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INFLUENCE OF CATTLE MANURE WITH TOGO ROCK PHOSPHATE SOIL AMENDMENT ON GROWTH AND YIELD OF SOYBEAN

(*Glycine max* (L) Merrill)

ALBERTA SERWAA BRONI

(MASTER OF PHILOSOPHY)

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DECLARATION

I, Alberta Serwaa Broni, declare that this thesis with the exception of quotations and references contained in published works which have all been identified and acknowledged is entirely my own original work and it has not been submitted either in part or whole for another degree elsewhere.

SIGNATURE:………………………………….

DATE:…………………………………………

SUPERVISOR'S DECLARATION

We hereby declare that the preparation and presentation of this work was supervised in accordance with the guidelines for supervision of thesis as laid down by the University of Education, Winneba.

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LIST OF ABBREVIATIONS

%	-	Percent
C	-	Carbon
Ca	-	Calcium
CEC	-	Cation Exchange Capacity
Cm	-	Centimeters
CM	-	Cattle Manure
CV	-	Coefficient of Variation
DAP	-	Days After Planting
ECEC	-	Exchangeable Cation Exchange Capacity
FAO	-	Food and Agriculture Oganization
FYM	-	Farm Yard Manure
g	-	gramme
GMA	-	Ghana Meteorological Agency
H_2O	-	Water
ha^{-1}	-	Per hectare
IITA	-	International Institute of Tropical Agriculture
K	-	Potassium
kg	-	kilogramme
L	-	Latin
l	-	litres
LSD	-	Least Significant Difference
Mg	-	Magnesium

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ml	-	mililitres
mm	-	millimeters
MoFA	-	Ministry of Food and Agriculture
N	-	Nitrogen
Na	-	Soduim
NH_3	-	Ammonia
^oC	-	Degress Celcius
Org. C	-	Organic Carbon
Org. M	-	Organic Matter
P	-	Phosphorus
P_2O_5	-	Phosphorus pentoxide
RP	-	Rock Phosphate
SAS	-	Statistical Analysis System
TEB	-	Total Exchangeable Base

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ABSTRACT

Glycine max plays vital role in diet, the economy of small holder farmers, Ghana and the global world as a whole. Hence the need for increasing production through soil amendment. Two field experiments were undertaken at different locations at the Multi – purpose Nursery, at the Akenten Appiah – Menka University of Skills Training and Enterpreneurial Development (AAMUSTED), Mampong – Ashanti during the 2018 minor rainy season and 2019 major rainy season. The study objective was to determine the effect of cattle manure and combination of cattle manure with Togo rock phosphate on soybean production. The Randomized Complete Block Design (RCBD) was used with five treatments and three replications. The treatments were no amendment (control), 5 t/ha CM, (5 t/ha CM + 25 kg/ha RP), 10 t/ha CM and (10 t/ha CM + 25 kg/ha RP). Results showed that application of cattle manure and combination of different rates of cattle manure with rock phosphate increased Mg concentrations, available phosphorus, and total phosphorus. Organic matter content and organic carbon were higher in the amended plots than the control. Effective root nodules on soybean increased in cattle manure with rock phosphate applied plots and recorded greater number than the control. Plant height and canopy spread for (5 t/ha CM + 25 kg/ha RP) were significantly ($P \leq 0.05$) higher among all the other treatments in both 2018 and 2019 cropping seasons. All the amended plots showed higher increase in number of pods, number of seeds per plant and grain yield than the control in 2018 and 2019 season. The control gave the highest diseased seeds weight as compared to the amended plots in 2018 and 2019 seasons. The (5 t/ha CM + 25 kg/ha RP) produced significantly ($P \leq 0.05$) higher grain yield than other amendments and control plots in 2018 and 2019 cropping seasons. The

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net profit for all the amended plots increased above the control. The combinations of cattle manure with rock phosphate are recommended for improving soil fertility and high yield of soybean in the transition and other ecological zones in Ghana.

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CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Soybean (*Glycine max* (L.) Merrill) is a legume plant belonging to the family Fabaceae. Like all other peas, beans, lentils and peanuts, soybean belongs to the subfamily papilionideae (Amout, 2019). Soybean is the world's leading source of protein and oil. Soybean has the highest protein content of all food crops and is second only to groundnut in terms of oil content among grain legumes (Ikeogu and Nwofia, 2013). Soybean crop is native of China and its spread from its native land of origin has been mainly due to its adaptability and predominant use as a food crop for human nutrition, source of protein for animals, medicinal plant and as an industrial crop (Ikeogu and Nwofia, 2013). Report by El – Agroudy *et al*. (2011) indicates that soybean contains 30 % oil with no cholesterol, 40 % protein as well as important vitamins needed for healthy growth in human.

An important factor in crop production is soil and its degradation is one of the limiting factors for sustainable agriculture (FAO, 2008). With increase in population, soil fertility management by long fallow periods is practically impossible (Kang and Mulongoy, 1992). Soil nutrient deficiency has been a major concern by both government and non – governmental organizations (NGOs) to improve food security and curb hunger in Africa (Rurangwa *et al*., 2018). Increasing the yield of oil seed crops like soybean has the potential to increase Ghana's foreign exchange earnings, to feed the local industries and increase farmers' income.

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The application of organic manure has multiple benefits due to the balanced supply of both macro and micronutrients. This can improve soil nutrients due to enhanced soil microbial activity, improving soil physical and chemical properties (Adekiya *et al*., 2019). Hence, organic agriculture is an alternative farming practice introduced into crop production to improve soil fertility, but organic manures are needed in a large quantity as they release nutrients slowly. The slow and gradual release of nutrients from organic manure is an advantage over sole chemical fertilization for achieving higher, grain yield, and quality of rice (Guo *et al*., 2017).

Many researchers' inculding Ayeni *et al*. (2010); Khojely *et al*. (2018) and Aher *et al*. (2018) have reported that application of organic manure improved the agronomic performance of soybean and increased crop yield. They also indicated that crop performance under the application of organic manures might be due to the cumulative effects on soil available nutrients, enhanced organic carbon, higher microbial population, increased enzyme activities and due to the residual effect. Again, organic fertilizers have a higher positive effect on microbial biomass and enhance soil health (Dutta *et al*., 2003). The use of organic manure including, poultry manure, cattle manure and other organic fertilizers is an excellent source of obtaining higher output in soybean cultivation.

The application of organic sources of nutrients significantly increased the productivity of soybean, enhance nutrient uptake, improve soil nutrient status, and accelerate soil enzyme activities. For soybean, to achieve maximum performance with sustenance of soil health, application of cattle manure was used as reported by (Aher *et al*., 2018). However,

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soybean requires phosphorus for its proper growth and nitrogen fixation and the crop's improvement can be inhibited due to phosphorus deficiency (Masso *et al*., 2016).

Phosphorus is an important nutrient for plant growth and their development (Van Slyke, 2001) and plays an essential role in leguminous plant, which include promoting root development, improvement of root nodulation and increasing grain yield as demonstrated by many researchers (Uchida, 2001; Pérez-Montaño *et al.*, 2014; MoFA, 2015). Tsvetkova and Geogiev (2003) stated that phosphorus deficiency affected the whole plant fresh and dry mass at the harvesting stage.

Combined application of organic materials and rock phosphate have been reported to be suitable for tropical and humid tropical soils (Agboola *et al.*, 1982; Yakubu *et al.*, 2010; Zapata and Roy, 2015) and to improve the soil's physical and chemical properties by enhancing biological activity and soil organic carbon accumulation (FAO, 2008; Agyarko *et al*., 2016). Most of these effects are due to an increase in soil organic matter resulting from manure application (Bakayoko *et al.*, 2009).

Nodulation response of soybean to increased phosphorus application is similar to the findings of Bekere and Hailemariam (2012) and Devi *et al.* (2012) who observed significant increases in soybean nodule dry weight with increasing levels of soil phosphorus. The combined applications of organic materials and rock phosphate have been reported to be suitable for humid tropical soils and to improve the soil's physical

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and chemical properties by enhancing biological activity and soil organic carbon accumulation (FAO, 2015).

Low yield of soybean in Ghana is attributed to depleted nutrients and the crop is mostly produced by smallholder farmers, with yield as low as 0.8 t/ha (Fianko, 2014; Mbanya, 2011). Despite the importance of the crop, yields of legumes are far below their potential. Low soybean yield in Ghana can be attributed to low level of adoption of technology such as soil management strategies that would improve soybean production as the main limitation to maximizing crop yield. Yakubu *et al.* (2010) have also reported large increase in legume yield due to addition of phosphorus fertilizer.

1.2 Problem Statement

Soybean is an economically important leguminous crop increasingly gaining considerable attention in sub – Saharan Africa, particularly Ghana (Mensah, 2014). The crop is a major source of vegetable oil and feed for the poultry and livestock industries and contains essential vitamins needed for healthy growth in human (Mensah, 2014).

