# EFFECTS OF NPK AND POULTRY MANURE RATES ON THE GROWTH, NITROGEN FIXATION AND GRAIN YIELD OF SOYBEAN (*Glycine max* (L) Merrill)



**BY:**

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**(BSc. Natural Resources Management (Hons); DipEd)**

**NOVEMBER, 2016**

**KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUMASI, GHANA**

**SCHOOL OF GRADUATE STUDIES**

**DEPARTMENT OF CROP AND SOIL SCIENCES**



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**(BSc. Natural Resources Management (Hons); DipEd)**

**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 requirements for the award of**

**Master of Philosophy Degree**

**in**

**Agronomy (Crop Physiology).**

**NOVEMBER, 2016**

## DECLARATION

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



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YeboahGyamfi

(Student)

**CERTIFIED BY:**

..... Date.....

Prof. Joseph Sarkodie-Addo

(Supervisor)

..... Date.....

Dr. E. A. Osekre

(Head of Department)

**DEDICATION**

To my families



## ACKNOWLEDGEMENTS

Praises be to God Almighty, “who made me and fashioned me together round about: gave me understanding, that I may learn….” (Psalm 119:73, KJV). “For in him we live and move and have our being” (Acts17:28, KJV).

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## ABSTRACT

Soybean is a legume and has a great potential to fix atmospheric nitrogen and improve soil fertility in addition to providing edible grains. Nitrogen fixation, however, is constrained by environmental factors which include soil nutrient inadequacy. A field experiment was carried out at Nkorang, Nkawie, which fall under the moist semideciduous forest vegetation zone in Ghana, to investigate the effects of different rates of NPK and poultry manure on growth, N fixation and grain yield of soybean under zero tillage cultivation.The experimental design used was a 3x3 factorial arranged in a randomized complete block design. The factors studied were poultry manure rates and NPK rates. NPK rates were 0, 45 and 90 kg/ha and poultry manure rates were 0, 2, and 4 tons/ha. Each treatment was replicated four times and there were nine plots per block.The field was slashed and glyphosate 360 (isopropylamine salt) was applied as a pre-plant herbicide at 2 L per hectare of water two weeks after slashing. Plots were then laid with each plot measuring 2.5 m x 4 m and planting was done at a spacing of 10cm x 5 cm. Data taken on plants included plant height, number of leaves, number of branches, crop growth rate, shoot biomass, leaf area, nodule number, number of effective nodules, number of pods per plant, number of seeds per pod, hundred seed weight, grain yield and amount of N fixed.The results of the experiment showed that application of NPK or poultry manure significantly affected the growth of soybean. Higher rates of NPK and poultry manure caused significantly higher growth in some parameters.Generally, yield components were not affected by NPK or poultry manure rates. This observation was mainly due to low rainfall at the onset of pod formation. In contrast, poultry manure rate at 2 tons/ha had a significanteffect ($p<0.05$) on grain yield apparently because of increased nodulation and N fixation. Generally, there were increase in nodulation and nodule effectiveness observed in poultry manure (2 tons/ha) treatments. Further studies

can be executed to verify the results, but such must be sited where irrigation can be done when rainfall fails.

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# CHAPTER ONE

## INTRODUCTION

Soybean *[Glycine max (L.)*Merrill] is an annual legume that belongs to the family Leguminosae and subfamily Papilionoidae (Berk, 1992).It produces pods on an erect stem and has opposite and ovate unifoliate primary leaves, alternate and trifoliolate secondary leaves and compound leaves with four or more leaflets occasionally present(SheafferandMoncada, 2012). It is a self pollinating diploid plant with 40 chromosomes (2n=40 chromosomes)(Chang andQiu, 2010).

In Ghana, average yield of soybeanis 1.5Mt/ha, however, achievable grain yield of soybean under rain-fed conditions is estimated at 2.5Mt/ha (40% more than average yield) (MOFA, 2011). According to Mbanya (2011), low yield of soybean in Ghana can be attributed to low level of adoption of technology such as soil fertility management strategies that would improve soybean production.

The poor soil fertility problem is well recognized as the main obstacle to maximizing crop yield (Hilhorst *et al*., 2000). Recent research works have brought to light some approaches to curb the poor soil fertility challenge which include the supply of organic and/or mineral nutrients to the soil. Nevertheless, the use of mineral fertilizers by smallholder farmers in sub-Saharan Africa is not properly adhered to owing to high costs, unavailability and at times lack of technical knowledge(Bationo *et al*., 2006). Adequate sources of organic fertilizers are also difficult to acquire as larger quantities are required as well as competitive alternative uses of organic sources; farmers prefer to give stovers to farm animals rather than use them as farm manure and consequently add nutrients to the soil. Again, organic fertilizers are also bulky and difficult to transport (Alimi *et al*., 2006).

The challenges arising out of the use of organic and inorganic fertilizers have led to exploration of other economical and environmentally friendly means of supplying nutrients to crops. One of suchmeans is biological nitrogen fixation. For a very long period, biological nitrogen fixation (BNF) in legumes has been a key constituent of many cropping systems throughout the world. Gregory (2006) stated thatglobal nitrogen fixation in the soil before extensive human activity was 90-140 million ton N $ha^{-1}$. Soybean has the capacity to acquire its total Ndemands from symbiotic nitrogen fixation and leaves excess nitrogen reserves in the soil for subsequent crops (Salvagiotti *et al*., 2008). Biological nitrogen fixation (BNF), therefore is an inexpensive and environmentally friendly means of improving crop yield, reducing N application and enhancing the soil quality. BNF consequently reduces the dependence on mineral fertilizers that could be costly and unavailable to smallholder farmers.

Even though rhizobia seem to be widely distributed in the soil (Herridge *et al*., 2002), N fixation is closely linked to the physiological condition of the host plant. Crop stress factors such as, nutrient deficiency, insufficientassimilates and crop disease occurrence can impair the growth and development of the crop, and subsequently, adversely affect the symbiotic relation of plants and rhizobia. As a result, the rhizobia strain existing in the soil will not be able to successfully infect plant roots and consequently aid N fixation to their maximum potential (Zahran, 1999).Eventually, little biomass is produced and amount of N fixed is reduced. The ability of the plant to ameliorate the soil, as well as improve yield will consequently be greatly hampered.

Biological nitrogen fixation (BNF) is largely influenced by four main factors namely, the effectiveness of the symbiotic relationship between the host plant and the rhizobia strain, capacity of the plant to store N, the amount of N in the soil available to crops and environmental limitations (Van Kessel and Hartley, 2000). Soil as a medium through which crops grow and develop, therefore, has greater effect on N fixation, growth and yield of crops. Hence, the control of the soil environment plays a very prominent role in securing crop productivity. In soil management, recent research has indicated that supplying starter soil nutrient at early stages of crop vegetative growth can increase pod yield and crop biomass (Yinbo *et al.*, 1997).

According to Omondi *et al.* (2014), cultivation of crops under no tillage system enhances biological nitrogen fixation and when it is practiced for a long period is able to improve most soil properties and consequently leads to yield increases. This is because no tillage contributes to increased soil fertility and soil organic carbon content, improved moisture conservation and other soil benefits.

It is therefore hypothesized that growing soybean under no tillage cultivation with the application of minimal NPK or poultry manure can enhance biological nitrogen fixation and produce yields equivalent to yields obtained by applying higher amount of mineral or organic fertilizers.

The general objective of the research was therefore to assess productivity of soybean by enhancing BNF through inorganic and organic fertilizer applications under no tillage cultivation.

The specific objectives were to:

i. determine the effects of NPK and poultry manure on growth and yield of soybean. ii. determine the effects of NPK and poultry manure on nodulation and N-

fixation.

iii. determine the combined effect of NPK and poultry manure on growth, Nfixation and yield of soybean



# CHAPTER TWO

# 2.0 LITERATURE REVIEW

## 2.1 Origin and Distribution of Soybean

Soybean is believed to have originated from eastern Asia and was first domesticated by Chinese farmers around 1100 BC (Myaka *et al*., 2005);but it is now widespread across the world. China was the global foremost producer and exporter of soybean during the early years of the twentieth century. In the late 1950s soybean production developed speedily in the USA, and the USA presently surpasses all other countries in soybean production in the world. Soybean production also emerged in Brazil, Argentina and other parts of the world (Chang and Qiu, 2010).

