KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY,

KUMASI.

SCHOOL OF GRADUATE STUDIES

DEPARTMENT OF CROP AND SOIL SCIENCES

RESPONSE OF COWPEA (*Vigna unguiculata* [L.] Walp) TO NITROGEN AND PHOSPHORUS FERTILIZERS AND RESIDUAL FERTILITY EFFECTS ON GROWTH AND YIELD OF MAIZE (*Zea mays* L.).

BY

MOSES AHMED DARAMY

SEPTEMBER, 2015

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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 Philosophy Degree in Agronomy (Crop Physiology)

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DECLARATION

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

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DEDICATION

This Thesis is dedicated to my family especially my father, Mr. Alhaji Ansgar Overamy Daramy, my mother, Mrs. Susan Fatmata Daramy Kamara, my brothers and sisters who have always been there for me and kept me in their thoughts and prayers throughout my studies.

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ABSTRACT

Generally, soils in tropical Africa including Ghana are inherently low in essential nutrients particularly nitrogen and phosphorus thereby resulting in low yields of crops. To this end, two field experiments were conducted on the same plot at the Plantation Section of the Department of Crop and Soil Sciences, Kwame Nkrumah University of Science and Technology (KNUST) during the major and minor cropping seasons of 2014 to evaluate cowpea (*Vigna unguiculata* [L.] Walp) response to nitrogen and phosphorus fertilizers and residual fertility effects on the growth and yield of succeeding maize (*Zea mays* L.) crop.

The design used in the studies was a 4×5 factorial arranged in randomized complete block with three replications. The factors studied were N and P fertilizer application rates. The N rates were 0, 10, 20, 30 and 40 kg N/ha and the P rates were 0, 15, 30 and 45 kg P_2O_5/ha. The Asontem cowpea and Abontem maize variety used were obtained from the CSIR- Crops Research Institute, with both having a maturity periods of 65 and 75 days respectively. The land was ploughed, harrowed and plots were laid out. Plot size was 4.1 × 1.9 m. Planting for the cowpea was done in June at a spacing of 60 × 20 cm, while that of the maize was done in September at a spacing of 70 × 30 cm. All necessary agronomic practices were carried out.

The results indicated that cowpea growth indices were not significantly ($P > 0.05$) affected by N and P fertilizer application rates. All nodulation parameters were also not significantly ($P > 0.05$) affected by N and P rates, except for number of nodules at 4 weeks after fertilizer application (WAFA). Grain yield and its component were not significantly ($P > 0.05$) affected by N and P fertilizer application rates. The results further indicated that residue quality was not responsive ($P > 0.05$) to N and P rates. However, application of N had significant ($P < 0.05$) effects on cowpea total plant N, seed N and crude protein content of seeds.

Furthermore, residual fertilization did not significantly ($P > 0.05$) affect the growth, dry matter and grain yield of the succeeding maize crop.

From the studies, it is recommended that, application of N to cowpea fields should highly depend on the N status of that particular field and that further studies should be conducted with higher P rates in other to determine the appropriate rate of P fertilizer that will produce significant effects on growth, grain yields and N contents of whole plant, seeds and residues of cowpea.

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LIST OF ABBREVIATIONS

ANOVA	Analysis of Variance
C: N	Carbon-to-Nitrogen ratio
CRI	Crops Research Institute
CSIR	Council for Scientific and Industrial Research
CV	Coefficient of variation
DAP	Days after planting
EC	Emulsifiable concentrate
EDTA	Ethylene Diamine Tetraacetic Acid
GMT	Greenwich Mean Time
ha	Hectare
IITA	International Institute of Tropical Agriculture
LA	Leaf Area
LAI	Leaf Area Index
LSD	Least Significant Difference
m^2	Meter square
ml	Milliliter (s)
MoFA	Ministry of Food and Agriculture
NPK	Nitrogen Phosphorus Potassium
RCBD	Randomized Complete Block Design
TSP	Triple Superphosphate
WAFA	Weeks After Fertilizer Application

CHAPTER ONE

1.0 INTRODUCTION

Cowpea (*Vigna unguiculata* (L.) Walp.) and maize (*Zea mays* L.) are important crops worldwide. Cowpea is an important grain legume in the tropics especially West Africa, covering 12.5 million hectares with annual production of about 3.3 million tons (El Naim and Jabereldar, 2010). According to FAO (2001), 64 % of the world`s production of cowpea is from West Africa on approximately 10 million hectares of land. In Africa, Nigeria, Niger, Mali, Kenya, Burkina Faso, Ghana, and Uganda are the major producers (Bennett-Lartey and Ofori, 2000). Cowpea is of main significance to the livelihoods of millions of relatively poor people in developing countries of the tropics (FAO, 2002). It is a multi-purpose legume providing grain, leaf and forage and also improves soil fertility. It has very high nutritive value and high palatability (Whitebread and Lawrence, 2006). Improvement in cowpea production would support 850 million people in the world with high incidence of undernourishment especially in sub-Saharan Africa (FAO, 2006).

Maize is presently the world's third most important cereal after wheat and rice (Belfield and Brown, 2008). It is however, the most important cereal in most African countries including Ghana (Al-Hassan and Jatoe, 2002). Maize has become a major cereal crop and an important constituent of human and animal diets as well as raw material for industry (USAID/EAT, 2012). It is a widely grown cereal in the tropics (Damsteegt and

Igwegbe, 2005) and plays a vital role as a food security crop in both rural and urban communities.

Despite the importance of cowpea and maize, the yields obtained by most farmers in western Africa are very low. In Ghana, the yields are among the lowest in the world, averaging about 700 kg/ha (MoFA - SRID, 2012) and 1.9 t/ha (MoFA, 2010) for cowpea and maize respectively. Low soil fertility and low application of external inputs are among the major factors accounting for low productivity of these crops. Haruna *et al.* (2011) reported that soils of tropical Africa are inherently low in nutrients particularly nitrogen and phosphorus. In spite of the low fertility status of soils, the use of inorganic fertilizer is limited due to several socioeconomic constraints (Partey *et al*., 2013b) and other factors. For instance, it is generally believed that cowpea does not require inorganic fertilizer (Kan` ankuk`a, 1999), because soil rhizobia are able to fix enough nitrogen for the crop. However, despite the N fixing ability, high productivity potential of the crop has been reported by various workers through the use of organic and inorganic fertilizer (Madukwe *et al.*, 2008; Singh *et al.*, 2011).

In tropical Africa, grain legumes like cowpea are an important component of the predominantly cereal/legume production systems (Steiner, 1984). Positive residual effects of N-fixing legumes on subsequent cereals have been widely reported (Kumwenda *et al*., 1995). The use of legumes in cropping systems offers substantial benefits because of their ability to ameliorate soil fertility decline through fixation of atmospheric nitrogen, enriching it with organic matter and improving the yield of the subsequent crops (Giller *et al*., 1997; Shoko *et al*., 2007). However, due to the predominantly infertile soils in tropical Africa, with low levels of nitrogen and available Phosphorus, the potential of legumes to grow and yield better together with their N-fixing ability and their effects on succeeding cereal crops is greatly hindered. Production of grain legumes on poor soils has led to very poor growth, yields (<0.5 t/ha) and low N_2 fixation (< 5 kg N/ha/yr) (Giller, 2001), because under such conditions the crops hardly satisfies their nutrient requirements and nutrient deficiency during different growth stages limits the expression of genetic yield potential (Fernandaz and Miller, 1986). Therefore in order to improve the growth and yield of cowpea together with its effects on succeeding crops, it is of utmost importance to have sufficient soil nutrients during their growth especially nitrogen and phosphorus which are widespread deficient but very important in tropical African soils.

The main objective of the study therefore, was to evaluate the effects of nitrogen and phosphorus fertilizer on cowpea response, and subsequent contribution to succeeding maize crop.

The specific objectives of the study were to:

(i) Determine the effects of nitrogen and phosphorus application on growth and yield of cowpea.

(ii) Determine the effects of nitrogen and phosphorus application on nodulation of cowpea

(iii) Determine the effects of nitrogen and phosphorus application on the nitrogen and crude protein content of cowpea seeds.

(iv) Determine the effects of nitrogen and phosphorus application on cowpea stover quality and total plant N.

(v) Determine the effects of resulting cowpea haulm and residual nitrogen and phosphorus fertilizer on succeeding maize growth and yield.

The above objectives were formulated to test the null hypotheses that:

(i) The application of nitrogen and phosphorus fertilizer does not lead to increase in growth and yield of cowpea.

(ii) The application of nitrogen and phosphorus fertilizer has no effect on nodulation of cowpea.

(iii) The application of nitrogen and phosphorus fertilizer has no effect on nitrogen and crude protein content of cowpea seeds.

(iv) Nitrogen and phosphorus application has no effect on cowpea stover quality and total plant N.

(v) Resulting cowpea haulm and residual nitrogen and phosphorus fertilizer have no effect on succeeding maize growth and yield.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 ORIGIN, DOMESTICATION AND DISTRIBUTION OF COWPEA

Cowpea (*Vigna unguiculata* (L.) Walp) is a member of the family Fabaceae and tribe phaseoleae (Maréchal *et al.*, 1978). Cowpea was known in India long before the days of Christ, and is also believed to have been known in Asia around the year 2300 BC and in Europe early enough to be known under the name *phaseolos*, *phaseolus* or *phaselus* (Burkhill, 1953). A lack of archaeological evidence has resulted in contradicting views supporting Africa, Asia and South America as its origin (Summerfield *et al*., 1974). One view is that cowpea was introduced from Africa to the Indian sub-continent approximately 2000 to 3500 years ago (Allen, 1983). Kitch *et al*. (1998) also reported that, the species *unguiculata* is thought to be West African Neolithic domesticated and whose progenitors were the wild weed species *dekindtiana* and *meusensis*. Before 300 BC, cowpeas had reached Europe and possibly North Africa from Asia. In the 17th century, the Spanish took the crop to West India. The slave trade from West Africa resulted in the crop reaching the southern USA early in the 18th century. Another view was that the Transvaal region of the Republic of South Africa was the centre of speciation of *V. unguiculata*, due to the presence of most primitive wild varieties (Padulosi and Ng, 1997). The determination of the origin and domestication of cowpea had been based on morphological and cytological evidence, as well as information on its geographical distribution and cultural practices (Ng, 1995; Ng and Maréchal, 1985). Early observations showed that the cowpeas present in Asia are very diverse and morphologically different from those growing in Africa, suggesting that both Asia and

Africa could be independent centers of origin for the crop. However, Asia has been questioned as a center of origin due to the lack of wild ancestors (Ng and Maréchal, 1985). Flight (1970) reported that, the oldest archeological evidence of cowpea was found in Africa in the Kintampo rock shelter remains in Central Ghana dating about 1450–1000 BC, suggesting Africa as center of origin. Presently cowpea is grown throughout the tropic and sub tropic areas around the world.

Ng (1995) postulated that during the process of evolution of *V. unguiculata*, there was change of growth habit, from perennial to annual breeding and from predominantly out-breeding to inbreeding, while cultivated cowpea (subsp. *unguiculata*) evolved through domestication and selection of the annual wild cowpea (var. *dekindtiana*). During the process of domestication and after the species was brought under cultivation through selection, there was a loss in seed dormancy and pod dehiscence, corresponding with an increase in seed and pod size. The precise location of origin of where cowpea was first domesticated is also still under speculation. But by reason of the highest genetic diversity of the crop and the presence of the most primitive form of wild cowpea, (Padulosi, 1993), Southern Africa is the most probable center of domestication. According to Padulosi and Ng (1997), Southern Africa is the center of genetic variability because the most ancient of wild cowpea occurs in Namibia from the west, across Botswana, Zambia, Zimbabwe and Mozambique to the east, and the Republic of South Africa and Swaziland to the south.

The wide geographical distribution of various *dekindtiana* throughout sub-Sahara Africa suggests that the species could have been brought under cultivation in any part of the region. However, the centre of maximum diversity of cultivated cowpea is found in West Africa, in an area encompassing the savannah region of Nigeria, southern Niger, part of Burkina Faso, northern Benin, Togo, and the north western part of Cameroon (Ng and Marechal, 1985). Carbon dating of cowpea (or wild cowpea remains from the Kimtampo rock shelter in central Ghana) has been carried out (Flight, 1976), and is the oldest archaeological evidence of cowpea found in Africa. This shows the existence of gathering (if not cultivation) of cowpea by African hunters or food gatherers as early as 1500 BC.

2.2 TAXONOMY AND BOTANY OF COWPEA

Cowpea (*Vigna unguiculata* (L) Walp.) is an annual food dicotyledonous legume belonging to the order *Fabaceae*, subfamily *Faboideae* (Syn. *Papillionoideae*), tribe *Phaseoleae*, subtribe *Phaseolinae*, genus *Vigna*, and section Catiang (Verdcourt, 1970; Maréchal *et al*., 1978).

