield and Yield Components of Groundnut

Generally, varieties had significant effect on the yield and yield components measured across both cropping season except number of filled cobs per plant and harvest index where no significant differences existed between the varieties during both cropping seasons. Dehyee recorded significantly higher number of plants harvested, pods per plant and per plot, unfilled pods per plant, pod weight per and haulm weight per plot than Yenyawoso during 2023 major season as well as greatest number of plants harvested. Yenyawoso recorded higher number of pods per plot, pod weight per plot, seed weight per plot, shelling percentage and pod and grain yield than Dehyee during 2023 minor season. These differences could be attributed to the inherent genetic traits of the varieties, such as their ability to resist stress, optimize nutrient uptake, or efficiently allocate resources to reproductive structures. Similarly, Bapela *et al.* (2022) stated that the ability of wheat genotypes to thrive and produce high yields is due to their inherent genetic variation and adaptation to the environment.

Groundnut plants that received SuperGro foliar fertilizer (10 ml SuperGro) demonstrated superior performance across several yield parameters, including the highest number of plants harvested, pods per plot, pod weight per plot, seed weight per plot, haulm weight per plot, and harvest index in 2023 major cropping season as well as higher number of plants harvested and pods per plant in the 2023 minor season. This can be attributed to the unique properties of foliar fertilizers, which are directly absorbed through the leaves, bypassing the soil and delivering nutrients more rapidly and efficiently to the plant's physiological processes and hence promoting higher development and yield (Pooja & Ameena, 2021). According to Vittal (2020), SuperGro, as a surfactant-based foliar fertilizer, enhances nutrient absorption by reducing surface tension, allowing for better coverage and penetration of the fertilizer on the leaf surface. Vittal (2020) further asserted that foliar fertilizer improves photosynthetic efficiency, as the nutrients are immediately available to support essential processes such as chlorophyll production and energy transfer, which are critical during the plant's growth and development phases. This was in consonance with Rácz & Radócz (2020) who asserted that foliar application ensures that nutrients are available during critical growth stages, reducing the risk of nutrient deficiencies that could otherwise limit yield potential.

Groundnut plants that received 50 kg/ha NPK recorded significantly higher number of pods per plant, improved shelling percentage, and greater overall pod and grain yield in 2023 major cropping season as well as higher haulm weight per plot during 2023 minor cropping season. This suggests that the moderate NPK application provided an optimal nutrient balance to promote both vegetative and reproductive growth which optimized overall pod production and yield. This is consistent with the findings of Rashid *et al.* (2020), who reported higher grain yield in maize treated with NPK at a rate of 25 and 50 kg/ha.

In contrast, groundnut plants that received 150 kg/ha NPK showed the highest 100-seed weight and number of filled pods per plant in the major season as well as higher number of pods per plot, pod weight per plot, pod and grain yield in the minor cropping season indicating that the higher nutrient availability favoured seed development and pod filling. The increased nutrient supply at 150 kg/ha likely enhanced seed quality and pod maturity, leading to better seed weight and pod filling performance hence translating into higher pod yield. The results of the experiment align with the findings of Akter (2023). Similarly, Ali *et al.* (2017) reported that seed yield progressively increased with increasing rates of NPK fertilizer, with the maximum yield achieved at 150 kg K_2O/ha.

During 2023 major cropping season, the significantly higher number of pods per plant, pods per plot, pod weight per plot, shelling percentage and pod yield and grain yield recorded by Dehyee that received 50 kg/ha NPK and higher 100 seed weight recorded by Yenyawoso that received 50 kg/ha NPK might be that the 50 kg/ha provided the optimal nutrient balance for the groundnut varieties while the higher rate of 150 kg/ha may have led to nutrient imbalances or excesses, negatively affecting plant performance and yield (Singh *et al.*, 2015). This was in agreement with Ng (2022) that over-application of NPK can sometimes result in reduced efficiency, hindering optimal plant growth and pod production.