Global production of soybean is 315.4 million Mt with USA, the largest producer of soybean, producing 108 million metric tons which represents 34% of the global soybean (soystat, 2016). In Africa,annual soybean production is about 1.5 million metric ton and soybean importationis as much as soybean production (IITA, 2009). In Ghana, annual soybean production is about 15,000 metric tons (MoFA and CSIR, 2005).

In Africa, soybean was first introduced in the early 19th century through Southern Africa (Ngeze, 1993). Subsequently, soybean cultivation, despite the initial challenge of seed viability loss during storage, begun in Ghana in 1910, It was incorporated into the traditional foods by the local farmers in the Northern sector. By the late 1960s and early 1970s, soybean research was intensified at the Crops Research Institute of CSIR and the University of Ghana's Agricultural Research Station. In the late 80's to the 90's, public and private partnership approach was adopted to launch a massive campaign on soybean production and utilization under the Ministry of Food and Agriculture (Plahar, 2006;

Tweneboah, 2000).

## 2.2 Botany of Soybean

Soybean is a diploidized tetraploid (2n=40), in the family *Fabaceae*, the subfamily *Papilionoideae*, the tribe *Phaseoleae*, the genus *Glycine* Willd and subgenus *Soja* (Moench). It is an erect and a thick non-woody annual crop that can reach a height of 1.5 metres. Three type of growth habit are recognized in soybean; they aredeterminate, semideterminate and indeterminate (Bernard and Weiss, 1973). Determinate growth is notable by the termination of vegetative activity of the apical bud when it turns into flowers at both axillary and apical flower clusters. Indeterminate cultivars express unceasing vegetative development for the period of flowering. Semi-determinate cultivars expressunceasing vegetative growths that abruptly endafter the inflorescence period (OECD, 2000).

The primary leaves are simple leaves with pointed oval shape that are arranged facing each other on the stem while the secondary leaves are compound leaves mostly trifoliolate and alternate. Secondary leaves in the form of compound leaves with fouror more leaflets may also be found in soybean. The root system of soybean is made of taproot from which the lateral root system develops. Most cultivars are covered with fine trichomes, however hairless forms can be found(Sheaffer and Moncada, 2012).

The nature of a soybean seed is usually elliptical, but there can be variation amongvarieties from near spherical to extended and flattened forms. The flowers are white or pale purple, which is very characteristic of Papilionadeae and are normally self pollinated but around 1% of cross pollination aided by insects occurs (Chaturvedi *et al*., 2011).

Gary and Dale (1997) have described soybean growth and development in two main stages: the vegetative stage and the reproductive stage. The vegetative stage starts with the emergence of seedlings, unfolding of unifoliate leaves, through to fully develop trifoliate leaves, development of nodes on the stem, nodulation plus the formation of branches. The reproductive stage begins with flower bud formation, through full bloom flowering, pod formation, pod filling to full maturity.

### 2.3 Importance of Mineral fertilizers in Soybean

Even though the Government of Ghana subsidizes the cost of fertilizers, these inputs have become so expensive that small scale farmers who represent approximately 80% of the farmers are unable to purchase and use them. In addition, inorganic fertilizers contribute mainly to soil fertility, but do not improve soil physical properties, such as soil structure, water retention capacity and aeration for crop production. The use of inorganic soil input alone can result in a decrease in soil organic carbon content (Bationo *et al.,* 2006). Pichot *et al*. (1981) observed that progressive use of mineral soil inputselevate nutrient leaching, reduced base saturation as well as heighten soil acidification.

Inorganic soil inputs, particularly nitrogen (N) inputs, have been a fundamental reason for the extremely high crop yield observed in this century (Robertson and Vitousek, 2009). Nitrogen is an inorganic element that plants require in huge amounts. It serves as a constituent of many plant cell components, including amino acids, nucleic acids, chlorophyll and enzymes. N availability to plants enhances rapid use of carbohydrates in the synthesis of proteins. Nitrogen deficiency in plants results in chlorosis in older leaves

and reduced plant growth in the stem, roots and leaves (Taiz and Zieger,2002). However, Keyser and Li (1992) stated that nodule development and nodule effectiveness is restrained as the level of mineral N within the rhizosphere raises, consequently resulting in inefficiencies in the amount of nitrogen fixed.



Phosphorus is a very vital constituent of plant physiological activities related to the efficient use of energy in plants. Phosphorusforms a significant constituent of plant cells; the sugar–phosphate transitory forms during respiration and photosynthesis, the phospholipids that make up plant membranes, the nucleotides used in plant energy utilization (such as ATP) and in DNA and RNA. In soybean, 25 molecules of ATP is required to fix a molecule of $N_2$ (Taiz and Zieger, 2002; Hopkins and Huner, 2009). On the whole, insufficient quantities of P reduce the rate of carbohydrate metabolism, whilst photosynthesis, carbohydrate manufacture approach, is uninhibited. The outcome is a buildup of carbohydrates in plant tissues and consequently, plant leaves appear dark green in colour. There is also a decrease in leaf surface area growth in addition to reduced leaf number. However, root development is not influenced as much as shoot development and subsequently results in a reduced shoot root dry weight ratio.

Potassium performs a primary function in the regulation of the movement of water into plant cells. Even though potassium may not be part of many enzyme structures, it activates over 60 enzymes especially enzymes that are used in respiration and photosynthesis (Taiz and Zieger, 2002; Hopkins and Huner, 2009). Potassium contributes to good root growth by allowing carbohydrates produced in the leaves to get to the root system to be used by nodules and has been shown to improve number and size of root nodules(Foth, 1990).

## 2.4 Importance of Organic Inputs in Soybean

Organic inputs are important sources of nutrients because, through mineralization, organic inputs release important soil nutrients such as nitrogen, phosphorus, magnesium and calcium into the soil (Fairhurst, 2012). Organic inputs help crops to efficiently respond to mineral fertilizer applied. It also helps in improving the soils ability to maintain water, and helps in root growth and the control of soil chemical and physical properties that influences the absorption and accumulation of soil nutrients. Also organic inputs help in adding nutrients that are absent in inorganic fertilizers. They create a favourable environment for root development, enhance plant root accessibility to phosphorus by making the nutrient available, and ameliorate soil related crop stress factors like soil acidity and helps in soil organic matter replenishment (Fairhurst, 2012). The amount of nutrients contained in a unit mass of inorganic manure is very low and the nutrients derived from organic manures are not enough to meet crop nutrient requirements. According to Fairhurst (2012) sources of organic fertilizers commonly have small quantities of nutrients compared with mineral fertilizer and larger quantities are needed to provide the required nutrients for crop growth and are therefore more costly to store, transport and apply. For example, the present use of animal droppings from animal rearing systems in West Africa is very minimal (0.5 - 2.0 $tonha^{-1}$) therefore, barely about 2.5 kg N and 0.6 kg P $ha^{-1}$is mineralized into the soil for crop use which is not enough to meet the requirement of crops.

## 2.5 Biological Nitrogen Fixation

Biological nitrogen fixation (BNF) is a process used by soil living microorganisms to fix nitrogen in leguminous plants (Gregoire, 2003). The amount of N generated by a legume is dependent on the crop species, soil condition, crop growth conditions, and crop management practices(Jensen and Nielsen, 2003). BNF process involves symbiotic association between rhizobia and a host specific legume and it serves a key function in

crop cultivation, since it makes it possible to convert nitrogen molecules in the atmosphere into forms which plants can absorb (Hopkins and Huner, 2009).

Before nodulation, host plants excrete flavonoids chemoattractant and the rhizobia in response, move towards the roots of the plant and release species-specificNod-factors which initiate early process of nodulation (Date and Halliday, 1987). The first nodules are formed within seven days after seedling emergence and become visible as the nodules increase in size. Ten to fourteen days afterward, the nodule bacteria are able to supply most of the nitrogen requirements of the plant. The nodules facilitate fixation of nitrogen molecules in the atmosphere into the soil, but takes up a lot of energy from the plant for the nodules to develop and function (Shantharam and Mattoo, 1997). Hence, the host plant suppresses the growth of most potential root nodules immediately after the preliminary bacterial inhabitation of root hairs (Spaink, 1995). The host plant also limit the number of nodules formed if there are nitrates available in the soil for plant use (Vandyk, 2003). The nodules which are pink in colour are effective while the nodules black, brown or white in colour are ineffective, or have not yet developed to a stage at which they can fix nitrogen. The red/pink colouration of effective nodules is as a result of the presence of leghaemoglobin, which absorbs oxygen and thereby creating an oxygen-free environment for nitrogenase enzyme to aid nitrogen fixation (Lindermann and Glover, 2003).