The genus *Vigna* is pan-tropical and highly variable with several species, whose exact number varies according to authors: 184 (Phillips, 1951), 170 (Faris, 1965), between 170 and 150 (Summerfield and Roberts, 1985), 150 (Verdcourt, 1970), 154 (Steele, 1976), and about 84, out of which some 50 species are indigenous to Africa (Maréchal *et al*., 1978). Verdcourt (1970) sub-divided the genus *Vigna* into eight sub-genera: *Vigna*, *Sigmoidotropis*, *Cochliasanthus*, *Plectotropis*, *Ceratotropis*, *Dolichovigna*, *Macrorhynchus* and *Haydonia*. Later, this classification was modified to seven sub-genera: *Vigna*, *Sigmoidotropis*, *Plectotropis*, *Macrorhyncha*, *Ceratotropis*, *Haydonia* and *Lasiocarpa* (Maréchal *et al*., 1978). All cultivated cowpeas are grouped under *V.*

unguiculata sub-species *unguiculata* which is sub-divided into four semi-groups, namely *Unguiculata*, *biflora* (or *cylindrica*), *sesquipedalis*, and *textilis* (Ng and Maréchal, 1985). Cowpea is one of common names in English: cowpea, bachapin bean, black-eyed pea, southern, Crowder pea, china pea and cow gram; in Afrikaans: *akkerboon*, *swartbekboon*, *koertjie*; in Zulu: *isihlumaya*; in Venda: *munawa* (plant), *nawa* (fruits) *imbumba*, *indumba*; in Shangaan: *dinaba*, *munaoa*, *tinyawa* (Aveling, 1999). It is also known internationally as *lubia*, *niebe coupe* or *frijol*. However, they are all species of *Vigna unguiculata* (L.) Walp, which in older reference may be identified as *Vigna sinensis* (L.) (Quinn, 1999).

2.3 MORPHOLOGY AND BIOLOGY OF COWPEA

Summerfield *et al*. (1974) and Kay (1979) described cowpea as an annual herb reaching heights of up to 80 cm with a strong taproot with many spreading lateral roots in the surface soil and many globular nodules. The root nodules are smooth and spherical, about 5 mm in diameter, numerous on the main taproot and its branches but sparse on the smaller roots (Chaturvedi *et al*., 2011). Growth forms vary and many are erect, trailing, climbing, or bushy, usually indeterminate growers under favourable conditions. The stems are striate, smooth or slightly hairy and sometimes tinged with purple. Leaves are alternate and trifoliate. The first pair of leaves is simple and opposite. The lateral leaflet is opposite and asymmetrical, while the central leaflet is symmetrical and ovate. Leaves exhibit considerable variation in size (6-16 x 4-11 cm) and shape (linear, lanceolate to ovate) and they are usually dark green. The leaf petiole is 5-25 cm long.

The flowers are arranged in racemose or intermediate inflorescence at the distal ends of 5-60 cm long peduncles. The flowers are conspicuous, self-pollinating, borne on short pedicels and the corollas may be white, dirty yellow, pink, pale blue or purple in colour (Kay, 1979). According to Fery (1985), the inflorescence is axillary and formed of a peduncle 10 to 30 cm long, at the end of which there is a rachis with each node bearing a pair of flowers and a cushion of extra floral nectaries that contribute to the attraction of insects. In cultivated forms, the flowers open in the early day and close in late morning approximately midday, with the dehiscence of the anthers taking place several hours before the flower opens. After blooming (opening once) they wilt and collapse.

The fruit is a dehiscent pod with varying shape and length which usually shatters when dry. It is pendulous, mostly linear although curved and coiled forms occur. The pod is green at early stage and when maturing it becomes usually yellow, light brown, pink or purple. The pod length may vary from less than 11 cm to more than 100 cm (Rachie and Rawal, 1976). Seeds are relatively large (0.2-1.2 cm long) and weigh 5-30 g/100 seeds. They are variable in size and shape: kidney, ovoid, crowder, globose and rhomboid (IBPGR, 1983). The seed coat varies in texture (such as smooth, rough, or wrinkled), colour (white, cream, green, buff, red, brown, black), and uniformity (solid, speckled, or patterned) (Timko and Singh, 2008). Seed shape is correlated with that of the pod. Where individual seeds are separate from adjacent ones during development, they become reniform, but as crowding within the pod increases, the seeds become globular (Chevalier, 1944). Seed germination is epigeal, very quick and very high.

2.4 CLIMATIC AND SOIL REQUIREMENTS OF COWPEA

Cowpea grows primarily under humid conditions. It is tolerant to heat and drought conditions. The crop is sensitive to frost. It germinates rapidly at temperatures above 18.33^{o}C; colder temperatures slow germination (Davis *et al.*, 1991). Cowpea can be grown under rain fed conditions as well as by using irrigation or residual moisture along river or lake flood plains during the dry season, with the minimum and maximum temperatures between 28 and 30°C (night and day) during the growing season (Dugje *et al.*, 2009). Most of the crop grown in agro-ecological zones requires an annual rainfall ranging between 500 and 1200 mm. However, with the development of extra-early and early maturing cowpea varieties, the crop can thrive in the regions with an annual rainfall less than 500 mm. The crop requires well drained sandy loam soils with pH of 5.5 to 6.5 (Davis *et al.*, 1991). The crop is tolerant to drought and well adapted to a wide range of soils, including sandy and even poor soils (Davis *et al.*, 1991).

2.5 COWPEA PRODUCTION

World cowpea production was estimated at 3,319,375 MT and 75% of that production is from Africa (FAOSTAT, 2000). West Africa is the key cowpea producing zone, mainly in the dry savanna and semi-arid agro ecological zones. The principal cowpea producing countries are Nigeria, Niger, Senegal, Ghana, Mali and Burkina Faso (Langyintuo *et al*., 2003). Cowpea is widely distributed throughout the tropics, but central and west Africa account for over 64 % of the area (with about 8 million hectares, followed by about 2.4 million hectares in central and southern America, 1.3 million hectares in Asia, and about 0.8 million hectares in eastern and southern Africa). Some cowpea is also cultivated in the Middle East and southern Europe. However, a substantial part of cowpea production comes from the drier regions of northern Nigeria (about 4 million ha, with 1.7 million tonnes), southern Niger Republic (about 3 million ha, with 1 million tonnes) and Brazil (about 1.9 million ha, with 0.7 million tonnes) (Singh *et al*., 1993).

Cowpea is an important component of sustainable cropping system in Ghana. It is cultivated for the leaves, green pods, grain and haulm for livestock feed. According to Lowenberg-DeBoer (2000), Ghana is one of the major producers of cowpeas in the world but in addition, it imports about 10,000 MT annually; about 30 percent of the Ghanaian imports are from Burkina Faso and the rest from Niger. In Ghana, cowpea is one of the widely cultivated legumes, it is grown throughout all the ten geographical regions (MOFA, 2010), mainly in the savanna and transitional zones (CRI, 2006). An average of 143,000 MT of cowpea is produced annually on about 156,000 ha of land in Ghana, making it the fifth highest producer of cowpea in Africa (TL II Project, 2012).

2.6 COWPEA PRODUCTION SYSTEMS

Traditionally, in West and Central Africa, and Asia, cowpeas are grown on small farms often intercropped with cereals such as maize, millet and sorghum by small scale farmers. Fertilizers and pesticides are generally not used, because they are too expensive or not available to the farmers (Abubakar and Olukosi, 2008).

In West Africa, both fodder and grain type varieties are grown sometimes as a pure crop and its commercial production is mostly done in these states.

2.7 COWPEA PRODUCTION CONSTRAINTS

Although cowpea is a hardy crop that can produce reasonably well under conditions that may render other crops unproductive, production is still constrained by several biotic and abiotic stresses (Hall *et al.*, 1997). In the developing world where soil infertility is high, rainfall is limiting, and most of the cowpea is grown without the use of fertilizers and plant protection measures such as pesticides and herbicides, a wide variety of biotic and abiotic constraints also limit growth and severely limit yield (Timko *et al.*, 2007a). The biotic factors that cause yield reduction include insect pests, parasitic flowering plants, as well as viral, fungal and bacterial diseases (Emechebe and Lagoke, 2002). The abiotic factors include poor soil fertility, drought, heat, acidity and stress due to intercropping with cereals (Singh and Ajeigbe, 2002). However, Terao *et al.* (1997) reported insect pests, plant diseases, parasitic flowering plants and drought to be major yield-reducing factors.

Several important pests attack cowpea throughout its growth stages from seedling until after harvest causing economic damage. The major insect pests which severely damage cowpea during all growth stages are the cowpea aphid (*Aphis craccivora* Koch), foliage beetles (*Ootheca sp, Medythia spp*), the flower bud thrips (*Megalurothrips sjostedti* Trybom) the legume pod borer (*Maruca vitrata* Fabricius) and the sucking bug complex, of which *Clavigralla spp*, *Anoplocnemis spp*, *Riptortus spp*, *Mirperus spp*, *Nezara viridula* Fab and *Aspavia armigera* L. are most important and are prevalent (Jackai and Daoust, 1986). Tremendous yield losses have been reported in Ghana, Cameroon and Nigeria (Ta'Ama, 1983) due to thrips infestation. It has been repored by Omo-Ikerodah *et al*. (2009) that yield loss in cowpea ranged between 20 to 80 % due to thrips infestation, while under severe infestation a 100% yield loss has been reported by Singh and Allen (1980)

Cowpea is attacked by over 35 major diseases caused by viruses, bacteria, fungi, and nematodes (Patel, 1985). The occurrence, severity, and yield loss due to each disease and mixed infections vary from place to place, but some diseases occur and cause significant damage across the cowpea growing regions of the world (Emechebe and Florini, 1997). Virus diseases cause serious losses of yield and quality in cowpea in many cowpea growing countries. Worldwide, more than 20 viruses have been identified which infect cowpea under field or experimental conditions (Thottappilly and Rossel, 1985) and are considered potential natural threat to cowpea production (Kuhn, 1990). Singh *et al*. (1984) reported that two bacterial diseases, bacterial pustule (*Xanthomonas spp*.) and bacterial blight (*Xanthomonas vignicola*), cause severe damage to cowpea worldwide. *Cercospora* leaf spot, brown blotch, *Septoria* leaf spot and scab are the most common fungal diseases (Abadassi *et al*., 1987). About 55 species of nematodes have been reported on cowpea (Caveness and Ogunfowora, 1985) but the most damaging and widespread species is *Meloidogyne incognita*.

Parasitic weeds such as *Striga gesnerioides* and *Alectra vogelii* are a major limitation to cowpea production in Africa (Timko *et al*., 2007b). *Striga* causes severe damage to cowpeas in the Sudan savanna and Sahel of West Africa, whereas *Alectra* is more prevalent in the Guinea and Sudan savannas of West and Central Africa and in portions of eastern and southern Africa (Timko and Singh, 2008).

Despite cowpea being more drought tolerant than many other crops, moisture availability is still a major constraint to growth and development, especially during germination and flower setting. Erratic rainfall adversely affects both plant population and flowering ability, resulting in tremendous reduction in grain yield and total biomass in general (Timko and Singh, 2008).

2.8 USES OF COWPEA

Cowpea is a grain legume food crop that plays a critical role in the lives of millions of people in Africa and other parts of the developing world. Cowpea is a multifunctional crop, providing food for man and livestock and serving as a valuable and dependable revenue-generating commodity for farmers and grain traders (Langyintuo *et al*., 2003). It can be used at all stages of its growth as a vegetable crop, and the leaves contain significant nutritional value (Ahenkora *et al*., 1998). The young leaves and shoots are consumed as spinach and provide one of the most widely used potherbs in tropical Africa (Mroso, 2003). Virtually all the components of the crop are important sources of food. Islam *et al.* (2006) emphasized that all the plant parts are nutritious providing protein and vitamins. Immature pods and peas are used as vegetables while several snacks and main dishes are prepared from the grains (Bittenbender *et al*., 1984). The crop is grown primarily in the third world for its cheap source of dietary protein, lysine (Bresami, 1985) and as supplement for meat (Stanton, 1966). The seeds make up the largest contributor to the overall protein intake of several rural and urban families, hence Agbogidi (2010b) described cowpea as the poor man's major source of protein. According to Diouf (2011), the crude protein content of the seeds and leaves of cowpea ranges, respectively between 23 and 32 %, about twice the protein content of most cereals (Kay, 1979), and between 13 and 17 % in the haulms on a dry weight basis with high digestibility value and high fibre level (Adeyemi *et al.*, 2012). Their amino acid complements those of cereals (Asumugha, 2002). Their mineral contents: calcium and iron are higher than that of meat, fish and egg and the iron content equate that of milk; the vitamins- thiamin, riboflavin, niacin (water soluble) and their levels compare with that found in lean meat and fish (Achuba, 2006) which make them very useful in blood cholesterol reduction (Johnson *et al*., 1983). Adeniji (2007) reported that daily consumption of 100– 135gm of dry beans reduces serum cholesterol level by 20 %, thereby reducing the risk for coronary heart diseases by 40 % (Ofuya, 1993). In addition, because grain legume starch is digested more slowly than starch from cereals and tubers, their consumption produces fewer abrupt changes in blood glucose levels following consumption (Phillips *et al*., 2003). Rangel *et al*. (2004) reported that protein isolates from cowpea grains have good functional properties, including solubility emulsifying and foaming activities and could be a substitute for soy protein isolates for persons with soy protein allergies. The crop is also used for forage for farm animals, hay, silage, pasture (Alzouma, 1989). Apart from the use of its grain as source of food for human and animal feed, the practice of feeding cowpea vegetative parts to livestock is popular among peasant farmers and of increasing economic significance.