Yet its production still lags behind annual consumption (Plahar, 2011) and average yield is as low as 0.8 t/ha and 1.0 t/ha as observed by smallholder farmers (Mensah, 2014; Rurangwa *et al*., 2018). The high demand is not met due to a number of production constraints such as declining soil fertility due to continuous cropping, inadequate information on the use of different sources of organic manure and pest infestation (Daria

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et al., 2012). Meanwhile, there is the need to increase soybean production to meet market demand.

Low fertility status of most cultivated tropical soils has been identified as a major factor causing low crop yield which directly affects the livelihood of smallholder farmers (Daria *et al.*, 2012). These low yields are as a result of low concentration of soil nutrients such as organic carbon, nitrogen, and phosphorus in soybean areas in Ghana (Masso *et al.*, 2016; Ulzen *et al*., 2018). However, with the increasing cost of industrial fertilizers in Africa and other developing world, it has become necessary to look for alternative means of enhancing the fertility of degraded soil. Recent studies have come to notice some approaches to curb the poor soil fertility challenge in developing nations which include the supply of organic and inorganic nutrients to the soil.

Rock phosphate, a naturally occurring mineral could serve as an appropriate alternative source of phosphorus in developing countries. Rock phosphate has been found to be much less expensive than inorganic phosphorus fertilizers (Lorion, 2011). Nevertheless, it has been found to have poor solubility when used as a fertilizer in the soil. Research shows that combining rock phosphate with organic material is found to be an effective technique for enhancing the solubility and nutrient availability to required plants (Akande e*t al*., 2012; Zatapa and Roy, 2015).

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1.3 Justification

The use of inorganic fertilizers has been the conventional way of fertilization to crops, however, the rising cost of fertilizers has compelled farmers to look for other alternatives to sustain crop production. Application of organic manure which is relatively more economical and environmentally safe could be the best alternative. Several soil amendments, which include materials such as chicken manure, cattle manure, cocoa husk compost and solid waste have been reported to improve crop production (Ismail *et al*., 2020).

The combined application of organic resources and mineral fertilizers is increasingly gaining recognition as one of the appropriate ways of addressing soil fertility depletion, especially in low – external input systems in Africa and forms an integral part of integrated soil fertility management (Vanlauwe *et al*., 2010). Importantly, organic inputs have several advantages in soil fertility management. Apart from providing essential plant nutrients, they contribute directly towards the build – up of soil organic matter and its associated benefits (Fairhurst, 2012).

Also, balanced ratio of nitrogen, phosphorus and potassium is required in the soil for soybean growth because the crop has the ability to fix nitrogen in the soil and suck up phosphorus and potassium from the soil (Nandagawali *et al.*, 2015). Significantly, combining rock phosphate with organic material is found to be an effective technique for enhancing the solubility and nutrient availability to required plants (Zatapa and Roy, 2015). Rock phosphate use has been found to be much less expensive than inorganic

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phosphorus fertilizers (Lorion, 2011). Several research have been conducted on amending rock phosphate with organic materials to facilitate the rate of decomposition after application to soils. The combination of agricultural waste with rock phosphate significantly improved the release of phosphorus and productivity of crop (Akande e*t al*., 2012; Zatapa and Roy, 2015; Agyarko e*t al*., 2016). A large increase in legume (soybeans) yield is due to addition of rock phosphate application to the soil before planting as reported by (Yakubu *et al*., 2010).

1.4 Research Objectives

The main objective of the study was to determine the effect of cattle manure and combination of cattle manure with Togo rock phosphate on soybean production.

1.4.1 Specific objectives

Specific objectives were to:

1. determine the effect of cattle manure, combination of cattle manure with Togo rock phosphate for improvement and maintenance of soil fertility on soybean.
2. compare the effectiveness of cattle manure and combination of cattle manure with Togo rock phosphate on growth and yield of soybean.
3. evaluate the response of soybean to cattle manure and combination of cattle manure with Togo rock phosphate on value/cost of production.

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CHAPTER TWO

LITERATURE REVIEW

2.1 Origin and Distribution

Soybean is native to Eastern Asia, mainly China, Korea and Japan, from where it spread to Europe, America, and other parts of the world in the 18th century (Kanchana *et al.*, 2015). Evidence in Chinese history indicates its existence more than 5,000 years ago, being used as food and a component of drugs (Yuan *et al.,* 2016). Some researchers have suggested Australia and Eastern Africa as other possible centres of origin of the genus *Glycine* (Kanchana *et al.,* 2015). It is widely grown on large scale in both the temperate and tropical regions such as China, Thailand, Indonesia, Brazil, the USA and Japan; where it has become a major agricultural crop and a significant export commodity (Chaudhary and Kastner, 2016).

The crop was first introduced to Africa in the early 19th century, through Southern Africa (Khojely *et al.,* 2018), and is now widespread across the continent (Wikipedia, 2019). However, Liu *et al*. (2012) indicated that soybean, might have been introduced at an earlier date in East Africa, since that region had long traded with the Chinese. The same report indicates that soybean has been under cultivation in Tanzania in 1907 and Malawi in 1909. In Ghana, the Portuguese missionaries have been reported the first to introduce the soybean in 1909. This early introduction did not flourish because of the temperate origin of the crop (Rees, 2012). However, serious attempts to establish the production of the crop in Ghana commenced in the early 1970s by collaborative breeding efforts of

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Ghana's Ministry of Food and Agriculture (MoFA) and the International Institute of Tropical Agriculture (IITA) (Sugri *et al.*, 2017).

2.2 Botanical Classification

Soybean (*Glycine max* (L). Merrill) is a legume plant belonging to the botanical family leguminosae. Like all other peas, beans, lentils and peanuts, which include some 500 genera and more than 12,000 species, it belongs to the subfamily papilionideae (Amout, 2019).

Soybean is an annual, erect hairy herbaceous plant, ranging in height of between 30 and 183 cm, depending on the genotype (Mawiya, 2016). Some genotypes have prostrate growth, not higher than 20 cm or grow up to 2 m high (Barro *et al.*, 2012). There are two types of growth habit of the soybean: determinate and indeterminate types with six approved varieties grown in Ghana (Asekabta, 2018). The determinate genotypes grow shorter and produce fewer leaves, but produce comparatively more pods, while the indeterminate types grow taller, produce more leaves and more pods right from the stem to shoot. Also, the flowers are small, inconspicuous and self – fertile; borne in the axils of the leaves and are white, pink or purple (Issifu, 2018). The stem, leaves and pods are covered with fine brown or gray hairs. The leaves are trifoliate, having three to four leaflets per leaf. It has a hairy pod that grows in clusters of three to five, each of which is five to eight centimeters long and usually contains two to four seeds (Milfont *et al.*, 2013). Soybean seeds occur in various sizes, and in many, the seed coat colour ranges from cream, black, brown, yellow to mottle. The hull of the mature bean is hard, water

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resistant and protects the cotyledons and hypocotyls from damage (Singh *et al.*, 2016). The nodulated root system consists of a tap root from which emerges a lateral root system (Dadson and Noureldin, 2001). The tap root may penetrate the soil as far as 150 cm deep, but most roots are in the top 30 – 60 cm of the soil. Nodules, when present, are small, spherical and sometimes lobed.

2.3 Nutritional Value and Uses

Nutritionally, Day (2013) indicated soybean as more protein – rich than any of the common vegetable or leguminous plant food sources in Africa. It has an average protein content of 40 %. The seeds also contain about 20 % oil on a dry matter basis, and this is 85 % unsaturated and cholesterol – free. Bekabil (2015) has reported that, soybean contributes to the feeding of both humans and domestic animals. Soybean can be cooked and eaten as a vegetable as well as processed into soy oil, soymilk, soy yogurt, soy flour, tofu and tempeh (Shurtleff and Aoyagi, 2016). Kanchana *et al.* (2015) also stated that soybean contains a lot of high – quality protein and is an important source of carbohydrates, oil, vitamins and minerals.

Research has shown that the quantity of proteins in one kilogram of soybean is equivalent to the quantity of proteins in three kilograms of meat or 60 eggs or 10 litres of milk and comparatively, the cost of buying one kilogram of soybean is much less than buying a similar quantity of meat or eggs (Shi *et al.*, 2012). It can, therefore, be an excellent substitute for meat in developing countries, where animal protein – rich foods such as meat, fish, eggs and milk are often scarce and expensive for resource poor families to

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afford. Soybean oil is also rich and highly digestible, odourless and colourless, which does not coalesce easily. It is one of the most common vegetable cooking oil used in food processing industries, all over the world.