Annually, $3\times10^{14}$g of$N_2$ is converted into $NH_4^+$ and deposited into soil (Rees *et al.*, 2005). According to Howard and Rees (1994), the total energy used to break the triple, double and the single bonds of $N_2$ molecule are 225, 100, and 39kcal/mol respectively. Before plants can assimilate atmospheric $N_2$, the nutrient should be fixed into the soil in

forms which plants can use. The most plant useable forms of nitrogen are $NH_4^+$ and $NO_3$. The conversion of $N_2$ into $NH_4^+$ and $NO_3^-$ is mostly done by microorganisms (Lindermann and Glower, 2003; Dogan *et al.*, 2011).



**2.6 Factors Affecting BNF**

Many plant stress factors in the environment influence effective $N_2$ fixation. Examples of environmental stress conditions affectingplants growth and development include nutrient deficiency,salt stress, adverse soil pH, toxic amounts of mineral in the soil, severe temperature conditions, soil water stress, inadequate assimilates from photosynthesis, and disease occurrence.The biological nitrogen fixation process which greatly relates to the physiology of the host plant is also indirectly affected (O'Hara *et al.*, 1988). As a result of these stresses, existing rhizobium in the soil may not be able to infect plant roots and subsequently carry out N fixation in their maximum potential (Zahran, 1999).

The rate of BNF is extremely dependent on rhizobia strain, type of legume crop, edaphic, and other ecological conditions (Shantharam and Mattoo, 1997). Extreme levels of soil water can negatively affect nodule functioning. Low water stress can decrease the mass nodule and affect nitrogenase functioning. After the exposure of plant to drought conditions for ten days, the nodule cell wall begun to deteriorate resulting in aging of bacteroids (Ramos *et al.*, 2003). High amounts of salt in the soil resulting in the buildup of $Na^+$decrease plant growth, nodule development by directly affecting the communication between rhizobia and the host plant and subsequently affects the potential of legumes to fix N through BNF (Singleton and Bohlool, 1984; Soussi *et al.*, 1998; Kouas *et al.*, 2010). High temperatures (≥40ºC) greatly decreases the functioning of nitrogenase and resulting in the development of ineffective nodules (Hungria and Franco, 1993). Extremely low or

extremely high soil pH can diminish rhizobia population in the host plant rhizosphere and consequently yielding ineffective N fixation (van Jaarsveld *et al.*, 2002).

Characteristically, soils with very low pH have small amounts of P, Ca and Mo coupled with extremely high levels of Al and Mn which affects both crop growth and bacteria population in the soil and consequently affect nitrogen fixation. Soils with high pH are more likely to have elevated amounts of sodium ions ($Na^+$), chloride ($Cl^-$), bicarbonate ($HCO_3^-$) and borate ($BO_3^-$) which have detrimental effects on BNF (Bordeleau and Prévost, 1994). According to Uddin *et al*. (2008), the number and size of nodulesare considerably constrained by the use of nitrogen fertilizer. The amount of N fixed in BNF is dependent on the amount photosynthetic assimilates allocated to root nodules, in relation to other competitive uses of assimilate (Voisin *et al*., 2003).

**2.7 Uses of Soybean**

Soybean is the most essential leguminous grain crop on the earth and among the most essential five of all field crops cultivated(SheafferandMoncada, 2012). The prominence of soybean is due to the high protein and oil contents which approximately constitute 40% and 20% respectively (Chang andQiu, 2010; SheafferandMoncada, 2012). By same mass comparison, soybean contains more proteins and iron than meat, more calcium than milk and more vitamins $B_1$, $B_2$, and $B_3$ than eggs It is also high content of minerals especially phosphorus, calcium, iron and vitamins (Pamplona-Roger, 2006). In Ghana, soybean is used in infant foods to prevent or control protein malnutrition in children. It is also used to enrich various traditional foods like banku, kenkey, soups and stews without changing taste or cooking time. The nutritional richness of soybean makes it an efficient ingredient in animal feed formulation as well (MOFA and CSIR, 2005). In addition, soybean oil has

a natural taste and nearly imperceptible odour, which causes it to be the ultimate preferred option of vegetable oil (Mpepereki *et al*., 2000).

Soybean consumption does not only give nutritional benefits but also possess extraordinary medicinal properties like reducing the risk of many cancers particularly of the prostrate, breast and colon as well as improve the health of the heart and arteries by preventing arteriosclerosis. It also helps to relieve unpleasant symptoms of menopauses because of its isoflavones, a type of vegetable hormone that partially replaces natural hormones by the ovaries (Pamplona-Roger, 2006).

Soybean is used in rotation with cereals to control *Striga hermonthica,* an endemic parasitic weed of the savanna zone of Ghana which causes at least 70% yield loss in cereals. This is because the soybean is a non-host plant to the striga but produces chemical substances that stimulate the germination of striga. The germinated striga seeds subsequently die off within a few days because they cannot attach themselves to a nonhost soybean plant to get water and nutrients (MOFA and CSIR, 2005).

An essential characteristic of the soybean plant is its capacity to make better the nutrient status of the soil by converting nitrogen in the atmosphere into plant useable forms through symbiosis with rhizobia in the soil. It has been estimated that between 50% and 80% of the entire nitrogen in a soybean plant may be provided from biological nitrogen fixation (Berk, 1992; Solomon *et al*., 2012) and leave N residue for subsequent plants in a rotation. This phenomenon helps to cut down the amount of nitrogen fertilizers that farmers have to purchase to apply to their fields to improve productivity (MOFA and CSIR, 2005).

# CHAPTER THREE

# 3.0MATERIALS AND METHODS

## 3.1 Experimental Site

The research was conducted at Nkorang, near Nkawie in the Atwima Nwabiagya District of Ashanti Region between September, 2015 and December, 2015 in the minor planting season. The district has geographical coordinates of latitudes 6º32' N and 6º 75' N and longitudes 1º52' W and 2º 00' W and has a total land area of 294.84 $km^2$ (Ghana Districts, 2016).

## 3.2 Soil Characteristics

The bedrock of the soils in the district is mainly Lower Birimian rocks, which consist of phyllites, greywaches, achists and gneiss, and the Cape Coast Granite. The predominant soils in the district are the Kumasi-Asuansi/Nta-Ofin Compound Associations and the Bekwai-Nzema/Oda Complex Associations (Ghana Districts, 2016). The soil at the experimental site was well drained, sandy loam overlying reddish-brown and gravelly light clay. It belongs to the Kumasi series, Ferric Acrisol developed over deeply weathered granite rocks (Asiamah, 1998).

## 3.3 Soil Chemical Analysis

Soil samples were dug out from the experimental site to a depth of 0 – 15 cm and 15 – 30cm. This is because the roots of soybean are generally concentrated in the first 30 cm of the soil. These samples were taken to the laboratory to determine their physical and chemical properties. The samples were dried and sieved using 4 mm and 2 mm mesh sieves for the determination of soil chemical properties.

### 3.3.1 Organic Carbon

The organic carbon content of samples taken from the experimental site was determined by using the Walkley-Black chromic acid wet oxidation method (Nelson and Sommers, 1982).In this method, organic carbon is oxidized by dichromate ion. Excess dichromate ion is back titrated with ferrous ion. Procedurally, one gram soil sample (< 0.15mm) was measured into a conical flask. Ten millilitres of 0.166 M (1.0 N) potassium dichromate solution was addto the soil. Twenty millilitres of concentrated sulphuric acid ($H_2SO_4$) was carefully added from a measuring cylinder to the resultant mixture and carefully rotated for a minute and subsequently allowed to stand for 30 minutes. 250 ml of deionized water and 10 ml concentrated orthophosphoric acid ($H_3PO_4$) were added and allowed to cool. One millilitre of diphenylamine indicator was added and titrated with 1.0 M ferrous sulphate solution until the colour changed from violet–blue to green. A blank titration is performed in the same manner.

Calculation:

% Oragnic C = $\frac{M \times 0.3\ 9 \times mc\ f(V_1 - V_2)}{}$

M = molarity of ferrous sulphate solution

V1= ml ferrous sulphate solution required for blank titration

V2= ml ferrous sulphate solution required for sample titration

g = weight of air-dry sample in gram mcf = moisture

correction factor (100 + % moisture) / 100

0.39 = 3 x 0.001 x 100% x 1.3 (3 = equivalent weight of C)

1.3 = a compensation factor for incomplete combustion of the organic matter.