The Yenyawoso variety treated with SuperGro foliar fertilizer (10 ml SuperGro) demonstrated superior performance in terms of the number of plants harvested and seed weight per plot in the major season as well as and harvest index across both cropping seasons compared to other treatments whereas Dehyee variety that received SuperGro foliar fertilizer (10 ml superGro) produced significantly higher number of filled pods per plot and haulm weight in the 2023 major cropping season. This might be that the SuperGro foliar fertilizer likely enhanced nutrient absorption through the leaves, improving plant health and growth. This increased efficiency in nutrient uptake may have contributed to higher seed production and a better harvest index, which indicates a more efficient conversion of biomass into harvestable yield (Pooja & Ameena, 2021). According to McBeath *et al.,* (2020) foliar fertilizers are absorbed directly through the leaves, potentially providing quicker and more targeted nutrient delivery than soil-based fertilizers, which explain the observed boost in both harvest quality and quantity. The higher number of unfilled pods per plant recorded by Dehyee grown on the unamended plot across both seasons could be due to nutrient deficiencies and varietal difference. According to Sinha & Tandon (2020), essential nutrients like nitrogen, phosphorus, and potassium are critical for pod filling and seed development**.**

The significantly higher number of plants harvested, 100-seed weight, and haulm weight per plot recorded by Dehyee that received 150 kg/ha to 250 kg/ha NPK during the 2023 minor cropping season could be due to the increased availability of essential nutrients. According to Xing *et al.* (2023), higher NPK rates likely provide sufficient nitrogen for robust vegetative growth, phosphorus for better root and seed development, and potassium for enhanced water efficiency and stress tolerance. This optimal nutrient supply might have improved plant vigor, seed size, and biomass (haulm weight), contributing to better overall growth and yield performance (Xing *et al.*, 2023). Again, Yenyawoso treated with 150 kg/ha NPK significantly outperformed varieties on unamended plots in terms of seed weight, number of pods per plot, pod weight, shelling percentage, pod yield and grain yield. The improved performance might be due to the balanced supply of nitrogen, phosphorus, and potassium. Nitrogen promoted vegetative growth and energy production, phosphorus enhanced root development and seed filling, and potassium supported nutrient transport and pod filling (Dikr & Abayechaw, 2022). Together, these nutrients improved overall plant health, leading to more pods, better-filled seeds, and higher yields. In contrast, the unamended plots suffered from nutrient deficiencies, resulting in lower yield and poor plant development.

Groundnut plants grown on the unamended plot, resulted in poor performance for the yield and yield component parameters measured across both cropping seasons. This outcome might be attributed to the inability of the initial soil nutrients to support the vegetative growth and pod filling. Similarly, Awuni *et al.* (2024) found that soybean plants planted without fertilizer (no amendment) produced significantly lower yield as compared to plants that received 100 kg/ha P.

5.6 Correlation matrix analysis

The strong correlation between the number of pods per plot and seed yield indicate more pods generally translated into higher yields. Similarly, the 100-seed weight showed a strong correlation with seed yield, reflecting that heavier seeds contribute to increased yield, likely due to better seed filling and nutrient allocation. The number of branches per plant was strongly correlated with haulm weight per plot, indicating that plants with more branches typically have more vegetative mass, which can be essential for supporting pod development and overall plant health. This was in consonance with Meghashree *et al.* (2018) who reported a significant positive correlation between plant biomass, number of leaves, root weight and core diameter of carrot.

Additionally, plant height and canopy spread were strongly correlated, highlighting that taller plants tend to have a more extensive canopy, which can improve light interception and photosynthesis, further supporting growth. This corroborates with Kusse *et al,* (2019), who observed a significant positive relationship between vegetative and yield component parameters such as cob length, cob diameter, grain yield, number of rows per cob, and number of grains per cob. Similarly, Wilkinson *et al.* (2020) also reported that there was significantly positive correlation between plant height and other vegetative and yield components of sweet potato.

5.7 Economic Analysis of Groundnut Varieties under Fertilizer Treatments

The results from the study revealed that the profitability of groundnut production was significantly influenced by the type of fertilizer applied, the rate of application, and the variety grown. The superior economic performance of the Yenyawoso variety across both seasons suggested a stronger responsiveness to nutrient inputs compared to Dehyee, aligning with reports by Konja *et al.* (2019), who observed that varietal differences significantly impact economic efficiency among groundnut farmers in Ghana.

The use of 10 ml SuperGro proved especially cost-effective due to its very low input cost and relatively high yield returns, leading to notably high benefit-cost ratios (BCR) in both cropping seasons. This corroborates the findings of Naab *et al.* (2025), who reported that integrated nutrient management practices, including bio-stimulants, improved yield outcomes and economic benefits under smallholder conditions. Although NPK applications also led to high net returns, the economic advantage diminished at higher rates due to increased input costs, an observation supported by Awuni *et al.* (2022), who cautioned against blanket fertilizer recommendations without economic threshold evaluations.