Industrially, soybean is useful as lubricants, emulsifiers and plasticizers (Samarth and Mahanwar, 2015). In livestock production, the cake obtained from soybean after oil extraction is an important source of protein feed for livestock such as poultry, pig and fish. The expansion of soybean production has led to significant growth of the poultry, pig and fish farming (Bouwman *et al*., 2013). The haulms, after extraction of seed, also provide good feed for sheep and goats (Beigh *et al.*, 2017). Soybean seed is composed of an average of 40 % protein, 30 % carbohydrate, 20 % oil and 5 % ash on a dry weight basis (SoyStats, 2011) and a significant amount of vitamins A and E as well as minerals.

Medically, soy foods are also rich in B – vitamins, particularly niacin, pyridoxine and folacin (Soya Nutritional Content, 2014). Soybean seeds contain about twice the protein and 10 times the fat of common beans. Soybeans has anti mutagenic effect, anti – inflammatory properties, reduction in synthesis of low – density lipoprotein, antioxidant properties, and reduced effects of DNA damage (Astadi *et al*., 2009; Wang *et al*., 2010). The total protein fraction of the seeds is a complex mixture of globulins, albumins, prolamins and glutelins. The dicotyledons, of soybeans, have globulins and albumin as major storage proteins (Drzewiecki *et al.*, 2003). Globulin is the main protein fraction representing 50 – 70 % of the total protein (Neves *et al*., 2006). The proportion of these fractions in the total protein differs between species and varieties, which explains the

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differences in the functional properties and nutritional quality of soybeans (Neves *et al.*, 2006). Furthermore, it contains essential amino acids necessary for growth and tissue repair. Anti – carcinogenic properties related to the unique benefits of soy isflavones, phytochemicals which exert biological effects in humans and other animals are very essential (De Mejia *et al.*, 2003).

According to Wikipedia (2009) regular intake of soy foods can help one to prevent hormone – related cancers such as breast cancer, prostate cancer and colon cancer. Also, it relieves menopausal symptoms, due to the oestrogen like effect of soy flavones. Regular consumption of soy products reduces the rate of cardiovascular diseases, by reducing total cholesterol, low density lipoprotein cholesterol, preventing plaque build – up in arteries which could lead to stroke or heart attack and preventing osteoporosis (Odegaard *et al*., 2011).

2.4 Varieties

A large number of soybean varieties exist, producing soybeans that vary greatly in shape and colour. Soybean varieties, which have been released by the Research Institutes and are grown in Ghana, are Salintuya I, Salintuya II, Quarshie, Anidaso, Nangbaar and Jenguma (SARI, 2012). Appiah – Kubi *et al*. (2014) indicated that Salintuya – 1, Anidaso and Quarshie are medium maturing (101 – 110 days) varieties. Nangbaar is an early maturing (≤ 100 days) variety while Jenguma is late maturing (110 – 115 days). Grain yield for Salintuya – 1 and Anidaso is 1.2 t/ha – 1.8 t/ha. That of Quarshie is 1.5 – 2.2 t/ha. Grain yield for Nangbaar is 1.5 – 2.5 t/ha and 1.7 – 2.8 t/ha for Jenguma (Tutu,

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2014). Tutu (2014) reported that the world average yield is about 1,800 kg/ha and with proper management, it is not difficult to obtain 2,500 kg/ha. Adu – Dapaah *et al.* (2015) reported that Nangbaar grows to a height of 42 cm and bears an average of 6 branches per plant. Two to three seeds are borne per pod. The immature pod is green while the mature pod is light brown in colour and has a very good field emergence.

Nangbaar recorded 50 % flowering on 45 day at Fumesua (Achina and Quain, 2019). Adu – Dapaah *et al.* (2005) added that at percentage moisture content of 8.37 ± 0.05, Nangbaar had one thousand seed weight of 115.5 ± 7.2 g, percentage protein content of 43.00 ± 0.18 and 16.77 ± 0.23 for percentage fat. Antwi – Boasiako (2016) found the 50 % flowering day for Anidaso on day 50 at Fumesua. Further, Adu – Dapaah *et al*. (2005) reported that at percentage moisture content of 10.03 ± 0.03, Anidaso had one thousand seed weight of 96.08 ± 8.2 g, percentage protein content of 46.38 ± 0.08% and 16.45 ± 0.07 for percentage fat. Seed length of Anidaso was found to be 6.59 ± 0.35 mm and 5.66 ± 0.37 mm for seed width (Adu – Dapaah *et al.*, 2015). Tutu (2014) reported that Jenguma has an average plant height of 65 cm. It has average 50 % flowering on 45 day. It has a maturity period of 110 – 115 days with yield potential of 2.5 t/ha.

2.5 Climatic and Growth Requirements

2.5.1 Climatic requirements of soybean

Soybean is a legume species that grows well in the tropical, subtropical and temperate ecological zones (Osman, 2011). Mawiya (2016) described soybean as being typically a short day plant, physiologically adapted to temperate climatic conditions. However, some

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have been adapted to the hot, humid, tropical climate. In the tropics, the growth duration of adapted genotypes is commonly 90 – 110 days, and up to 140 days for the late maturing ones (Mahad, 2018). The relatively short growth duration is primarily due to sensitivity to the day length.

This affects the extent of vegetative growth, flower induction, production of viable pollen, and length of flowering, pod filling and maturity characteristics (Hatfield & Prueger, 2015). Most legumes require an optimum temperature of between 17.5 ^{o}C and 27.5 ^{o}C for development (Thakur *et al.,* 2010). The minimum temperature at which soybean develops is 10 ^{o}C, the optimum being 22 ^{o}C and the maximum about 40 ^{o}C. The seeds germinate well at temperatures between 15 ^{o}C and 40 ^{o}C, but the optimum is about 30 ^{o}C (Shaban, 2013). Queiroz *et al*. (2020) has also suggested the optimum temperature for growth as between 23 – 25 ^{o}C.

2.5.2 Water management

Soybean is adapted to a wide array of climatic, soil and growth conditions, although it is mostly grown under rain – fed conditions (Fageria *et al.,* 1997). Soybean yield is highly affected by soil water availability. Some moisture is necessary for germination, and early development. Positively, it is most important that the plants receive rainfall or irrigation at the time of their seed – filling period. However, soybeans can withstand some drought once they are well established (FAO, 2002**).** Yet, the crop experiences moisture stress during the dry spell ranging from 15 to 21 days at any growth stage under rainfed conditions, resulting in significant reduction in the yield (Rana *et al.,* 2016). Yield in

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terms of pod length and plant biomass can significantly be affected by moisture stress or rainfall (Rana *et al*., 2016). However, soybeans require the greatest amount of water during late flowering to complete pod filling.

Water requirement is necessary at the peak during the vegetative stage and decreases at maturity stage (Rienke and Jone, 2005; Mahama, 2011). However, moisture stress exerts a detrimental effect on plant growth and metabolism (Khan *et al.,* 2018) yet high moisture requirement is critical at the time of flowering, pod – forming stage, pod filling periods, good seed size and seed weight. High relative humidity can cause deterioration of seeds. One percent increase in moisture content can reduce the seed longevity to half. Short duration varieties are recommended in areas where soybean is produced under rain – fed conditions. Nutrients and minerals transport is also affected by relative humidity (Roriz *et al.,* 2014). However, Dogan *et al.* (2007) observed that any water stress imposed on soybeans during beginning of pod and full seed formation result in substantial reduction in yield. Soybean is very susceptible to drought during the pod – filling stage. However dry weather is necessary for ripening.

2.5.3 Soil requirement

Soybean is tolerant to a wide range of soil conditions but does best on warm, moist, and well drained fertile loamy soils, that provide adequate nutrients and good contact between the seed and soil for rapid germination and growth (Ibirinde, *et al.*, 2018; Adu *et al*., 2014). Belfield *et al.* (2011) and Calcino (2018) reported that, soybean does well in

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fertile sandy soils with pH range of 5.5 to 7.0. The crop can tolerate acidic soils than other legumes but does not grow well in water logged, alkaline and saline soils.

2.6 Pests and Diseases

2.6.1 Pests Management

Soybeans have few serious insect pests compared to other cultivated crops (Panizzi, 2013). However, an abundance of non – pest and beneficial insects are characteristically present in soybean fields. Beneficial insects usually keep harmful insect populations below economic thresholds. The potential for economic loss is possible each growing season, and growers should inspect fields regularly to check for insect damage. Good pest management is the result of sampling fields, evaluating plant damage, correctly identifying insects, and determining insect populations (Macfadyen *et al.*, 2015). Thresholds vary with the development of the crop.