### 3.3.2 Organic Matter

The percentage organic matter of soil sample was determined by multiplyingthe organic carbon content by 1.724 (The Van Bemmelen factor). This method is based on the assumption that soil organic carbon makes up 58% of soil organic matter.



### 3.3.3 Soil pH

The soil pH was determined by first making a soil suspension from the soil sample in soil water ratio of 1:2.5. The pH of the soil was then determined by an Electrocalomel electrode (Mclean, 1962) pH meter.

### 3.3.4 Total Nitrogen

Thetotal nitrogen content of the soil sample was determined by using the Kjeldahl method. A soil sample of mass 10 g sieved with a with a 2 mm wire mesh was chemically decomposed by heating with a 30 mls of concentrated sulphuric acid together with a mixture of 100 g $K_2SO_4$, 10 g $CuSO_4$ and 1g selenium as catalyst. The solution obtained, mainly ammonium sulphate, is made alkaline by adding 15ml of 40% NaOH to evolve ammonia gas which was distilled and trapped in a receiving acid solution of 10ml $H_3BO_3$ (4%) and 4 drops of indicator. The acid solution captures the ammonia to form ammonium-borate complex. The ammonium-borate solution obtained was then titrated with $H_2SO_4$, the standard acid, as the receiving solution to determine amount of $NH_3$in the captured solution.Using atomic mass number comparison that 14.007 g of nitrogen is contained in one equivalent mass of $NH_3$, the percentage of nitrogen in the soil was computed using the formula:-

$$\text{Total N in the sample} = \frac{(\text{volume of standard acid} - \text{volume of blank titre}) \times \text{Molarity of titrating acid} \times 14.007}{\text{Mass of soil sample in grams}}$$

### 3.3.5 Available Phosphorous

The amounts of phosphorus in soil sample were determined by using the Bray-1 test method and Bray -1 solution was used to extract phosphorus from soil ample (Jackson, 1958). Phosphorus in the sample was determined on a spectrophotometer by the blue ammonium molybdate using ascorbic acid as a reducing agent. A 5 g sample soil was measured into 100 ml extraction bottle and 35 ml of Bray's no. 1 solution (0.03M $NH_4F$ and 0.025M HCl) was added. The bottle was placed in a reciprocal shaker and shaken for about 10 minutes and filtered through hardened filter (Whatman. 42). Exactly 5 ml of the filtrate were pipetted into 25ml test tubes and 10 ml of ammonium paramolybdate was added as a colouring agent. Ascorbic acid was henceforth added. After shaking well to mix, the mixtures were made to stand for 15 minutes to develop a blue colour. The colour was measured using a 21D spectrophotometer at 660 nm wavelength. The available phosphorus was extrapolated from a standard curve.

Calculation:

P (mg / kg) = $\frac{(a-b) \times 3\ 5 \times 1\ 5 \times mc\ f}{}$

where:

a = mg P/l in the sample extract b

= mg P/l in the blank s = sample

weight in gram mcf = moisture

correction factor 35 = volume of

extracting solution

15 = final volume of sample solution.

### 3.3.6 Exchangeable Bases (Ca, Mg, K, Na)

The exchangeable base cations were extracted by transferring a 10 g soil sample into a 250 ml of buffered 1.0 M of ammonium acetate ($NH_4OAc$) at pH of 7.0. EDTA titration method

was used to assess the Ca and Mg content in soil sample (Moss, 1961) while Potassium and Sodium content in the soil sample were measured using the flame photometer.

### 3.3.6.1 Potassium and Sodium

Sodium and potassium contents of the soil were determined by using the flame photometer method. A preparation of standard series of potassium and sodium were done by diluting both 1000 mg/l potassium and sodium solutions to 100 mg/l. This was done by taking a 25 mg portion of each into one 250 ml volumetric flask and made to volume with water. Portions of 0, 5, 10, 15 and 20 ml of the 100 mg/l standard solution were respectively put into 200 ml volumetric flasks. 100 milliliters of 1.0 M $NH_4OAc$ solution was added to each flask and made to volume with distilled water. The standard series obtained was 0, 2.5, 5.0, 7.5, 10.0 mg/l for potassium and sodium. Potassium and sodium were measured directly in the percolate by flame photometry at wavelengths of 766.5 and 589.0 nm respectively.Calculations: Exchangeable K (cmol / kg soil) =

$$\frac{(a-b)\times 250\times mcf}{10\times 391\times g}$$

Exchangeable Na (cmol/kg soil) = $\frac{(a-b)\times 250\times mcf}{10\times 230\times g}$

Where:

a = mg/l K or Na in the diluted sample. b =

mg/l K or Na in the diluted blank sample. s

= air-dried sample weight of soil in grams.

mcf = moisture correcting factor

### 3.3.6.2Magnesium and Calcium

A 25 ml portion of the extract was transferred into a conical flask and the volume made to 50 ml with distilled water. Potassium ferrocyanide (1 ml) at 2%, 26 hydroxylamine hydrochloride (1 ml), potassium cyanide (1 ml) at 2% (from a burette), ethanolamine

buffer (10 ml) and 0.2 ml Eriochrome Black T solutions were added. The mixture was titrated with 0.01 M ethylene diaminetetraacetic acid (EDTA) to a pure turquoise blue colour. A 20 ml 0.01 M EDTA in the presence of 25 ml of 1.0 M ammonium acetate solution was added to provide a standard blue colour for titration. The titre value again was recorded. The titre value of calcium was subtracted from this value to get the titre value for magnesium.



Calculation: Ca + Mg (cmol)/kg =

$$\frac{0.1 \times V_1 - V_2 \times 1\ 0\ 0\ 0}{0.1 \times W}$$

Where:

W = weight in grams of air - dry soil extraction.

V = ml of 0.01 M EDTA used in the sample titration.

$V_2$= ml of 0.01 M EDTA used in the blank titration.

0.01 = concentration of EDTA used

**3.3.6.3 Determination of Calcium only**

A 25 ml portion of the extract was transferred to a 250 ml conical flask and the volume made to 50 ml with distilled water. Hydroxylamine hydrochloride (1 ml), potassium cyanide (1 ml of 2% solution) and potassium ferrocyanide (1 ml of 2%) were added. After a few minutes, 4 ml of 8 M potassium hydroxide and a spatula of murexide indicator were added. The solution obtained was titrated with 0.01 M EDTA solution to a pure blue colour. Twenty milliliters of 0.01 M calcium chloride solution was titrated with 0.01 M EDTA in the presence of 25 ml 1.0 M ammonium acetate solution to provide a standard pure blue colour. The titre value of calcium was recorded.

### 3.4 Physical soil Analysis

#### 3.4.1 Soil Particle Proportions

Bouyoucos hydrometer method (Bouyoucos, 1936) was used to determine the particle proportions in a soil sample. A 40 g soil was weighed and dried overnight in an oven at a constant temperature of 105 $^{o}$C. The soil sample was then placed in a desiccator to cool and afterwards weighed again to determine the oven dry weight. A 100 ml of sodium hexametaphosphate was added to the soil as a dispersing agent. The mixture was then placed on a hot plate and heated until the initial sign of boiling was detected. The mixture was then weighed into a shaking cap and vibrated for 5 minutes. The sample was sieved through a 50 μm sieve mesh into a 1.0 L cylinder. The sand portion left in the sieve was dried and further separated using graded sieves of varying sizes into coarse, medium, and fine sand. These were weighed and their weights taken. The 1.0 L cylinder containing the dispersed sample was filled to the mark and covered with a watch glass. The cylinder with its content was agitated to allow the particles to be in suspension. It was then placed on the bench and hydrometer readings taken at 40 seconds to determine the amount of silt and clay. A second hygrometer reading is taken at 6 hours to determine the amount of clay only. At each hydrometer reading, the temperature was also taken. The percent sand, silt and clay were calculated as follows:

% Clay = corrected hydrometer reading at 6 hours x 100/weight of sample

% Silt = corrected hydrometer reading at 40 seconds x 100/weight of sample - % clay.

% Sand = 100 % - % silt - % clay

The various portions were expressed in percentage and using the textural triangle, the texture was determined.

### 3.4.2 Bulk Density

About 1 – 2 cm surface soil was removed from the sampling spot and the spot was leveled. A 5 cm diameter thin-sheet metal tube of known weight ($W_1$) and volume V was driven 5 cm into the soil surface. The soil around the tube was excavated and excess soil trimmed from the tube ends. The soil was put in an oven at 105 $^{o}$C for 2 days and its weight ($W_2$) recorded.