The consistently higher profitability of input-applied treatments over the control emphasizes the need for informed fertilizer use in groundnut production. This supports the findings of Abubakari *et al.* (2019), who demonstrated that strategic input use significantly enhanced gross margins and returns in the Tolon District. Moreover, the seasonality of returns observed in this study reflects the influence of environmental conditions such as rainfall and temperature on fertilizer use efficiency, as previously highlighted by Tetteh *et al.* (2020).

This study therefore affirms that cost-effective fertilizer application especially low-cost alternatives like SuperGro combined with responsive varieties like Yenyawoso, offers a viable pathway for enhancing groundnut productivity and profitability. These findings have practical implications for smallholder farmers and extension agencies aiming to promote resource-efficient and economically sustainable groundnut production systems in Ghana and beyond.

CHAPTER SIX: CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

The following conclusions were drawn based on the findings of the field studies across both cropping seasons:

Objective 1:

- Fertilizer treatments, particularly 50-150 kg/ha NPK and 10 ml Super Gro, enhanced soil chemical properties, while excessive application (250 kg/ha) slightly reduced soil P^H.

Objective 2:

- Yenyawoso outperformed Dehyee across both seasons, especially with 150 kg/ha NPK showed earlier flowering and pegging.
- Yenyawoso grown on 10 ml SuperGro produced the greatest CGR than unamended plot.

Objective 3:

- Dehyee and Yenyawoso groundnut varieties showed improved yields and pod characteristics with the application of 10 ml SuperGro and 150 kg/ha NPK in the minor season.
- Yenyawoso generally outperformed Dehyee in the minor season with NPK applications of 50 kg/ha and 150 kg/ha, respectively.

Objective 4:

- Fertilizer rates, variety, and their interaction significantly impact groundnut production profitability with greater economic benefit.
- Yenyawoso and 10 ml SuperGro significantly improved grain yield and economic returns with greatest benefit-cost ratio in major season.

6.2 Recommendations

Based on the findings of the study, the following recommendations are made:

6.2.1 Recommendations for farmers' adoption

- Farmers are encouraged to grow groundnut and apply 50 kg/ha NPK and 10 ml Super Gro for enhanced vegetative growth that can directly translate into greaer grain yield.
- Farmers are encouraged to grow the Dehyee groundnut variety and apply 50 kg/ha of NPK fertilizer, and the Yenyawoso variety with 150 kg/ha of NPK fertilizer, as these combinations was found to result in greater grain yields.
- Farmers should adopt and plant Yenyawoso groundnut variety and also apply 10 ml Super Gro and a moderate NPK fertilizer rate (50–150 kg/ha), as this treatment consistently maximized grain yield and economic returns across both major and minor cropping seasons.
- Farmers are encouraged to grow Yenyawoso and Dehyee and apply 50 -150 kg/ha NPK as this combination proved superior in grain yield.

6.2.2 Recommendation for future research

- Additional research should be conducted to delve into the partial budget analysis of the different fertilizer rates used.
- The work should be repeated in other agro-ecological zones of Ghana to confirm the results attained.

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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)

Appendix 2: Climatic data for 2023 major rainy season at the experimental site

Month	Total Rainfall (mm)	Relative Humidity (%)		Mean Temperature (^{O}C)	
		6:00 hrs	15:00hrs	Min	Max
March, 2023	57.8	88	55	23.1	33.8
April	258.8	91	59	22.7	33.3
May	71.3	90	60	23.2	32.8
June	198	92	70	23	30.3
July	198.9	91	71	21.8	28.4
Total	784				

(Ghana Meteorological Agency– Asante Mampong, 2023)

Appendix 3: Climatic data for 2023 minor rainy season at the experimental site

Month	Total Rainfall (mm)	Relative Humidity (%)		Mean Temperature (^{O}C)	
		6:00 hrs	15:00hrs	Min	Max
August, 2023	213.4	93	74	22.5	29.0
September	196	92	69	22.4	30.6
October	286.4	90	62	23.0	32.0
November	91.1	91	59	23.5	33.1
December	0	74	44	22.7	34.5
Total	786.9				

(Ghana Meteorological Agency– Asante Mampong, 2023)