It forms a major component of the tropical farming system because of its ability to improve marginal lands through nitrogen fixation and as a cover crop (Abayomi *et al.*, 2008) and also serves as a residue, which benefits the succeeding crops. Cowpea is well recognized as a key component in crop rotation schemes because of its ability to help restore soil fertility for succeeding cereal crops (Tarawali *et al*., 2002). The crop can fix about 240 kg/ha of atmospheric nitrogen and make available about 60-70 kg/ha nitrogen for succeeding crops grown in rotation with it (CRI, 2006). Cowpea grows quickly and permits the establishment of a good cover of the ground which decreases erosion, soil temperature and competition with weeds (Blades *et al.*, 1997). It is a deep rooted crop and does well in sandy soils and more tolerant to drought than soybean (Lauriault and Kirksey, 2007). Its drought tolerance, relatively early maturity and nitrogen fixation characteristics fit very well to the tropical soils where moisture and low soil fertility is the major limiting factor in crop production (Hall, 2004). In areas facing food insecurity, such as Africa, peasants or small-scale farmers have used cowpea for intercropping with the other main crops such as maize (*Zea mays*), pearl millet *(Pennisetum glaucum)* and sorghum (*Sorghum bicolor*).

Among the legumes, cowpea is the most extensively grown, distributed and traded food crop consumed (Agbogidi, 2010a). This is because the crop is of considerable nutritional and health value to man and livestock (Agbogidi, 2010b). They form a major staple in the diet in Africa and Asian continents (Awe, 2008). The very early maturity characteristics of some cowpea varieties provide the first harvest earlier than most other crops during production period. This is an important component in hunger fighting strategy, especially in Sub-Saharan Africa where the peasant farmers can experience food shortage a few months before the maturity of the new crop.

Wide array of legumes are produced in Ghana, but cowpea is preferred on account of its short life cycle, fodder use and quality. The dry seeds may be boiled and eaten with

“Gari” (a cassava product). It is also boiled together with rice and a colouring agent to give “Waakye”. The boiled seeds could also be served with fried ripe plantain (Quaye *et al.*, 2009). It is also used in preparation of weaning foods. In Ghana and other African countries like Tanzania and Niger, cowpea is used for preparation of stew that is either used together with cereal dishes or directly mixed with the cereals as maize, wheat, sorghum and rice. In Mali, cowpea is boiled and also prepared in traditional dishes called “Fary” and “Akra”. The young leaves are used to prepare green sauce for different dishes. During the raining season, farmers can use immature pods to resolve their food problems before other crops are harvested.

2.9 EFFECTS OF NITROGEN AND PHOSPHORUS FERTILIZATION ON COWPEA

2.9.1 Effects of nitrogen (N) on growth and yield of cowpea

The careful use of fertilizer can improve yield of crops (Sharma *et al.*, 1996). Nitrogen is a major plant nutrient and plays an important role in the plant growth and development (Taiz and Zeiger, 2006). Although major nitrogen requirement of legumes is met by biological nitrogen fixing rhizobia soils of tropical Africa including Ghana has a sparse population of native rhizobia which are ineffective nodulators and inefficient N-fixers thus there nitrogen fixing ability may be disappointing (Sarkodie-Addo *et al.*, 2006). Therefore, nitrogen availability to the legumes can be increased either with manual inoculation or with application of commercial nitrogen fertilizer. The nitrogen not only improves the yield and yield components of legumes (Baboo and Mishra, 2001) but also affects the biological nitrogen fixation (Akter *et al.*, 1998). Nitrogen application to cowpea plants increased plant growth, dry matter content, yield and its quality as well as the nutritional value of seeds (Amujoyegbe and Alofe, 2003; Singh *et al.*, 2007). It has been observed that application of nitrogen fertilizer significantly and positively influenced the plant height, number of primary and secondary branches per plant of many legumes (Subhan, 1991; Achakzai *et al.*, 2002b; Toğay *et al.*, 2005). Nitrogen is required by plants in comparatively larger amounts than other elements (Marschner, 1995). Nitrogen deficiency generally results in stunted growth and chlorotic leaves caused by poor assimilate formation that leads to premature flowering and shortening of the growth cycle. The presence of N in excess promotes development of the above ground organs with abundant dark green (high chlorophyll) tissues of soft consistency and relatively poor root growth. This increases the risk of lodging and reduces the plants resistance to harsh climatic conditions and to foliar diseases (Lincoln and Edvardo, 2006). Nitrogen (N) fertilizer use has played a significant role in increase of crop yield (Modhej *et al.*, 2008). Gohari *et al.* (2010) reported that, the greatest seed yield, 100 seed weight, number of pods per plant and number of seeds per plant was obtained by the use of 30 kg/ha nitrogen fertilizer. Nitrogen is an integral component of many compounds, including chlorophyll and enzymes, essential for plant growth processes. It is an essential component of amino acids and related proteins. Nitrogen is essential for carbohydrate use within plants and stimulates root growth and development as well as the uptake of other nutrients. This element encourages above ground vegetative growth and gives a deep green colour to the leaves (Brady, 1990). Nitrogen is also important for plant growth due to its influence on leaf area index and consequently light interception (Grindlay, 1997). According to Varela and Seif (2004), applying nitrates to soil will increase leaf area which invariably increases sunlight interception for a higher rate of photosynthesis. Increasing the leaf area index will lead to increased light interception and subsequently increase dry matter production. Therefore, selection of optimum nitrogen rates is essential for better performance of the cowpea.

2.9.2 Effects of Nitrogen (N) on nodulation and N- fixation of cowpea

Although leguminous crops like cowpea, can fix atmospheric nitrogen with rhizobia, they require mineral nitrogen as starter dose when grown on deficient soils such as those of tropical Africa in other to establish the plants during early growth period when nodules have not stated functioning (Osborne and Riedell, 2006). Nitrogen shortage early in the life of the plant will adversely affect nodule weight and thus total nitrogenase activity per plant (Huxley and Summerfield, 1973). Nitrogen application at either vegetative, flowering or pod filing stage can potentially increase the proportion of plant N derived from N fixation (Yinbo *et al*., 1997). Good establishment and vigorous growth of legumes ensure good development of nodules and thus results in high N fixation. However, high soil N, particularly mineral N, during initial growth retards nodule formation (Tewari, 1965). Anne-Sophie Voisin *et al.* (2002) reported that mineral N in the soil inhibited symbiotic nitrogen fixation but it was relative to start of nodulation and N_2 fixation at early vegetative growth at low concentration.

2.9.3 Effects of phosphorus (P) on the growth and yield of cowpea

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. Phosphorus (P) is an essential macronutrient for legume growth and function (Ribet and Drevon, 1996). Legumes are phosphorus loving plants; 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 (Singh *et al*., 2011; Owolade *et al.*, 2006; Rajput, 1994). Again, phosphorus application decreases zinc concentration in the cowpea grain which can affect the nutritional quality (Buerkert *et al*., 1998). Moreover, dry matter production is increased 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). Deficiency in phosphorus results in stunted shoot and root growth due to reduced cell division and reduced cell enlargement. Phosphorus deficiency stimulated uptake of excess cations over anions by plants and hence enhanced proton release that could increase acidification which may facilitate P acquisition (Tang *et al*., 2001). Low levels of phosphorus (P) in the soil hinder the growth, development and function of various leguminous species (Okalebo, 2009). 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. Application of phosphorus is therefore recommended for cowpea production on soils low in phosphorus.

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 contrast with reports of Rajput (1994) and Sharma *et al. (*2002) on cowpea and soybean respectively, that increasing levels of phosphorus up to 60 kg/ha significantly improved plant height. Rajput (1994) reported significant effect of phosphorus on number of leaves per plant particularly at 50 kg/ha. Magani and Kuchinda (2009) observed that phosphorus application 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.

Dwivedi *et al.* (1997) observed that phosphorus influenced crop growth rate and net assimilation rate with maximum attained at 80 kg/ha. 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. 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. Olaleye *et al.* (2012) found that the total cowpea biomass was significantly ($p < 0.001$) increased 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).

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 application in cowpea shortened the time from planting to harvesting of green pods and hastened maturity.

2.9.4 Effects of phosphorus (P) on nodulation and nitrogen fixation of cowpea

Application of phosphorus fertilizer to legumes is geared towards enhancing not only their growth and yield, but also nodulation and nitrogen fixation (Robson and O‘Hara, 1981). Phosphorus plays a key role in the symbiotic N fixation process by increasing top and root growth, decreasing the time needed for developing nodules to become active and of benefit to the host legume, increasing the number and size of nodules and the amount of N assimilated per unit weight of nodules, increasing the percent and total amount of N in the harvested portion of the host legume, improving the density of rhizobial bacteria in the soil surrounding the root (Armstrong, 1999). Robson and O‘Hara (1981) concluded that P nutrition increased symbiotic nitrogen fixation in most legumes by stimulating host plant growth rather than by exerting specific effects on rhizobial growth or on nodule formation and function. Symbiotic nitrogen fixation has a higher P requirement for maximum activity than growth supported by nitrate assimilation because of the high energy requirement for the reduction of atmospheric nitrogen by nitrogenase system (Rotaru and Sinclair, 2009). P deficiency affects nodule functioning and host plant growth in legumes (Tsvetkova and Georgiev, 2003).

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 the assertion of 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. 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. 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).

2.10 ORIGIN, DISTRIBUTION, CLASSIFICATION AND BOTANY OF MAIZE

Maize belongs to the tribe Maydeae of the grass family *Poaceae*. It is cultivated globally being one of the most important cereal crops worldwide (IITA, 1991). The genus *Zea* consists of four species of which *Zea mays* L. is economically important. The other *Zea* sp., referred to as teosintes, is largely wild grasses native to Mexico and Central America (Dubreuil *et al.*, 2006). It has determinate growth habit and the shoot terminates into the inflorescences bearing staminate flowers. Maize is generally protandrous, that is, the male flower matures earlier than the female flower. The center of origin of *Zea mays* has been established as the Mesoamerican region, now Mexico and Central America (Matsuoka *et al.*, 2002). It is believed that teosinte (*Z. mexicana*) is an ancestor of maize (Warburton *et al.*, 2011), although opinions vary as to whether maize is a domesticated version of teosinte.

Maize was domesticated in Central Mexico (Matsuoka *et al.* 2002) between 9,000 and 6,000 years ago (Benz, 2000). *Zea mays* was introduced into Africa in the 16th century from its native Mesoamerica, and now is one of the most widely grown cereal crops in Africa. Its evolution in Mesoamerica led to diversification into approximately 55 races (Sanchez *et al*. 2000).

Maize (*Z. mays L.*) is a tall, monoecious annual grass with overlapping sheaths and broad conspicuously distichous blades. Plants have staminate spikelets in long spike-like racemes that form large spreading terminal panicles (tassels) and pistillate inflorescences in the leaf axils, in which the spikelets occur in 8 to 16 rows, approximately 30 cm long, on a thickened, almost woody axis (cob).

The whole structure (ear) is enclosed in numerous large foliaceous bracts and a mass of long styles (silks) protrude from the tip as a mass of silky threads (Hitchcock and Chase, 1971). Pollen is produced entirely in the staminate inflorescence. Shed pollen usually remains viable for 10 to 30 minutes, but can remain viable for longer durations under favorable conditions (Coe *et al.*, 1988). The ear is produced entirely in the pistillate inflorescence enclosed in numerous large foliaceous bracts and a mass of long styles (silks) protrude from the tip as a mass of silky threads (Hitchcock and Chase, 1971). Maize is wind pollinated and both self and cross pollination is usually possible.

2.11 CLIMATIC AND SOIL REQUIREMENTS OF MAIZE

Maize needs a regular supply of water and suffers badly in times of drought. It requires rainfall of about 600 – 1,200 mm per annum and this must be well distributed throughout the year (Awuku *et al.*, 1991). According to these authors, maize needs water particularly at the time of tasselling and silking. The best maize growing areas in West Africa have minimum rainfall of 1,000 -1,300 mm per annum, well – distributed during the growth period (Tweneboah, 2000). According to Tweneboah (2000), certain growth periods are particularly important if severe reductions in yield are to be avoided. In particular, the tesselling – to – silking stage is critical because grain formation is initiated during this short period. Availability of soil moisture at the time of tasselling is therefore essential for the production of high yields (Tweneboah, 2000). Experiments in a number of countries have demonstrated that soil moisture deficiency that causes wilting for 1 -2 days during tasselling can reduce yield up to 20 %, and 6 – 8 days of wilting at this stage can reduce yield by 50 % which cannot be made up by later availability of soil moisture either by precipitation or irrigation (Tweneboah, 2000). Maize has two periods in its growth when inadequate moisture availability can disastrously affect yield. The first is during establishment, when stand can be substantially reduced because of inability of seeds to imbibe water against the gradient of soil water potential. Studies conducted by Rouanet (1987) have shown that maize is particularly sensitive to shortage of water 30 – 40 days either side of flowering. This stage of the plant growth is also a critical period. To obtain high yields, it is most important that water deficits do not occur just prior to tasselling till completion of grain filling. Of all the growth stages, tasselling is the most sensitive period to water shortage as far as grain yield is concerned (Adjetey, 1994).