Calculation: Bulk density (g $cm^{-3}$) =_____

### 3.4 Land Preparation

The land was previously cropped to cassava under no tillage system. The experimental site was cleared by slashing using cutlass, and was left for two weeks. Emerging weeds were sprayed with glyphosate (isopropylamine salt) 360 g/L pre-plant herbicide at a rate of 150 ml in 15 L of knapsack sprayer equivalent to 2 L of glyphosate 360 per hectare.

Plots were subsequently laid out using measuring tape, garden line and pegs.

### 3.5 Variety Used for the Experiment

Salintuya-1 variety used was acquired from the Crops Research Institute (CRI) of the Council for Scientific and Industrial Research (CSIR) at Fumesua, Kumasi. It was released in 1992 by Savanna Agricultural Research Institute (SARI) of CSIR Salintuya-1 is an intermediate maturity cultivar with small seeds which are circular and yellow in colour. The average 100 dry seed weight is 13.0g and matures between 101-114 days. It derives about 51-60% of its $N_2$ from the atmosphere. It is moderately resilient to pod shattering, quite superior in managing *Striga* in cereals and nodulate fairly well with the native *rhizobia.* Salintuya-1 grain yield is between 1.2 -1.8 tons per hectare (MoFA and CSIR, 2005).

### 3.6 Experimental Design, Layout and Treatments

The experiment was a 3 x 3 factorial with treatments arranged in a randomized complete block with four replications (blocks). The two factors were rate of NPK fertilizer application and rate of poultry manure application. The NPK rates comprised of control (0), 45 and 90kg/ha. Poultry manure rates were control (0), 2 and 4tons/ha. The planting distance was 5cm x 10cm corresponding to a population density of 240,000 plants per hectare. Each block consisted of 9 plots, each measuring 2.5m x 4m, given a total of 36 plots and a total land area of 360$m^2$, with one metre between blocks. The experiment was carried out during the minor season (September - December, 2015). Seeds were planted on each plot, on September 1, 2015. Seedling emergence occurred five to ten days after sowing.

### 3.7 Cultural Practices

#### 3.7.1 Thinning

Thinning was done to approximately 10cm between plants in a row, 20 days after sowing, when the soil was moist and seedlings well established. This resulted in a total of 40 plants per row.

#### 3.7.2 Weeding

Weed control was performed by hoeing, on the 2nd and 6th weeks after sowing. Each weed control activity was carried out completely within a day for all the blocks.

### 3.8 Pest Management

There were incidences of leaf eating grasshoppers few days after seedling emergence. The experimental site was therefore sprayed using a knapsack sprayer two weeks after planting with Cypermetrin + Dimethoate 10 EC at rate of 100ml in 15l of water.



### 3.9 Data Collection

#### 3.9.1 Vegetative Growth

Vegetative growth data were taken on the same ten tagged plants from each plot. Data was collected at 45 and 65 days after planting (DAP).

##### 3.9.1.1 Plant Height

Plant height was measured from the ground level to tip of the apex of the stem for the ten randomly tagged plants in the four middle rows. This was done using a meter rule at the various sampling periods. The mean plant height was determined for each treatment.

##### 3.9.1.2 Number of Leaves

Number of leaves from the ten tagged plants from each plot was tallied and the mean number of leaves was recorded.

##### 3.9.1.3 Number of Branches

Branches of the ten tagged plants from each plot were tallied and the mean number of branches was recorded.

##### 3.9.1.4 Leaf area

Leaf area (LA) was determined 65 DAPfrom ten plants per plot on the broadest active leaf per plant. The length and the maximum width of leaves were determined using a meter.

Area of each leaf was determined by multiplying length by maximum width and the actual leaf area of the leaf was determined using the model =1.129+ 1.344. According to Ilkaee *et al*. (2011), the actual leaf area of soybean,  is related to the measured leaf area, by the model =1.129+ 1.344.



### 3.9.1.5 Nodulation and N-fixation data

Ten random plants from each plot were selected at mid flowering to assess nodulation. The sample plants were carefully uprooted by digging around the plant using a spade and all nodules including detached ones were collected and kept in the labeled polythene bags and sent to the laboratory where they were washed and counted. Subsequently, data on nodule number and number of effective nodules were determined.Moreover, ten plants were randomly selected during harvest to determine the amount of N fixed through BNF by using the Kjeldahl method. The seed N, tissue N and leaf N were determined and summed to determine the total N the sampled plants.

### 3.9.1.6 Nodule Number and Effectiveness

The nodules collected were cut opened using a knife and a hand lens to determine their effectiveness. Nodules with pink or reddish colour were declared effective. The percentage effective nodules were then calculated.

### 3.9.1.7 Nodule Dry Weight

All nodules from each treatment were oven dried to constant weight at 80$^{o}$C for 48 hours. These were weighed and the average weight was calculated.

### 3.9.2 Determination of Amount of N-fixed by N-Difference Method

The nitrogen difference method is used when only the ability to analyse total N is available (Bell and Nutman, 1972). Hence this classical difference method relies solely on Kjeldahl nitrogen determination and was calculated as follows:

a) $N_2$ fixed = Total N (fs) – Total N (nfs)

b) % Ndfa (by TND) = [Total N (fs) – Total N (nfs)] x 100 Total N (fs) Where, fs = fixing crop, nfs = non fixing crop, %Ndfa = proportion of N derived from atmosphere, TND = total nitrogen difference.

### 3.9.3 Yield data

At harvest, when about 85% of pods had turned brown (Dugje *at al*., 2009), four middle rows of each plot were harvested for yield analysis. From this harvested lots, ten plants from each were sampled for number of pods, number of seeds per pod, 100 seed weight and harvest index after which, the used samples were returned to the harvest lots.

#### 3.9.3.1Number of Pods per Plant

For pod number, ten plants were taken from each plot and all the pods were plucked, manually counted and the average pod number was calculated.

#### 3.9.3.2 Number of Seeds per Pod

The number of seeds per pod was also determined by taking ten plants from each plot. When all the pods were plucked and counted, they were shelled and the seeds were counted. The average was then calculated.

### 3.9.3.3 Hundred Seed Weight

The 100 seed weight was determined by numbering 100 seeds from the seedlot from each plot. The selected 100 seeds were weighed to represent the mean seed weight.

### 3.9.3.4 Harvest Index

After shelling the pods of the ten plants from each plot, the seeds, chaff and the total biomass were oven dried at 80$^{o}$C for 48 hours and the dry weight was then measured. Harvest Index was thereafter calculated as: $Harvest\ Index = \frac{Economic\ yield}{Biological\ yield}$, where, economic yield is the seed yield and the biological yield is the summation of the total biomass, chaff and seed weight.

### 3.9.3.5 Grain Yield

The grain yield per unit hectare was determined byfirst drying the harvested plants from the four middle rows of each plot in the sun for two weeks, followed by threshing. The mass of grains in grams (g) was then converted to kilogram per hectare to represent mean grain yield for a unit hectare.

### 3.9.4 Data analysis

All data collected were analysed using the SAS9.1.3statistical package. Data on number of nodule were transformed logarithmically before the analysis. The Least Significant Difference (LSD) was used to compare the differences in the treatment means at 5% probability level.

# CHAPTER FOUR

## 4.0 RESULTS

### 4.1 Plant Height

At 45 DAP plant height was not significantly affected ($p>0.05$) by NPK application (Table 4.1). Application of poultry manure, however, significantly affected soybean plant height. Poultry manure rates of 2 and 4 tons/ha had similar effects, and either effect was significantly higher than the control treatment effect.

At 65 DAP, plant height was significantly affected by both NPK and poultry manure application. Effects of 45 and 90 kg/ha NPK rates were similar and both effects were significantly higher that the control treatment effect. Application of 4 tons/ha of poultry manure produced the greatest effects, but this was significantly higher than the control treatment effect only.