Treatment for insects should occur only when plant damage or insect counts exceed economic thresholds. Before employing chemical control measures for insects in soybeans, growers should be relatively sure that yield increases and/or the elimination of further damage will offset insecticide and application costs. Evaluation of the extent of insect infestations and timing insecticide applications are best accomplished by regularly surveying fields. Economic thresholds established for the major pests and applying insecticides should be based on careful scouting and using thresholds for the various pests. Economic thresholds may be based on insect counts or plant damage. Percent defoliation is often used for foliage feeders (Panizzi, 2013).

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Pests of soybean include, bean fly and stem fly, soybean aphids, green stink or green soldier bud, soybean folder and green looper (Stanley and Preetha, 2016). Bean fly and stem fly larvae puncture and mine the lower part of the leaves, feeding as miner on the leaf by destroying the petiole and the stem. The nymph and adult of soybean aphid cause injury by sucking the plant sap. Heavily infested plants appear stunted and curled leaves. The affected plant parts turn yellowish, dry up and eventually fall. Green stink bug or green soldier bug is a polyphagous insect which feeds on wide range of plants especially legumes. Both nymphs and adults pierce suck the juice of the stems developing pods and seeds. They destroy the harvestable pods and reduced both yield and quality of the crop.

Another pest of economic importance is soybean leaf folder (Mangang, 2017). The damage done by this pest often results in the serious defoliation of the host plant, hence, affecting its photosynthetic activity. The larva glues together the edges of a leaf on which it feeds inside. Its attack is evident in the large number of dried folded leaves. Green looper, on the other hand feed on the tender green foliage resulting in complete defoliation

Stink bugs are piercing sucking insects which normally suck sap of pods pericarp and developing seeds. This causes flat seeds and dropping of pods (Tukamuhabwa and Obua, 2015). Some other pests of soybeans are tobacco caterpillar, leaf roller, leaf miner, white fly, Bihar hairy caterpillar, gridle beetle, Japanese beetle, spider mites, bean leaf beetle, soybean pod borer, corn earworm and stink bugs (Ziaee, 2012).

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2.6.2 Diseases of soybean

Downy mildew is one of the most common foliar diseases of soybean which causes serious problem in soybeans production. This disease reduces seed quality and seed size. If more defoliation occurs, yields can also be reduced. Symptoms are found on young plants, but the disease does not become widespread in a field until the late vegetative or early reproductive stages (Dongre *et al*., 2012). Soybean cyst nematode feeds on the soybean roots resulting in stunted plants with reduced yields (Hartman *et al.*, 2011).

Damping – off disease affect seedlings before they could emerge. During post emergence, infected seedlings rot at the stem near the soil surface (Atwa *et al.*, 2019). Some other diseases of soybeans are red crown rot, pod and stem blight, Pythium rot, Phytophthora root rot, sudden death syndrome, brown stem rot, white mold, soybean mosaic, brown spot, soybean rust, sudden death syndrome (Bandara *et al.*, 2020).

2.6.3 Pest and disease control

Soybeans are prone to different viral and fungal diseases affected by different organisms. These diseases may result in low yield and poor quality grains and should be controlled from soil preparation till harvesting in order to achieve better yields. Integrated mechanisms such as chemical, mechanical, biological and other cultural practices can be used to control the diseases (Soybeans Production Guideline, 2010). Crop management that integrates several different disease management strategies

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generally improves success and the potential for profitable soybean production (Pratt *et al.*, 2009).

Monitoring soybean fields to identify the early stages of disease and pest occurrences and keeping good records on their existence and distribution allows for timely and economical application of management inputs. Correct identification of soybean diseases is essential for effective disease management (Pratt *et al.*, 2009). Some specific control measures in soybean production include crop rotation, biological control, cultivation of disease and pest – resistant crops, weed removal, proper soil preparation, inoculation with a soybeans group strain of rhizobium, intercropping with cereals, avoidance of too much moisture or very humid conditions, especially during the flowering and harvesting period and use of registered insecticides and pesticides/ chemical control (Luna and House, 2020).

2.7 Sources of Organic Manure

Organic manures are natural products used by farmers to enhance sustainable crop production. There are a number of organic manures like farmyard manure, green manures, compost prepared from crop residues and other farm wastes, and biological wastes – animal bones, slaughterhouse refuse (Robert, 2013).

Animal manures are the solid, semisolid, and liquid by – products generated by animals grown to produce meat, milk, eggs, and other agricultural products for human use and consumption. They are mixtures of animal faeces, urine, bedding materials (e.g. straw, sawdust, rice hulls, wood chips), and other materials associated with animal production,

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such as waste feed, soil, wash waters, and any chemical or physical amendments used during manure handling and storage.

Manures have been used as beneficial soil amendments since the dawn of civilization and were the primary soil amendment used in agriculture until the advent of chemical fertilizers in the 1940s (Larney and Angers, 2012). Today, manures continue to be regarded as valuable agricultural resources, because they are important sources of plant nutrients and are well recognised to improve soil physical and biological properties through the addition of organic matter.

2.8 Effects of Cattle Manure on Physical and Chemical Properties

Manure is an important source of crop nutrients and organic carbon. It generally decreases soil bulk density and increases total porosity, soil water retention, macro – and micro porosity (Shi *et al*., 2016; Xin *et al*., 2016). Moreover, soil organic matter increases following repeated applications of solid cattle manure. Research shows an inconsistent relationship between manure and the soil pH, with works that show an increase in pH as a function of manure application (Han *et al.*, 2016). Ano and Ubochi (2010) reported a consistent increase in soil pH with the application of 10, 20, 30, and 40 tonnes per hectare of rabbit, swine, goat, chicken, and cattle manures.

The increase in the pH as a function of manure application has been attributed to the calcium carbonate and bicarbonate found in manure, the addition of cations such as Ca and Mg, and the presence of organic anions in the manure, which can neutralize H^+ ions, (Butterly *et al.*, 2013). The presence of these substances in the manure depends on the

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animal diet. Cation exchange capacity (CEC) is a measure of the retention of positively charged ions on the surface of soil particles, (Goldberg *et al.*, 2020). The CEC of soil generally increases with the increase of clay content and organic matter. Studies have shown that there is an increasing trend in the CEC with an increase in the rate of applied manure. This trend can be attributed to the organic matter in manure and the increasing pH with manure application. Cattle manure also helps to improve the physical condition of the soil and provides the required plant nutrients. It enhances cation exchange capacity and acts as a buffering agent against undesirable soil pH fluctuations (Giwa and Ojeniyi, 2004; Ojeniyi *et al.*, 2007; Akanni and Ojeniyi, 2008). The application of organic manure has been found to have higher comparative economic advantage over the use of inorganic fertilizer.

Although the value of organic matter is hard to quantify, higher quality soils are associated with increased yields and higher economic returns (Sun *et al.*, 2013). From the biological point of view, soil organic matter is a primary source of energy for soil microorganisms and thus the whole soil food net, as well as a source of major nutrients, most notably nitrogen, phosphorus and sulphur for plant and the soil biota.

The application of organic manure has been found to have higher comparative economic advantage over the use of inorganic fertilizer. Cattle manure has good impart on physical and chemical properties of soil. According to Kihandan *et al.* (2007) manure application is one of the most effective ways of improving fertility in tropical soils. Again, addition of manure to soils in general does not only influence soil chemical properties but it also

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has great impacts on soil physical conditions such as soil water structure, bulk density and resistance against erosion and the effects of manure on soil water, soil temperature and bulk density (Gilley *et al*., 2020). Organic matter promotes soil aggregation, which allows the formation of pores and thus storage of water. Nyamangara *et al.* (2012) found that the addition of cattle manure to soil increased water retention (Usowicz *et al*., 2020). According to Kihandan *et al.* (2007), manure application is one of the most effective ways of improving fertility in tropical soils. Azimzadeh (2002) and Rasulzadeh and Yaghubi (2010) also reported lower soil bulk density in surface layer of soil in conservation tillage system when cattle manure was added because of higher organic carbon in conservation tillage systems.

Franzluebbers (2002) reported cattle manure improved soil properties such as aggregation, water – holding capacity, soil bulk density, porosity and resistance to water and wind erosion. Cattle manure application is effective on clay loam soil than loam soil as it decreases soil compaction (Shahgholi and Janatkhah, 2018). Cattle manure also helps to improve the physical condition of the soil and provides the required plant nutrients.

2.9 Effects of Organic and Inorganic Fertilizers and their Combination on Soil Characteristics

Conventional farming increases crop productivity, but usually depends on chemical fertilizer input and pesticides (Bitew *et al*., 2017 and Li *et al*., 2016) and thus adversely affects soil quality and nutrient use efficiency (Mahajan *et al*., 2021; Yadav *et al*., 2017).