Maize tolerates a wide range of environmental conditions but it is essentially suited for warm climates with adequate moisture. Temperatures of 21 – 30^0 C are suitable (Adjetey, 1994). High temperature and low moisture result in pollen being shed before silk is receptive or death of tassel and drying of silk (Adjetey, 1994). Temperature strongly influences the development of maize. After seedling emergence, high soil and air temperatures accelerate leaf appearance (Strulk, 1983) and also advance tassel initiation. Maximum plant yields are obtained when temperatures of the late vegetative and reproductive phases are relatively lower than 30^0 C (Adjetey, 1994). According to Awuku *et al*. (1991), maize requires an average temperature of 25^0 to 30^0 C. Tweneboah (2000) stated that the optimum temperature for maize ranges from 18 – 21^0 C. The minimum temperature for germination is 10^0 C. Germination and especially emergence will be far more rapid and uniform at temperatures above 16^0 C. At about 20^0 C, maize usually emerges 5-6 days after sowing (Raemaekers, 2001). Reaemaekers (2001) stated that the critical temperature affecting yield is around 32^0 C. The aspect of light that influences maize growth substantially is the amount of light (intensity) received during the growth period. Maize requires a lot of clear sunshine (Adjetey, 1994).

Maize grows satisfactorily in a variety of soils but requires well-drained, deep loams or silty loams with high to moderate organic matter and nutrient content and pH 5.5 – 8.0 for best production (Tweneboah, 2000). Adjetey (1994) stated that maize grows on a wide variety of soils but it prefers deep, fertile, well – drained loam and silty loam soil with the soil pH not less than 4.5. Maize does not like water –logged or shallow soil. According to Baffour (1990), maize normally does very well on moist soils and does badly on pure clayey or sandy soils. The best soils for maize are normally loams and loamy soils rich in humus (Baffour, 1990). Raemaekers (2001) stated that the ideal soil for maize is a deep, medium textured, well drained, fertile soil with a high water holding capacity. Clayey and sandy soils are not conducive for its growth. However, maize is grown on a wide variety of soils and gives high yields if the crop is well managed (Raemaeker, 2001). Maize is quite tolerant of salt during germination; increasing salinity delays germination but, up to a point it has no detrimental effect on the percentage of emergence (Raemaekers, 2001). On the whole, maize is considered to be relatively sensitive to salinity and is not suited for growing in saline soils or irrigation with saline water (Raemaekers, 2001).

2.12 IMPORTANCE OF MAIZE

Maize is a widely grown cereal in the tropics (Damsteegt and Igwegbe, 2005). In many countries including Ghana, maize has become a major cereal staple and an important component of animal and human diets. It was considered to be the third most important cereal crop in the world after wheat and rice up to the end of the 1980s (Sleper and Poehlman, 2006). Currently, maize ranks second in production among the major grain cereals worldwide but due to a shift in cereal demand, maize is expected to be the leading cereal surpassing both wheat and rice (Pingali, 2001).

In the developed countries, maize is used primarily as animal feed and secondarily for production of food and industrial products including starch, sweeteners, and alcohol (Rosegrant, 2008). In developing countries, maize is often grown as a food crop for human consumption, as well as for the market, but it is increasingly being used as animal feed (WABS, 2008). In some developing countries, maize is a food crop of second choice after wheat or rice, but in Africa and Latin America, maize is usually the staple crop of first choice. Maize is an important source of carbohydrate, protein, iron, vitamin B, and minerals. Its grains have great nutritional value as they contain 72 % starch, 10 % protein, 4.8 % oil, 8.5 % fibre, 3.0 % sugar and 1.7 % ash (Chaudhary, 1983). *Zea mays* is the most important cereal fodder and grain crop under both irrigated and rainfed agricultural systems in the semi-arid and arid tropics (Hussan *et al*., 2003).

2.13 PRODUCTION STATUS OF MAIZE

The industrialized world still produces and uses more maize than the developing world, but the trend indicates that by 2020, developing countries will demand more maize than the industrialized world as a result of both population growth and increasing urbanization (Pingali, 2001). Between now and 2050, the demand for maize in the developing world will double, and by 2025, maize production is expected to be highest globally, especially in the developing countries (Rosegrant *et al.,* 2009).

It is estimated that 140 million hectares of maize is grown globally and approximately 96 million of that total production area is in developing countries (Pingali and Pandey, 2001). Despite that, only 46 % of the world maize is produced in developing countries. Low average yield in the developing world is considered one of the causes of the wide gap between the global share of area and share of production. The Food and Agricultural Organization reported worldwide average maize productivity at 4 t/ha, but yield in Africa averages only 1.7 t/ha (FAOSTAT, 2012). In Ghana, average yield in farmer fields is around 1.6 t/ha (MOFA, 2011). The cropping system used in the USA leads to yields that are 65 % above the global average (FAOSTAT, 2012). Wide disparities in climatic conditions (tropical versus temperate) and farming technologies account for the yield differential between the developed and the developing world (Pingali, 2001). Latin America and sub-Saharan Africa produce the most tropical maize while temperate environment production mainly include the USA, China, and Argentina.

2.14 CEREAL- LEGUMES CROPPING SYSTEM IN TROPICAL AFRICA

Interest in the role of annual legumes in the smallholder cropping systems based on cereals like maize (*Zea mays*) in Tropical Africa has increased during the last 15 years as efforts to develop and test sustainable soil fertility improvement options for these systems have expanded (Waddington *et al*., 2004). Dual purpose grain legumes, such as cowpea are available for human food and for the improvement of soil fertility. These legumes derive a large proportion of their N needs from biological N-fixation, often have a relatively low N harvest index, and produce a substantial amount of both grain and biomass, making them attractive to smallholder farmers (Giller, 2001).

Recycling crop straw by application to the land can supply valuable quantities of plant nutrients and organic matter to meet crop nutrition requirement and maintain soil fertility (Prassad *et al.*, 2002). The adoption of legumes into cereal based cropping systems offers opportunities to increase and sustain productivity and income of smallholder farmers (Wijnhoud *et al.*, 2003). Incorporation of organic materials in the form of crop residues enhances the organic carbon level of the soil (Sarkar *et al.*, 1988).

N_2-fixing legumes can have a positive impact on soil fertility by enhancing nitrogen availability and therefore benefiting a cereal crop grown in the subsequent season (Armstrong *et al.*, 1999). The incorporation of legume residues in cereal production is known to have improved the nutrient content of the soil, as well as its physical and chemical properties thereby minimizing cost and reducing dependence on inorganic fertilizers by farmers. Several studies have shown that some legumes can grow well before cereal crops, producing large amounts of residues and fixing atmospheric N_2, leading to considerable increase in yields of succeeding cereal crops (McDonagh *et al.*, 1995; Toomsan *et al.*, 2000). Rotation of cereals with legumes has been extensively studied in recent years. Use of rotational systems involving legumes is gaining importance throughout the region because of economic and sustainability considerations.

The beneficial effect of legumes on succeeding crops is normally exclusively attributed to the increased soil N fertility as a result of N_2 fixation. The amount of N_2 fixed by leguminous crops can be quite high, although it has been demonstrated that legumes can also deplete soil nitrogen (Rupela and Saxena, 1987). Cereal–legume rotation effects on cereal yields have been reported (Bagayoko *et al.*, 2000; Bationo *et al.*, 1998; Bationo and Ntare, 2000). In all these studies, the yield of cereal after cowpea was significantly higher than in continuous cereal cultivation. Cowpea yield also significantly responded to crop rotation, indicating that factors other than N alone contributed to the yield increases in the cereal–legume rotation systems. The role of N_2-fixation by legumes like cowpea to improve N-availability and soil fertility maintenance has great potential. Crop sequences where cereals follow legumes often benefit the cereals (Peoples and Craswell, 1992). Research has shown that legume roots, rhizodeposits (Khan *et al.*, 2002) and residues (Vesterager *et al.*, 2007) are important N pools. The positive added effect of legumes on following crops may, apart from N provision, include improved control of pest and disease cycles, improved soil physical properties, increased availability of other nutrients than N, reduction of phytotoxic and allopathic effects of decomposing cereal residues (Karlen *et al.*, 1994). Legumes can contribute N to cereal based systems when their above and below ground residues decompose to supply N to subsequent cereals. However, in smallholder farming systems, legume crop residues have a high value to farmers as fodder and or fuel but their immediate value in maintaining soil fertility is often not perceived (Muhamman and Gungula, 2006).

Intercropping or rotation of cereals with grain legumes (due to their N_2-fixing abilities) and crop residue management have been recommended as alternatives to improve cereal yields in tropical soils. Unfortunately, the full potentials of these management practices on cereal yield improvement are not achieved since the grain legumes mobilize most of their fixed N into the grain which is exported when the grain is harvested. This decline in soil fertility is/are worsened if the crop residues are not returned into the soil since for most of the degraded soils in Tropical Africa the only real means of restoration is to increase their organic matter content in a mulch-based system. The most efficient way of improving the N content of these soils is to grow legume crops sole in a rotation system and retain their residue in the field against the following cropping season.

The identification and alleviation of technical and socioeconomic constraints in order to increase legumes like cowpea in the present cropping systems needs more attention.

2.15 EFFECTS OF RESIDUAL FERTILIZATION

The immediate short-term effects of applied fertilizers are often emphasized to the neglect of residual effects. Yet when farming is continued on the same site for several years, residual effects of fertilizer treatments may considerably affect the soil chemical properties and consequently crop yield (Enwezor *et al.*, 1989). Reviewing the residues of fertilizers on succeeding crops, Cooke (1970) reported that past manuring with farmyard manure and fertilizers leaves residues of nitrogen, phosphorus and potassium in soil that benefit following crops. He further indicated that the residues of inorganic nitrogen fertilizers usually last only for a season, but the residual effects of continued manuring with phosphorus and potassium may last for many years. Akande *et al.* (2003) also reported an increase in soil available P of between 112 and 115 % and 144 and 153 % respectively for a two year field trials, after applying rock phosphate with poultry manure on okra. Akande *et al.* (2005) further reviewing the effect of rock phosphate amended with poultry manure on the growth and yield of maize and cowpea reported that when rock phosphate application had continued over a period of several years a large pool of undissolved rock phosphate could accumulate. However, residues of fertilizers left in the soil often raise yields in ways that are difficult to compare with fresh fertilizer dressings, sometimes responses to fresh dressings are unaffected by residues of previous dressings, but usually residues lessen the size of the fresh dressing needed (Cooke, 1970).

Ofori (1968) found persistent high residual effects in maize on three P- deficient soils in Ghana when phosphorus was applied at a rate of 14 – 59 kg P/ha in the previous season. Cooke (1970) showed that when soil contains residues of inorganic nitrogen, larger maximum yields are possible than may be obtained from soil without residues. The results also showed that dressings of inorganic N fertilizers had large residual effects in the first year after the dressings stopped but much smaller effects in the second and third years.

The residual effect of a single dressing of phosphorus and potassium is usually much smaller than the direct effect the year before and may be too small to measure accurately in experiments. But the cumulative residual effects of many annual dressings are large and may be sufficient for normal yields of crops with small additions of fertilizer (Cooke, 1970).

2.16 QUALITY OF AN ORGANIC CROP RESIDUE

In West Africa, organic residues may play central roles in halting the alarming soil fertility decline. Organic inputs can have fertilizer equivalency values of 50 to 100 kg

N/ha (Ladha *et al.*, 1988). While there is significant evidence that the addition of organic residues (obtained from trees/shrubs and crops) to soils can improve overall soil fertility, smallholder farmers are increasingly challenged in the selection of appropriate plant materials for soil nutrient management practices (Partey, 2011). The resource quality of plant materials varies with the plant species, plant parts and their maturity, so it is essential that these are known for each plant material. Plant materials are classified by taxonomic family, genus, and species and whether they are able to nodulate and fix N or not. The material is further described according to plant part; leaf, stem, root, or stover and whether the material is fresh or litter.

Crop residues are added to soils as sources of plant nutrients and to improve the physical properties of the soil. These materials do not contain the same quantity of nutrients. In fact, incorporating some organic materials into the soil can induce nitrogen deficiencies in plants (Barbarick, 1993). The composition of the added material determines whether nitrogen is released for plant growth or tied up in an unavailable form by the microorganisms that decompose the organic fertilizers (Barbarick, 1993).

Palm (2001) formulated a simple decision tool for managing organic resources. This system distinguished organic resources based on their chemical characteristics and decomposition patterns suggesting how each can be managed for short-term nutrient release within cropping systems (Palm *et al*., 2001; Vanlauwe *et al*., 2005). According to this decision support system, high quality organic residues (generally high in nitrogen and low in lignin and polyphenols) can be solely incorporated into soils with no N fertilizer additions while low quality organic residues would have to be applied in combination with N fertilizers (Palm *et al*., 2001). The incorporation of low quality organic resources with low N concentration and wide C-to-N ratio could result in initial net N immobilization unless supplementary N is provided through the application of N fertilizers (Bhupinderpal-Singh and Rengel, 2007).