**Table 4.1: Effects of NPK and poultry manure rates on plant height (cm) of soybean**

| Treatments | Plant height (cm) at | |
|---|---|---|
| | 45 DAP | 65 DAP |
| **NPK rates (kg/ha)** | | |
| 0 (N0) | 35.38 | 37.08 |
| 45 (N1) | 36.35 | 42.67 |
| 90 (N2) | 38.19 | 44.39 |
| LSD (5%) | NS | 3.87 |
| **Poultry Manure rates (ton/ha)** | | |
| 0 (P0) | 32.64 | 38.36 |
| 2 (P1) | 37.63 | 41.33 |
| 4 (P2) | 39.65 | 44.42 |

| | | |
|---|---|---|
| **Interactions** | | |
| N0*P0 | 31.15 | 36.30 |
| N0*P1 | 37.52 | 37.52 |
| N0*P2 | 37.47 | 37.40 |
| N1*P0 | 32.35 | 40.05 |
| N1*P1 | 35.32 | 39.45 |
| N1*P2 | 41.37 | 48.50 |
| N2*P0 | 34.42 | 38.72 |
| N2*P1 | 40.50 | 47.00 |
| N2*P2 | 40.10 | 47.35 |
| LSD (5%) | 2.87 | 3.87 |
| CV (%) | 9.24 | 11.09 |



### 4.2 Number of Leaves and Number of Branches

The results of the effects of NPK and poultry manure rates on the number of leaves per plant and the number of branches are presented in Table 4.2. Application of NPK did not significantly ($p>0.05$) affect the number of leaves per plant and the number of branches on both sampling occasions. Poultry manure rates did not significantly ($p>0.05$) affect number of leaves on both days and number of branches at 65 DAP. However, at 45 DAP, 2 tons/ha poultry manure rate produced significantly greater number of branches than the control treatment only.

**Table 4.2: Effects of NPK and poultry manure on the number of leaves and number of branches of soybean.**

| | Number of Leaves | | Number of Branches | |
|---|---|---|---|---|
| **Treatments** | **45 DAP** | **65 DAP** | **45 DAP** | **65 DAP** |
| **NPK rates (kg/ha)** | | | | |
| 0 (N0) | 39.38 | 66.28 | 10.16 | 12.28 |

| | | | | |
|---|---|---|---|---|
| 45 (N1) | 39.13 | 67.26 | 10.08 | 13.64 |
| 90 (N2) | 41.83 | 68.96 | 9.69 | 13.21 |
| LSD (5%) | NS | NS | NS | NS |
| **Poultry Manure rates (ton/ha)** | | | | |
| 0 (P0) | 38.08 | 68.46 | 9.15 | 12.91 |
| 2 (P1) | 41.40 | 68.20 | 10.57 | 13.27 |
| 4 (P2) | 40.86 | 65.83 | 10.21 | 12.96 |
| **Interactions** | | | | |
| N0*P0 | 35.62 | 63.80 | 8.97 | 11.80 |
| N0*P1 | 43.55 | 67.27 | 10.60 | 12.97 |
| N0*P2 | 38.95 | 67.77 | 10.90 | 12.07 |
| N1*P0 | 37.20 | 67.77 | 9.17 | 13.60 |
| N1*P1 | 35.82 | 67.00 | 10.46 | 13.47 |
| N1*P2 | 44.37 | 67.00 | 10.60 | 13.85 |
| N2*P0 | 41.40 | 73.80 | 9.30 | 13.32 |
| N2*P1 | 44.82 | 70.35 | 10.65 | 13.35 |
| N2*P2 | 39.25 | 62.72 | 9.12 | 12.95 |
| LSD (5%) | NS | NS | 1.23 | NS |
| CV (%) | 24.70 | 16.83 | 14.58 | 10.15 |

### 4.3 Leaf Areaand Shoot Biomass

The results of leaf area and crop growth rate are presented in Table 4.3. NPK rates did not significantly affect ($p>0.05$) leaf area. However, poultry manure application significantly affected leaf area of soybean. The control treatment effect was significantly lower ($p>0.05$) than the manure application treatments. Differences in the manure applied treatments were not significant at 5% probability.

Both poultry manure and NPK treatments significantly affectedthe total shoot biomass ($p<0.05$). The control treatment shoot biomass was significantly lower than other NPK treatments, but NPK treatments effects were not significant from each other. Similarly, poultry manure treatment effects on shoot biomass were statistically the same, but they were significantly higher than the control effect.



**Table 4.3: Effects of different rates of poultry manure and NPK on leaf area and shoot biomass of soybean**

| Treatments | Leaf area ($m^2$) | Shoot biomass (kg/ha) |
|---|---|---|
| **NPK rates (kg/ha)** 0 | | |
| (N0) | 0.42 | 2824.00 |
| 45 (N1) | 0.41 | 3484.00 |
| 90 (N2) | 0.42 | 3360.00 |
| LSD (5%) | NS | 409.3 |
| **Poultry Manure rates (ton/ha)** | | |
| 0 (P0) | 0.32 | 2652 |
| 2 (P1) | 0.44 | 3376 |
| 4 (P2) | 0.47 | 3644 |
| **Interactions** | | |
| N0*P0 | 0.47 | 2016 |
| N0*P1 | 0.79 | 2952 |
| N0*P2 | 0.72 | 3516 |
| N1*P0 | 0.55 | 2976 |
| N1*P1 | 0.60 | 3666 |
| N1*P2 | 0.87 | 3810 |
| N2*P0 | 0.57 | 2964 |
| N2*P1 | 0.77 | 3510 |
| N2*P2 | 0.71 | 3606 |
| LSD (5%) | 0.08 | 409.3 |
| CV (%) | 14.80 | 16.06 |

### 4.4 Number of Pods, Number of Seeds and Hundred Seed Weight

The results of the effects of rates of NPK and poultry manure on number of pods per plant, number of seeds per pod and hundred seed weight of soybean are presented in Table 4.4. Number of seeds per pod and hundred seed weight were not significantly affected by NPK and poultry manure applications. Application of poultry manure did not significantly ($p>0.05$) affect number of pods. However the number of pods per plant was significantly influenced by NPK rates. NPK rate of45kg/ha treatment produced the greatest number of pods, but this was not significantly higher that the control treatment effect only. Other treatment differences were not significant.

**Table 4.4: The effects of NPK and poultry manure on number of pods per plant, number of seeds per pod and 100 seed weight of soybean.**

| Treatments | Number of Pods Per Plant | Number of Seeds Per Pod | 100 Seed Weight (g) |
|---|---|---|---|
| **NPK rates (kg/ha)** | | | |
| 0 (N0) | 23.35 | 2.37 | 11.50 |
| 45 (N1) | 31. 42 | 2.17 | 11.67 |
| 90 (N2) | 29.46 | 2.38 | 11.75 |
| LSD (5%) | 6.82 | 0.22 | 0.88 |
| **Poultry Manure rates (ton/ha)** | | | |
| 0 (P0) | 24.60 | 2.32 | 11.42 |
| 2 (P1) | 30.55 | 2.37 | 12.00 |
| 4 (P2) | 29.08 | 2.32 | 11.50 |
| **Interactions** | | | |
| N0*P0 | 14.97 | 1.75 | 8.75 |
| N0*P1 | 25.30 | 1.82 | 9.75 |
| N0*P2 | 23.37 | 1.73 | 10.00 |
| N1*P0 | 22.90 | 1.68 | 9.50 |

| | | | |
|---|---|---|---|
| N1*P1 | 37.45 | 1.64 | 10.25 |
| N1*P2 | 33.92 | 1.68 | 9.25 |
| N2*P0 | 29.52 | 1.73 | 10.00 |
| N2*P1 | 28.90 | 1.85 | 10.00 |
| N2*P2 | 29.95 | 1.75 | 9.25 |
| LSD (5%) | 6.82 | 0.22 | 0.88 |
| CV (%) | 27.35 | 13.98 | 10.87 |



### 4.5 Harvest Index and Grain Yield

The result of NPK and poultry manure effects on the grain yield and harvest index of soybean is shown in Table 4.6. Treatment means for both harvest index and grain yield were not significantly affected by NPK application. Application of poultry manure did not affect harvest index as well. However, it significantly affected grain yield. Grain yield from the 2 tons/ha treatment was the greatest, and this was significantly higher than the control treatment effect only.

