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DRY MATTER ACCUMULATION, PARTITION AND YIELD IN THREE COWPEA (*Vigna unguiculata* (L) Walp) VARIETIES AS INFLUENCED BY PHOSPHORUS FERTILIZER APPLICATION

A thesis submitted to the Department of Crop and Soil Sciences, Faculty of Agriculture of the College of Agriculture and Natural Resources, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana in partial fulfillment of the requirement for the award of Master of Science Degree in Agronomy (Crop Physiology)

BY

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DECLARATION

I hereby certify that this thesis has not been submitted for a degree to any other University and it is entirely my own work and all help and references have been duly acknowledged.

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DEDICATION

This thesis is dedicated to my wife, Millicent and my daughter, Nhyira.

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NYANSAPƆ WƆSANE NO BADWENMA

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ABSTRACT

Phosphorus is a major limiting nutrient in Ghanaian soils. Selection of cowpea varieties that produce good seed yield under low soil phosphorus or those with high phosphorus response efficiency can be a low input approach in solving this problem in Ghana. Two field experiments were conducted in 2012 at the Plantation Crops Section of the Department of Crop and Soil Sciences, Kwame Nkrumah University of Science and Technology to evaluate the effect of phosphorus fertilizer application on dry matter accumulation, partition and yield in three cowpea varieties.

The design used in both studies was a 3×4 factorial arranged in randomized complete block design with four replications. Three cowpea varieties Asetenapa (IT81D-1951), Asomdwee (IT94K-410-2) and IT89KD-347-57 combined four P rates (0, 20, 40 and 60 kg P_2O_5 ha^{-1}) application. The land was ploughed, harrowed and plots were laid out. Plot size was 3 m × 5 m. Each plot consisted of nine rows in both seasons and planting was done at the beginning of the rains at a spacing of 60 × 20 cm. All agronomic practices were observed. Response variables measured were phenological observations, growth and yield components, and nodulation.

The results indicated that growth and growth components varied significantly with cowpea varieties. Asetenapa flowered earlier followed by Asomdwee and IT89KD-347-57. Phosphorus fertilizer application significantly reduced days to 50 % flowering. Dry matter production and distribution were significantly affected by cowpea varieties. Asetenapa and Asomdwee were more efficient in partitioning photosynthate into the economic parts. Yield and yield components were significantly affected by cowpea variety and P fertilizer application rates over the control. Asomdwee produced the greatest seed yield of 1557.00 kg ha^{-1} and 1415.00 kg ha^{-1} for major and minor seasons respectively. P fertilizer application resulted in increased seed yield with each increase in P rate. The highest seed yield of 1682.00 and 1476.00 kg ha^{-1} for major and minor seasons respectively was produced when 60 kg P_2O_5 ha^{-1} was applied. The interaction of variety and P fertilizer application was not significant for seed yield.

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LIST OF ABBREVIATIONS

ANOVA	Analysis of Variance
CGR	Crop Growth Rate
CRI	Crop Research Institute
CSIR	Council for Scientific and Industrial Research
CV	Coefficient of variation
DAP	Days after planting
DAS	Days after sowing
DM	Dry Matter
Dw	Dry weight
EC	Emulsifiable concentrate
ha	Hectare
HI	Harvest Index
IITA	International Institute of Tropical Agriculture
kg/ha	Kilogram (s) per hectare
LA	Leaf Area
LAI	Leaf Area Index
Lsd	Least Significant Difference
MoFA	Ministry of Food and Agriculture
NAR	Net Assimilation Rate
NPK	Nitrogen Phosphorus Potassium
RCBD	Randomized Complete Block Design
RGR	Relative Growth Rate
RLAER	Relative Leaf Area Expansion Rate
SRI	Soil Research Institute
TDM	Total Dry Matter
TSP	Triple Superphosphate

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CHAPTER ONE

1.0 INTRODUCTION

Cowpea (*Vigna unguiculata* (L) Walp) considered as "poor man's meat" and "rich man's vegetable" (Singh and Singh, 1992), is a major grain legume in Sub-Saharan Africa. Cowpea fixes atmospheric nitrogen up to 240 kg ha^{-1} and leaves about 60-70 kg nitrogen for succeeding crops (CSIR - CRI, 2006). Cowpea is consumed in many forms: the young leaves, green pods, and green seeds are used as vegetables; dry seeds are used in various food preparations; and the haulms are fed to livestock as nutritious supplement to cereal fodder (Dugje *et al.*, 2009). It is a major source of vegetable protein (23-30 %). It contains minerals; calcium and iron and amino acids such as lysine, tryptophan and methionine which improve human nutrition and health status (Davis *et al.*, 2000).

Phosphorus is a major mineral nutrient required by plants, but is one of the most immobile, inaccessible, and unavailable nutrients present in soils (Narang *et al*., 2000). It limits plant growth and productivity on 40% of the world's arable soil (Vance, 2001). Phosphorus plays key roles in many plant processes such as energy metabolism, nitrogen fixation, synthesis of nucleic acids and membranes, photosynthesis, respiration and enzyme regulation. It influences nodule development through its basic functions as an energy source (Bekere *et al*., 2012). However, the element is generally deficient and limits biological nitrogen fixation in highly weathered tropical soils (Kumaga and Ofori, 2004). It is the most important essential nutrient for seed production and for formation of healthy and sound root system which is essential for the uptake of nutrients from the soil (Das *et al*., 2008). It plays a vital role in cell division, flowering, fruiting and nodulation.

It is required for the physiological processes of protein synthesis and energy transfer in plants (Oti *et al.*, 2004). Application of phosphorus has been reported by several authors to improve yield of cowpea by enhancing number of pods per plant, number of seeds per pod and mean seed weight. Again, phosphorus application is mentioned to decrease zinc concentration in the cowpea grain which can affect the nutritional quality (Buerkert *et al.*, 1998). Moreover, dry matter production is reported to increase by phosphorus application and its distribution is also affected, for instance, phosphorus deficient plants usually have more dry matter partitioned to roots than shoots, probably as a result of higher export rates of photosynthates to roots (Fageria *et al.*, 2006).

Dry matter production and its accumulation is the best measure and index of the total performance and response of a crop to weather and environmental conditions (Mall *et al.*, 2000). Crop productivity depends not only on dry matter accumulation, but also on its effective partitioning to the kernel; this is a key to yield stability (Kumar *et al.*, 2010). Dry matter partitioning is the end result of the flow of assimilates from source organs to vegetative and reproductive sinks (Marcelis, 1996).

Most of the world's cowpea production is in Africa, with Nigeria, Kenya, Niger, Burkina Faso, Ghana, and Uganda being major producers (Bennett-Lartey and Ofori, 2000). However, yield of cowpea in such countries is estimated to be 45% of that of developed countries (Akibode, 2011). Among the factors responsible for such low yield is an edaphic factor (soil physiochemical-characteristics) particularly P deficiency which is the most limiting soil fertility factor for cowpea production (IITA, 2003) which occurs as a result of either inherent low levels of soil P or depletion of the P through cultivation.

In recent years, cowpea improvement has been intensified in Ghana by various research institutions with the results that a number of improved varieties have been released. This trend has been possible largely through the use of diverse cowpea germplasm, local and exotic, in improvement programmes (Bennett-Lartey and Ofori, 2000). The yields of the crop in Ghana, however, are among the lowest in the world, national average is 700 kg ha^{-1} (MoFA - SRID, 2013). Hence, efforts have been made to improve cowpea production in Ghana through various means including the introduction of new varieties. At present however, there are not much agronomic information on the growth and yield on recent released varieties; Asomdwee (IT94K-410-2) and IT89KD-347-57 by the Crop Research Institute (CRI) of Council for Scientific and Industrial Research (CSIR).

Attempts to improve food production should be approached via a good understanding and manipulation of crops and their environment (Willey, 1996). This may be achieved by a compatible management of agronomic/cultural practices such as mineral phosphorus fertilizer management strategies. Selection of cowpea varieties that produce good yield under low soil phosphorus or those with high phosphorus response efficiency can be a low input approach in solving this problem in Ghana since, phosphorus is a major limiting nutrient in Ghanaian soils (CSIR-SRI, 2000). Therefore, this work is undertaken on the null hypothesis that P fertilizer influences dry matter production, distribution, growth and yield in cowpea.

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To actualize and achieve the broad objective of the study, the following specific objectives are spelt out;

1. To assess the effects of phosphorus fertilizer on dry matter production and distribution among the three cowpea varieties,
2. To determine the influence of phosphorus fertilizer on growth and yield of the three cowpea varieties and
3. To recommend the variety that produces highest yield under no P application condition.

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CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 The role of cowpea genotype/ variety in determining growth and yield

Genotypes play an important role in crop production and the potential yield of a genotype within the genetic limit is determined by its environment. The release of high yielding varieties has contributed a great deal towards the improvement of cowpea yields. The yield potential of these high yielding varieties can be further exploited through better agronomic practices including phosphorus fertilizer application (Acquah, 2007).

Ezedinma (1976) reported that the genotypes with continued growth even after flowering affected the grain dry matter production during post-flowering period and eventually decreased the pod yield. Wein and Ackah (1978) compared different cowpea genotypes for variation in pod development period and its influence on seed weight and number of seeds per pod. The study indicated that genotypes with longer pod development period having higher seed growth would be a desirable character for maintaining higher yield. Addo-Quaye *et al.* (2011) observed that cowpea varieties have different capacities for dry matter accumulation.

Kalpana (2000) reported that determinate cowpea genotypes had higher values of photosynthetic rate, transpiration rate, stomatal conductance, as compared to the indeterminate genotypes. Beebe *et al.* (1997) stated that efficient genotypes are those which are able to produce superior yields under phosphorus deficiency conditions, irrespective of the mechanisms involved. Earlier studies conducted by several workers also revealed varietal differences in the seed yield of cowpea (Nirmal *et al.*, 2001).

2.2 Dry matter production and partitioning

Das *et al*. (2008) defined total dry matter as the sum of the dry matter accumulation in the various components of the plant namely leaf, petiole, branches, stem and the reproductive parts of the plant. According to Thakur *et al.* (2011), dry matter produced by green plants is divided into roots, shoots and grains. This process can be referred to as dry matter partitioning in plants. In general, root weight is not taken into account when discussing the dry matter partitioning and hence, the photosynthetic products are divided into shoots and grains. Dry matter accumulation in plant gradually increases with crop age and peaks at maturity. The accumulation of dry matter is more in leaf than stem during early crop growth stage 20 days after sowing (DAS) and declines thereafter. The accumulation of dry matter is observed to be higher in the stem during the mid growth stage as compared to leaf. Dry matter partitioning is the end result of the flow of assimilates from source organs via a transport path to the sink organs. The dry matter partitioning among the sinks of a plant is primarily regulated by the sinks themselves. The effect of source strength on dry matter partitioning is often not a direct one, but indirect via the formation of sink organs (Marcelis, 1996). Reproductive-stage, heat-tolerance genes cause greater partitioning of carbohydrates to pods (Ismail and Hall, 1998) whereas, the delayed-leaf-senescence trait is associated with greater partitioning of carbohydrate to stem bases and also probably to roots (Gwathmey *et al.,* 1992).

The total dry matter yield is the net result of crop efficiency in utilizing the solar radiation, soil nutrients and available moisture and is a function of rate and duration of photosynthesis and its subsequent translocation into different plant parts (Thakur *et al.*, 2011). Rate and duration of photosynthesis is a function of green leaf area and its duration. The dry matter production and its partitioning are the best measures and indices of the total performance and response of a crop to weather conditions (Mansur *et al.*, 2009). The biological productivity of plants is based on their ability to produce and accumulate dry matter (Patil *et al.*, 2002). Plant productivity is partly determined by the distribution of assimilates among various organs (Marcelis, 1996).

Patil *et al.*(2002) using Amarathus reported that dry matter accumulation was maximum in leaves at 70 days after sowing, in stem at 85 DAS and in inflorescence at harvest. The dry matter in stem also declined from 85 DAS to harvest. The dry matter accumulation in leaves, stem and inflorescence showed independent behaviour over the crop growth period. The dry matter accumulation in leaves was maximum at 70 DAS and declined thereafter. This decline in the leaf dry matter may be due to senescence and translocation of dry matter to other plant parts. The dry matter accumulation in stem continued up to 85 DAS and thereafter, it remained constant (Patil *et al.*,2002).

In grain crops, both current assimilation transferred directly to kernels and remobilization of assimilates stored in vegetative plant parts contribute to grain yield (Arduini *et al*., 2006) and may buffer the yield against unfavorable climatic conditions during grain filling (Tahir and Nakata, 2005). Dry matter partitioning is the end result of a co-ordinated set of transport and metabolic processes governing the flow of assimilates from source organs via a transport path to the sink organs (Fang, *et al.*, 2010). The yield of a crop does not only depend on the dry matter production alone but also in its distribution to reproductive parts; as major part of the dry matter is translocated to sink from source (Mansur *et al.*, 2009). Dry matter of cowpea increased up to 90 DAS and thereafter decreased although that was in contrast to the dry matter accumulation pattern in the dry season where the total dry matter of cowpea continued increasing up to maturity (Ullah *et al.*, 2011).

Dry matter accumulation in pod and seed increased continuously with physiological maturity whereas dry matter of pod shell increased up to 40 days after anthesis and reduced afterwards (Aggarwal *et al.*, 2002). The attainment of physiological maturity in a plant usually marks the end of the increment of dry matter accumulation (Aggarwal *et al.*, 2002).

Stern and Donald (1961) stated that, leaf area index influences crop growth rate, and that dry matter production by a crop also increases as the leaf area index increases until a maximum value is attained; thereafter as the leaf area index increases further, the rate of dry matter production declines. This is because; the lowermost leaves become heavily shaded that, photosynthetic contribution becomes less than respiration. Liu *et al.* (2004) indicated that leaf area index, leaf area duration and dry matter accumulation during the reproductive period strongly influence the yield components.

Addo-Quaye *et al.* (2011) using cowpea at two locations, Cape Coast (Coastal savanna) and Twifo Hemang (Transition zone) in Ghana reported that total dry matter accumulation followed a similar pattern at both locations which was a linear increase in total dry matter yield from the first week of sampling to the time of final sampling. This was attributed to increased leaf area index which in turn led to increasing light interception by the leaves resulting in increasing rate of photosynthesis and hence dry matter yield. They also reported significant differences among Bengpla, UCC early and Ayiyi cowpea varieties in total dry matter production.