In Africa, most of the available organic residues have competitive uses and are often low in nutrient concentrations (Vanlauwe *et al*., 2005) to be used as sole nutrient sources for crops. In most parts of the tropics, residues from cereal crops such as maize (*Zea mays*) are among the most abundant but low quality organic resources in Sub-Saharan Africa, which although potential in soil management practices, are often burnt before cropping. In the past, farmers had complained about delayed decomposition of maize residues when left on farmlands, which cause N immobilization in the short term (Partey *et al*., 2013a). While the application of maize residues with inorganic fertilizers is a viable option (Smaling *et al*., 2002), regular application of inorganic fertilizers is seldom practiced in Sub-Saharan Africa (Mateete *et al*., 2010) due to several socioeconomic constraints (Partey *et al.*, 2013b). The low level of fertilizer use will mean that farmers will continuously crop farmlands without adequate nutrient replenishment. This therefore necessitates the exploration of suitable high quality organic residues, which can serve as alternatives to inorganic fertilizers.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 EXPERIMENTAL SITE

Two field studies were conducted on the same plot during the major and minor cropping seasons of 2014 at the Plantation Section of the Crop and Soil Sciences Department, Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, from June to December 2014. Kumasi is situated in the semi-deciduous forest vegetational zone of Ghana. It is about 356 m above sea level on latitude 06° 43‟N and longitude 01° 33‟W (Asiamah, 1998) . According to the classification of Asiamah (1998), 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, which according to pre-sowing soil test results, is low in fertility especially in nitrogen and phosphorus as they were below the critical level reported by Pam and Brian (2007) (Appendix 1).

3.2 CLIMATE

The rainfall pattern of the area is bimodal with an average annual rainfall of 1422.4 mm. 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, when most of the rain falls as heavy convectional storms, followed by main dry season from late November to mid-March. The average relative humidity for 2014 varied from 83.88 % (09 hours GMT) during the major and minor rainy seasons to 58.42 % (15 hours GMT) during the dry season (Metrological Department, KNUST, 2014). Annual average maximum and minimum temperatures for 2014 were 31.59^{0}C and 22.09^0 C respectively. The mean daily maximum and minimum temperatures during the period of the experiment were 29.01^0 C and 21.32^0 C, and 31.85^0 C and 22.34^0 C for the major and minor season, respectively. Total rainfall recorded during the experiment were 466.55 mm and 317.85 mm (major and minor season) and relative humidity varied from 77.84% (09 hours GMT) to 51.34% (15 hours GMT) during the major season and 83.67% (09 hours GMT) to 59.17% (15 hours GMT) during the minor season (Metrological Department, KNUST, 2014).

3.3 PHYSICAL AND CHEMICAL SOIL ANALYSIS

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

3.3.1 Organic Carbon

The Walkley-Black wet combustion procedure (Nelson and Sommers, 1982) was used to determine organic carbon.

3.3.2 Soil pH

This was measured in 1:2.5 soil to water suspension by the use of a glass Electrocalomel electrode (Mclean, 1962) pH meter.

3.3.3 Total Nitrogen

The Macro Kjeldahl method described by Bremmer and Mulvaney (1982) 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 1 g selenium with 30 mls of concentrated sulphuric acid. This was followed by distillation with 10 ml boric acid (4 %) and 4 drops of indicator and 15mls 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.

3.3.4 Available phosphorous

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

3.3.5 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.

3.3.6 Particle size analysis

Particle size was analyzed using the hydrometer method (Bouyoucos, 1962).

3.4 EXPERIMENT ONE: TO EVALUATE THE RESPONSE OF COWPEA TO NITROGEN AND PHOSPHORUS FERTILIZER APPLICATION.

3.4.1 Land preparation

The land was previously cropped to cassava. The experimental site was cleared by slashing, ploughed and harrowed with a tractor. It was then levelled and the plots were laid out using measuring tape, garden line and pegs.

3.4.2 Variety used for the experiment

The Asontem cowpea variety used was obtained from the Crops Research Institute (CRI) of the Council for Scientific and Industrial Research (CSIR) at Fumesua, Kumasi. Asontem is an early maturity genotype (65 days) with small seed size, rounded and brown seed colour.

3.4.3 Experimental design, layout, treatments and planting

The experimental design was a 5 x 4 factorial arranged in randomized complete block, with three replications (blocks). The experiment consisted of five (5) levels of nitrogen (Factor A) using urea (46 % N) with four levels of Phosphorus fertilizer (Factor B) using triple super phosphate (46 % P_2O_5). The nitrogen fertilizer levels were: 0, 10, 20, 30 and 40 kg N/ha. The phosphorus fertilizer levels were: 0, 15, 30 and 45 kg P_2O_5 /ha. The different N and P rates were selected based on the recommendations of 20 kg/ha N (Osiname, 1978) and 30 kg P_2O_5 /ha (Agboola and Obigbesan, 1977) as the optimum rates in tropical African soils. Therefore N and P rates below and above the recommended optimum rates were tested to observe their performances. There were 60 plots, each measuring 4.1×1.9 m with 1m between replications (blocks) and 0.5 m between plots. Three seeds were planted per hill at 4 to 5 cm deep with 60 cm for inter row spacing and 20 cm for intra-row spacing. The seedlings were thinned to 2 stands per hill at 14 days after planting (DAP), corresponding to a population density of 143,774 per hectare. Planting was done on the 17th June, 2014.

3.4.4 Fertilizer application

Fertilizer rate was calculated as mass of fertilizer (g)/ plot and the amount per plot divided by 7 rows to get the amount applied per row. Fertilizer was applied by side band placement method at 14 DAP.

3.4.5 Weeding

This was done by hoeing at 13 and 35 DAP.

3.4.6 Pest management

There were incidences of grass hoppers at vegetative stage and aphids from flowering to the end of pod filling. Lambda master 2.5 % E.C. [Active ingredients (Lambda-Cyhalothrin, 9.8 %)] at the rate of 100 ml in 15 L of water using knapsack sprayer, at 10 days interval to control the grass hoppers and other leaf chewing insects, whiles the aphids were controlled by using sunpyrifos 48 % E.C. [Active ingredients (Chlorpyrifos-methyl)] at an interval of 7 days at a rate of 50ml to 15 L of water.

3.5 DATA COLLECTION

Sampling for growth analysis was done at 2, 4, and 6 weeks after fertilizer application. Five consecutive plants from the second row of each plot were tagged for the following measurements.

3.5.1. Plant height

The plant height was measured from the ground level to the highest tip of the stem for the five tagged plants. This was done using a meter rule at the various sampling periods, and the average height calculated for each plot.

3.5.2 Number of leaves

Number of leaves from the tagged plants were counted at the periods indicated above and the mean calculated for each plot.

3.5.3 Leaf Area (LA)

Leaf area was estimated by taken the product of the length and breadth at the broadest point of the longest leaf on each tagged plant and then multiplied by a conversion factor of 0.75 (Adeoye *et al.*, 2011).

3.5.4 Stem girth

The stem girth was measured at 2 cm above soil level with the aid of a venire calipers and the average recorded.

3.5.5 Leaf area index (LAI)

Leaf area index (LAI) was determined from LA using instantaneous approach. This was done by calculating number of plants per one (1) square meter of land (16 plants) for each plot and the leaf area index was deduced using the equation below:

$$\text{LAI} = \text{Leaf Area of number of plants per meter squre} \div 1 \text{ meter squre of land}$$

3.5.6 Number of Branches

The number of branches of the five tagged plant from each plot were counted at every sampling period and the average recorded.

3.5.7 Dry matter yield

Five (5) plants per plot at two (2) and four (4) weeks after fertilizer application were uprooted gently and the root system was removed, the above ground parts were put in labeled envelops and oven dry at 80^0 C for 48 hours. The average dry weight of the biomass was computed as dry matter yield per plant.

3.5.8 Number of nodules and effective nodules

Number of nodules and effective nodules were collected at two (2) and four (4) weeks after fertilizer application. Five (5) plants from each plot at each sampling time were dug out gently, all nodules including detached ones were collected and kept in labelled polytene bags and sent to the laboratory where they were washed and counted and mean calculated for each plot.

Fifteen (15) randomly selected nodules were cut opened using a razor and a hand lens to determine their effectiveness. Nodules with pink or reddish colour were declared effective and fixing nitrogen, while those with cream to whitish or greenish were recorded as ineffective (Mpepereki and Makonese, 1998). The percentage effective nodules were then calculated.

3.5.9 Nodule dry weight

All nodules (effective and ineffective) per plot were kept in labelled envelops and oven dried at 80^0 C for 48 hours. Average dry weight of nodules per plant was computed for each plot.

3.5.10 Number of pods per plant

Pods from five (5) randomly selected plants in the border rows (as the middle rows were reserved for yield per hectare data) of each plot were plucked, counted and the average number of pod calculated.

3.5.11 Number of seeds per pod

The number of seeds per pod was determined by threshing pods from the five randomly selected plants after oven dried at 80^{o} C for 48 hours. The seeds were counted and divided by number of pods to obtain mean number of seeds per pod for each plot.

3.5.12 100 Seed Weight

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

3.5.13 Harvest Index

After shedding the pods of the five plants from each plot, the seeds, chaff and the total biomass were oven dried at 80^{0}C for 48 hours and dry weight measured. Harvest index was calculated by using the formula suggested by Donald (1963) and expressed as a percentage.

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

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

3.5.14 Pod yield per hectare

Pod yield per hectare was determined by harvesting plants from the central 1.44 m^2 area of each plot. These were put in labeled envelops, 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.

3.5.15 Seed yield per hectare

The Seed yield per hectare was determined by threshing the pods from the 1.44 m^2 area and the clean seeds weighed. The resulting weights, in grams per meter square were then extrapolated to kg per ha basis.

3.5.16 Total nitrogen content in the cowpea seeds and residues

The oven-dried seeds and residues were ground separately using a micro-hammer mill and store in an air tight labeled plastic container prior to analysis. Total nitrogen was determined for grains and residues separately.

The Macro Kjeldahl method described by Bremmer and Mulvaney (1982) was used. A 2 g each for seeds and residues were weighed and digested with a mixture of 100g potassium sulphate, 10 g copper sulphate and 1 g selenium with 30 mls of concentrated sulphuric acid. This was followed by distillation with 10ml boric acid (4 %) and 4 drops of indicator and 15mls of 40 % NaOH. It was then titrated with Ammonium sulphate solution. Based on the relation that 14g of nitrogen is contained in one equivalent weight of NH_3, the percentage of nitrogen in the seeds and residues were 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.

3.5.17 Crude protein content of cowpea seeds

The nitrogen content of the seeds from each plot was multiplied by a conversion factor of 6.25 to determine the crude protein content of the seeds (Okwu *et al*., 2006).

3.6 EXPERIMENT TWO: TO DETERMINE THE EFFECT OF RESIDUAL FERTILITY ON SUCCEEDING MAIZE GROWTH AND YIELD.

3.6.1 Land preparation

The plots were left intact after the first experiment while the land was manually cleared of weeds and debris. All the cowpea residues including empty pods were left on each plot after harvest. No tillage operation was done.

3.6.2 Variety used for the experiment

The Abontem maize variety used was obtained from the Crops Research Institute (CRI) of the Council for Scientific and Industrial Research (CSIR) at Fumesua, Kumasi. Abontem is an early maturity genotype (75 days) with yellow seed colour.

3.6.3 Planting

Planting was done on the 8th September, 2014. Three seeds were planted per hill at 4 to 5 cm deep with 70 cm for inter row spacing and 30 cm for intra- row spacing. The seedlings were thinned to 2 stands per hill at 14 days after planting (DAP), corresponding to a population density of 107,830 per hectare.

3.6.4 Weeding

This was done once by hoeing at 35 DAP.

3.6.5 Pest management

There were incidences of stem borers from the early vegetative stage to tasselling. These were minimized using sunpyrifos [Active ingredients (Chlorpyrifos-methyl)] at an interval of 7 days and at a rate of 50ml to 15 L of water.

3.7 DATA COLLECTION

Sampling for growth indices was done at 25, 45, and 65 DAP. Five consecutive plants from the second row of each plot were tagged for the following measurements.

3.7.1. Plant height

The plant height was measured from the ground level to the apical portion of the stem. This was done with the use of a meter rule at the various sampling periods and the average height calculated for each plot.

3.7.2 Number of leaves

Number of leaves from the tagged plants were counted at the periods indicated above and the mean calculated for each plot.

3.7.3 Leaf Area (LA)

Leaf area was estimated by taken the product of the length and breadth at the broadest point of the longest leaf on each tagged plant and then multiplied by a conversion factor of 0.75 (Adeoye *et al.*, 2011).

3.7.4 Stem girth

The stem girth was measured at 2 cm above soil level with the aid of a venier calipers and the average recorded for each plot.

3.7.5 Dry matter yield

Five (5) plants each per plot was harvested at 25, 45 and 65 DAP at ground level and separated into stems and leaves. The various plant parts were put in different labeled envelops and oven dried at 80^0 C for 48 hours in each sampling time.

The average dry matter per plant was determined by weighing each part and the average dry weight was computed for each plot.

3.7.6 Mean number of cobs per plant

Five random plants were collected from the border rows, the cobs in these plants were counted and the average number of cobs was determined for each plot.

3.7.7 Number of grains per cob

Five (5) cobs were selected at random from each plot. The number of grains in five (5) rows was counted, an average calculated and multiplied by the number of rows on the cob. The mean number of grains per cob for each plot was then computed.

3.7.8 1000-grain weight

The 1000 grain weight was determined by counting 1000 grains from the threshed cobs which have been oven dried at 80^{o} C to constant weight. These were weighed to represent the 1000-grain weight for each plot.