**Table 4.5: The effect of NPK and poultry manure on grain yield and harvest index of soybean**

| Treatments | Harvest index (%) | Grain yield (kg/ha) |
|---|---|---|
| **NPK rates (kg/ha)** | | |
| 0 (N0) | 41.50 | 1128.43 |
| 45 (N1) | 40.92 | 1147.13 |
| 90 (N2) | 41.25 | 1147.13 |
| LSD (5%) | NS | NS |
| **Poultry Manure rates (ton/ha)** | | |
| 0 (P0) | 41.58 | 1052.49 |
| 2 (P1) | 41.74 | 1197.66 |
| 4 (P2) | 40.36 | 1140.32 |

| | | |
|---|---|---|
| **Interactions** | | |
| N0*P0 | 23.62 | 883.07 |
| N0*P1 | 21.76 | 1404.94 |
| N0*P2 | 19.13 | 1097.27 |
| N1*P0 | 18.7 | 1160.12 |
| N1*P1 | 24.12 | 1150.12 |
| N1*P2 | 20.17 | 1231.14 |
| N2*P0 | 22.66 | 1114.27 |
| N2*P1 | 19.34 | 1137.90 |
| N2*P2 | 21.75 | 1092.55 |
| LSD (5%) | NS | 119.25 |
| CV (%) | 19.59 | 10.64 |



### 4.6 Nodule Number, Nodule Effectiveness and Nodule Dry Weight

The results on the number of nodules per plant, number of effective nodules and nodule dry weight are presented in Table 4.5.All the parameters were not significantly ($p>0.05$) affected by NPK application. Poultry manure application did not significantly affect nodule production. However, number of effective nodule and nodule dry weight were affected by manure application. Effective nodules were significantly higher in the 2 tons/ha rate than in the 4 tons/ha and control treatments. Again, nodule dry weight was significantly higher in the 2 tons/ha treatment than in both control and 4 tons/ha manure treatments

**Table 4.6: Effects of NPK and poultry manure rates on the number of nodules per plant, number of effective nodules and nodule dry weight of soybean**

| Treatments | Number of Nodules per Plant | Number of Effective Nodules per plant | Nodule dry Weight (g) |
|---|---|---|---|
| **NPK rates (kg/ha)** | | | |
| 0 (N0) | 1.93 | 0.79 | 0.29 |
| 45 (N1) | 1.38 | 0.86 | 0.33 |
| 90 (N2) | 0.98 | 0.63 | 0.23 |
| LSD (5%) | NS | NS | NS |

| | | | |
|---|---|---|---|
| **Poultry Manure rates (ton/ha)** | | | |
| 0 (P0) | 0.56 | 0.43 | 0.09 |
| 2 (P1) | 2.83 | 1.39 | 0.55 |
| 4 (P2) | 0.90 | 0.46 | 0.21 |
| **Interactions** N0*P0 | | | |
| | 0.22 | 0.17 | 0.00 |
| N0*P1 | 4.40 | 1.92 | 0.68 |
| N0*P2 | 1.175 | 0.27 | 0.20 |
| N1*P0 | 0.30 | 0.22 | 0.04 |
| N1*P1 | 3.92 | 1.74 | 0.70 |
| N1*P2 | 0.90 | 0.62 | 0.24 |
| N2*P0 | 1.15 | 0.90 | 0.23 |
| N2*P1 | 1.15 | 0.50 | 0.28 |
| N2*P2 | 0.62 | 0.47 | 0.20 |
| LSD (5%) | 1.47 | 0.84 | 0.26 |
| CV (%) | 57.2 | 31.57 | 22.75 |

### 4.7 Amount of N2 Fixed

The result of the effects of NPK and poultry manure on the amount of N fixed in soybean is shown in Table 4.7. 45 kg/ha of NPK and 2 tons/ha of poultry manure generally caused an increase in the amount of N fixed over other treatments. However, the effect of both poultry manure and NPK treatments on amount of N fixed was not significant ($p<0.05$) There were also statistically no significant differences in the treatment means for both NPK and poultry manure treatment means.

**Table 4.7: Effects of NPK and Poultry manure on the amount of N fixed by soybean**

| Treatments | N-fixed (kg/ha) |
|---|---|
| **NPK rates (kg/ha)** | |
| 0 (N0) | 37.9 |
| 45 (N1) | 49.9 |
| 90 (N2) | 48.3 |
| LSD (5%) | NS |
| **Poultry Manure rates (ton/ha)** | |
| 0 (P0) | 34.5 |
| 2 (P1) | 52.9 |
| 4 (P2) | 46.7 |
| LSD (5%) | NS |

| **Interactions** | |
|---|---|
| N0*P0 | 23.5 |
| N0*P1 | 59.4 |
| N0*P2 | 37.1 |
| N1*P0 | 43.2 |
| N1*P1 | 56.8 |
| N1*P2 | 56.1 |
| N2*P0 | 35.1 |
| N2*P1 | 47.6 |
| N2*P2 | 38.8 |
| CV (%) | 39.2 |



### 4.8 Correlation between some measured growth, N fixation and yield parameters of soybean

A simple correlation coefficient was worked out to ascertain the degree of relationship between growth, N fixation and yield parameters of soybean in the study location. The information on Pearson correlations among some measured growth, N fixation and yield parameters is displayed in Table 4.8.There were significant correlation ($p$<0.05) between plant height and shoot biomass (r=0.57), nodule mass and number of effective nodules(r=0.97), and amount of N fixed and nodule effectiveness (r=0.59).

**Table 4.8: Pearson correlation coefficient of some measured growth, N fixation and yield parameters**

| | Shoot biomass | Leaf area | Height | Nodule mass | Effective nodules per plant | Nodule number per plant | No. of pods per plant | Amount of N fixed | Grain Yield |
|---|---|---|---|---|---|---|---|---|---|
| **Shoot biomass** | 1.00 | | | | | | | | |
| **Leaf area** | **0.58** | 1.00 | | | | | | | |
| **Plant Height** | **0.57** | **0.59** | 1.00 | | | | | | |
| **Nodule mass** | 0.22 | 0.03 | 0.10 | 1.00 | | | | | |
| **Effective nodules per plant** | 0.14 | -0.07 | 0.06 | **0.96** | 1.00 | | | | |
| **Nodule number plant** | 0.12 | 0.02 | 0.01 | **0.96** | **0.95** | 1.00 | | | |
| **Number of pods per plant** | 0.47 | 0.37 | 0.38 | 0.17 | 0.06 | 0.06 | 1.00 | | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Amount of N fixed** | 0.08 | 0.01 | 0.07 | 0.34 | **0.59** | 0.46 | 0.37 | 1.00 | |
| **Grain yield** | 0.18 | 0.32 | 0.01 | 0.24 | 0.21 | 0.29 | 0.19 | 0.24 | 1.00 |

**Bold** means significant at $p<0.05$

# CHAPTER FIVE

# 5.0 DISCUSSION

## 5.1Effects of NPK and Poultry Manure on Growth of Soybean

Plant height results indicated that both NPK and poultry manure treatments effects on plant height were significant ($p>0.05$) over the control treatment at 65 DAP. Poultry manure rates at 2 tons/ha and 4 tons/hacaused a mean plant height of 41.33 cm and 44.42 cm which represented an increase of approximately 8% and 16% respectively over the control treatment. NPK treatment at 45 kg/ha and 90 kg/ha resulted in mean plant height of 15% and 19% increase in plant height over the control. Increased plant height means increased source production which according to Caliskan *et al*. (2008) and Summerfield and Wien (1980) have direct effect on grain yield.

The number of branches and number of leaves per plant were not significantly ($p>0.05$) affected by both NPK rates and poultry manure rates. This result is contrary to the results obtained by Yagoub *et al.* (2012) and Orellana *et al.* (1990), who stated that the use of fertilizers results in higher number of leaves and branches in soybean. In a related study, Xuewen (1990) reported that variation in quantity of nitrogen applied had slight effect on the average number of leaves per plant.

The mean leaf area of soybean was significantly ($p>0.05$) affected by poultry manure treatments but not NPK treatments. Mean leaf area was increased by 2tons/ha and 4tons/ha of poultry manure by 46% and 37% respectively over the control treatment. This result can be ascribed to the low carbon-nitrogen ratio in the poultry manure (20.55:16.61, Appendix 2) which aided faster decomposition of the manure. The low C:

N ensured that microorganisms obtained adequate nitrogen for their needs and mineralized excessorganic nitrogen in poultry manure to ammonium ($NH_4^+$) for plant use. According to Mellendorf (2011), maximum crop yield can best be attained if the crop population is able to make sufficiently large leaves to efficiently intercept light at reproductive stage of crop growth. However, correlation between leaf area and grain yield was not significant ($p>0.05$)

The shoot biomass of soybean was significantly ($p>0.05$) affected by NPK and poultry manure treatments over their respective controls. Shoot biomass production increased with application of either poultry manure or NPK fertilizers. Poultry manure rate at 4 tons/haproduced 3644 kg/ha biomass which was 37% greater than the biomass produced by the control treatment (Table 4.3). NPK rate at 45 kg/ha produced 3484kg/ha of biomass which was 23% higher than the shoot biomass of the control but it was not significantly different from NPK rate at 90kg/ha. The increase in shoot biomass can be attributed to the availability of nutrients from the treatments applied. Nutrient availability (especially N) enhances physiological functioning and metabolism in plants and influences positively biomass production especially by increase in leaf dry weight
(Hopkins and Huner, 2009; Chatzistathis and Therios, 2013).