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Despite the excessive use of mineral N fertilizer, a huge amount is lost and or unavailable to plants in most present farming systems. Applied N losses produces serious environmental problems, such as water pollution and enhanced greenhouse gas emission, and particularly leads to degradation of soil physiochemical and biological properties (Pathak, 2011; Akhtar *et al*., 2018). Furthermore, the overuse of chemical fertilizer causes soil acidification and reduced soil microbial biomass, which ultimately reduces soil fertility (Lal, 2015; Cai *et al*., 2018). Moreover, sole mineral fertilization enhances the decomposition of soil organic matter, which leads to degraded soil structure and declined soil aggregation and loss of nutrients through leaching, fixation, and greenhouse gases emission (Chen *et al*., 2014; Nin *et al*., 2016). Continuous, the use of chemical fertilizer on soil over long periods may affect its capability to maintain healthy crop growth and productivity (Singh, 2018).

From the above, our continued overreliance on chemical fertilizer for crop production is not sustainable. Accordingly, there is growing interest in the use of organic manure for advanced farming to decrease the associated problems without compromising crop productivity. Currently, the most challenging issue is to enhance grain yield, in order to feed the population on a sustainable basis with the least cost to the environment (Mueller *et al*., 2012; Morone *et al*., 2019). Previous investigations have recommended several N fertilizer management strategies, including optimal chemical fertilizer dosage (Chen *et al*., 2015) side – deep placement, and slow – release fertilization (Yang *et al.*, 2018). However, the development of these practices was restricted because they are labor – intensive and there is a lack of improved technology (Anadon *et al.*, 2018). In contrast to

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chemical fertilizer application, organic manure, a by - product derived from animal waste, has been utilized to increase crop productivity (Nkoa, 2014). The application of organic manure has multiple benefits due to the balanced supply of both macro and micronutrients. Adekiya *et al.* (2019) stated that application of organic manure can enhance soil nutrients due to enhanced soil microbial activity, improving soil physical and chemical properties.

Guo *et al*. (2017) stated that the slow and gradual release of N from organic manure is an advantage over sole chemical fertilization for achieving higher, grain yield and quality of rice. Furthermore, manure fertilization provides soil organic carbon, but the residual effect of manure fertilization is higher in soil nutrient availability for crop growth and development (Biratu *et al*., 2019). The alkaline nature of organic manure is the main reason for increased soil pH, while mineral N nitrification can develop protons to decrease soil pH. Organic manure is quite low in nutrient content and its nutrient releasing ability is also low to meet crop requirements in a short time, hence the sole application of manure could not meet the usual intensity of agriculture production. Organic manure coupled with mineral fertilizers has been confirmed to be a better approach to improve and sustain soil fertility and crop production than the sole application of mineral or organic manure (Iqbal *et al*., 2020; Kumar *et al*., 2017).

2.10 Effects of Cattle Manure on Crop Growth and Yield

Cattle manure is achieving more importance for getting higher yield and quality. Cattle manure being bulky organic material releases the soil compactness and improves the

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aeration in addition to the supply of essential plant nutrients and organic matter and increase soil microbial establishment along with accumulation of excess humus content (Meena *et al.*, 2019). Organic foods such as fruits, vegetables, food crops gain much higher value not only in the international market but also in the domestic market. According to Abou *et al.* (2012), vegetative growth and yield of different crops were increased with addition of organic cattle manure.

Application of cattle manure improved vegetative growth and increased root diameter, root size in carrot (Dawuda *et al.*, 2011). Application of organics improved the agronomic performance of soybean and increased crop yield. The improved crop performance under the application of organic manures might be due to the cumulative effects on soil available nutrients, enhanced organic carbon, higher microbial population, increased enzyme activities and the residual effect (Aher *et al.*, 2018). The application of organic sources of nutrients significantly increased the productivity of soybean, enhanced nutrient uptake, improved soil nutrient status, and accelerate soil enzyme activities. Application of cattle manure was reported by (Aher *et al.*, 2018) to achieve maximum performance with sustenance of soil health. Efthimiadou *et al*. (2010) obtained the highest plant height, dry weight, leaf area index and yield of sweet maize under cattle manure treatments (with or without chemical fertilizer).

2.11 Nutrient Content of Rock Phosphate

Phosphate Rock is a raw material that contains phosphate mineral for manufacturing superphosphate fertilizers. Direct application of rock phosphate as fertilizer can be done

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in an acid soil because of its low cost and slow release of P into the soil (Sale and Mokwunye, 1993; Lorion, 2011).

The Phosphate concentration in phosphate rock ranges from 10 – 17 % Phosphate. Phosphate rocks which have PO_4/CO_3 ratio less than 5 are considered very reactive. Rock phosphate fertilizers contain small amounts of the heavy metal cadmium **(**Grant, 2018). The various phosphate minerals present in phosphate rock have diverse origins and chemical and physical properties. The phosphorus content of phosphate rocks is commonly known as phosphorus pentoxide (P_2O_5). The main phosphate minerals in phosphate rock are Ca – phosphates, mainly apatites. Pure fluor – apatite contains 42 % P_2O_5, and francolite, the carbonate – substituted form of apatite, may contain 34 % P_2O_5 (El-Anwar *et al.*, 2019).

2.12 Effects of Organic and Inorganic Manures and their Combination on Growth and Yield of Soybean

The use of organic manure can conserve and improve soil physical, chemical, and biological fertility that causes an increase in soil and plant productivity. However, the use of manure takes along time and in relatively large quantities to have a positive impact on the soil and plants. The use of organic manure + inorganic fertilizers can increase the weight of roots, shoot, and yield of soybean by 98 % compared to without fertilizer. Application of fertilizers also improves the allocation of dry matter to the pods, increases the efficiency of water use, and increases the use of soybean N compared to using only NPK inorganic fertilizers or no fertilizers. Addition of organic fertilizers can increase soil

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organic carbon content. Continuous use of soil without the addition of organic fertilizers can reduce C – organic by 39 – 43 % compared to soil with the addition of organic fertilizer. Ghosha *et al.* (2012) reported that application of organic manure, rice straw, and green manure increased soil organic – C by 26, 18, and 6 %. Application of 5,000 kg manure/ha also produced the highest cowpea that was higher than that of 300 kg NPK fertilizer/ha (Kuntyastuti and Muzaiyanah, 2017).

Khahim *et al*. (2013) reported that application of organic manures in combination with recommended chemical fertilizer significantly influenced stover yield of soybean. Abdul *et al*. (2012) reported that increase in phosphorus application significantly increased plant height. Rezaei *et al*. (2014) reported that a combination of crop residues and mineral fertilizer resulted in higher pearl millet yields compared to sole application of crop residues or fertilizer in Niger. Habib *et al*. (2012) reported that maximum maize leaf area, leaf area duration, crop growth rate and net assimilation rate resulted from combined application of inorganic fertilizer and poultry manure. Furthermore, Efthimiadou *et al*. (2010) obtained the highest plant height, dry weight, leaf area index and yield of sweet maize under cow manure treatments (with or without chemical fertilizer). According to Habib *et al*. (2012), high crop growth rate contributed to high grain yield.

2.13 Residual Effects of Organic Manure

To all agricultural production systems, long – term fertilization is important and contribute considerably to the remarkable escalations in sustainable food production systems (Li and Han, 2016; Ghosh *et al.*, 2019). Best management practices of soil fertility and health, understanding of the mineralization process of carbon is required. C –

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mineralization is vital biogeochemical processes that fortify soil sustainability (Cai *et al*., 2019; Chen *et al.*, 2020). Application of organic manure is very common farming practice traditional management practices for augmentation and mineralization of soil organic matter as results of improvement in soil sustainability (Jiang *et al.*, 2014; Pan *et al.*, 2020).

Soil microbes play remarkable role in essential processes such as soil organic matter dynamics, nutrient transformation, decomposition of crop residues (Padhan *et al.*, 2020) and also regulate the nutrient accessibility of soil system by immobilization of nutrients as microbial biomass and mineralization of nutrients (Li and Han, 2016; Wang *et al.*, 2019). Hence, soil biological properties have been measured as most important indicators of fluctuations in the soil quality (Zornoza *et al.*, 2015).

The long – term fertilization had more insistent on soil characteristics, like microbial diversity, activity and biomass (Hartmann *et al.,* 2015). Long – term fertilization stimulated the production of hydrolytic enzyme or extracellular enzyme activities related to C (β – glucosidase and invertase), N (urease), P (phosphatase) and S (arylsulphatase) cycles (Li and Han, 2016). Subsequently, observing changes in various enzymatic activity offer a potential for better understanding of the nutrient cycling, availability, and soil quality. Some long – term effect of combined use NPK and FYM on soil biological properties have been studied in different cropping systems undervarying climatic conditions in India (Bhatt *et al.*, 2016).