3.7.9 Grain yield

The grain yield per hectare was determined by threshing all the cobs from an area of 2.10 m^2 and the clean grains were weighed. The resulting weights, in grams per meter square were then extrapolated to kg per ha basis.

3.7.10 Harvest Index

After harvest, the five randomly selected plants in the border rows were oven dried at 80^{o} C to constant weight. Harvest index was calculated by using the formula suggested by Donald (1963) and expressed as a percentage.

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

Where economic yield is seed yield of the 5 plants whilst the total biological yield is the summation of total biomass and seed yield plus cobs.

3.8 DATA ANALYSIS

All the data collected were subjected to analysis of variance (ANOVA) using GenStat statistical package. The treatment means were compared using the Least Significant Difference (LSD) at 5 % level of probability.

CHAPTER FOUR

4.0 RESULTS

4.1 RESULTS OF EXPERIMENT ONE

4.2 PLANT HEIGHT

Table 4. 1: Effects of N and P rates on plant height of cowpea in three sampling periods.

	Plant height (cm)		
Treatments	2 WAFA	4 WAFA	6 WAFA
N rates (kg/ha)			
0	20.17	151.30	181.90
10	19.97	144.70	183.10
20	19.43	143.90	173.30
30	20.77	157.40	172.60
40	21.35	155.70	184.00
LSD (5%)	**NS**	**NS**	**NS**
P rates (kg P_2O_5/ha)			
0	20.57	149.80	171.40
15	20.40	148.70	182.40
30	20.52	153.80	182.30
45	19.86	150.10	179.90
LSD (5%)	**NS**	**NS**	**NS**
CV (%)	**12.5**	**11.7**	**6.7**

NS = not significant. WAFA = Weeks after fertilizer application

The results of plant height for three sampling periods during the experiment are presented in Table 4.1. Nitrogen and phosphorus rates did not significantly affect ($P > 0.05$) cowpea plant height at all the sampling periods.

4.3 NUMBER OF LEAVES

Table 4. 2: Effects of N and P rates on leaf number of cowpea in three sampling periods.

	Leaf number		
Treatments	2 WAFA	4 WAFA	6 WAFA
N rates (kg/ha)			
0	9.20	23.77	34.73
10	8.80	21.52	35.60
20	9.15	21.22	34.25
30	8.95	24.27	36.83
40	9.15	23.12	36.93
LSD (5%)	**NS**	**NS**	**NS**
P rates (kg P_2O_5/ha)			
0	8.81	21.79	35.33
15	9.16	22.13	35.41
30	9.29	24.15	34.56
45	8.93	23.04	37.37
LSD (5%)	**NS**	**NS**	**NS**
CV (%)	**16.6**	**21.1**	**10.3**

NS = not significant. WAFA = Weeks after fertilizer application

Table 4.2 showed the number of leaves per plant as influenced by N and P rates over three sampling periods. Leaf number per plant was not significantly ($P > 0.05$) affected by N and P rates on all sampling occasions.

4.4 LEAF AREA (LA)

Table 4. 3: Effects of N and P rates on leaf area of cowpea over three sampling periods.

	Leaf area (cm^2)		
Treatments	2 WAFA	4 WAFA	6 WAFA
N rates (kg/ha)			
0	30.62	39.82	54.93
10	28.73	41.93	54.27
20	28.90	39.84	53.17
30	29.35	40.17	54.56
40	32.52	40.65	53.23
LSD (5%)	**NS**	**NS**	**NS**
P rates (kg P_2O_5/ha)			
0	29.41	38.11	51.94
15	28.90	41.07	54.80
30	31.62	41.34	53.20
45	30.17	41.41	56.19
LSD (5%)	**NS**	**NS**	**NS**
CV (%)	**13.4**	**10.0**	**9.3**

NS = not significant. WAFA = Weeks after fertilizer application

Results of leaf area per plant recorded at different growth stages are shown in Table 4.3. The leaf area did not differ significantly ($p > 0.05$) by nitrogen and phosphorus fertilizer application at all the sampling times.

4.5 LEAF AREA INDEX (LAI)

Table 4. 4: Effects of N and P rates on leaf area index of cowpea in three sampling periods.

	Leaf area index		
Treatments	2 WAFA	4 WAFA	6 WAFA
N rates (kg/ha)			
0	4.901	6.373	8.791
10	4.597	6.712	8.683
20	4.624	6.374	8.507
30	4.694	6.429	8.523
40	5.191	6.504	8.516
LSD (5%)	**NS**	**NS**	**NS**
P rates (kg P_2O_5/ha)			
0	4.705	6.099	8.311
15	4.623	6.575	8.767
30	5.049	6.615	8.511
45	4.827	6.626	8.826
LSD (5%)	**NS**	**NS**	**NS**
CV (%)	**13.5**	**10.0**	**8.3**

NS = not significant. WAFA = Weeks after fertilizer application

Results of leaf area index as affected by nitrogen and phosphorus fertilizer application are presented in Table 4.4. The leaf area index did not differ significantly (P > 0.05) with nitrogen and phosphorus fertilizer application at all the sampling periods.

4.6 NUMBER OF BRANCHES

Table 4. 5: Effects of N and P rates on number of branches of cowpea in three sampling periods.

	Number of branches		
Treatments	2 WAFA	4 WAFA	6 WAFA
N rates (kg/ha)			
0	1.850	3.967	7.920
10	1.870	3.967	7.400
20	1.570	3.900	7.530
30	1.800	4.000	7.730
40	2.080	3.983	7.970
LSD (5%)	**NS**	**NS**	**NS**
P rates (kg P_2O_5/ha)			
0	1.650	3.960	7.790
15	1.830	3.907	7.330
30	1.960	3.840	7.510
45	1.890	4.147	8.210
LSD (5%)	**NS**	**NS**	**NS**
CV (%)	**43.9**	**16.1**	**11.6**

NS = not significant. WAFA = Weeks after fertilizer application

Results of the number of branches per plant at varying sampling times during the experiment are presented in Table 4.5. Number of branches per plant was not affected by N and P rates at all the sampling periods.

4.7 STEM GIRTH

Table 4. 6: Effects of N and P rates on stem girth of cowpea in three sampling periods.

	Stem girth (cm)		
Treatments	2 WAFA	4 WAFA	6 WAFA
N rates (kg/ha)			
0	0.328	0.538	0.823
10	0.313	0.553	0.865
20	0.305	0.563	0.827
30	0.328	0.635	0.885
40	0.335	0.567	0.888
LSD (5%)	**NS**	**NS**	**NS**
P rates (kg P_2O_5/ha)			
0	0.319	0.549	0.868
15	0.332	0.579	0.871
30	0.321	0.605	0.827
45	0.316	0.552	0.865
LSD (5%)	**NS**	**NS**	**NS**
CV (%)	**18.9**	**19.9**	**7.1**

NS = not significant. WAFA = Weeks after fertilizer application

Results of stem girth per plant at 2, 4 and 6 weeks after fertilizer application are presented in Table 4.6. Stem girth per plant was not significantly ($p > 0.05$) affected by N and P rates at all the sampling periods.

4.8 SHOOT DRY MATTER

Table 4. 7: Effects of N and P rates on shoot dry matter yield of cowpea in two sampling periods.

	Shoot dry matter (g)	
Treatments	2 WAFA	4 WAFA
N rates (kg/ha		
0	2.836	10.750
10	2.433	11.180
20	2.726	10.630
30	2.727	12.870
40	2.87	12.200
LSD (5%)	**NS**	**NS**
P rates (kg P_2O_5/ha)		
0	2.771	10.650
15	2.653	11.620
30	2.726	11.700
45	2.728	12.130
LSD (5%)	**NS**	**NS**
CV (%)	**26.4**	**30.8**

NS = not significant. WAFA = Weeks after fertilizer application

Table 4.7 showed result of nitrogen and phosphorus fertilizer application on shoot dry matter per plant. Nitrogen and phosphorus fertilizer application had no significant effect ($P > 0.05$) on shoot dry matter yield at all sampling periods.

4.9 NODULATION PARAMETERS

Table 4. 8: Influence of nitrogen and phosphorus levels on number of nodules, effective nodules and dry weight of nodules per plant at 2 and 4 WAFA.

	Number of nodules		Effective nodules (%)		Nodule dry weight (g)	
Treatments	2 WAFA	4 WAFA	2 WAFA	4 WAFA	2 WAFA	4 WAFA
N rates (kg/ha)						
0	17.88	25.02	80.00	85.00	0.008	0.051
10	17.57	20.32	66.70	90.00	0.005	0.031
20	17.40	19.78	88.30	78.30	0.007	0.032
30	18.18	17.73	76.70	81.70	0.005	0.029
40	19.28	18.73	73.30	71.70	0.010	0.032
LSD (5%)	**NS**	**3.94**	**NS**	**NS**	**NS**	**NS**
P rates (kg P_2O_5/ha)						
0	16.99	17.81	69.30	76.00	0.007	0.028
15	18.31	18.92	77.30	70.70	0.005	0.030
30	16.31	20.55	82.70	90.70	0.007	0.036
45	20.65	23.99	78.70	88.00	0.010	0.046
LSD (5%)	**NS**	**3.52**	**NS**	**NS**	**NS**	**NS**
CV (%)	**26.9**	**23.5**	**37.1**	**33.4**	**89.1**	**57.4**

NS = not significant. WAFA = Weeks after fertilizer application

Results on number of nodules per plant, effective nodules per plant and nodule dry weight per plant as influenced by nitrogen and phosphorus fertilizer application at two sampling periods are presented in Table 4.8.

At the first sampling period, that is at 2 weeks after fertilizer application both nitrogen and phosphorus rates did not significantly ($P > 0.05$) affect nodule number per plant. However at 4 weeks after fertilizer application, nodule number was significantly ($P < 0.05$) affected by both nitrogen and phosphorus fertilizer rates. Nodule number was nearly successively decreased with increasing level of nitrogen. The 0 kg N/ha nitrogen treatment produced the greatest number of nodule per plant (25.02) which was significantly higher than all the other treatments and the least number of nodules was produced by the 30 kg/ha N treatment (17.73). All other treatment differences were not significant.

Among the P treatments, number of nodules was greatest in the 45 kg P/ha treatment and this was significantly higher than the control and 15 kg P/ha treatment effects only. All other treatment effects were similar.

Percentage nodule effectiveness was neither affected by nitrogen levels nor by phosphorus rates for both sampling times as shown in Table 4.8. Similarly, nodule dry weight did not show significant ($P > 0.05$) effect due to nitrogen and phosphorus fertilizer application at all the sampling times.

4.10 YIELD COMPONENTS.

The results of number of pods per plant, number of seeds per pod and 100 seed weight are presented in Table 4.9. N and P rates did not significantly ($P > 0.05$) affect all the components of yield measured in the study.

Table 4. 9: Effects of N and P rates on yield components of cowpea.

Treatments	No. of pods/ plant	No. of seeds/ pod	100 seed weight (g)
N rates (kg/ha)			
0	9.45	14.61	15.30
10	7.07	14.78	15.47
20	8.08	14.71	15.22
30	9.40	14.57	15.41
40	9.78	14.45	15.03
LSD (5%)	**NS**	**NS**	**NS**
P rates (kg P_2O_5/ha)			
0	8.36	14.56	15.30
15	8.43	14.59	15.10
30	9.40	14.41	15.51
45	8.84	14.93	15.24
LSD (5%)	**NS**	**NS**	**NS**
CV (%)	**31.3**	**7.3**	**3.3**

NS = not significant.

4.11 HARVEST INDEX, POD YIELD AND GRAIN YIELD.

The results of harvest index, pod yield and grain yield are presented in Table 4.10. N and P rates effect was not significant (P > 0.05) for these parameters.

Table 4. 10: Effects of N and P rates on harvest index, pod and grain yield of cowpea.

Treatment	Harvest index (%)	Pod yield (kg/ha)	Grain yield (kg/ha)
N rates (kg/ha)			
0	45.78	2025	1541
10	39.38	1843	1407
20	42.53	1545	1194
30	41.98	2047	1557
40	43.63	1930	1482
LSD (5%)	**NS**	**NS**	**NS**
P rates (kg P_2O_5/ha)			
0	44.28	1848	1409
15	42.19	1862	1416
30	43.69	1863	1436
45	40.48	1939	1484
LSD (5%)	**NS**	**NS**	**NS**
CV (%)	**13.4**	**27.7**	**27.2**

NS = not significant

4.12 SEED N, RESIDUE N, PLANT TOTAL N AND SEED CRUDE PROTEIN CONTENT

Results of % total seed N, % total residue N, % plant total N and % seed crude protein content as affected by nitrogen and phosphorus fertilizer application are presented in Table 4.11.

Cowpea seed N was greatest in the 30 kg N/ha treatment and this was significantly higher than all other treatment effects, except that of the 20 kg N/ha treatment. The control treatment effect was significantly lower than all other treatment effects. P application did not significantly ($P > 0.05$) affect seed N in cowpea.

N and P application did not significantly ($P > 0.05$) affect cowpea residue N content. Total plant N was significantly affected by N application (Table 4.11). Total plant N was greatest following application of 30 kg N/ha, but this was significantly higher than the control and 40 kg N/ha treatment effects only. The control treatment effect was significantly lower than all other treatment effects. P application, on the other hand did not affect cowpea total plant N content.