2.2.1 Effect of Phosphorus on dry matter accumulation and partitioning

Meena *et al*. (2005) using chickpea plants reported that dry matter production increased significantly with each increase in phosphorus levels and highest dry matter recorded with 60 kg ha^{-1}. Singh and Ahuja (1985) recorded that applied P increased leaf area and accumulation of more dry matter in groundnut. Das *et al*. (2008) using 0, 30, 60, 90 and 120 kg ha^{-1} on chickpea reported that phosphorus fertilizer applied showed a marked influence on the total dry matter accumulation which increased progressively over time regardless of the different levels of applied phosphorus fertilizer. Phosphorus deficiency leads to early senescence of older leaves and stunting of new leaves (Moot *et al*., 2007) resulting in reduced leaf area for light interception and consequently reduced dry matter yields.

Fageria *et al*. (2006) reported that partitioning of photosynthate and their effects on dry matter distribution was influenced by several environmental factors such as low temperature, drought and mineral nutrient deficiency. Nitrogen and phosphorus are the most important nutrients which affect the assimilate production and distribution and directly or indirectly also affect the source–sink relation (Arduini *et al*., 2006). For instance, phosphorus and nitrogen deficient plant usually have more dry matter partitioned to roots than shoots, probably as a result of higher export rates of photosynthates to roots. Dry matter yield of cowpea per plant increased significantly with levels of phosphorus fertilizer for all the sampling periods (Magani and Kuchinda, 2009).

Kumar *et al.* (2010) assessing the effect of phosphorus and seed rate on growth and productivity of bold seeded *kabuli* chickpea reported that dry matter accumulation increased significantly with phosphorus levels at all the growth stages except at 30 DAS. They also mentioned that dry matter production increased significantly with each increase in phosphorus levels and highest dry matter was recorded with 60 kg ha^{-1} application. The maximum dry matter accumulation was recorded between 90 and 120 DAS and thereafter, it showed a declining trend. This might be due to photosynthates translocation from green plants (source parts to sink).

2.3 Plant growth analysis and functions

Growth analysis is a physiological probe on the development of the crop in chronological sequence to elucidate and account for the causes of differences in yield through the events that have occurred at different stages of growth. Plant growth analysis is considered to be a standard approach to study of plant growth and productivity (Wilson, 1981). Growth and yield are functions of a large number of metabolic processes, which are affected by environmental and genetic factors. Studies of growth pattern and its understanding not only tell how plant accumulates dry matter, but also reveal the events which can make a plant more or less productive singly or in population (Ahad, 1986).

Plant growth analysis is an explanatory, holistic and integrative approach to interpreting plant form and function. It uses simple primary data in the form of weights, areas, volumes and contents of plant components to investigate processes within and involving the whole plant (Evan, 1996). The most common growth functions are crop growth rate, leaf area index, leaf area duration, net assimilation rate, leaf area ratio and relative crop growth rate. These are normally calculated from total shoot dry weights and leaf area indices recorded over a given period (Clawson *et al*., 1986).

Growth of plant communities has been studied by a technique called "growth analysis" where calculations are made relative to the total dry matter present and the leaf area index during the growing season. The total assimilate accumulated by the crop is called total dry matter, and that portion partitioned to formation of seed is called economic yield. The fraction, economic yield / total dry matter, is termed as the harvest index. The concept of harvest index was described as the migration coefficient (the ratio of grain yield to the total dry matter at maturity) (Donald and Hamblin, 1976). Addo-Quaye *et al.* (2011) using Bengpla, UCC early and Ayiyi cowpea varieties reported significant differences in crop growth rate, net assimilation rate and leaf area index.

2.3.1 Crop Growth Rate

According to Dictionary of Biology (2004) crop growth rate is a measurement of the productivity of a plant which is the increase in dry mass per unit of plant mass over a specified period of time. Crop growth rate is a dynamic character that determines the final yield in cereal and legume crops (Boote, *et al.,* 2001). Its rate depends on net assimilation rate and leaf area index, the later depending on light-intercepting efficiency and photosynthetic efficiency of the leaf (Kokubun, 1988).

Law-Ogbomo and Egharevba (2009) in evaluating effects of planting density and N.P.K fertilizer on growth and fruit yield of tomato reported that crop growth rate generally increased progressively throughout the sampling period. Fageria *et al*. (2006) reported that values of crop growth rate are normally low during early growth stages and increases with time, reaching maximum values at about the time of flowering. They observed that analysis of crop growth rate is important for evaluating treatments differences among crop species or cultivars within species in relation to yield.

2.3.2 Relative Growth Rate

Fageria *et al*. (2006) defines relative growth rate as the increase in total dry matter per unit of total dry matter per day. It is also called the 'efficiency index' and it gives the efficiency of current dry matter to produce future dry matter. Relative leaf area expansion rate (RLAER) is the increase in total leaf area per unit of leaf area per day. It is measured as increase in m^2 (total leaf area) per m^2 (unit leaf area) day^{-1}. In RLAER, the concept of relative growth rate is applied to leaf area instead of dry matter accumulation. It is affected by a range of factors such as temperature, radiation, water, nutrient supply and age of plant. Relative growth rate decreases as the plant ages due to the fact that an increasing part of the plant is structural rather than metabolically active tissue and as such does not contribute to growth (Chattjrvedi *et al.*, 1980). Also, it may decrease as a result of shading of plant parts and increased age of lower leaves (Law-Ogbomo and Egharevba, 2009).

2.3.3 Net Assimilation Rate

Dictionary of Botany (2003) stated that net assimilation rate is a value that relates plant productivity to plant size. It is obtained by dividing the rate of increase in dry weight by leaf size (usually leaf area). It is useful as a measure of the photosynthetic efficiency of plants. Quero *et al*. (2008) indicated that net assimilation rate reflects the balance of photosynthetic rate against respiration and tissue loss rates.

Net assimilation rate is the increase in plant dry weight per unit leaf area per unit time. It is expressed as g m^{-2} day^{-1}. Net assimilation rate measures productive efficiency of leaves on a plant or in a crop stand. It is highest when all leaves are exposed to full sunlight and therefore highest when plants are small and leaves are few enough that none of the leaves is shaded by others and decline as the plant ages, probably due to abscission of the lower leaves (Tayo, 1982).

Watson (1952) reported differences between and within species (a crop) in net assimilation rate. Productivity was much more closely related to the leaf area component of growth rate. Net assimilation rate decreases during the growing season as more and more leaves are fully or partially shaded. Also, the decrease in net assimilation rate with plant age may be due to older average leaf age and resulting lower photosynthetic efficiency. Other factors such as temperature, levels of solar radiation, carbon dioxide concentration in the surrounding air, mineral nutrition, water supply and leaf area developed also affect net assimilation rate (Fageria *et al.*, 2006).

Poorter and Remkes (1990) observed that specific leaf area strongly correlates to relative growth rate, while net assimilation rate and leaf mass ratio are largely independent of relative growth rate. Cornelissen *et al*. (1998) found specific leaf area to be the primary determinant of relative growth rate, while Veneklaas and Poorter (1998) reported net assimilation rate to be the primary determinant of relative growth rate.

2.4 Growth functions and yield

In a crop, growth parameters like optimum leaf area index and crop growth rate at flowering have been identified as the major determinants of yield (Sun *et al*., 1999). A combination of these growth parameters explain different yields better than any individual growth variable (Ghosh and Singh, 1998). Srivastava and Singh (1980) reported that growth process i.e. crop growth rate, relative growth rate and net assimilation rate directly influenced the economic yield of lentil.

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Similarly, Thakur and Patel (1998) reported that dry matter production, leaf area index, leaf area duration, crop growth rate, net assimilation rate and relative growth rate are ultimately reflected in higher grain yield. Tesfaye *et al*. (2006) reported that attainment of high leaf area index that reduces soil water evaporation intercepts and converts radiation into dry matter efficiently and partitioning of the dry matter to the seed is the major requirement of a high seed yield in grain legumes in semiarid environments.

Meadley and Milbourn (1971) stated that the major source of dry matter for pea yield was the photosynthate produced during the post flowering period. Srivastava and Singh (1980) observed comparatively higher crop growth rate in podding stage than in early growth stage in different varieties.

Karim and Fattah (2007) reported that leaf area index, net assimilation rate and crop growth rate increased to pod filling period, leaf area duration was decreased to first pod setting and biomass increased in all vegetation period in chickpea. Leaf area duration was found to be highly correlated with biomass and seed yield of chickpea (Lopez-Bellido *et al*., 2008). Genotypic differences in growth and yield of cowpea has been reported (Ankomah *et al*., 1995).

2.5 Influence of P on growth and yield

Magani and Kuchinda (2009) in assessing effect of phosphorus fertilizer on growth, yield and crude protein content of cowpea in Nigeria reported that plant height increased with increasing level of phosphorus compared to the control but was not statistically significant. This is in contrasts with Rajput (1994) and Sharma *et al. (*2002) on cowpea and soybean respectively, that increasing levels of phosphorus up to 60 kg ha^{-1} significantly improved plant height.

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According to Marie-Hrlbne and Bertrand (1997), number of branches in leguminous plants is highly variable, and is an important determinant of grain yield. Branching is also strongly influenced by environmental conditions such as soil physical conditions or soil water status. Environmental conditions can modify the contributions of branches to final yield. Rajput (1994) reported significant effect of phosphorus on number of leaves per plant particularly at 50 kg ha^{-1}. Magani and Kuchinda (2009) observed that phosphorus addition increased branching in cowpea in the range of 2.2 - 15.1 branches per plant but was not consistent statistically. They also indicated that application of phosphorus increased number of leaves per plant in the range of 22.9 – 297.8 but was not consistent statistically.

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Dwivedi *et al.* (1997) observed that phosphorus influenced crop growth rate and net assimilation rate with maximum attained at 80 kg ha^{-1}. Seyed and Hossein (2011) indicated that relative growth rate and crop growth rate were highly significantly different among phosphorus rates of 0, 35 and 70 kg ha^{-1}.

Egle *et al*. (1999) reported that increasing phosphorus as a fertilizer promotes reproductive yields and inflorescence production (Besmer and Koide, 1999), particularly when phosphorus is limiting in natural systems (Feller, 1995). Conversely, limitation of phosphorus supply has been shown to decrease the production of floral structures (Ma *et al*., 2001). Phosphorus deficiency can delay blooming and maturity as reported by Sison and Margate (1981) that phosphorus applied singly in cowpea shortened the time from planting to harvesting of green pods and hastened maturity.

Okeleye and Okelana (1997) observed significant increase in nodulation, grain yield, total dry matter, number of flower, pods and seed per plant for cowpea varieties in response to phosphorus application. Owolade *et al.* (2006) reported that application of higher doses of phosphorus significantly increased the number of pods/plants with the highest number of pods (75.1) obtained when the crop received 120 kg ha^{-1} of phosphorus fertilizer whilst Singh *et al*. (2011) indicated that cowpea showed significant response to applied phosphorus on pods per plant with highest response to the application of 60 kg ha^{-1}. According to Mokwunye and Bationo (2002), phosphorus is essential for photosynthesis, pod development and grain filling in leguminous crops.

Rajput (1994) observed that application of 50 kg ha^{-1} had significant effect on number of seeds per pod. Owolade *et al.* (2006) reported that application of higher doses of phosphorus significantly increased the number of seeds per pods on cowpea with control giving 12.6 seeds per pod and other treatments such as 30, 60, 90 and 120 kg ha^{-1} resulting in 12.8, 14.2, 16.8 and 16.9 seeds per pod respectively.

Rajput (1994) observed no significant effect of phosphorus application on mean seed weight (1000-seed weight) which contrasts the findings of Singh *et al*. (2011) who indicated that cowpea showed significant response to applied phosphorus on 100-seed weight with highest response to the application of 60 kg ha^{-1}.

Agboola and Obigbesan (1977) showed that 30 kg ha^{-1} was the optimum rate of phosphorus application for maximum grain yield of cowpea. Similarly, Tenebe *et al.* (2000) reported that although grain yield increased with increasing P-levels, there was no accruing yield advantage if cowpea was fertilized with 40 kg ha^{-1} and beyond. But Singh *et al*. (2011) indicated that cowpea showed significant response to applied phosphorus on grain yield with highest response to the application of 60 kg ha^{-1}. Uarrota (2010) also stated that yield was positively affected by a linear increase in phosphorus with the maximum yield 900 kg ha^{-1} achieved when 40 kg ha^{-1} was applied.

Bationo *et al.* (2000) indicated that application of phosphorus fertilizers can triple cowpea stover production whilst Singh *et al*. (2011) reported highest response of stover yield to the application of 60 kg ha^{-1}. Olaleye *et al.* (2012) found that the total cowpea biomass was significantly ($p < 0.001$) influenced by the application of phosphorus.

Singh *et al*. (2011) indicated that P does not have significant influence on the harvest index of the crop implying that harvest index is a genetic trait and will only be influenced by varietal differences in the range of 36 % to 40 % which contrasts the findings of Malagi (2005) that harvest index differed significantly due to different levels of fertilizers with the lowest harvest index noticed with highest dose of fertilizer (NPK).

2.6 Influence of P on nodulation parameters

Tewari (1965) indicated that increasing levels of nitrogen depressed the formation of both effective and ineffective nodules, but phosphorus did not produce any significant effects. Ssali and Keya (2012) reported that application of phosphorus increased nodule mass and nitrogen fixation at all the three stages (i.e. flowering, pod-filling, and physiological maturity) but the effects of phosphorus were more pronounced at the flowering and pod filling stages. According to Magani and Kuchinda (2009) phosphorus increases nodulation in cowpea whilst Fatokun *et al.* (2002) observed that P fertilizer significantly enhanced nodule dry weights of the cowpea but nodule number was depressed by phosphorus which contrasts Siddiqui *et al.* (2007) that before developing nodules, cowpea depends on phosphorus, which not only helps seedling growth but also aids early nodulation, leading to optimum growth and biomass production. The beneficial effect of phosphorus supply is caused by a strong stimulating effect on nodulation and nitrogen fixation capacity of leguminous plant. Genotypic differences in the effects of phosphorus on nodulation has been reported by (Ankomah *et al*., 1995).

The establishment and maintenance of an effective symbiosis depends on several factors of which a favorable environment, that will allow maximum nitrogen fixation, is extremely important (Singleton, *et al*., 1982). Several environmental factors such as soil pH, soil fertility, temperature extremes impose limitations on the symbiotic association between the host plant and microsymbiont (Van-Wyk, 2003). Furthermore, the amount of nitrogen fixed by symbionts is variable; depending on the host legume, cultivar, presence of saturated or near-saturated soil water for movement, soil texture and composition, bacterial species and growing conditions - especially pH and the presence of soil nitrogen (Gardner *et al*., 1985).