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2.14 Effects of Rock Phosphate on Growth and Yield of Soybean

Due to the low income of Ghanaian farmers, there is an increasing interest in the use of cheaper alternative phosphorus fertilizers such as indigenous rock phosphate for direct application. The direct application of rock phosphate is an agronomic and economically sound alternative to the more expensive superphosphates in the tropics (Borges *et al.*, 2019). Rock phosphate can be utilized as direct application fertilizer in acid soils because of the low input cost and slow release of P to the soil. Phosphorus enhances seed germination and early growth, stimulates blooming, enhances bud set, aids in seed formation and hastens maturity (Abdu, 2020).

Jennifer (2014) observed that an increase in the concentration of soil P resulted in an increase in dry matter accumulation and total leaf area in soybean. An increase in leaf area will also result in an increase in photosynthetic area as well as the number of pods per plant which have been found to be highly correlated with the accumulation of dry matter and yield (Turuko and Mohammed, 2014). Phosphorus has an important role in producing energy in various metabolic processes and as a major nutrient element, where phosphorus compounds are of absolute necessity for all living organisms, nucleon proteins making up the essential substances of the cell and for cell division and development of meristematic tissues (Turuko and Mohammed, 2014).

However, it has been observed that phosphorus deficiency causes nutritional problems in new reclaimed soils (Abd El – Salam *et al.*, 2005). Bekere and Hailemariam (2012) and Devi *et al*. (2012) observed significant increases in soybean nodule dry weight with

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increasing levels of soil phosphorus from rock phosphate. Bolan *et al*. (2011) observed that insufficient P could restrict mycorrhizal development. The availability of P derived from rock phosphate may be enhanced in the rhizosphere of legumes, thus stimulating the colonization of roots by arbuscular mycorrhizal fungi colonization. According to Chien *et al.* (2013) the relative agronomic efficiency of rock phosphate would be higher for crops with lower phosphorus demands, such as legume crops than for cereal crops, such as maize. Bationo *et al*. (2014) also indicated that leguminous crops are more efficient in using phosphate rock than cereals. The low level of P, Ca and pH serve as precursors for phosphorous dissolution.

2.15 Effect of Root Nodules on Seed Yield of Legumes

Several leguminous plant species enter into symbiotic relationship with root – nodule bacteria, *Bradyrhizobium japonicum* (Noisangiam *et al.*, 2012). This specialized groups of bacteria form symbiotic association with vascular plants and are responsible for biological process for reduction of molecular nitrogen into ammonia. The nodule establishment occurs due to the sequence of multiple interactions between the bacteria and the leguminous plant (Hopkins and Hurner, 2004). Legume nodules are complex organs, containing several interacting processes that operate at specific levels, including; nodule formation, carbon metabolism, oxygen supply, cellular redox, and transmembrane transport (Sulieman and Phan Tran, 2014).

For legume crops such as soybean, nitrogen supplied from nodule is the most important feature for maintaining better growth rate of photosynthetic organs and producing flower

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buds at the vegetative growth stage (Nakamura *et al.,* 2010). With soybeans high demand for photosynthates from pods and nodules facilitate the initial rate of energization of the thylakoid membrane and stimulate the photosynthesis. The nitrogen which is produced by the converting atmospheric nitrogen in the air to nitrates which is used by leguminous plants help them to grow very well. Subsequently seed yield is mostly increased when the root nodules are well formed (Sańko-Sawczenko *et al.*, 2019; Technology brief for soybean production in Ghana, 2017).

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CHAPTER THREE

MATERIALS AND METHODS

3.1 Experimental Site and Location

Two field studies were carried out at different locations at the Multipurpose Crop Nursery Research site of the Akenten Appiah – Menka University of Skills Training and Enterpreneurial Development (AAMUSTED), Mampong – Ashanti. The field experiment was conducted during the 2018 minor rainy season (August – December, 2018) and 2019 major rainy season (March – July, 2019). Asante Mampong lies within the transition agro ecological zone of Ghana which lies between the forest and the Northern Savanna Zones. Asante Mampong (01^{O} 24’ W: 07^{O} 01’ N) is at an elevation of 257.7 m above sea level (Abbey, 1993).

3.2 Soil and Climate of the Experimental Area

The soil belongs to the Bediese soil series of the savanna ochrosol. It is deep red sandy – loam and free from stones, well drained, friable, and permeable with moderate organic matter content and water holding capacity with pH of 5.5 – 6.5. The soil is classified as Chromic Luvisol according to FAO/UNESCO legend (Asiamah, 1988). The area has a bimodal rainfall pattern with the major rainy season occurring from March and ending July and minor rainy season from September and ends in December. The soil is good for tuber, cereal, vegetables and legume crop production (Asiamah, 1988).

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3.3 Vegetation of the Experimental Area

The vegetation of the experimental area is semi – deciduous with thick grass cover. Some common weeds found include *Pennisetum purperum*, *Cyperus rotundus*, *Chromolaena odorata*, *Imperata cylindrical, and Centrosema pubescens*.

3.4 Experimental Design and Treatments

The experiment was arranged in a randomized complete block design (RCBD) with 5 treatments and 3 replications given a total of 15 plots. Each experimental plot measured 2.4 m x 1.2 m.

There were five treatments namely;

1. Control (no amendment)
2. 5 t/ha CM
3. 5 t/ha CM + 25 kg/ha RP
4. 10 t/ha CM
5. 10 t/ha CM + 25 kg/ha RP

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Table 3.1: Treatment Combinations

	Treatments	Cattle Manure (kg/m^2)	Rock Phosphate (g/m^2)
T_1	No Amendment	0.00	0.00
T_2	5 t/ha CM	1.50	0.00
T_3	5 t/ha CM + 25kg t/ha RP	1.50	15.00
T_4	10 t/ha CM	3.00	0.00
T_5	10 t/ha CM + 25kg t/ha RP	3.00	15.00

3.5 Land Preparation

The land was cleared, ploughed, harrowed and leveled. The field was subsequently laid out before sowing using measuring tape, garden lines and pegs. The field was demarcated into 15 plots with 3 replications and labelled randomly based on the treatment names and their replications such that each treatment name appeared once within each block. The size of each bed measured 2.4 cm x 1.2 cm x 0.3 m high. A well decomposed cattle manure and rock phosphate treatments were incorporated into the soil based on treatment label. The plots were watered and left for three weeks before sowing of seed. The same method was carried out for the land preparation during second experiment.

3.6 Soybean Variety Used for the Experiment

Nangbaar, a soybean variety was acquired from the Crops Research Institute (CRI) of the Council for Scientific and Industrial Research Institute (CSIR) at Fumesua, Kumasi. It was released in the year 2005 by CRI of the CSIR at Fumesua. Adu – Dapaah *et al.*

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(2005) and Achina and Quain, (2019) reported that Nangbaar grows to a height of 42 cm and bears an average of 6 branches per plant with three seeds borne per pod. The immature pod is green while the mature pod is light brown in colour. It has a very good field seedling emergence. According to SARI, (2012) grain yield for Nangbaar is 1.5 – .5 t/ha (15 – 25 bags/ha).

3.7 Cattle Manure Preparation and Application

Ten kilogrammes of dried cattle manure was obtained at Akenten Appiah – Menka University of Skills Training and Enterpreneurial Development (AAMUSTED), Mampong – campus at the animal farm and heaped under shade and covered with black plastic sheet to decompose. The cattle manure was thoroughly mixed and was passed through a 2 mm sieve mesh to get a fine texture after which sample was taken to the laboratory for chemical analysis. Sub-samples of cattle manure (1.5 kg and 3.0 kg) were weighed and incorporated into the the soil based on treatments and watered for further decomposition. After two weeks, soil samples were collected, labelled and sent to the laboratory to be analyzed at the Soil Research Institute – CSIR, Kwadaso – Kumasi. Sowing of soybean seeds was done in 3 weeks time after treatments application.

3.8 Rock Phosphate Preparation and Application

Rock phosphate a naturally occurring organic fertilizer was obtained from Crop and Soil Science Laboratory at (AAMUSTED), Mampong – campus. The rock phosphate was sieved through a 2 mm sieve to obtain a uniform mixture. Sample was taken to the laboratory for chemical analysis. The sub – sample of rock phosphate (15g) was weighed

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using electronic weighing scale and mixed thoroughly with weighed cattle manure based on the treatment. The combined mixtures (treatments) were incorporated onto respective plots according to treatment and watered. Two weeks after incorporation, soil samples were taken from their various plots, labelled and taken to the laboratory for analysis at the Soil Research Institute – CSIR, Kwadaso – Kumasi. Sowing of soybean seeds was done 3 weeks after treatments application.