Seed crude protein content was greatest in the 30 kg N/ha treatment, which was significantly higher than all other treatment effects, except that of the 20 kg N/ha treatment only. The control treatment effect was significantly lower than those of all other treatment effects, except that of the 10 kg N/ha treatment. All other treatment differences were not significant. P application did not significantly affect seed crude protein content.

Table 4. 11: Effects of N and P rates on seed nitrogen, residue nitrogen, total plant nitrogen and seed crude protein content of cowpea

Treatments	Seed N (%)	Residue N (%)	Total plant N (%)	Seed crude protein (%)
N rates (kg/ha)				
0	3.46	1.34	4.81	21.65
10	3.61	1.50	5.11	22.58
20	3.69	1.40	5.10	23.12
30	3.82	1.51	5.34	23.93
40	3.61	1.47	5.09	22.60
LSD (5%)	**0.15**	**NS**	**0.24**	**0.94**
P rates (kg P_2O_5/ha)				
0	3.64	1.47	5.12	22.81
15	3.56	1.39	4.96	22.30
30	3.70	1.40	5.11	23.17
45	3.65	1.52	5.17	22.82
LSD (5%)	**NS**	**NS**	**NS**	**NS**
CV (%)	**5.0**	**15.7**	**5.8**	**5.0**

NS = not significant.

4.13 RESULTS OF EXPERIMENT TWO

4.14 PLANT HEIGHT

The results of plant height for three sampling periods during the experiment are presented in Table 4.12. Residual nitrogen and phosphorus fertilizer did not significantly affect ($P > 0.05$) maize plant height at all the sampling periods.

Table 4. 12: Effects of residual N and P on plant height of maize in three sampling periods.

	Plant height (cm)		
Treatments	25 DAP	45 DAP	65 DAP
Residual N rates (kg/ha)			
0	75.87	167.80	225.10
10	80.98	175.70	230.30
20	79.72	168.60	226.80
30	78.80	173.50	229.70
40	76.09	165.60	225.80
LSD (5%)	**NS**	**NS**	**NS**
Residual P rates (kg P_2O_5/ha)			
0	76.17	166.30	225.50
15	77.55	168.90	232.50
30	79.66	169.80	222.60
45	79.77	175.90	229.60
LSD (5%)	**NS**	**NS**	**NS**
CV (%)	**7.6**	**8.8**	**4.4**

NS = not significant. DAP = Days after planting

4.15 NUMBER OF LEAVES

Table 4.13 shows the number of leaves per plant as influenced by residual N and P over three sampling periods. Leaf number per plant was not significantly ($P > 0.05$) affected by residual N and P rates on all sampling occasions.

Table 4. 13: Effects of residual N and P on leaf number of maize in three sampling periods.

	Leaf number		
Treatments	25 DAP	45 DAP	65 DAP
Residual N (kg/ha)			
0	7.467	9.517	10.800
10	7.533	10.217	11.133
20	7.683	9.783	10.383
30	7.733	10.017	10.883
40	7.533	9.833	10.967
LSD (5%)	**NS**	**NS**	**NS**
Residual P rates (kg P_2O_5/ha)			
0	7.400	9.827	10.987
15	7.813	9.987	10.800
30	7.547	9.947	10.827
45	7.600	9.733	10.720
LSD (5%)	**NS**	**NS**	**NS**
CV (%)	**8.0**	**6.0**	**5.8**

NS = not significant. DAP = Days after planting

4.16 LEAF AREA (LA)

Results of leaf area per plant recorded at different growth stages are shown in Table 4.14. The leaf area did not differ significantly ($P > 0.05$) by residual nitrogen and phosphorus fertilizer at all the sampling times.

Table 4. 14: Effects of residual N and P on leaf area of maize in three sampling periods.

	Leaf area (cm^2)		
Treatments	25 DAP	45 DAP	65 DAP
Residual N rates (kg/ha)			
0	199.10	486.10	544.70
10	227.50	504.90	564.30
20	209.10	498.20	540.10
30	212.00	503.80	555.10
40	200.50	465.80	528.80
LSD (5%)	**NS**	**NS**	**NS**
Residual P rates (kg P_2O_5/ha)			
0	199.50	486.00	556.40
15	209.40	496.30	545.70
30	211.50	484.60	534.80
45	218.00	500.10	549.40
LSD (5%)	**NS**	**NS**	**NS**
CV (%)	**14.0**	**8.2**	**7.2**

NS = not significant. DAP = Days after planting

4.17 STEM GIRTH

Results of stem girth per plant at 25, 45 and 65 days after planting are presented in Table 4.15. Stem girth per plant was not significantly ($P > 0.05$) affected by residual N and P rates at all the sampling periods.

Table 4. 15: Effects of residual N and P on stem girth of maize in three sampling periods.

	Stem girth (cm)		
Treatments	25 DAP	45 DAP	65 DAP
Residual N rates (kg/ha)			
0	0.760	1.465	1.618
10	0.808	1.510	1.712
20	0.743	1.462	1.610
30	0.797	1.535	1.653
40	0.740	1.435	1.690
LSD (5%)	**NS**	**NS**	**NS**
Residual P rates (kg P_2O_5/ha)			
0	0.713	1.467	1.649
15	0.769	1.477	1.705
30	0.783	1.451	1.601
45	0.813	1.531	1.671
LSD (5%)	**NS**	**NS**	**NS**
CV (%)	**16.1**	**9.5**	**9.7**

NS = not significant. DAP = Days after planting

4.18 TOTAL SHOOT DRY MATTER

Table 4.16 shows result of residual nitrogen and phosphorus fertilizer on total shoot dry matter yield per plant. Residual nitrogen and phosphorus fertilizer had no significant effect ($P > 0.05$) on total shoot dry matter yield at all sampling periods.

Table 4. 16: Effects of residual N and P on total shoot dry matter yield of maize in three sampling periods

	Total shoot dry matter (g)		
Treatments	25 DAP	45 DAP	65 DAP
Residual N rates (kg/ha)			
0	2.79	28.98	59.80
10	3.63	34.73	72.00
20	3.02	30.12	56.90
30	3.01	30.46	64.10
40	2.75	31.44	62.90
LSD (5%)	**NS**	**NS**	**NS**
Residual P rates (kg P_2O_5/ha)			
0	2.83	29.07	53.90
15	3.09	32.63	66.10
30	3.05	30.89	65.80
45	3.19	32.00	66.80
LSD (5%)	**NS**	**NS**	**NS**
CV (%)	**24.9**	**21.0**	**23.0**

NS = not significant. DAP = Days after planting

4.19 LEAF DRY MATTER

Leaf dry matter as affected by residual N and P fertilizer is presented in Table 4.17. At all the sampling periods, leaf dry matter was not significantly affected ($P > 0.05$) by residual nitrogen and phosphorus fertilization.

Table 4. 17: Effects of residual N and P on leaf dry matter of maize in three sampling periods.

	Leaf dry matter (g)		
Treatments	25 DAP	45 DAP	65 DAP
Residual N rates (kg/ha)			
0	2.05	12.63	23.76
10	2.57	14.13	26.71
20	2.19	11.52	23.48
30	2.16	12.43	23.93
40	1.96	13.29	22.14
LSD (5%)	**NS**	**NS**	**NS**
Residual P rates (kg P_2O_5/ha)			
0	2.09	12.57	22.77
15	2.19	13.13	24.10
30	2.17	12.63	24.51
45	2.29	12.86	24.62
LSD (5%)	**NS**	**NS**	**NS**
CV (%)	**26.2**	**21.8**	**20.0**

NS = not significant. DAP = Days after planting

4.20 STEM DRY MATTER

Residual fertility did not significantly affect maize stem dry weight (Table 4.18).

Table 4. 18: Effects of residual N and P on stem dry matter of maize in three sampling periods.

	Stem dry matter (g)		
Treatments	25 DAP	45 DAP	65 DAP
Residual N rates (kg/ha)			
0	0.73	16.35	23.60
10	1.02	20.60	26.50
20	0.82	18.60	22.10
30	0.84	18.04	26.00
40	0.79	18.16	26.90
LSD (5%)	**NS**	**NS**	**NS**
Residual P rates (kg P_2O_5/ha)			
0	0.70	16.49	23.20
15	0.89	19.50	25.30
30	0.88	18.26	24.70
45	0.89	19.14	26.80
LSD (5%)	**NS**	**NS**	**NS**
CV (%)	**30.7**	**24.0**	**33.6**

NS = not significant. DAP = Days after planting

4.21 YIELD COMPONENTS

The results of number of cobs per plant, number of seeds per cob and 1000 grain weight are presented in Table 4.19. Residual N and P fertilization did not significantly ($P > 0.05$) affect all the components of yield measured in the study.

Table 4. 19: Effects of residual N and P rates on yield components of maize

Treatments	No. of cobs/ plant	No. of seeds/ cob	1000 grain weight (g)
Residual N rates (kg/ha)			
0	1.06	377.70	174.80
10	1.08	381.70	167.00
20	1.08	371.40	167.80
30	1.05	368.80	173.50
40	1.05	355.20	184.00
LSD (5%)	**NS**	**NS**	**NS**
Residual P rates (kg P_2O_5/ha)			
0	1.02	369.20	165.50
15	1.02	379.80	173.50
30	1.13	354.70	176.50
45	1.08	380.20	178.20
LSD (5%)	**NS**	**NS**	**NS**
CV (%)	**11.8**	**18.6**	**9.4**

NS = not significant

4.22 HARVEST INDEX AND GRAIN YIELD.

The results of harvest index and grain yield are presented in Table 4.20. Residual N and P fertilizer effect was not significant ($P > 0.05$) for these parameters.

Table 4. 20: Effects of residual N and P rates on harvest index and grain yield of maize.

Treatments	Harvest index (%)	Grain yield (kg/ha)
Residual N rates (kg/ha)		
0	43.48	2505.00
10	44.10	2733.00
20	45.35	2667.00
30	43.82	2714.00
40	44.20	2562.00
LSD (5%)	**NS**	**NS**
Residual P rates (kg P_2O_5/ha)		
0	42.01	2351.00
15	44.86	2760.00
30	45.42	2521.00
45	44.46	2913.00
LSD (5%)	**NS**	**NS**
CV (%)	**10.0**	**25.5**

NS = not significant.

CHAPTER FIVE

5.0 DISCUSSION

5.1 DISCUSSION OF EXPERIMENT ONE

5.1.1 Effect of N and P fertilizer application on growth and dry matter yield of cowpea

The result obtained from this study in terms of growth and dry matter yield of cowpea reveals that different rates of nitrogen fertilizer application had no significant effect on the growth and dry matter yield of cowpea. The non responsiveness to nitrogen application rates observed in this study for these parameters confirms that the nitrogen fixing ability of the crop can satisfy the crop`s nitrogen requirement (Singh, 1997) and that legumes seeded fields do not need nitrogen fertilization (Smith *et al*., 1986). This result, however, contradicts those of Dart *et al*. (1997) and Minchin *et al*. (1981). The non significant effects on growth and dry matter yield as a result of nitrogen application in the present study might also be due to the already available soil N (Appendix 1) which could have been adequate for cowpea growth so no positive response was shown by the plants in growth and dry matter production. However, in soils very low in nitrogen contents it has been reported that cowpea hardly satisfies their nitrogen requirements, and thus the recommendations of 5-10 kg N/ha and 20 kg N/ha basal application for good growth and yield of cowpea without compromising nodulation and N-fixation have been suggested (Atkins, 1986; Osiname, 1978).

Phosphorus fertilizer application had no significant effect on the growth and dry matter production at all the sampling times. The result is in line with reports of FPDD (2002), but contradicts reports of Uzoma *et al*. (2006), Okeleye and Okelana (1997), Owolade *et al*. (2006), Bationo *et al.* (2000), Singh *et al*. (2011), Olaleye *et al.* (2012), Magani and Kuchinda (2009) who reported increase in cowpea growth and dry matter yield following P application. The low response might be due to the fact that phosphorus fertilizers are slow release of nutrients for plant uptake for growth. Another possible explanation for this might be due to the process of P fixation which might have limits the use of the applied P by the plants. P has the tendency to be fixed in the soil into forms unavailable for plant use. Olusola (2009) reported that plant will only take up about 15-30 % of applied P while about 60 % of the P fertilizer is adsorbed or fixed by the soil.

5.1.2 Effect of N and P fertilizer application on nodulation parameters of cowpea

Application of nitrogen was observed to have a significant ($P < 0.05$) influence on number of nodules/plant. Nitrogen application rates did not significantly ($P > 0.05$) affect number of nodules at two weeks after fertilization, but it did significantly ($P < 0.05$) affect number of nodules at 4 weeks. Number of nodules was depressed by increasing application of nitrogen fertilizer as recorded in Table 4.8. Many studies have been performed to test the effect of nitrogen on root nodulation. However, it is generally accepted that when sufficient levels of nitrogen are present in the soil, nodulation is inhibited (Gentili and Huss-Danell, 2002; Laws and Graves, 2005). In the present study, nitrogen application rates depressed nodulation only at 4 WAFA, but did not affect nodulation in the previous sampling date. This finding contradicts the report of Atkins

(1986) that application of 5-10 kg N/ha is necessary for early vegetative growth so that nodulation is enhanced at latter stages of growth. The results suggest that the inhibiting effect of nitrogen on nodulation is a gradual process, and that the degree of suppression could be more during the latter periods of growth.