Rhizobial activities and nitrogen fixation without proper fertilization by phosphorus is depressed because it promotes early root formation and the formation of lateral, fibrous and healthy roots. Leguminous crops meet their nitrogen requirement through biological nitrogen fixation depending on proper growth, development and also leghemoglobin content of the root nodules. It is reported that phosphorus is effectively translocated into grain at high rates, since phosphorus is necessary for the production of protein, phospholipids and phytin in bean grain (Rahman *et al*., 2008). In particular, phosphorus appears essential for both nodulation and nitrogen fixation. Nodules are strong sinks for phosphorus and range in phosphorus content from 0.72 to 1.2 %; as a consequence, nitrogen fixation-dependent plants will require more of this element. Nodulation, nitrogen fixation, and specific nodule activity are directly related to the P supply (Zahran, 2000).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Experimental site

The experiments were conducted at the Plantation Section of the Crop and Soil Sciences Department, Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, from June to August 2012 and repeated from October to December 2012. Kumasi is situated in the semi-deciduous forest vegetational zone of Ghana. It is about 356m above sea level on latitude 06° 43'N and longitude 01° 33'W. The soil at the experimental site is well drained, sandy loam overlying reddish-brown and gravelly light clay. It belongs to the Kumasi series, Ferric Acrisol developed over deeply weathered granite rocks (Asiamah, 1998).

3.2 Weather conditions

The rainfall is bimodal with an average annual rainfall of 1422.40 mm for the experimental year (Appendix 1). The major rainy season extends from mid-March to July, with a short dry period in August, while the minor rainy season extends from September to November. The main dry season also extends from late November to mid-March. Annual average maximum and minimum temperatures for the year were 31.58 °c and 22.08 °c respectively (Appendix 1). The annual average relative humidity varied from 83.75 % (09 hours GMT) and 58.83 % (15 hours GMT). Average annual sunshine duration was 4.94 hours (Appendix 1).

The data on rainfall, temperature (maximum and minimum), relative humidity (at 0900 and 1500 GMT) and sunshine duration that prevailed during the cropping seasons are presented in Table 3.1.

Table 3.1: Meteorological data during the cropping seasons in the year 2012

Weather Condition		Major Season (June to August)	Minor season (October to December)
Total Rainfall (mm)		431.5	282.8
Mean Daily Temperatures (^oC)	Maximum	28.87	32.10
	Minimum	21.23	22.37
Relative Humidity (%)	0900 GMT	76.67	83.33
	1500 GMT	49.67	58.33
Sunshine Duration (Hours)		3.17	6.43

(Meteorological station, KNUST, 2012)

3.3 Soil characteristics

Soil samples were taken randomly from the experimental site to a depth of 0 – 15 and 15 – 30 cm. These samples were taken to the laboratory to determine their chemical properties. The samples were dried and sieved using a 2 mm mesh and the following properties determined.

3.3.1 Organic carbon

Modified Walkley and Black wet oxidation method (Allison, 1965) was used to determine organic carbon.

3.3.2 Organic matter

Percent organic carbon was multiplied by 1.724 (The Van Bemmelen factor) to get percent organic matter.

3.3.3 Soil pH

This was measured in 1:2.5 soils to water suspension by the use of a pH meter (Piper, 1966).

3.3.4 Total nitrogen

The Modified Kjeldahl method described by Jackson (1967) was used. A 10 g soil sample (< 2 mm in size) was digested with a mixture of 100 g potassium sulphate, 10 g copper sulphate and 1g selenium with 30ml of concentrated sulphuric acid. This was followed by distillation with 10 ml boric acid (4 %) and 4 drops of indicator and 15 ml of 40 % NaOH. It was then titrated with ammonium sulphate solution. Based on the relation that 14 g of nitrogen is contained in one equivalent weight of NH_3, the percentage of nitrogen in the soil was calculated using the formula:-

$$\text{Total N in the sample} = \frac{14\,(A-B) \times N \times 100}{1000 \times W}$$

where,

A = Volume of standard acid used in the titration.

B = Volume of standard acid used in blank titration.

N = Normality of the standard acid.

W = Weight of soil sample used.

3.3.5 Available phosphorous

The Bray-1 test method was used for the determination of phosphorus with dilute acid fluoride as the extractant (Jackson, 1967).

3.3.6 Exchangeable bases (Ca, Mg, K, Na)

The exchangeable base cations were extracted using ammonium acetate at pH of 7.0. Calcium and Magnesium were determined using the Ethylene Diamine Tetraacetic Acid (EDTA) titration method (Heald, 1965) while potassium and sodium were determined by the flame photometer method.

3.4 Experimental details

3.4.1 Treatment details

The experiment consisted of 3 cowpea varieties (Factor A) with four levels of P fertilizer (Factor B) using triple super phosphate (46 % P_20_5).

The cowpea varieties were:

Asetenapa (IT81D-1951)	-	V_1
Asomdwee **(**IT94K-410-2)	-	V_2
IT89KD-347-57	-	V_3

Levels of P

0 kg P_2O_5 ha^{-1}	-	P_0 (Control)
20 kg P_2O_5 ha^{-1}	-	P_1
40 kg P_2O_5 ha^{-1}	-	P_2
60 kg P_2O_5 ha^{-1}	-	P_3

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3.4.2 Design and layout of experiment

The design was a 3×4 factorial arrangement laid out in a randomized complete block design (RCBD) with four replications. There were 48 plots, each measuring 3×5 m with 1m between blocks and 0.5 m between plots within a block and 1m between replications. Field layout is presented in Figure 3.1.

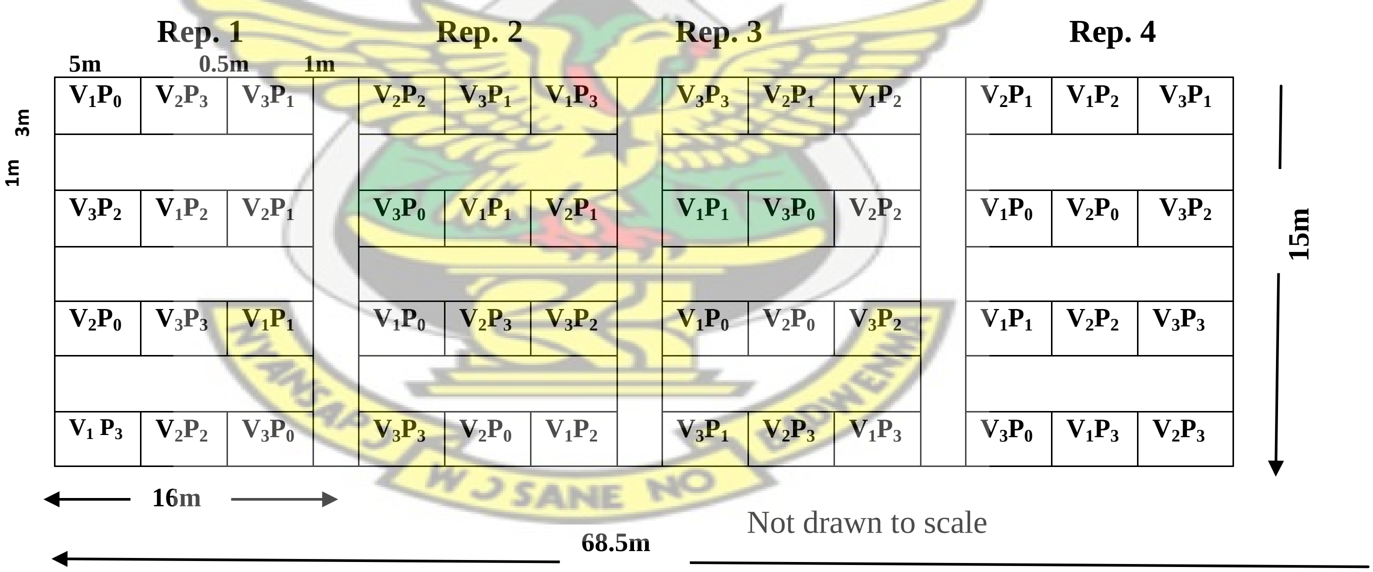

Fig. 3.1: Field layout for 3×4 factorial in RCBD experiment

Plate 3.1: General view of experimental plot at 20 DAP

Plate 3.2: General view of experimental plot at 45 DAP

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Plate 3.3: General view of experimental plot at 60 DAP

3.4.3 Source of planting materials

Seeds of cowpea were obtained from the Legumes and Oil Seed Improvement Division, Crop Research Institute (CRI) of the Council for Scientific and Industrial Research (CSIR), Fumesua - Kumasi. The characteristics of the varieties are given in Table 3.2.

Table 3.2: Characteristics of the varieties for the experiments:

Characteristics	Asetenapa[1]	Asomdwee[1]	IT89KD-347-57[2]
Origin of line	IITA, Nigeria	IITA, Nigeria	IITA, Nigeria
Genotype	IT81 D-1951	IT94-410-2	IT89KD-347-57
Maturity (days)	63-70	65-72	70
Growth habit	Erect	Semi-erect	Erect
Yield potential (kg/ha)	2500	2900	2000
Other features	Fairly resistant/ tolerant to insect-pests and diseases	Moderately tolerant to *Cercospora* leaf spot and other important diseases and moderately tolerant to insect-pests especially thrips	Aphids resistance and precocity (the ability to induce fruitfulness without the need for completing the juvenile phase)

(Source: CSIR – CRI[1] and http//expeng.msu.edu- Arega Cowpeas Africa sheet[2])

3.5 Agronomic operations

3.5.1 Land preparation

The land was previously cropped to maize, okro and groundnuts. The site for the experiment was manually cleared by slashing, and ploughing and harrowing with a tractor. The land was then levelled and the plots laid out.

3.5.2 Germination test and planting

Germination test was done on 100 seeds randomly selected from each variety before planting. Asetenapa, Asomdwee and IT89KD-347-57 gave 96, 95 and 97 per cent

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respectively. The seeds were planted at 4 to 5 cm deep with 60 cm for inter row spacing and 20 cm for intra-row spacing at 3 seeds per hill which was thinned to 2 stands per hill at 14 days after planting (DAP), corresponding to a population density of 166,666 plants per hectare.. The major season planting was done on June 8, 2012 whilst the minor season's was done on October 3, 2012.

3.5.3 Fertilizer application

Fertilizer rate was calculated as mass of fertilizer (g) /plot and the amount per plot divided by 9 rows to get the amount applied per row. Fertilizer was applied by side band placement method at 21 DAP for both experiments.

$$\text{Mass of fertilizer (g) /plot} = \frac{\left(\frac{\text{Mass of nutrient recommended (kg) /ha}}{\text{Analysis of fertilizer (\%)}}\right) \times 1000\text{ g} \times \text{plot size (m}^2\text{)}}{10000\text{ m}^2}$$

For instance 20 kg P_2O_5 ha^{-1} was calculated as

$$\text{Mass of fertilizer (g) /plot} = \frac{\left(\frac{20\text{ kg } P_2O_5\text{ ha}^{-1}}{46/100}\right) \times 1000\text{ g} \times 15\text{ m}^2}{10000\text{ m}^2}$$

$$= 65.22\text{ g per plot}$$

$$\text{Mass of fertilizer (g) / row} = \frac{\text{Mass of fertilizer (g) /plot}}{\text{No. of rows per plot}}$$

$$= \frac{65.22\text{ g}}{9}$$

$$=7.25 \text{ g / row}$$

$$\text{Mass of fertilizer (g) / hill} = \frac{\text{Mass of fertilizer (g) /row}}{\text{No. of hills per row}}$$

$$= \frac{7.25 \text{ g/row}}{15}$$

$$= 0.48 \text{ g/hill}$$

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The same method was repeated for 40 and 60 kg P_2O_5 ha^{-1}

3.5.4 Weed control

At 32 DAP, one manual weeding using hoe was carried out to keep plot free from weeds.

3.5.5 Pest and disease control

For both experiments, four sprayings were carried out using Cymetox Super EC (a.i cypermethrin 30 g/l and dimethoate 250 g/l) at 30, 40, 50 and 60 DAP at the rate of 30, 30, 90 and 90 ml/15litres water knapsack sprayer respectively (as outlined by CSIR - CRI, Agra Cowpea Demonstration/ Field Trial Guide, 2012).

3.6 Data collection

3.6.1 Vegetative growth

Samplings for growth (vegetative) analysis for both experiments started on 30, 45 and 60 DAP. Five plants within the inner rows were tagged at random in a diagonal direction from each plot for observations and recording on various growth parameters.

3.6.1.1 Plant height

The plant height was measured from the ground level to the highest tip of the stem at 30 and 45 DAP for the five plants tagged. This was done with the use of a meter rule at the various sampling periods. The average plant height was calculated for each treatment.

3.6.1.2 Number of primary branches per plant

Number of branches on the main stems of the five tagged plants on each plot was counted and mean value was estimated and expressed as number of primary branches per plant for each plot.

3.6.1.3 Number of leaves per plant

Number of leaves borne on each plant was counted and mean value calculated and expressed as number of leaves per plant.

3.6.1.4 Leaf Area (LA)

The leaf area was estimated by the disc method on dry weight basis at different growth stages of 30, 45 and 60 DAP as per the procedure suggested by Watson (1952). Leaves on five plants sampled for dry matter distributions were stripped, weighed and sample of stripped leaves was taken and oven dried at 80 ^{0}C for 48 hrs and weighed (X g). Fifty leaf discs of fresh leaves were taken using a 1.0cm diameter cork borer and oven dried at 80 ^{0}C for 48 hrs and weighed as (Y g). By using ratio and proportion, dried weight of fresh leaves sample was used to calculate the total leaf dry weight. Using the known diameter of the cork borer, the area of each leaf disc was calculated using the formula for calculating area of circle (πr^2). The leaf area was calculated by the following formula and the mean of five plants was expressed in cm^2 per plant.

$$LA = \frac{\text{Total leaf dry weight}}{\text{Disc dry weight}} \times \text{Total disc area}$$

3.6.1.5 Leaf Area Index (LAI)

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Leaf area index (LAI) was determined from LA using instantaneous approach at 30, 45 and 60 DAP. This was done by calculating number of plants per square meter of land (16 plants). Leaf Area Index was deduced using the equation below:

$$LAI = \frac{\text{Leaf Area of number of plants /m}^2}{1\text{m}^2 \text{ of land}}$$

3.6.1.6 Dry matter production and distribution

Five randomly selected plants from destructive sampling area at 30, 45 and 60 DAP were used for dry matter production and distribution. The sampled plants were separated into leaves, petioles, branches, stem and reproductive parts. Each part was put in labelled envelopes and oven dried at 80 ^{0}C for 48hrs. The average dry weight (DW) of each part was computed as dry matter per plant. Average total dry matter production per plant was calculated from the summation of DW in each part separated.