**5.2 Effects of NPK and Poultry Manure on Nodulation and N-Fixation**

As shown in Table 4.6,only poultry manure rates had significant ($p>0.05$) effect on number of nodules of soybean.Poultry manure rates at 2tons/ha had significantly higher number of nodules per plant and greater number of effective nodules per plant than other poultry manure treatment and NPK treatments. Poultry manure rate at 2tons/ha yielded 5 times more number of nodules that the control and 3 times more nodules than poultry manure

rate at 4tons/ha. Higher number of nodules was observed in poultry manure treatments than NPK treatments because, according to Dong *et al.* (2014), addition of organic manure to soils increase soil organic carbon, total nitrogen and total phosphorus contents, which are key determinants affecting soil microbial community. Microbial populations therefore quickly multiply under organic manure treatments hence the increase in number of nodules in poultry manure treatments than NPK treatments.
NPK rates, however, did not reduce nodule effectiveness.

Significant differences in nodule number also resulted in significant differences in the mass of nodules and there was a positive correlation between nodule mass and nodule number (Table 4.8). The implication of these results is that treatments that produced more nodules also produced larger nodules. Similar observation was made by Bebeley (2013). However, contradictory observations have been made by Addu (2003), SarkodieAddo (1991) and Sarkodie-Addo *et al.* (2006) who reported that negative correlation between nodule mass and nodule number.

There was a high range of nodule number per plot ranging from 0 to 96 per with an average of 10.6 nodules per plot. The ANOVA for nodule number as shown in Appendix 3 shows that there were differences in block means which suggest that the rhizobia population were not evenly distributed in all the blocks. The high coefficient of variation may be attributed to the non-uniform distribution of rhizobia in the soil.

Despite the fact that there were significant differences in the nodule number and number of effective nodules, N fixation differences were not significant. Even though nodulation is prerequisite for N fixation, Giller (2001) stated that rhizobia root infection and the

consequent formation of nodules in plant roots does not guarantee an effective nitrogen fixation symbiosis.

### 5.3 Effects of NPK and Poultry Manure on Yield and Yield Components

There was a general increase in the number of pod per plant in both NPK and poultry manure treatments relative to their respective controls (Table 4.4). The observation is in agreement with Achakzai (2012) who observed that the number of pods of soybean increases with increase in N availability. However, the number of pods per plant was significantly ($p>0.05$) affected by NPK treatments but not poultry manure treatments.

The number of seeds per pod in soybean in this experiment was not affected by the treatments. However, according to Achakzai (2012), pod yield and pod number per peaplant significantly increased with increasing quantity of N fertilizer application. There was no significant effect of treatments on number of seeds per pod and this observation can be attributed to the generally low level of rainfall experienced during the period of the experiment (Appendix 4). According to Desclaux *et al.* (2000), the growth stages in soybean which is most affected during drought stress are pod formation and grain filling period that had considerable effects on soybean yield. Taiz and Zieger (2002) stressed that drought at reproductive growth stage upsets photosynthesis and remobilization in plants which negatively affect the grain yield by lessening the grain number and grain weight.

Arise in harvest index is an indication that more dry matter was converted into seed when external inputs were made available for the plant. Also, it is an indication of how much of the biological development of the plant is translated into economic value. The results on harvest index as shown in Table 4.6 showed that differences in harvest index were not

significant. The low level of soil N in addition to non significant amount of N fixed is a contributing factor to the non responsiveness of harvest index as inadequate amount of nutrients were available to plants and hence not enough assimilates were made available for seed filling. However, the results indicated that the means of harvest index was within the range for soybean as reported by Salado-Navarro *et al*. (1993), Ball *et al.* (2000) Kumidini *et al*. (2001) and Pederson and Laver (2004). Also the apparent low rainfall within the period of the experiment is a contributory factor to the low harvest index recorded. This is because, Richard *et al.* (2000) reported that minimal water supply at reproductive stage of soybean can upsets photosynthesis and remobilization and consequently reduce grain yield.

There were approximately 2% and 14% percent increases in the mean grain yield of soybean of NPK and poultry manure treatments,respectively,relative to their control means but treatment differences were not significant. The hundred seed weight of soybean was also not significantly affected by both NPK and poultry manure treatments. The no significant effects of NPK treatments on the grain yield of soybean may be due to the N deficiency from rate of application and low N fixation. According to Salvagiotti *et al.*, (2008), soybean seeds have elevated amounts of protein (about 40% of dry mass); consequently, they demand a significant amount of nitrogen in order to attain a good yield. It is estimated that about 8 kg nitrogen is needed for every 100 kg of soybean seed. Hence insufficient N supply can greatly affect grain yield. Moreover, water which is needed for the physiological functioning of all plants was not sufficiently available, and according to Desclaux *et al*. (2000) and Souza *et al.* (1997), pod set and seed filling period in soybean growth is the most sensitive stage to drought stress that largely affect grain yield because leaf senescence is accelerated and seed filling period is shortened.

# CHAPTER SIX

## 6.0 CONCLUSIONS AND RECOMMENDATIONS

### 6.1 Conclusions

Soybean growth was significantly affected by application of either NPK fertilizer or poultry manure which resulted in significant increases in the growth of soybean. The significant effect of NPK and poultry manure treatments on growth of soybean was evident in increase in plant height, leaf area, crop growth rate and shoot biomass.

Generally, yield and yield components of soybean were not significantly ($p>0.05$) affected by both NPKand poultry manure treatments. These observations weremainly due to minimal rainfall during the onset of pod formation.However only 2 ton/ha of poultry manure increased grain yield of soybean.

The number of nodules formed and nodule effectiveness were significantly ($p>0.05$) affected by poultry manure treatments only. Only 2 ton/ha of poultry manure resulted in significantly higher number of nodules and higher number of effective nodules.

### 6.2 Recommendations

It is that this work must be replicated in order to make conclusive recommendations.

Also, future work must not solely rely on rainfall but support rainfall with irrigation.

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## APPENDICES

**Appendix 1: Physical and Chemical Analysis of Soil Samples at Experimental Site.**

| **Sample Identification** | | **0-15 cm Soil Depth** | **15-30cm Soil Depth** |
|---|---|---|---|
| % Organic Carbon | | 2.55 | 1.52 |
| % Organic Matter | | 4.40 | 2.61 |
| % Total N | | 0.41 | 0.17 |
| Available P (mg/kg) | | 12.25 | 10.11 |
| Exchangeable Cations (cmol/kg) | K | 0.11 | 0.07 |
| | Ca | 3.72 | 2.34 |
| | Mg | 0.84 | 0.74 |
| | Na | 0.05 | 0.05 |
| pH | | 6.17 | 5.16 |
| Sand | | 58.10 | 56.70 |
| Silt | | 26.64 | 25.42 |
| Clay | | 15.26 | 17.88 |
| Bulk density | | 1.38 g/cm$^3$ | |

**Appendix 2: Chemical Analysis of Poultry Manure.**

| **Sample Identification** | **Amount (g/100g)** |
|---|---|
| Nitrogen content | 16.61 |
| Organic Carbon | 20.55 |

**Appendix 3: Analysis of Variance of Nodule Number**

| Source | Degree of freedom | Sum of Squares | Mean square | F-Ratio | Probability |
|---|---|---|---|---|---|
| Block | 3 | 89.90 | 28.30 | 9.28 | 0.0003 |
| NPK | 2 | 5.56 | 2.78 | 0.91 | 0.4152 |
| Poultry Manure | 2 | 35.84 | 17.92 | 5.88 | 0.0084 |
| NPK*poultry manure | 4 | 18.34 | 4.58 | 1.50 | 0.2325 |
| Error | 24 | 73.17 | 3.05 | | |
| Total | 35 | 217.81 | | | |

**Appendix 4: Rainfall Information at the Experimental Site**

| Month | Rainfall (mm) |
|---|---|
| August | 45.6 |
| September | 100.8 |
| October | 108.8 |
| November | 103.6 |
| December | 60.2 |

**(Courtesy: Quality Control Company, COCOBOD)**