3.9 Crop Propagation

Nangbaar seeds were planted on each plot during the minor and the major rainy season. Sowing was three seeds per hill at a depth of 3 cm and was later thinned to two per hill at two weeks after planting with a spacing of 60 cm between row and 10 cm within rows. There were 4 rows on each plot with 24 plants per each row giving a total plant population of 96 on each experimental plot. Each experimental plot size measured 2.4 m x 1.2 m with a total of 15 plots

3.10 Cultural Practices

3.10.1 Thinning

Plants were thinned to 2 per hill at two weeks after planting. There were 24 plants on each of the 4 rows making a total plant population of 96 on each plot.

3.10.2 Weed control

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.

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3.10.3 Pest management

The crops were attacked by grasshoppers and were sprayed with 15 litres knapsack sprayer using Karate 2.5 EC (active ingredient: Lamda – cyhalothrin 5 g/l) at a rate of 10 ml at flowering and pod formation stage for the two experiments.

3.11 Data Collection

3.11.1 Soil sampling and sample preparation

Soil samples from the experimental site were collected from 5 randomly chosen spots on each experimental plot from a depth of 0 – 20 cm. Soil samples from each plot were bulked and thoroughly mixed in a bucket, air dried and was passed through a 2 mm sieve mesh to get a uniform mixture after which sub – samples were put in plastic bags. The soil samples were labelled and sent to the laboratory and analyzed to determine the chemical properties of the soil before and after two weeks of treatments application at the Soil Research Institute – CSRI, Kwadaso – Kumasi.

3.11.2 Soil chemical analysis

3.11.2.1 Soil pH

Soil pH was determined using an H 1 9017 Microprocessor pH meter in a 1:2:5 suspension of soil and water. A 10 g soil sample was weighed into plastic pH tube to which 25 ml water was added from a measuring cylinder. The suspension was stirred frequently for 30 minutes. After calibrating the pH meter with buffer solutions at pH 4.0 and 7.0, the pH was read by immersing the electrode into the upper part of the suspension.

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3.11.2.2 Soil organic carbon and organic matter

Soil organic carbon was determined by the modified Walkley – Black method as described by Nelson and Sommers (1982). The procedure involves a wet combustion of the organic matter with a mixture of potassium dichromate and sulphuric acid. After the reaction, the excess dichromate is titrated against ferrous sulphate. Approximately 1.0 g of air – dried soil was weighed into a clean and dry 250 ml Erlenmeyer flask. A reference sample and a blank were included. Ten ml 0.1667 M potassium dichromate ($K_2Cr_2O_7$) solution was accurately dispensed into the flask using the custom laboratory dispenser. The flask was swirled gently so that the sample was made wet.

Then using an automatic pipette, 20 ml of concentrated sulphuric acid (H_2SO_4) was dispensed rapidly into the soil suspension and swirled vigorously for 1 minute and allowed to stand on a porcelain sheet for about 30 minutes, after which 100 ml of distilled water was added and mixed well. Ten ml of ortho – phosphoric acid and 1 ml of diphenylamine indicator was added and titrated by adding 1.0 M ferrous sulphate from a burette until the solution turned dark green at end – point from an initial purple color. The volume of $FeSO_4$ solution used was recorded and % C calculated.

Calculation:

The organic carbon content of soil was calculated as:

$$\%\ \mathrm{O.C} = \frac{\mathrm{M} \times 0.39 \times \mathrm{mcf} \times (\mathrm{V_1} - \mathrm{V_2})}{\mathrm{w}}$$

where:

M = molarity of ferrous sulphate solution.

mcf = moisture correcting factor $\frac{(100 + \%\ \mathrm{moisture})}{100}$

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V_1 = ml of ferrous sulphate solution required for blank.

V_2 = ml of ferrous sulphate solution required for sample.

w = weight of air – dry sample in grams.

0.39 = 3 × 0.001 × 100 % × 1.3 (3 = equivalent weight of carbon, 1.3 = compensation factor for incomplete oxidation of the organic carbon).

3.11.2.3 Total nitrogen

Total nitrogen was determined by the Kjeldahl method as described by Sáez-Plaza *et al.*, 2013. Approximately 0.2 g of air – dried soil was weighed into a 500 ml long – necked Kjeldahl flask and one spatula of Kjeldahl catalyst (mixture of 1 part selenium + 10 parts $CuSO_4$ + 100 parts Na_2SO_4) added. A 5 ml of concentrated H_2SO_4 was added to the mixture and then digested on a Kjeldahl digestion apparatus for 1 hour. The flask was removed after a clear mixture was obtained and then allowed to cool. About 40 ml of distilled water was added to the digested material and transferred into a 100 ml distillation tube. A 20 ml of 40 % NaOH was added to the solution and then distilled.

The digested material was distilled for 4 minutes and the distillate received into a flask containing 20 ml of 4 % boric acid (H_3BO_3) prepared with bromocresol green indicator producing approximately 75 ml of the distillate. The colour change was from pink to green after distillation, after which the content of the flask was titrated with 0.02 M HCl from a burette. At the end – point when the solution changed from weak green to pink, the volume of 0.02 M HCl used was recorded and % N calculated. A blank distillation

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and titration were also carried out to take care of traces of nitrogen in the reagents as well as the water used.

Calculation:

14 g of N is in one equivalent weight of NH_3

$$\text{Total N (\%)} = \frac{14 \times (A - B) \times N \times 100}{1000 \times 0.2}$$

where:

A = Volume of standard HCl used in the sample titration

B = Volume of standard HCl used in the blank titration

N = Normality of standard HCl

3.11.2.4 Available phosphorus (Bray's No.1 method)

The available phosphorus was extracted with Bray's No. 1 extracting solution (0.03 M NH_4F and 0.025 M HCl) as described by Bray and Kurtz (1945). Phosphorus in the extract was determined by the blue ammonium molybdate method with ascorbic acid as the reducing agent using a spectrophotometer.

Approximately 5 g of soil was weighed into 100 ml extraction bottle and 35 ml of extracting solution of Bray's no. 1 (0.03 M NH_4F in 0.025 M HCl) was added. The bottle was placed in a reciprocal shaker and shaken for 10 minutes after which the content was filtered through Whatman no. 42 filter paper. The resulting clear solution was collected into a 100 ml volumetric flask.

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An aliquot of about 5 ml of the clear supernatant solution was pipetted into 25 ml test tube and 10 ml coloring reagent (ammonium paramolybdate) was added as well as a pinch of ascorbic acid and then mixed very well. The mixture was allowed to stand for 15 minutes to develop a blue color to its maximum. The colour was measured photometrically using a spectronic 21 D spectrophotometer at 660 nm wavelength. Available phosphorus was extrapolated from the absorbance read. A standard series of 0, 1.2, 2.4, 3.6, 4.8 and 6 mg P/l was prepared from a 12 mg/l stock solution by diluting 0, 10, 20, 30, 40 and 50 ml of 12 mg P/l in 100 ml volumetric flask and made to volume with distilled water. Aliquots of 0, 1, 2, 4, 5 and 6 ml of the 100 mg P/l of the standard solution were put in 100 ml volumetric flasks and made to the 100 ml mark with distilled water.

Calculation:

$$\mathrm{P}\ (\mathrm{mgkg}^{-1}) = \frac{(\mathrm{a} - \mathrm{b}) \times 35 \times 15 \times \mathrm{mcf}}{\mathrm{w}}$$

where:

a = mg/l P in sample extract.

b = mg/l P in blank.

mcf = moisture correcting factor $\frac{(100 + \%\ \mathrm{moisture})}{100}$

35 = volume of extracting solution.

15 = final volume of sample solution.

w = sample weight in grams.

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3.11.2.5 Exchangeable cations

Exchangeable bases (calcium, magnesium, potassium and sodium) in the soil were determined in 1.0 M ammonium acetate extract (Black, 1986) and the exchangeable acidity (hydrogen and aluminium) was determined in 1.0 M KCl extract (Ocloo *et al.*, 2014).

3.11.2.6 Cation exchangeable capacity

Five kilogram (5 kg) of soil was weighed and transferred into a 50 ml centrifuge tube. Twenty – five millilitres sodium acetate solution was added to the tube and a stopper was fixed and shaken in a mechanical shaker for 5 minutes. The solutions were centrifuged at 2000 rpm for 5 minutes till supernatant liquid was clear. The liquid was decanted and the extraction was repeated three times. The mechanical shaker, the centrifuge, and decantation process with ethanol was repeated until the electrical conductivity (EC) of the decant read less than 40 m S/cm (Motsara, 2008). Sodium (Na) was absorbed by using the ammonium acetate solute on. The decant was collected in 100 ml volumetric flask fitted with a funnel and filter paper. A series of Na standard solutions in the range of 0 – 10 me/litre of Na was prepared to determine the sodium concentration by flame photometry. The flame photometric reading was taken, and 25ml sample extract was fed onto the flame photometer and the reading was taken again, corresponding to the concentration of Na. The displaced Na was actually a measure of the CEC of the soil (Motsara, 2008).