3.6.1.7 Growth functions and analysis

3.6.1.7.1 Crop Growth Rate (CGR) was calculated using the formula (Radford, 1967):

$$CGR = \frac{W_2 - W_1}{T_2 - T_1} \text{ (g m}^{-2} \text{ day}^{-1}\text{)}$$

where W_1 and W_2 were total dry weight (above ground) at sampling periods T_1 and T_2 respectively.

3.6.1.7.2 Relative Growth Rate (RGR) = $\frac{\ln W_2 - \ln W_1}{T_2 - T_1}$ ($g\ g^{-1}\ day^{-1}$)

where W_1 and W_2 were total dry weight (above ground) at sampling periods T_1 and T_2 respectively (Harper, 1983).

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3.6.1.7.3 Net Assimilation Rate (NAR) was calculated using the formula by Harper, (1983): = $\frac{W_2 - W_1}{T_2 - T_1} \times \frac{\ln LA_2 - \ln LA_1}{LA_2 - LA_1}$ ($g\ m^{-2}\ day^{-1}$)

where W_1 and W_2 were total dry weight (above ground) at sampling periods T_1 and T_2 respectively. LA_1 and LA_2 were leaf areas at sampling periods T_1 and T_2 respectively.

3.6.2 Phenological data

3.6.2.1 Days to 50 % flowering

The number of days taken from planting to 50 per cent flowering of the plants was recorded as days to 50 per cent flowering.

3.6.3 Total biomass (kg/ha)

After harvesting, plants (above ground parts) from the net plot area were allowed to dry to a constant weight, recorded and converted to kg per ha.

3.6.4 Yield and yield components

For both experiments, at physiological maturity when about 85 % of pods had turned brown (Dugje *et al.*, 2009) and more than 75 % of leaves had senescenced. One square meter area of plants from the central rows on each plot was harvested for the yield analysis. From this harvested area, 16 plants were sampled for number of pods per plant, number of seeds per pod, 100-seed weight, the seed yield and total biomass per square meter, and finally harvest index was computed.

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3.6.4.1. Number of pods per plant

Five plants were taken from each plot (harvested area). All the pods were counted and the average number of pod per plant calculated.

3.6.4.2 Number of seeds per pod

The number of seeds per pod was determined by taking five randomly selected plants from each plot. Pods were shelled, seeds counted and the average number of seeds per pod for each plot calculated.

3.6.4.3 Hundred-seed weight (g)

Hundred-seed weight was determined by randomly counting 100-seed from the threshed and oven dried seeds from each plot. These were weighed to represent the 100-seed weight.

3.6.4.4 Seed yield (kg/ha)

Seed yield per hectare was determined by threshing the harvested plants from the central one square meter of each plot. These were put in labelled envelopes, oven dried at 80 ^{O}C for 48 hours, and then weighed. The resulting weights, in grams per meter square were then extrapolated to kg per ha basis to get the average seed yield per hectare.

3.6.4.5 Harvest Index (HI)

Harvest index was calculated by using the formula suggested by Donald (1963) and expressed as a percentage.

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$$\text{Harvest Index} = \frac{\text{Economic yield}}{\text{Total biological yield (Above ground part)}} \times 100\ \%$$

where economic yield is seed yield whilst the total biological yield is the summation of total biomass and seed yield plus pod chaff.

3.6.5 Nodulation parameters

3.6.5.1 Number of nodules and effective nodules per plant

The plants to be uprooted were watered up to saturation point. The five plants used for dry matter production and distribution were then uprooted and the root system washed by keeping them in a bucket containing water. The nodules were then separated and counted and expressed in per plant basis at 45 DAP. Nodules were cut open to determine apparent effectiveness, using a razor blade and hand lens. Nodules with pink or reddish colour were considered effective and fixing nitrogen, while those with green or colourless were recorded as ineffective nodules.

3.6.5.2 Dry weight of nodules per plant

Nodules (effective and ineffective) per plot were kept in labelled envelops and sent to the laboratory to oven dry at 80 ^{0}C for 48hrs. Average dry weight of nodules per plant was computed and expressed in grams.

3.7 Statistical analysis

The data recorded were subjected to Analysis of Variance (ANOVA) using GenStat statistical package 9th edition. Treatment means were compared using the Least significant difference (Lsd) at 5 % level of probability. Simple charts were drawn using Ms excel 2010 edition.

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CHAPTER FOUR

4.0 RESULTS

4.1 Soil characteristics

Table 4.1 shows the results of soil chemical analysis of the soil at the experimental site.

Table 4.1: Results of soil characteristics of experimental site

Chemical Properties	Value		Remarks
	Horizon		
	0-15cm	15-30cm	
Organic Carbon (%)	0.72	0.50	Very low#
Organic Matter (%)	1.24	0.86	Very low #
Soil pH(1:2.5 Soil: Water)	5.57	5.50	Moderately acidic*
Total N (%)	0.11	0.08	Low*
Available P ($mgKg^{-1}$)	5.65	5.22	Low*
Exchangeable bases ($cmolkg^{-1}$)			
K	0.16	0.09	Very low*
Ca	2.00	2.80	Low*
Na	0.38	0.37	Moderate*
Mg	1.00	0.80	Low*

* Pam and Brian (2007)
# Hill Laboratories, Technical note

The soil at depth 0 - 15 cm and 15 -30 cm was moderately acidic and low in organic matter (Table 4.1). The macro elements were below the critical levels required for the proper growth and development of cowpea (Aune and Lai, 1995). This indicates that the soil was depleted.

4.2 Vegetative growth

4.2.1 Plant height

The results of plant height recorded at 30 and 45 DAP are presented in Table 4.2.

Plant height differed significantly ($p < 0.05$) among the varieties at 30 and 45 DAP for both seasons. Asomdwee recorded significantly highest plant height of 28.8 cm at 30 DAP and 117.7 cm at 45 DAP for the major season. Again in the minor season, Asomdwee had a height of 31.6 cm at 30 DAP and 41.9 cm at 45 DAP. This was followed by Asetenapa whereas IT89KD-347-57 recorded the least plant height at both seasons.

Phosphorus fertilizer application did not influence ($p > 0.05$) plant height at both seasons and sampling periods except at 45 DAP during the major season, where the effect of 20 kg P_2O_5 ha^{-1} application was significantly higher than the other P rates.

Variety and phosphorus fertilizer application interaction effect on plant height was not significant ($p > 0.05$) for both seasons at all sampling periods.

Table 4.2: Influence of variety and phosphorus fertilizer application on plant height over two sampling periods.

Treatments	Plant height (cm)			
	30 DAP		45 DAP	
	Major Season 2012	Minor Season 2012	Major Season 2012	Minor Season 2012
Varieties				
Asetenapa	26.1	30.4	111.3	40.3
Asomdwee	28.8	31.6	117.7	41.9
IT89KD-347-57	24.2	25.5	84.6	33.7
Lsd (5 %)	3.1	3.1	14.6	4.2
P levels(kg P_2O_5 ha^{-1})				
0	26.5	27.1	96.9	36.0
20	26.9	30.0	123.5	39.7
40	27.2	30.3	105.3	40.2
60	24.9	29.2	92.4	38.7
Lsd (5 %)	NS	NS	16.9	NS
CV (%)	16.1	14.8	19.5	15.0

NS - Non Significant

4.2.2 Number of primary branches per plant

The results of number of primary branches per plant as affected by variety and phosphorus fertilizer application at different growth stages are given in Table 4.3.

The number of primary branches per plant differed significantly ($p < 0.05$) with respect to variety for both seasons and at sampling times. At both seasons and sampling periods, IT89KD-347-57 produced the highest number of primary branches than the other varieties. Treatment effect of Asomdwee was also significantly greater than that of Asetenapa during the major season at 45 and 60 DAP sampling.

Table 4.3: Effect of variety and phosphorus fertilizer application on number of primary branches per plant over three sampling periods

Treatments	Number of primary branches per plant					
	30 DAP		45 DAP		60 DAP	
	Major Season 2012	Minor Season 2012	Major Season 2012	Minor Season 2012	Major Season 2012	Minor Season 2012
Varieties						
Asetenapa	1.3	1.1	1.7	1.1	2.0	1.1
Asomdwee	1.6	1.4	2.4	1.5	2.7	1.5
IT89KD-347-57	2.5	2.4	3.3	2.6	3.6	2.7
Lsd (5 %)	0.3	0.3	0.3	0.4	0.3	0.4
P levels(kg P_2O_5 ha^{-1})						
0	1.7	1.4	2.3	1.5	2.6	1.5
20	1.8	1.6	2.4	1.7	2.8	1.7
40	1.9	1.6	2.5	1.7	2.8	1.7
60	2.0	1.9	2.6	2.1	2.9	2.1
Lsd (5 %)	NS	NS	NS	NS	NS	NS
CV (%)	20.9	28.6	15.7	28.3	14.1	29.0

NS – Non Significant

The number of primary branches per plant did not differ significantly ($p > 0.05$) with phosphorus fertilizer application.

The interaction of variety and phosphorus fertilizer application was not significant ($p > 0.05$) on number of primary branches per plant at the different seasons and sampling times.

4.2.3 Number of leaves per plant

Table 4.4 shows the number of leaves per plant as influenced by various treatments over three sampling periods. The number of leaves per plant differed significantly ($p < 0.05$) with variety at all sampling times. The IT89KD-347-57 consistently produced the highest number of leaves over the other varieties which produced similar number of leaves at all times.

The number of leaves per plant did not differ significantly ($p > 0.05$) by phosphorus application.

Variety and phosphorus interaction on number of leaves per plant was not significant ($p > 0.05$) at the different seasons and sampling times.

Table 4.4: Effect of variety and phosphorus fertilizer application on number of leaves per plant over three sampling periods.

Treatments	Number of leaves per plant					
	30 DAP		45 DAP		60 DAP	
	Major Season 2012	Minor Season 2012	Major Season 2012	Minor Season 2012	Major Season 2012	Minor Season 2012
Varieties						
Asetenapa	11.5	13.3	28.1	16.2	21.5	18.2
Asomdwee	11.5	12.8	28.4	15.6	24.2	17.5
IT89KD-347-57	13.6	16.7	34.1	21.5	29.7	24.2
Lsd (5 %)	1.45	2.60	3.7	2.6	3.7	2.9
P levels(kg P_2O_5 ha^{-1})						
0	10.9	13.3	27.3	16.1	22.1	18.2
20	12.2	14.7	29.8	17.8	24.7	20.0
40	12.4	13.5	30.7	18.1	25.8	20.4
60	13.4	15.6	32.9	19.0	27.8	21.4
Lsd (5 %)	NS	NS	NS	NS	NS	NS
CV (%)	16.9	25.3	17.1	20.0	20.3	19.9

NS – Non Significant

4.2.4 Leaf Area (LA)

Results of leaf area per plant recorded at different growth stages are shown in Table 4.5. At the sampling periods and for both seasons, varietal effect on leaf area was significant ($p < 0.05$) except at 30 DAP for both seasons. At 45 DAP during both seasons; Asomdwee and Asetenapa recorded statistically similar LA which was significantly higher than that of IT89KD-347-57. Asomdwee and Asetenapa produced statistically similar LA which was significantly lower than the effect of IT89KD-347-57 during the minor season. However, in the major season, effects of both Asetenapa and IT89KD-347-57 were significantly lower than that of Asomdwee.

The leaf area did not differ significantly (*p > 0.05*) by phosphorus fertilizer application at all the sampling times and seasons.

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Table 4.5: Variety and phosphorus fertilizer application effect on leaf area over three sampling periods

Treatments	Leaf Area (cm^2)					
	30 DAP		45 DAP		60 DAP	
	Major Season 2012	Minor Season 2012	Major Season 2012	Minor Season 2012	Major Season 2012	Minor Season 2012
Varieties						
Asetenapa	769.27	971.24	1116.00	1089.04	1511.65	1171.54
Asomdwee	862.19	1083.95	1252.00	1151.83	1731.22	1224.17
IT89KD-347-57	814.71	1217.29	960.00	1415.56	1241.11	1535.06
Lsd (5 %)	NS	NS	151.50	233.99	326.88	234.45
P levels(kg P_2O_5 ha^{-1})						
0	790.92	973.39	1060.00	1072.62	1381.50	1141.93
20	944.64	1288.88	1228.00	1326.44	1395.11	1361.61
40	735.45	1068.69	1011.00	1227.54	1405.08	1307.88
60	790.54	1032.34	1139.00	1248.65	1796.95	1429.61
Lsd (5 %)	NS	NS	NS	NS	NS	NS
CV (%)	23.1	28.5	19.0	26.7	30.4	24.9

NS – Non Significant

4.2.5 Leaf Area Index (LAI)

Results of leaf area index as affected by variety and phosphorus fertilizer application are presented in Table 4.6. During the sampling periods and for both seasons, varietal effect on leaf area index was significant ($p < 0.05$) except at 30 DAP for both seasons. However, at 45 DAP during the major season, Asetenapa and Asomdwee recorded statistically similar LAI but effect of either was significantly higher than that of IT89KD-347-57. In the minor season, Asetenapa and Asomdwee recorded statistically similar LAI but effect of the latter was significantly lower than that of IT89KD-347-57. At 60 DAP during major season, Asomdwee produced statistically greater LAI than that of IT89KD-347-57 only, whilst in the minor season, the effect of IT89KD-347-57 was significantly greater than that of Asetenapa only.

The leaf area index did not differ significantly ($p > 0.05$) with phosphorus fertilizer application at all the sampling times and seasons.

The interaction of variety and phosphorus fertilizer application was not significant ($p > 0.05$) on leaf area index at the different seasons and sampling times.