Percent nodule effectiveness was not significantly affected by nitrogen rates at all the sampling periods. Although nodule number at 2 weeks after fertilizer application was numerically higher in the 40 kg N/ha treatment, but it did not necessarily produce the greatest number of effective nodules. In the same vein at 4 weeks after fertilizer application, the control N treatment (0 kg N/ha) numerically produced the greatest number of nodules but did not produce the greatest number of effective nodules. This could be due to the fact that some fixing bacteria are effective in nodule production but inefficient in N fixation. There are several cases where it has been reported that effective nodulation did not result in efficient N fixation (Sarkodie-Addo, 1991; Blair, 1989). Indeed Giller (2001) reported that the ability to form nodules is not enough to obtain an effective N fixation symbiosis.

Nodule dry weight results showed that the treatment (40 kg N/ha) which produced numerically the greatest nodule number produced the greatest nodule dry weight at 2 WAFA. Similarly, at 4 WAFA the control treatment which produced the greatest number of nodules had the greatest nodule dry weight and that with the lowest (30 kg N/ha) nodule number produced the lowest nodule dry weight. The indication of these results is that most of the treatments that produced more nodules also had the tendency to produce larger nodules thereby resulting in greater weight. This result is contradicting those reported by Blair (1989) and Sarkodie-Addo (1991) who found a negative correlation between nodule numbers and nodule dry weights.

The different levels of phosphorus had an effect on the nodule numbers and the result obtained was significant only at 4 WAFA (Table 4.8). The cowpea responded to the various P rates applied with the control (0 kg P_2O_5/ha) having the least nodule number followed by 15 kg P_2O_5/ha, 30 kg P_2O_5/ha, and 45 kg P_2O_5/ha respectively having the greatest number of nodules. In general, increasing the rate of phosphorus application increased the number of nodules on cowpea roots. This was in agreement with the report of Armstrong (1999) who noted that increasing P increased the number of nodules on cowpea roots but contradicts Tewari (1965). Significant increase in nodulation was also observed by Olaleye *et al*. (2011) following P application. P is known to initiate nodule formation as well as influence the efficiency of the rhizobium-legume symbiosis thereby enhancing nitrogen fixation (Haruna and Aliyu, 2011).

Nodule dry weight results (Table 4.8) showed that the treatment (45 kg P_2O_5/ha) which produced numerically the greatest nodule number also produced the greatest nodule dry weight at 2 WAFA. In effect, at 4 weeks after fertilizer application, there was a clear distinct increase in both nodule number and nodule dry weight in which dry weight of nodules systematically numerically increased with increasing nodule number. The treatment (45 kg P_2O_5/ha) which produced the greatest number of nodules had the greatest nodule dry weight and that with the lowest (0 kg P_2O_5/ha) nodule number produced the lowest nodule dry weight. The indication of these results is that treatments that produced more nodules also produced larger nodules thereby resulting to greater weight. This result is contradicting those reported by Blair (1989) and Sarkodie-Addo (1991) who found a negative correlation between nodule numbers and nodule dry weights. However, nodule dry weight results at all the sampling periods showed no significant difference among each other with respect to the various P rates which contradicts the result of Armstrong (1999) who reported significant increase in nodule dry matter following P application.

5.1.3 Effects of N and P fertilizer application on yield components, harvest index and yield of cowpea

All the yield parameters, harvest index, pod yield and consequently grain yield were not significantly affected at 5 % significant level as a result of nitrogen fertilizer application. The result agrees with the report of IITA (1975) that cowpea plants dependent on symbiotically fixed N gave seed yields the same as those plants relying on applied N, but contradicts that which was reported by Abayomi *et al.* (2008) and Minchin *et al.* (1981). The results of this study suggest that the biological nitrogen fixation process can cater for the N needs of cowpea crop if effective symbiosis is established.

No significant effect ($P > 0.05$) was observed in the components of yield due to different rates of phosphorus fertilizer application. The results obtained in this study contradict those of Singh *et al*. (2011), Owolade *et al.* (2006) and Rajput (1994) who reported significant effects of P on 100 seed weight, number of pods per plant and number of seeds per pods. However, in all these studies higher rates of P were used as compared to the present study. Legumes have been reported to have high P requirement, they require phosphorus for growth and seed development and most especially in nitrogen fixation which is an energy-driving process (Nkaa *et al.*, 2014).

Harvest index (HI) is the proportion of grain in the total aboveground biomass of the crop expressed in percentage. P did not have significant influence on the HI of the crop. The result is in line with Singh *et al*. (2011) who failed to record significant difference in harvest index of cowpea following P application and they suggested that harvest index is a genetic trait and will only be influenced by varietal differences.

Grain yield is the utmost aim of cowpea production in almost all parts of the world. There was no significant effect of P fertilizer rates on both pod and grain yields. However, pod and grain yields increase numerically with each increase in P fertilizer with the highest rate (45 kg P_2O_5/ha) of P produced the greatest pod yield (1939 kg/ha) and grain yield (1484 kg/ha) respectively while the control (0 kg P_2O_5 /ha) produced the least pod yield (1848 kg/ha) and grain yield (1409 kg/ha) as shown in Table 4.10. The observed non significant increase in cowpea yield with P application agrees with the results of Agboola and Obigbesan (1977) and Osiname (1978) who observed that P application did not significantly increase cowpea yield but contradicts the result of Singh *et al*. (2011). The numerical but not statistical increase in both pod and grain yield with increasing level of P could probably be as a result of the 45 kg P_2O_5/ha which was the highest rate in the study is not the optimum rate of P required for cowpea variety (Asontem) to produce significantly higher yield. Differential response of cowpea genotype to P fertilizer has been reported (Okeleye and Okelana, 1997). According to

Tayo (1980), this has important implication for fertilizer management in cowpea cultivation, as fertilizer requirement may vary with different genotypes. It is therefore vital that fertilizer needs of each genotype should be determined prior to large scale field application.

5.1.4 Effects of N and P fertilizer application on seed N, residue N, total plant N and seed crude protein of cowpea

Nitrogen concentration in the seeds showed significant difference in the 5% significant level as a result of nitrogen fertilizer application. This result agrees with Amujoyegbe and Alofe (2003), Singh *et al.* (2007) who reported that nitrogen application to cowpea increased its quality as well as the nutritional value of seeds. The higher N content in the seeds is an indication that the plant made use of the applied N treatments to improve their seed N contents.

In the case of N content in the residue of cowpea, the greatest value (1.51 %) was obtained in the 30 kg/ha N treatment. On the other hand, the lowest (1.30 %) residue N content was obtained in the control treatment. The non significant differences observed in terms of N content of residues might be due to the fact that N needs for all treatments was very high at grain filing, thus each treatment remobilized as much N as possible from the vegetative parts. Since the N concentration in grain legume plants should first be utilized to maximize grain yields, the low concentration of N in grain legume residues was not unexpected. However, any excess N left over after crop maturity will enrich the legume residues and if incorporated into the soil will improve soil fertility and benefit subsequent crop.

Concerning the total plant N there was a significant difference between the mean values of total plant N in cowpea for the different nitrogen treatments ($P < 0.05$). The significant response of cowpea to N application in terms of total plant nitrogen may be due to increased availability of nitrogen from the soil and that the plant made use of the applied treatments to improve their total plant N contents. This result agrees with earlier workers who reported that nitrogen application to cowpea plants increased its quality as well as the nutritional value of seeds (Amujoyegbe and Alofe, 2003; Singh *et al.*, 2007).

Generally, crude protein content in cowpea seeds significantly increased with increasing application of N fertilizer. This increase in crude protein as a result of nitrogen application was mainly due to structural role of nitrogen in building up amino acid (Chintala *et al*., 2012a). This result is in agreement with what was reported by Singh *et al*. (2006) that application of N significantly increased protein percentage in cowpea.

Phosphorus fertilizer did not show any significant effects in all the quality traits studied. The results are contrary to earlier reports that P increases the nitrogen content in cowpea tissue (Uzoma *et al*., 2006) and seed crude protein content (Kudikeri *et al.*, 1973).

5.2 DISCUSSION OF EXPERIMENT TWO

5.2.1 Effects of residual N and P fertilizer on growth and yield of succeeding maize crop

Maize growth and yield following incorporation of cowpea residue enriched with N and P fertilizer applications did not show significant treatment differences (Table 4.12 – 4.20). However, positive residual effects of fertilizer on succeeding crops have been reported (Cooke, 1970). Legumes have also been reported to contribute immensely in improving soil fertility and yield of subsequent cereals (Kumwenda *et al*., 1995). The use of legumes in cropping systems offers considerable benefits because of their ability to ameliorate soil fertility decline through fixation of atmospheric nitrogen, enriching it with organic matter and improving the yield of the subsequent crops (Giller *et al*., 1997; Shoko *et al*., 2007). The non significant effects observed in this study as a result of residual N and P fertilizer could be attributed to the fact that N is a highly mobile nutrient and it can be lost through leaching, erosion, runoff, volatilization, nitrification, denitrification and consumption by plant and other organism. P on the other hand has the tendency to be fixed in the soil into forms unavailable for plant use by reacting with soil particles, Fe, Al, Ca and Mg. Hassan *et al.* (2005) reported that in most soils in spite of the considerable addition of P-fertilizers, the amount available for plants is usually low since it is converted to unavailable form by its reaction with the soil constituents.

Grain legumes have been reported to contribute less nitrogen to subsequent crops in rotation (Giller *et al*., 1997), because most of the N fixed by grain legumes is translocated to the grains, hence, the N requirement of cereal crops can seldom be met from the residual effects of grain legumes. In evaluating medium-maturing soybean lines for their nitrogen fixation potential, Sarkodie-Addo *et al.* (2006) reported that for grain legumes to play any important role in the maintenance of soil fertility for other crop in rotation, they must obviously leave behind more N in their residue, and that increasing the amount of legume N contribution through residual effects are generally possible only if grain yield is decreased which according to Schwenke *et al.* (1998) can rarely be justified in economic terms, but they maintained that it is worthwhile especially where maintenance of soil fertility is the main aim.

However, in a similar study where maize was planted over plots where cowpea residues were incorporated and compared with plots which received recommended fertilizer application in Ghana (2 bags NPK 15:15:15: and 1 bag urea), maize yields was greatest in plots in which residues of the cowpea variety Asontem was incorporated (Fattah 2015, unpublished data). In that study, the maize yield from plots that received the recommended fertilizer rate was not different from any of the cowpea residue incorporated plots. In this study, the maize yields obtained were greater than those reported by Fattah (2015, unpublished data) including plots that received the recommended fertilizer rates. The results indicate that if farmers would incorporate cowpea residues into their plots, there would not be any need to apply fertilizer to the succeeding maize crop. Cereal–legume rotation effects on cereal yields have been reported (Bagayoko *et al.*, 2000; Bationo *et al.*, 1998; Bationo and Ntare, 2000). In all these studies, there was a positive effect on cereal yield following cowpea. According to Giller (2001), if after harvesting grains and legume residue are effectively recycled, net nitrogen accrued from such practice can be as much as 140 kg N/ha depending on the legume.

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

The following conclusions can be made from the results obtained in these studies.

(i) Generally, application of N and P fertilizers had no significant effect on growth, dry matter, components of yield and grain yield of cowpea.

(ii) Nodule number was significantly affected by N and P applications, although % effective nodules and dry weight of nodules remained unaffected.

(iii) Application of N had significant effects on cowpea seed N and crude protein content of seeds, but where not responsive to P rates.

(iv) Residue quality was not responsive to N and P rates. However, application of N had significant effects on cowpea total plant N.

(v) Residual fertility did not significantly affect the growth and grain yield of the succeeding maize crop.

6.2 RECOMMENDATIONS

The following recommendations should be considered:

1. Application of N to cowpea fields should highly depend on the N status of that particular field. Therefore soil testing is recommended prior to planting to establish the need for starter N application in cowpea cultivation.
2. Further studies should be conducted with higher P rates in other to determine the appropriate rate of P fertilizer that will produce significant effects more particularly on growth, grain yields and N contents of whole plant, seeds and residues of cowpea.
3. Further studies on the residual fertility effects on maize after cowpea should also be conducted, this time soil physiochemical studies should be done on plot basis before planting of the maize in other to establish more conclusive results on residual fertility effects on succeeding crop.

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APPENDIX

Appendix 1: Physico- chemical properties of top soil (0-30 cm depth) of the experimental field

Properties	Soil depth 0- 15 cm	Soil depth 15- 30 cm
PH (1:2.5 H_2O)	5.57	5.50
Total Nitrogen (%)	0.15	0.12
Available Phosphorus (mg/kg)	5.65	5.22
Organic Carbon (%)	0.72	0.50
Exchangeable bases (cmol/kg)		
K	0.16	0.09
Ca	2.00	2.80
Na	0.38	0.37
Mg	1.00	0.80
Texture		
Sand (%)	84.30	80.90
Slit (%)	3.90	4.07
Clay (%)	11.80	15.03
Soil texture	Sandy loam	Sandy loam