Table 4.6: Influence of variety and phosphorus fertilizer application on leaf area index over three sampling periods

Treatments	Leaf area index					
	30 DAP		**45 DAP**		**60 DAP**	
	Major Season 2012	Minor Season 2012	Major Season 2012	Minor Season 2012	Major Season 2012	Minor Season 2012
Varieties						
Asetenapa	1.23	1.55	1.79	1.74	2.42	1.87
Asomdwee	1.38	1.73	2.00	1.84	2.77	1.96
IT89KD-347-57	1.31	1.95	1.54	2.26	1.99	2.46
Lsd (5 %)	NS	NS	0.24	0.37	0.52	0.38
P levels(kg P_2O_5 ha^{-1})						
0	1.27	1.56	1.70	1.72	2.21	1.83
20	1.51	2.06	1.96	2.12	2.23	2.18
40	1.18	1.71	1.62	1.96	2.25	2.09
60	1.26	1.65	1.82	2.00	2.88	2.29
Lsd (5 %)	NS	NS	NS	NS	NS	NS
CV (%)	23.1	28.5	19.0	26.7	30.4	24.9

NS – Non Significant

4.2.6 Total (shoot) dry matter production (TDM)

Table 4.7 shows result of variety and phosphorus fertilizer application on total (shoot) dry matter production per plant. Total (shoot) dry matter produced per plant was significantly ($p < 0.05$) affected by cowpea variety on all sampling occasions and seasons. During the major season at 30 DAP, TDM of Asetenapa (8.86 g $plant^{-1}$) was significantly higher than that of Asomdwee (7.45 g $plant^{-1}$) and IT89KD-347-57 (8.02 g

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plant^{-1}) at 30 DAP. In the major season at 45 and 60 DAP, TDM of Asomdwee (14.84 and 19.41 g plant^{-1}) and IT89KD-347-57 (15.04 and 18.00 g plant^{-1}) were both higher than that of Asetenapa (12.67 and 15.38 g plant^{-1}). During the minor season at 30 and 45 DAP; IT89KD-347-57 (8.09 and 14.64 g plant^{-1}) recorded the greatest than those of the other varieties. However, at 60 DAP TDM was significantly lower in IT89KD-347-57 (15.04 g plant^{-1}) than in other varieties.

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Table 4.7: Effect of variety and phosphorus fertilizer application on total (shoot) dry matter production over three sampling periods

Treatments	Total (shoot) Dry Matter Production (gplant^{-1})					
	30DAP		45DAP		60DAP	
	Major Season 2012	Minor Season 2012	Major Season 2012	Minor Season 2012	Major Season 2012	Minor Season 2012
Varieties						
Asetenapa	8.86	6.83	12.67	13.05	15.38	18.39
Asomdwee	7.45	6.93	14.84	13.45	19.41	18.50
IT89KD-347-57	8.02	8.09	15.04	14.64	18.00	15.04
Lsd (5%)	0.83	0.69	1.27	0.81	1.51	0.96
P levels($kgP_2O_5ha^{-1}$)						
0	7.65	7.18	13.82	13.35	16.85	16.86
20	7.97	7.39	14.52	13.78	17.62	17.37
40	8.14	7.19	14.29	13.80	17.50	17.33
60	8.67	7.36	14.09	13.93	18.42	17.67
Lsd (5%)	NS	NS	NS	NS	NS	NS
CV (%)	14.1	13.2	12.4	8.2	11.9	7.8

NS – Non significant

Phosphorus fertilizer application had no significant effect ($p > 0.05$) on total (shoot) dry matter production at all samplings periods and seasons. On all occasions, treatment effect of 20, 40 and 60 kg P_2O_5 ha^{-1} produced higher dry matter than the control

(0 kg P_2O_5 ha^{-1}).

4.2.7 Dry matter accumulation

4.2.7.1 Dry matter accumulation in the varieties

Figures 4.1a to 4.3b depict dry matter partitioning in the varieties. Generally, between 30 to 45 DAP dry matter (DM) accumulation in the leaf and stem increased for both seasons. However, there was a greater accumulation in stem than in leaf. For all the sampling periods in the major season, Asetenapa partitioned greatest DM in leaf followed by IT89KD-347-57 and Asomdwee whilst in the minor season, IT89KD-347-57 recorded the least DM in the leaf followed by Asomdwee and Asetenapa. Between 45 and 60 DAP, there was a decline in DM in the leaf in the major season but the opposite was recorded in the minor season.

From 45 to 60 DAP in both seasons, DM in stem increased but the marginal increase was however, lower compared to the increase from 30 to 45 DAP (Figures 4.1a to 4.3b).

DM accumulation in the reproductive parts in the major season followed in the order of Asomdwee > Asetenapa > IT89KD-347-57. Similar trend was observed in the minor season. DM accumulation in reproductive parts increased with time for both seasons in the varieties.

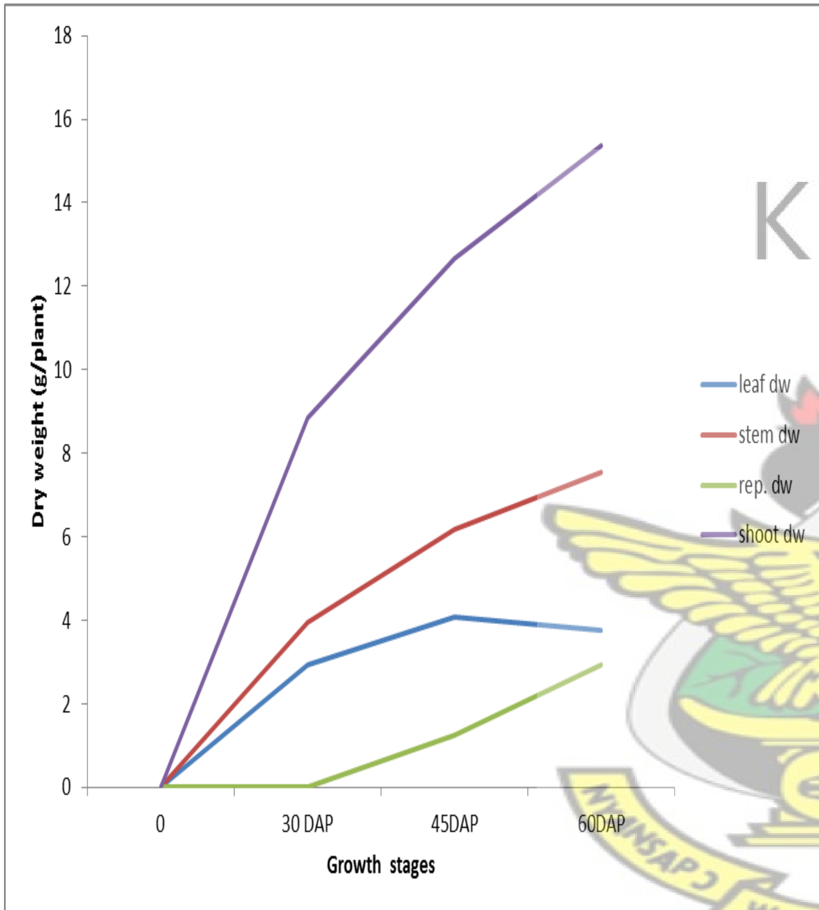

Fig 4.1a: Dry matter production and distribution in Asetenapa variety during the major season

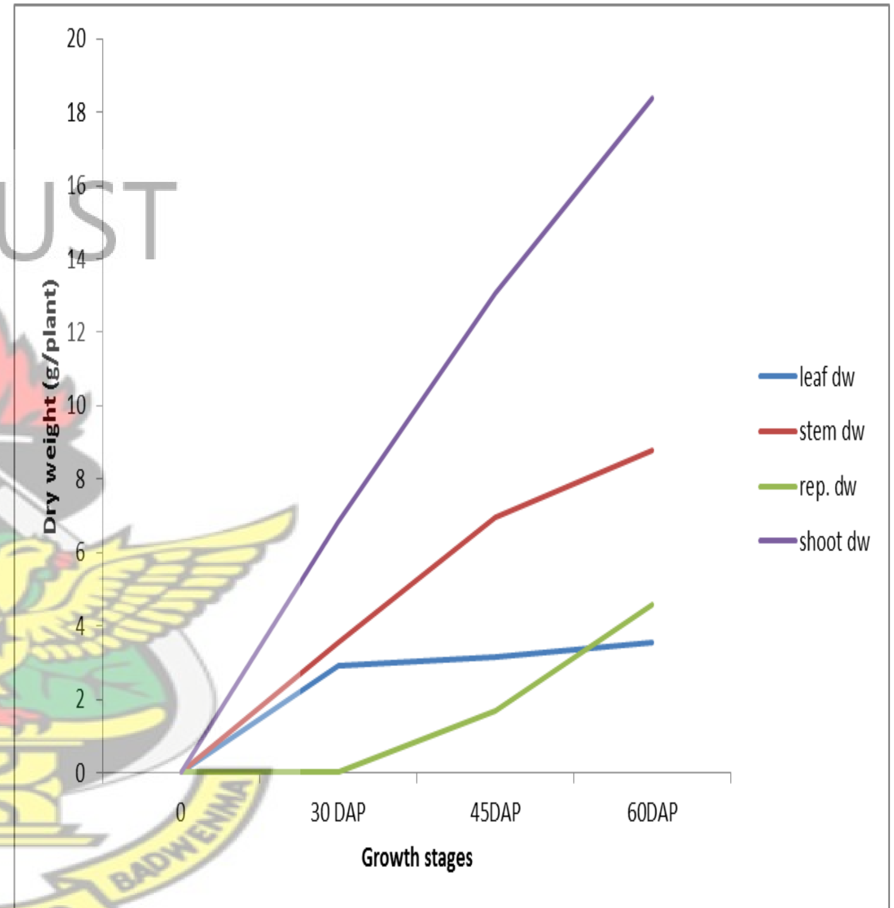

Fig. 4.1b: Dry matter production and distribution in Asetenapa variety during the minor season

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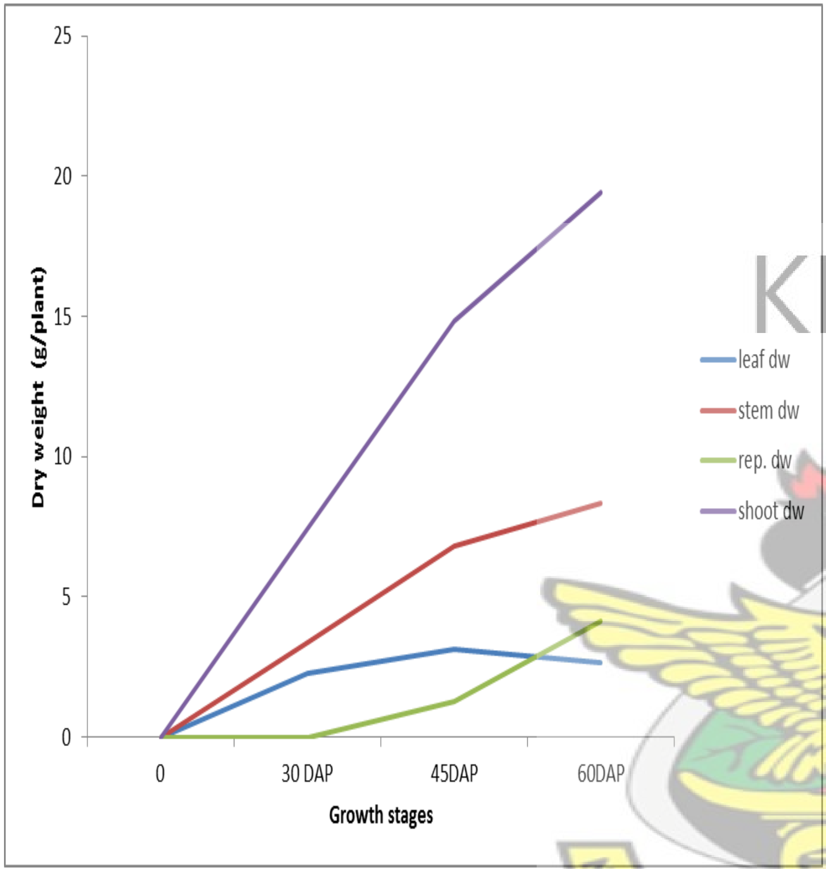

Fig 4.2a: Dry matter production and distribution in Asomdwee variety during the major season

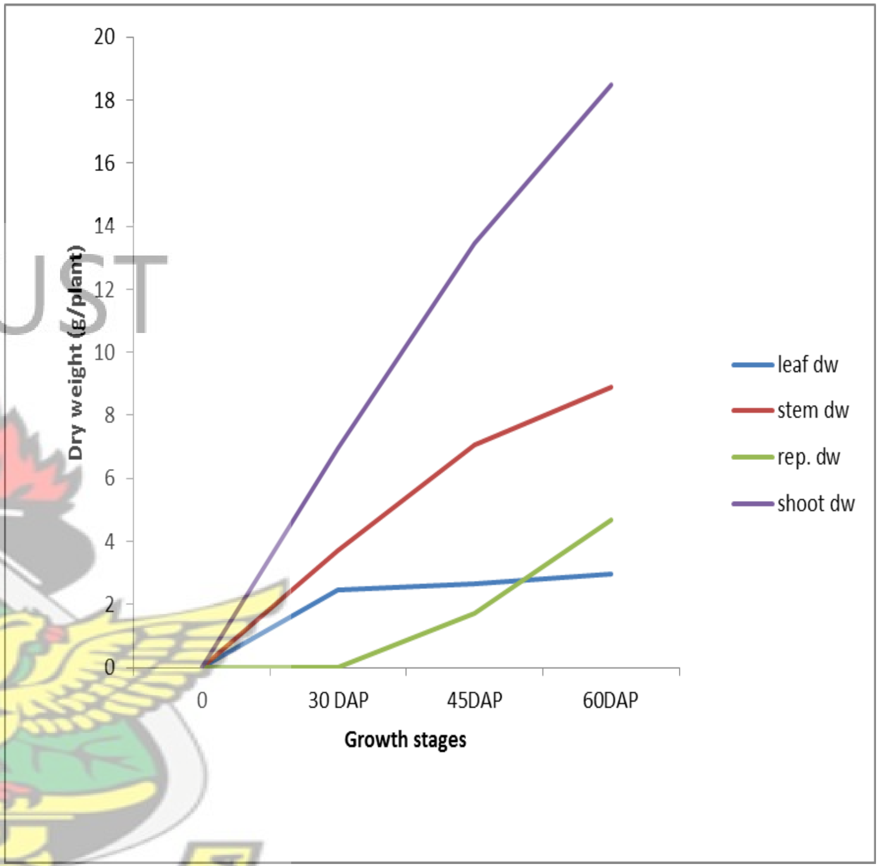

Fig 4.2b: Dry matter production and distribution in Asomdwee variety during the minor season

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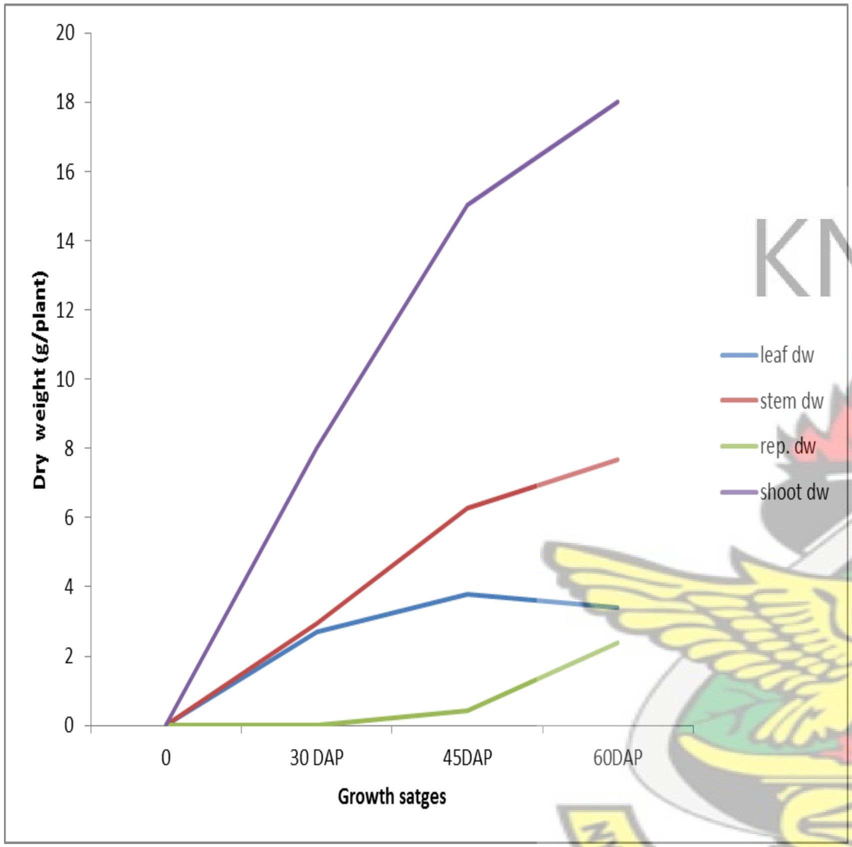

Fig 4.3a: Dry matter production and distribution in IT89KD-347-57 variety during the major season

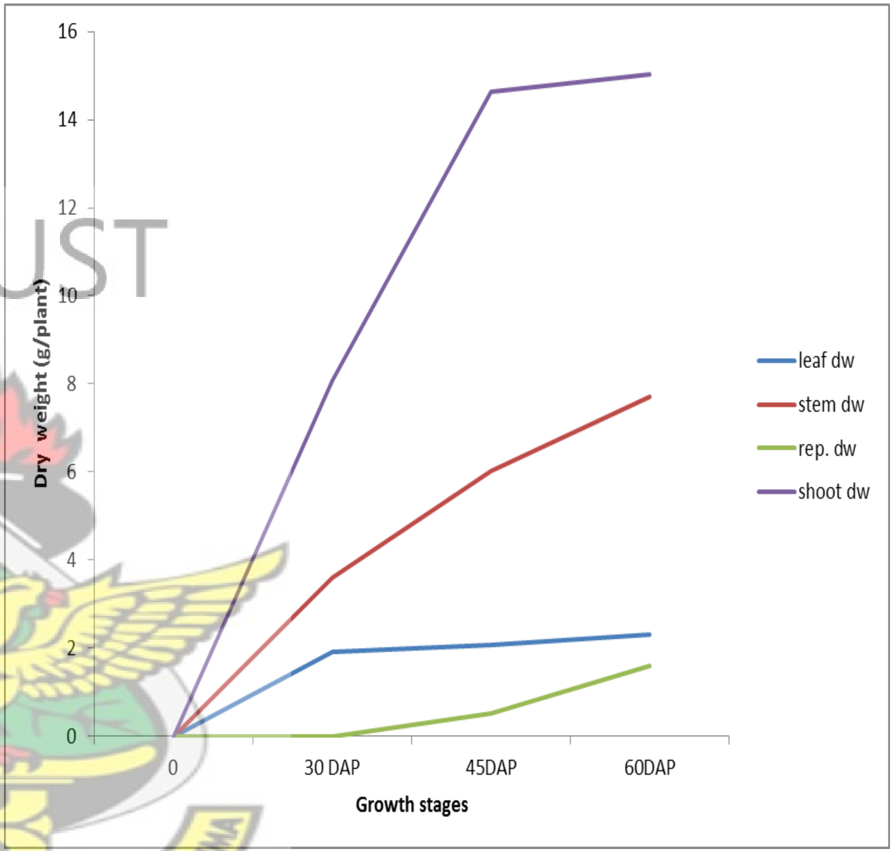

Fig 4.3b: Dry matter production and distribution in IT89KD-347-57 variety during the minor season

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4.2.7.2 Dry matter accumulation as influenced by P fertilizer application

Dry matter (DM) partitioning to leaf, stem and reproductive parts as affected by P fertilizer application is presented in Figures 4.4a and 4.4b. During the major season at all the sampling periods, leaf dry weight increased with P rates. Similar trend was observed in the minor season except between 40 and 60 kg P_2O_5 ha^{-1} rates. There was an increase in DM in leaf from 30 to 45 DAP in both season but contrary observation was made between 45 and 60 DAP.

DM accumulation in the stem was higher in the control (0 kg P_2O_5 ha^{-1}) than in the different P application rates for both seasons. DM in stem increased throughout the sampling periods at both seasons (Figures 4.4a and 4.4b).

DM partitioning to the reproductive parts in the major season was in the order of 60 kg P_2O_5 ha^{-1} > 40 kg P_2O_5 ha^{-1} > 20 kg P_2O_5 ha^{-1} > control (0 kg P_2O_5 ha^{-1}). Similar observation was made in minor season. Furthermore, DM in reproductive parts increased exponentially between 40 and 60 DAP in both seasons.

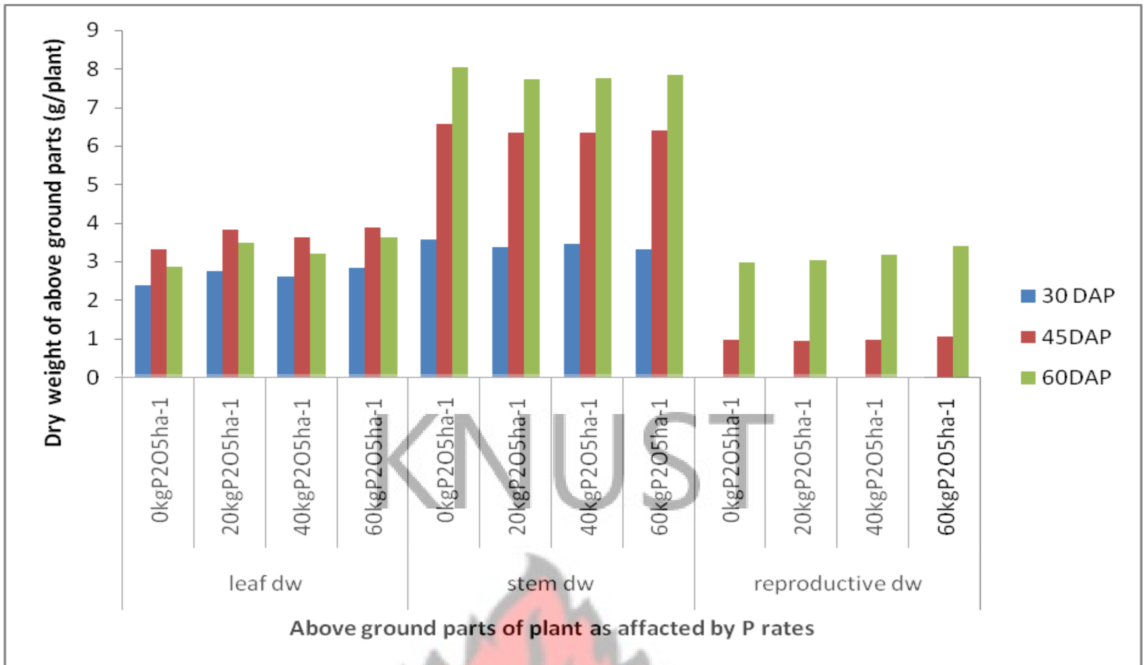

Fig 4.4a: Dry matter accumulation of above ground parts of cowpea plant as affected by P fertilizer rate in the major season

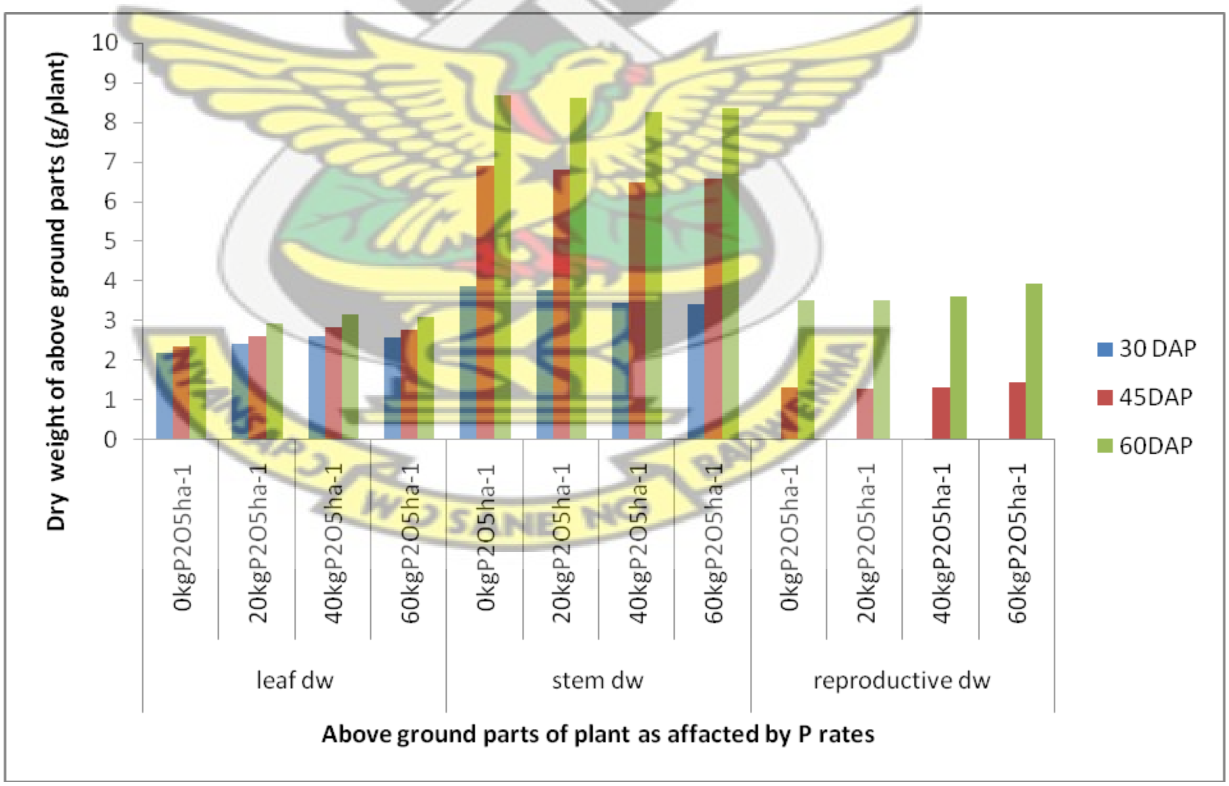

Fig 4.4b: Dry matter accumulation of above ground parts of cowpea plant as affected by P fertilizer rate in the minor season

4.3 Growth functions and analysis

4.3.1 Crop Growth Rate (CGR)

Results of crop growth rate as affected by variety and phosphorus fertilizer application are presented in Table 4.8. CGR did differ significantly (*$p < 0.05$)* among cowpea varieties except between 30 - 45 DAP in the minor season. In the major season between 30 - 45 DAP, Asomdwee and IT89KD-347-57 varieties recorded similar CGR but both were greater than that of Asetenapa. In the major season at 45 - 60 DAP, treatment effect of Asomdwee was significantly greater than that of Asetenapa variety only. During the minor season between 45 - 60 DAP, treatment effect of the IT89KD-347-57 was significantly lower than those of the other two varieties.

Phosphorus fertilizer application had no significant ($p > 0.05$) effect on CGR at all the sampling periods and seasons. Variety and phosphorus fertilizer application interaction was not significant ($p > 0.05$) on CGR at the different seasons and sampling times.

4.3.2 Relative Growth Rate (RGR)

Influence of variety and phosphorus fertilizer application on relative growth rate is presented in Table 4.9. RGR differed significantly ($p < 0.05$) with variety during major season sampling at 30 - 45 DAP and minor season sampling at 45 - 60 DAP. During the major season at 45 DAP, RGR of the Asomdwee and IT89KD-347-57 varieties were similar, but both were significantly higher than that of the Asetenapa. However, during the minor season at 60 DAP, Asomdwee and Asetenapa varieties had RGR that were similar and significantly higher than that of the IT89KD-347-57 variety.

Phosphorus fertilizer application had no significant ($p > 0.05$) effect on RGR at different periods at both seasons. The interaction effect of variety and phosphorus fertilizer application was not significant ($p > 0.05$) on RGR at the different seasons and sampling times.

Table 4.8: Influence of variety and phosphorus fertilizer application on crop growth rate

Treatments	**Crop Growth Rate (g m^{-2} day^{-1})**			
	30 - 45 DAP		**45 - 60 DAP**	
	Major Season 2012	Minor Season 2012	Major Season 2012	Minor Season 2012
Varieties				
Asetenapa	4.06	6.64	2.90	3.82
Asomdwee	7.88	6.96	3.67	3.82
IT89KD-347-57	7.49	6.98	3.17	2.02
Lsd (5 %)	1.16	NS	0.62	0.54
P levels(kg P_2O_5 ha^{-1})				
0	6.58	6.53	3.25	2.97
20	6.98	6.81	3.31	3.07
40	6.57	7.05	3.42	3.19
60	5.78	7.00	3.01	3.66
Lsd (5 %)	NS	NS	NS	NS
CV (%)	24.8	19.2	26.5	23.1

NS – Non Significant

Table 4.9: Variety and phosphorus fertilizer application effect on relative growth rate

Treatments	Relative Growth Rate (g g^{-1} day^{-1})			
	30 - 45 DAP		45 - 60 DAP	
	Major Season 2012	Minor Season 2012	Major Season 2012	Minor Season 2012
Varieties				
Asetenapa	0.024	0.035	0.013	0.022
Asomdwee	0.046	0.043	0.014	0.021
IT89KD-347-57	0.042	0.034	0.012	0.015
Lsd (5 %)	0.006	NS	NS	0.004
P levels(kg P_2O_5 ha^{-1})				
0	0.039	0.038	0.013	0.019
20	0.040	0.039	0.013	0.018
40	0.038	0.036	0.013	0.019
60	0.033	0.036	0.012	0.022
Lsd (5 %)	NS	NS	NS	NS
CV (%)	21.2	33.0	23.1	24.9

NS – Non Significant

4.3.3 Net Assimilation Rate (NAR)

Results of net assimilation rate as affected by variety and phosphorus fertilizer application are presented in Table 4.10. NAR was significantly (*p < 005)* influenced by cowpea variety only at 45 - 60 DAP during the minor season where Asomdwee and Asetenapa recorded similar NAR but effect of either was statistically higher than

IT89KD-347-57. Phosphorus fertilizer application had no significant (*p > 005)* effect on NAR at both sampling periods and seasons. Interaction of variety and phosphorus fertilizer application was not significant (*p > 005)* on NAR at the different seasons and sampling times.

Table 4.10: Influence of variety and phosphorus fertilizer application on net assimilation rate

Treatments	Net Assimilation Rate (g m^{-2} day^{-1})			
	30 - 45 DAP		45 - 60 DAP	
	Major Season 2012	Minor Season 2012	Major Season 2012	Minor Season 2012
Varieties				
Asetenapa	3.24	4.52	1.36	3.44
Asomdwee	3.74	4.14	1.13	2.99
IT89KD-347-57	3.70	3.35	1.12	0.17
*Lsd (*5 %*)*	NS	NS	NS	0.63
P levels(kg P_2O_5 ha^{-1})				
0	3.77	4.39	1.25	2.46
20	3.64	3.87	1.23	2.08
40	3.48	3.95	1.05	2.04
60	3.35	3.79	1.28	2.23
*Lsd (*5 %*)*	NS	NS	NS	NS
CV (%)	18.1	33.2	34.8	39.5

NS- Non Significant

4.4 Phenological data

4.4.1 Days to 50 % flowering

Results of days to 50 per cent flowering as affected by variety and phosphorus fertilizer application are presented in Table 4.11. Days to 50 per cent flowering differed significantly *($p < 0.05$)* with cowpea variety in both seasons. Asetenapa in both seasons flowered earlier followed by Asomdwee and IT89KD-347-57.

Phosphorus fertilizer application reduced days to 50 per cent flowering significantly *($p < 0.05$)* in both seasons.

The interaction of variety and phosphorus fertilizer application was not significant *($p > 0.05$)* on days to 50 per cent flowering at the different seasons.

4.5 Total biomass

Table 4.11 gives the results of total biomass yield at harvest as affected by variety and phosphorus fertilizer application. Total biomass yield significantly *($p < 0.05$)* differed with cowpea variety for both seasons. In both seasons, total biomass of the Asomdwee and Asetenapa varieties were similar, but significantly lower than that of IT89KD-347-57 variety.

Phosphorus fertilizer application did influence total biomass yield significantly *($p < 0.05$)* at both seasons. In both seasons total biomass of 60 kg P_2O_5 ha^{-1} rate was significantly higher that the control effect only.

Variety and phosphorus interaction on total biomass yield was not significant *($p > 0.05$)* at both seasons.

Table 4.11: Variety and phosphorus fertilizer application effect on days to 50 % flowering and total biomass yield

Treatments	Days to 50 % Flowering		Total Biomass ($kg\ ha^{-1}$)	
	Major Season 2012	Minor Season 2012	Major Season 2012	Minor Season 2012
Varieties				
Asetenapa	43.8	43.1	2631.0	2468.0
Asomdwee	44.8	44.3	2980.0	2680.0
IT89KD-347-57	46.4	45.2	3612.0	3052.0
Lsd (5 %)	0.7	0.7	509.7	283.9
P levels($kg\ P_2O_5\ ha^{-1}$)				
0	47.0	46.1	2591.0	2417.0
20	46.1	45.4	3023.0	2679.0
40	44.6	43.7	3175.0	2857.0
60	42.4	41.6	3510.0	2981.0
Lsd (5 %)	0.8	0.9	588.6	327.8
CV (%)	2.2	2.3	23.0	14.4

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4.6 Yield and yield components

Results of number of pods per plant, number of seeds per pod and 100-seed weight as affected by variety and phosphorus fertilizer application are presented in Table 4.12.

4.6.1 Number of pods per plant

Number of pods per plant among the cowpea varieties differed significantly *($p < 0.05$)* during both seasons (Table 4.12). In both seasons, Asomdwee produced greatest number of pods per plant (22.2) than the other varieties. However, in the minor season difference in effects of Asetenapa and Asomdwee were not significant but the effect of the latter was different from IT89KD-347-57.

Phosphorus fertilizer application significantly *($p < 0.05$)* influenced number of pods per plant in both seasons, with higher application rates 40 and 60 kg P_2O_5 ha^{-1} supporting significantly greater pod number that the control and 20 kg P_2O_5 ha^{-1} rates.

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Table 4.12: Influence of variety and phosphorus application on number of pods per plant, number of seeds per pod and hundred- seed weight at harvest

Treatments	**Number of pods per plant**		**Number of seeds per pod**		**100-seed weight(g)**	
	Major Season 2012	Minor Season 2012	Major Season 2012	Minor Season 2012	Major Season 2012	Minor Season 2012
Varieties						
Asetenapa	18.4	19.4	12.2	13.4	13.1	11.7
Asomdwee	22.2	21.6	12.6	13.2	12.6	11.3
IT89KD-347-57	13.7	19.0	14.4	15.2	11.9	10.6
Lsd (5 %)	2.5	2.3	0.9	0.9	0.8	0.7
P levels(kg$P_2O_5ha^{-1}$)						
0	12.8	14.9	11.7	12.4	11.9	10.7
20	17.0	18.8	13.0	14.0	12.2	10.9
40	20.6	22.5	13.7	14.5	12.8	11.6
60	21.8	23.9	13.8	14.8	13.2	11.7
Lsd (5 %)	2.9	2.6	1.0	1.1	1.00	0.8
CV (%)	19.0	15.6	9.4	9.0	9.1	8.9

4.6.2 Number of seeds per pod

Number of seeds per pod was significantly greater in the IT89KD-347-57 variety than in the rest in both seasons (Table 4.12). Phosphorus rate of 60 kg P_2O_5 ha^{-1} also resulted in greater number of pods than the control treatment effect only during the two seasons. Other P treatments effects were similar.

4.6.3 Hundred - seed weight

One hundred-seed weight was significantly great in both seasons in Asetenapa variety (Table 4.12) than in the other varieties. Asomdwee and IT89KD-347-57 varieties had similar mean seed weight at both seasons.

Phosphorus fertilizer application significantly *($p < 0.05$)* influenced 100- seed weight for both seasons. Also, 100-seed weight increased with P application.

4.6.4 Seed yield

Results of seed yield as affected by variety and phosphorus fertilizer application are presented in Table 4.13. Seed yield differed significantly *($p < 0.05$)* among the cowpea varieties for both seasons. In the major season Asomdwee produced greater seed yield of 1557.00 kg ha^{-1} and this was significantly higher than that of IT89KD-347-57 variety only. In the minor season, seed yield produced by the Asomdwee variety was significantly higher than those of the other varieties.

Phosphorus fertilizer application significantly *($p < 0.05$)* influenced seed yield in both seasons. This showed that P treatments supported significantly higher seed yield than the control treatment.

Table 4.13: Influence of variety and phosphorus fertilizer application on seed yield, and harvest index at harvest

Treatments	Seed yield (kg ha^{-1})		Harvest Index (%)	
	Major Season 2012	Minor Season 2012	Major Season 2012	Minor Season 2012
Varieties				
Asetenapa	1407.0	1160.0	34.8	32.0
Asomdwee	1557.0	1415.0	34.3	35.0
IT89KD-347-57	1132.0	1182.0	24.5	28.0
Lsd (5 %)	245.1	192.9	4.7	3.0
P levels(kg P_2O_5 ha^{-1})				
0	1030.0	963.0	29.6	30.0
20	1354.0	1190.0	31.3	31.0
40	1395.0	1379.0	31.3	33.0
60	1682.0	1476.0	32.7	34.0
Lsd (5 %)	283.0	222.7	NS	NS
CV (%)	25.0	21.4	21.0	17.4

NS - Non Significant

4.6.5 Harvest Index (HI)

Cowpea variety significantly *($p < 0.05$)* differed in HI for both seasons (Table 4.13). Asetenapa (34.8 %) and Asomdwee (34.3 %) produced similar HI but statistically different from IT89KD-347-57 (24.5 %) in the major season. The trend of HI was the same in the minor season as values of Asetenapa and Asomdwee were significantly higher than that of the IT89KD-347-57 variety.

HI was not significantly ($p > 0.05$) influenced by phosphorus fertilizer application during both seasons.

4.7 Nodulation parameters

Results on number of nodules, effective nodules per plant and dry weight of nodules per plant as influenced by variety and phosphorus fertilizer application are presented in Table 4.14.

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Table 4.14: Influence of variety and phosphorus levels on number of nodules, effective nodules and dry weight of nodules per plant at 45 DAP

Treatments	45 DAP					
	Number of nodules / plant		**Number of effective nodules / plant**		**Dry weight of nodules / plant (g)**	
	Major Season 2012	Minor Season 2012	Major Season 2012	Minor Season 2012	Major Season 2012	Minor Season 2012
Varieties						
Asetenapa	111.8	142.5	80.7	86.7	34.4	40.7
Asomdwee	109.7	139.2	82.9	86.6	35.5	40.7
IT89KD-347-57	73.6	92.0	45.6	59.9	21.3	33.0
Lsd (5 %)	18.8	24.7	17.9	17.0	6.7	5.1
P levels(kg P_2O_5 ha^{-1})						
0	80.1	99.6	52.7	62.5	23.7	29.3
20	94.3	118.9	68.7	77.0	30.7	35.8
40	106.2	135.3	70.7	80.4	31.5	40.3
60	112.9	144.4	86.9	91.2	35.7	47.1
Lsd (5 %)	21.8	28.5	20.7	19.6	7.7	5.9
CV (%)	26.6	27.6	35.7	30.4	30.5	18.7

4.7.1 Number nodules per plant

Cowpea variety significantly *($p < 0.05$)* influenced number of nodules per plant for both seasons (Table 4.14). Asetenapa and Asomdwee produced similar nodule but effect was significantly higher than that of IT89KD-347-57 in both seasons.

P application significantly *($p < 0.05$)* affected nodule number. The control treatment effect was significantly lower that of 40 and 60 kg P_2O_5 ha^{-1} application in both seasons

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4.7.2 Number of effective nodules per plant

Cowpea varietal effect on effective nodules followed similar pattern as nodule number with Asomdwee and Asetenapa produced significant effect than the IT89KD-347-57 variety. P rate of 60 kg P_2O_5 ha^{-1} resulted in significant higher number of effective nodules than the other P treatments in both season.

4.7.3 Dry weight nodules per plant

Nodules dry weight of the Asetenapa and Asomdwee significantly *($p < 0.05$)* higher than that of the IT89KD-347-57 variety in both seasons (Table 4.14). P rates of 40 and 60 kg P_2O_5 ha^{-1} treatments supported significantly greater nodule dry weight than the control treatment effect only.

4.8 Correlation matrix of selected growth and yield components

The results of the correlation matrix for plant height, CGR, LAI, TDM, number of pods per plant, number of seeds per pod and seed yield are presented in Tables 4.15 and 4.16. For major season, the results showed significant *($p < 0.05$)* positive correlation between plant height and LAI (r = 0.784), TDM and CGR (r = 0.871) and number of pods per plant and seed yield (r = 0.950). Also, the minor season results indicated significant *($p < 0.05$)* positive correlation between plant height and CGR (r = 0.930), LAI and number of seeds per pod (r = 0.925), TDM and number of pods per plant (r = 0.781), TDM and number of seeds per pod (r = 0.781), TDM and seed yield (r = 0.833) and number of pods per plant and seed yield (r = 0.976).

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Table 4.15: Correlation coefficient of selected parameters for major season experiment

	Plant height	LAI	TDM	CGR	No. of pods/plant	No. of seeds/pod	Seed yield
Plant height	1.000						
LAI	0.784*	1.000					
TDM	-0.130	0.148	1.000				
CGR	-0.007	0.063	0.871*	1.000			
No. of pods/plant	0.378	0.504	0.223	0.101	1.000		
No. of seeds/pod	-0.463	-0.418	0.557	0.294	0.159	1.000	
Seed yield	-0.463	0.572	0.217	-0.190	0.950*	0.204	1.000

*= significant at 5 %

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Table 4.16: Correlation coefficient of selected parameters for minor season experiment

	Plant height	LAI	TDM	CGR	No. of pods/ plant	No. of seeds/pod	Seed yield
Plant height	1.000						
LAI	-0.425	1.000					
TDM	0.111	0.925*	1.000				
CGR	0.930*	0.616	0.331	1.000			
No. of pods/plant	0.502	0.238	0.808*	0.739	1.000		
No. of seeds/pod	-0.243	0.851*	0.781*	0.074	0.611	1.000	
Seed yield	0.534	0.225	0.833*	0.745	0.976*	0.530	1.00

*= significant at 5 %

CHAPTER FIVE

5.0 DISCUSSION

5.1 General observations

Crop growth is mainly dependent on the environmental factors. The fluctuations in weather conditions greatly influence growth, development and yield potential of a crop. The total rainfall received (431.5 mm) during the major season experiment was 34.5 per cent higher than that of the minor season (282.8 mm) (Table 3.1). The germination and early crop growth was uniform due to sufficient available soil moisture but, the varieties experienced mild moisture stress during flowering to pod development period in the minor season (Appendix 1). There was no major incidence of pests and diseases during both seasons. Mean minimum and mean maximum temperature, relative humidity (at 0900 and 1500 GMT) and sunshine duration were lower in the major season compared to the minor season (Appendix 1).

5.2 Cowpea variety and phosphorus fertilizer application on growth and growth components

Plant height was affected by cowpea variety at the various growth periods and seasons. Asomdwee was consistently the tallest, followed by Asetenapa and IT89KD-347-57 at all sampling periods. Moreover, treatment effect of 20, 40 and 60 kg P_2O_5 ha^{-1} on plant height was higher than the control except 60 kg P_2O_5 ha^{-1} which was not consistent. This is in agreement with the findings of Magani and Kuchinda (2009) but contrast that of Rajput (1994) and Sharma *et al.* (2002). Differences in plant height could also be attributed to genetic effect (Magani and Kuchinda, 2009).

IT89KD-347-57 consistently produced the greatest number of primary branches and leaves per plant, followed by Asetenapa and Asomdwee at all sampling periods. The variation in number of primary branches and leaves per plant could partly be due to genetic makeup of the varieties (Magani and Kuchinda, 2009) and weather conditions (Marie-Hrlbne and Bertrand, 1997).

Higher CGR values were recorded for Asomdwee and IT89KD-347-57 varieties in the major season but were not consistent in the minor season. This indicates that among varieties, Asomdwee and IT89KD-347-57 produced more dry matter per unit area than Asetenapa in the major season. This variation could be due to genotypic constitution and growing conditions indicating different growth potential (Ankomah *et al*., 1995). The reduction in CGR between sampling periods contrasts the report of Addo-Quaye *et al*. (2011) that UCC-Early variety of cowpea increased from the initial sampling (30 DAP) stage to the final sampling stage (51 DAP). The higher NAR values of Asomdwee and IT89KD-347-57 in the major season at 45 DAP suggest that the leaves of the two varieties were more efficient in producing dry matter than Asetenapa in the major season (Table 4.10). In the minor season, NAR was in order Asetenapa > Asomdwee > IT89KD-347-57. This indicates that apart from solar radiation, NAR could be influenced by water supply which was limited during the minor season (Fageria *et al.*, 2006). The reduction in NAR between sampling periods confirms the report of Addo-Quaye *et al.* (2011). This is an indicative of the fact that there was sufficient leaf area on plants but there were many leaves which had reduced assimilatory activity (Fageria *et al.*, 2006). There was inconsistency in RGR among the varieties (Table 4.9). This inconsistency could partly be due to changes in weather conditions (Fageria *et al*., 2006). RGR was higher at 45 DAP for both seasons but gradually declined at 60 DAP. According to Chattjrvedi *et al.* (1980) RGR decreases as the plant ages due to the fact that an increasing part of the plant is structural rather than metabolically active tissue and does not contribute to growth.

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Days to 50 % flowering differed in order of Asetenapa (43-44 days), Asomdwee (44 -45 days) and IT89KD-347-57 (45-46 days). This variation could be due to genotypic difference. Phosphorus fertilizer application is reported to shorten the time from planting of cowpea to harvesting of green pods and hastened maturity (Sison and Margate, 1981). This report was confirmed when 0, 20, 40 and 60 kg P_2O_5 ha^{-1} were applied, resulting in (46-47 days), (45-46days), (42 days) and (42 days) to 50 % flowering respectively. Lower days to 50 % flowering recorded in the minor season could be attributed to the moisture stress experienced during the growing period (Refay, 2009).

5.3 Effect of cowpea variety and phosphorus fertilizer application on dry matter production and distribution

Total dry matter production varied among the cowpea varieties on each sampling occasion and season. This shows that the varieties had unequal growth and dry matter production potential. This is because aside the conditions of growth (environment), dry matter production is influenced by genotype (variety), therefore production of different dry matter attest to the fact that the growth potentials are different in these varieties. This confirms the report of Addo-Quaye *et al*. (2011) that cowpea varieties have different capacities for dry matter production. Dry matter production increased throughout the sampling periods and seasons. This is in agreement with Das *et al.* (2008) that dry matter production in plant gradually increases with crop age and attains maximum at maturity.

Phosphorus fertilizer application had no significant effect on the dry matter production. However, the results indicated higher dry matter production by the other rates (20, 40 and 60 kg P_2O_5 ha^{-1}) over the control (0 kg P_2O_5 ha^{-1}). Das *et al*. (2008) reported that 0, 30, 60, 90 and 120 kg P_2O_5 ha^{-1} on chickpea showed a marked influence on the total dry matter accumulation which increased progressively over time regardless of the different levels of applied phosphorus fertilizer.

Dry matter partitioning in the above ground parts such as leaves, stem and reproductive part (pods) varied significantly among the varieties. Dry weight of leaves increased rapidly from 30 to 45 DAP. This could be attributed to production and formation of new leaves. However, there was a decline from 45 to 60 DAP and this decline may be due to mutual shading, competition, leaf senescence and translocation of dry matter to other plant parts as reported by (Patil *et al.*, 2002) .

Phosphorus fertilizer application rates of 20, 40 and 60 kg P_2O_5 ha^{-1}produced higher dry weight of leaves than the control (0 kg P_2O_5 ha^{-1}) which confirms the report by Moot *et al.*(2007) that phosphorus deficiency leads to early senescence of older leaves and stunting of new leaves. The initial soil analysis of low P level in the soil used for the experiments corroborates the report of Moot *et al.* (2007).

Dry matter accumulation in stem increased from 30 to 60 DAP during both seasons. Although, dry matter accumulation in stem was not significantly influenced by phosphorus fertilizer application, effect of the control (0 kg P_2O_5 ha^{-1}) was higher. This could be the result of low initial levels of macro elements (Table 4.1) below critical levels required for proper dry matter production and partitioning (Aune and Lai, 1995).

Asomdwee translocated highest dry matter into the reproductive part followed by Asetenapa and IT89KD-347-57. This could be attributed to phenological difference among the varieties as Asetenapa and Asomdwee flowered earlier than IT89KD-347-57. All the phosphorus fertilizer application rates resulted in higher translocation of photosynthate to the reproductive part than the control (0 kg P_2O_5 ha^{-1}). The increased dry matter accumulation in reproductive part (pods) indicates a better translocation of the available photosynthate towards seed (Acquah, 2007). Variation in dry matter distribution among the above ground parts confirms that dry matter partitioning among the sinks of a plant is primarily regulated by the sinks themselves (Marcelis, 1996).

5.4 Yield and yield components as affected by cowpea variety and phosphorus fertilizer application

Among varieties evaluated, Asomdwee recorded the highest seed yield of 1557.00 kg ha^{-1} (major season) and 1415.00 kg ha^{-1} (minor season) followed by Asetenapa (Table 4.13). Asetenapa and IT89KD-347-57 were not consistent in seed yield. Earlier revealed varietal differences in the seed yield of cowpea (Sanginga *et al.*, 2000 and Nirmal *et al.*, 2001). Yield data available in Table 3.2 by the CSIR-CRI indicates Asomdwee as the highest among the three varieties. Seed yield was increased with P fertilizer throughout the experiments with highest yield (1682.00 kg ha^{-1} for major season) and (1476.00 kg ha^{-1} for minor season) when 60 kg P_2O_5 ha^{-1} was applied. Seed yield is governed by a number of factors which have a direct or indirect impact on seed yield per unit land area. Among them are yield components such as number of pods per plant, number of seeds per pod and 100-seed weight over a given land area (Acquah, 2007).

Number of pods per plant was significantly higher in Asomdwee (22.2 for major season and 21.6 for minor season) than in Asetenapa and IT89KD-347-57 (Table 4.12). Number of pods per plant increased with P fertilizer application rates with the control producing the least and maximum by the application of 60 kg P_2O_5 ha^{-1}. This confirms reports of Egle *et al.* (1999) and Besmer and Koide (1999) that increasing P rate promotes reproductive yields and inflorescence production.

IT89KD-347-57 consistently produced the maximum number of seeds per pod followed by Asetenapa and Asomdwee but the latter two varieties were not consistent. The number of seeds per pod could be attributed to genetic makeup of the varieties (Acquah, 2007). The effect of phosphorus fertilizer application rates of 20, 40 and 60 kg P_2O_5 ha^{-1} produced statistically similar number of seeds per pod but was different from the control. This indicates that number of seeds per pod of a variety can be modified by soil management practices such fertilizer application.

100-seed weight is an important yield component in cowpea. Asetenapa and Asomdwee varieties produced similar 100 -seed weight but significantly higher than IT89KD-347-57. Phosphorus fertilizer application rates of 40 and 60 kg P_2O_5 ha^{-1} produced statistically similar 100-seed weight but different from 0 and 20 kg P_2O_5 ha^{-1}. The effect of 20 kg P_2O_5 ha^{-1} was different from the control (0 kg P_2O_5 ha^{-1}). The variation in 100-seed weight between major and minor season could be as a result of variation in weather conditions such as rainfall, temperature, sunshine duration and relative humidity (Asare, 2011).

The differences observed in seed yield per hectare and yield components could be attributed to the differences in dry matter production and its accumulation in different plant parts. Asomdwee and Asetenapa varieties recorded significantly higher total dry matter production at 60 DAP than IT89KD-347-57. But the total dry matter production per plant does not reflect the efficiency of genotype, whereas, its accumulation in different plant parts is the real index of the efficiency (Mansur *et al.*, 2009). Variation in seed yield could be caused by difference in photosynthetic ability of plant which depends upon dry weight of leaves and leaf area. LA, LAI, CGR and NAR differed (Tables 4.5, 4.6, 4.8 and 4.10). These growth functions, according to Stern and Donald (1961) could influence yield.

The correlation analysis for major season (Table 4.15) showed significant positive correlation between plant height and LAI of cowpea, TDM and CGR, seed yield and number of pods per plant. The results confirm the report of Boote, *et al., (*2001). The results again showed a positive linear relationship between seed yield and number of pods per plant. A positive correlation between CGR and DM production has been reported by Thakur and Patel (1998). According them greater growth means more dry matter availability for both sustained growth and storage resulting in higher seed yield.

The minor season correlation analysis indicates positive linear correlation between the plant height and CGR of cowpea. This observation is possible as plant height is a function of CGR. Hence, plants with tallest height could contribute to greater CGR (Fageria *et al.,* 2006). The results showed a positive linear relationship between seed yield and number of pods per plant. This indicates that the higher TDM, the greater number of pods per plant, seeds per pod and seed yield. The results also confirm the report of Baligar and Jones (1997) that legume seed yield is a function of number of pods per plant and number of seeds per pod.

Variations in phosphorus fertilizer application rates on seed yield and yield components might be attributed to the delayed senescence of lower leaves and rapid growth of new leaves which resulted in increased leaf area for light interception (Moot *et al.*, 2007). P is reported to increase production of floral structures (Ma *et al.,* 2001). Consistently, IT89KD-347-57 recorded significantly highest total biomass followed by Asomdwee and Asetenapa. The number of branches per plant of the varieties might have accounted for the significant total biomass differences resulting in partitioning of more photosynthate to the vegetative part. These consequently resulted in differences in migration coefficient (HI) as reported by Acquah, (2007).

The 60 kg P_2O_5 ha^{-1} fertilizer application rate continuously produced the highest total biomass yield and this confirms the observations of Singh *et al.* (2011). The enhancement by P fertilizer on yield and yield components resulted in P improving HI (Rahman *et al.*, 2008).

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Difference in yield among varieties and P fertilizer application rates could be attributed to differences in nodulation parameters such as number and dry weight of nodules and effective nodules. Zahran (2000) reported that nodulation, nitrogen fixation and specific nodule activity are related to the P supply. Results obtained corroborate this assertion.

Interaction of cowpea variety and phosphorus fertilizer application on seed yield was consistently insignificant indicating that the inherent genetic differences of the varieties did not affect their respond to P fertilizer application and that each of the varieties responded in a similar manner to different fertilizer rates. Similar report was made by Fatokun *et al.* (2002). However, there was an increase in seed yield with each increase in P fertilizer. For example, 60 kg P_2O_5 ha^{-1} when applied to Asomdwee, Asetenapa and IT89KD-347-57 produced different seed yields. Asomdwee produced superior seed yield at no P fertilizer application. All the varieties increased seed yield with P fertilizer application compared to the control.

Variation in yield and yield components between the seasons could be attributed to changes in weather conditions more importantly rainfall and temperature. According to Cartelle *et al*. (2006) low rainfall and high temperatures during the grain filling period have a significant effect on seed yield

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CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

The results of this study revealed that the varieties (Asetenapa, Asomdwee and IT89KD-347-57) had significantly different growth and growth components. This indicates that cowpea varieties have unequal growth potential which ultimately influenced yield and yield components.

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Dry matter production and partition varied among the varieties. Asomdwee was most efficient in partitioning much of it assimilates into economic yield followed by Asetenapa and IT89KD-347-57. P application did not affect dry matter production and partition.

The study also indicates that application of P fertilizer significantly improved yield and yield components but contrary was observed for growth.

Asomdwee produced superior seed yield of 1118 and 1165kg ha^{-1} for major and minor seasons respectively. Therefore, Asomdwee is recommended for soils with low P status. Further studies on effect of integrated nutrient management on dry matter production and partition, growth and yield in the varieties should be conducted.

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APPENDICES

Appendix 1: Meteorological data for the year 2012 at KNUST Sub-station

Month	Rainfall (mm)	Temperature (^{O}C)		Relative Humidity (%)		Sunshine Duration (Hrs)
		Maximum	Minimum	09 GMT	15 GMT	
January	18.5	33.8	20.4	90.0	71.0	5.9
February	48.5	33.7	22.2	89.0	71.0	4.6
March	126.1	33.6	23.1	90.0	63.0	4.6
April	206.5	33.0	23.5	84.0	61.0	5.7
May	238.4	31.9	23	85.0	52.0	5.2
June	359.8	30.1	22.4	79.0	46.0	3.9
July	55.8	28.0	20.8	71.0	35.0	2.7
August	15.9	28.5	20.5	80.0	68.0	2.9
September	70.1	30.0	21.9	87.0	64.0	4.5
October	182.3	31.5	22.3	85.0	63.0	5.8
November	40.5	32.7	22.8	82.0	58.0	7.0
December	60.0	32.1	22	83.0	54.0	6.5

(Meteorological station, KNUST, 2012)

Appendix 2: Combined effect of variety and P fertilizer application on seed yield for major season

Seed yield (kg ha^{-1})				
Varieties	**P fertilizer application (kg P_2O_5 ha^{-1})**			
	0	**20**	**40**	**60**
Asetenapa	975.00	1346.00	1543.00	1764.00
Asomdwee	1118.00	1486.00	1540.00	2087.00
IT89KD-347-57	998.00	1231.00	1103.00	1196.00

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Appendix 3: Combined effect of variety and P fertilizer application on seed yield for minor season

Seed yield (kg ha^{-1})				
Varieties	**P fertilizer application (kg P_2O_5 ha^{-1})**			
	0	20	**40**	**60**
Asetenapa	900.00	1037.00	1210.00	1491.00
Asomdwee	1165.00	1451.00	1590.00	1453.00
IT89KD-347-57	824.00	1083.00	1337.00	1483.00