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3.11.2.7 Determination of calcium and magnesium

For the determination of the calcium plus magnesium, a 25 ml of the extract was transferred into an Erlenmeyer flask. A 1.0 ml portion of hydroxylamine hydrochloride, 1.0 ml of 2.0 percent potassium cyanide buffer, 1.0 ml of 2.0 percent potassium ferrocyanide, 10.0 ml ethanolamine buffer and 0.2 ml Eriochrome Black T solution were added. The solution was titrated with 0.01 M EDTA (ethylene diaminetetraacetic acid) to a pure turquoise blue colour. The titre value was recorded.

3.11.2.8 Determination of calcium and magnesium

A 25 ml aliquot of the extract was transferred into a 250 ml Erlenmeyer flask and the volume made up to 50 ml with distilled water. This was followed by adding 1 ml hydroxylamine, 1 ml of 2.0 % potassium cyanide and 1 ml of 2.0 % potassium ferrocyanide solution. After a few minutes, 5 ml of 8.0 M potassium hydroxide solution and a spatula of murexide indicator were added. The resultant solution was titrated with 0.01 M EDTA solution to a pure blue colour.

Calculation:

The concentrations of calcium + magnesium or calcium were calculated using thee quation:

$$\mathrm{Ca + Mg\ (or\ Ca)(cmolkg^{-1})} = \frac{0.01\ \times\ (\mathrm{Va}\ - \mathrm{Vb}) \times 1000}{\mathrm{w}}$$

where:

Va = ml of 0.01 M EDTA used in sample titration

Vb = ml of 0.01 M EDTA used in blank titration

w = weight (g) of air – dried soil used

0.01 = concentration of EDTA

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3.11.2.9 Determination of exchangeable potassium and sodium

Potassium and sodium in the extract were determined by Atomic Absorption Spectrophotometer (AAS). A standard series of potassium and sodium were prepared by diluting both 1000 ppm potassium and sodium solutions into 50 ppm. This was done by taking a 5 ml portion of each into one 100 ml volumetric flask and made to volume with distilled water. Portions of 1.0, 2.0, 4.0 and 8.0 ml of the 50 ppm standard solution were put into 100 ml volumetric flasks respectively. 10 ml of lanthanum and caesium solution was added to each flask and made to volume with distilled water. The standard series obtained was 0.5, 1.0, 2.0 and 4.0 ppm for potassium and sodium. Potassium and sodium were measured directly in the extract by AAS at wavelengths of 766.5 and 589.0 respectively.

Calculations:

$$\text{Exchangeable K (ppm soil)} = \frac{(a-b) \times 25 \times 20}{10 \times 39.1}$$

$$\text{Exchangeable Na (ppm soil)} = \frac{(a-b) \times 25 \times 20}{10 \times 23}$$

where:

(a-b) = concentration from reading (AAS)

25 = dilution factor of the extract

20 = extraction ratio

3.11.3 Vegetative growth data

Vegetative growth data were taken on 8 randomly selected tagged plants from each plot. Data was collected at 21, 35, 49, 63, and 77 days after planting (DAP).

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3.11.3.1 Plant height

Plant height was measured from the ground level to the tip of the stem for the 8 randomly tagged plants in the two middle rows. This was done using a meter rule at the various sampled plants from 21 days after planting (DAP) and at 2 weeks interval. The mean plant height was determined for each treatment and recorded.

3.11.3.2 Number of leaves per plant

Number of leaves per plant from the 8 randomly tagged plants from each plot was physically counted and the mean number of leaves per plant was recorded. This was done at 21 DAP and at 2 weeks interval.

3.11.3.3 Canopy spread

The canopy spread was taken at 21 DAP and every two weeks by measuring from the tip of one leaf and the other diagonally with the widest spread. The measurement was done with a meter rule and the mean records taken.

3.11.3.4 Fresh shoot and dry shoot weight

At 21 DAP and every two weeks, six plants were randomly sampled from the outer rows on each plot. The six plants were uprooted and separated into shoot and root. They were then taken to Crop and Soil Science laboratory and chopped into pieces. The fresh shoot from each treatment were weighed and recorded using electronic weighing scale and were packaged into bigger envelopes, labelled and oven dried at 70 ^{o}C for 48 hours. The dry shoot weight was recorded after the drying.

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3.11.3.5 Fresh root and dry root weight

Roots of six plants from each plot outer rows were randomly dug out with hand trowel, washed with clean water under a sieve and fresh root weight taken with electronic weighing scale. The roots were oven dried at 70 ^{o}C for 48 hours and the dry matter weight was recorded afterwards at the Crop and Soil Science Laboratory at Akenten Appiah – Menka University of Skills Training and Enterpreneurial Development (AAMUSTED), Mampong Campus. This was done at 21 DAP and every 2 weeks throughout the cropping seasons.

3.11.3.6 Number of effective nodules

Roots of the six plants from each plot outside the harvesable area after separating the shoot were observed with hand lens to identify root nodules. The root nodules were carefully collected using knife to detach its base from the root. The nodules collected were cut opened using a knife and a hand lens to determine their effectiveness. Nodule with pink or reddish colour were declared effective. The percentage effective nodules were then calculated. The nodules were collected at 21 DAP and every two weeks.

3.11.4 Yield and yield components

At harvest, when about 85 % of pods had turned brown (Dugje *et al*., 2009), two middle rows of each plot were harvested for yield analysis. From this harvested lots, data were taken on number of pods per plant, pod length, number of seeds per pod, pod weight per plant, quality and diseased seed weight per plant, number of pods per plot, pod weight per

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plot, seed weight per plot, 100 – seed weight, plant biomass at harvest, harvest index and grain yield. After which the used samples were returned to the harvest lots.

3.11.4.1 Number of pods per plant

For pod number, the 8 tagged plants were taken from each plot and all the pods were plucked, manually counted and the average pod number was calculated.

3.11.4.2 Number of seeds per plant

The seeds from the 8 tagged plants were taken from their pods of each plot and all their seeds were manually counted and the average seed number was calculated.

3.11.4.3 Pod length

From the harvested pods from the 8 tagged plants, 20 pods were randomly selected from each plot and their mean length were taken means recorded.

3.11.4.4 Number of seeds per pod

The number of seeds per pod was determined by counting the seeds from 20 pods randomly selected from each plot and their average recorded.

3.11.4.5 Number of pods per plot

Pods from the middle rows were harvested and counted and their means estimated.

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3.11.4.6 Number of seeds per plot

Pods from the harvestable area from the middle rows per plot were harvested, plucked, opened and their seeds manually counted from each plot and their means estimated.

3.11.4.7 Pod weight per plant

The harvested pods from the 8 tagged plants from the middle rows of each plot were weighed in grammes using electronic scale and their means recorded.

3.11.4.8 Seed weight per plant

The seeds from harvested pods from the 8 tagged plants from the middle rows of each plot were weighed in grammes using electronic weighing scale and their means recorded.

3.11.4.9 Quality and diseased seeds weight per plot

The seeds from 20 pods were grouped as quality and diseased. Clean and healthy seeds were grouped as quality seeds and mouldy, rotten, wrinkled, unhealthy seeds were also classified as diseased seeds. The quality seeds and diseased seeds grouped from each plot was weighed using electronic scale and their means calculated and converted to grams.

3.11.4.10 Plant biomass

Plants from the middle rows of each plot were weighed in grammes with electronic weighing scale at harvest and their above ground means recorded.

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3.11.4.11 Pod weight per plot

Pods from the middle rows were harvested and weighed with electronic weighing scale. Mean weight for each plot was recorded in grammes

3.11.4.12 Seed weight per plot

Pods from the middle rows were harvested and their seeds weighed in grammes for each plot and their means recorded.

3.11.4.13 Hundred seed weight

100 – seeds were counted from the seed lot from each plot. The selected seeds were weighed with the electronic weighing scale to obtain the mean 100 – seed weight.

3.11.4.14 Grain yield

The grain yield per hectare was determined by harvesting the dried plants from the two middle rows of each plot and shelled. The mass of seeds in grams was then converted to tonne per hectare to represent mean grain yield per hectare.

3.11.4.15 Harvest index

The shoot of all plants from the two middle rows per plot were harvested and weighed. The pods were separated later and shelled. Seeds were weighed using an electronic wighing scale and the mean estimated in tonne per hectare. Harvest index was then estimated as the ratio of grain yield to total shoot weight. Harvest index was then calculated as aqthe ratio of grain yield to total shoot weight of the crop.

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3.12 Correlation Matrix Analysis of Yield and Yield Components

The correlation matrix analysis was performed to examine the correlation between yield and yield components obtained from treatment plots during the 2018 minor rainy season and 2019 major rainy seasons.

3.13 Economic Analysis of the Treatments

Cost/benefit analysis was done to determine the relative economic returns on the applied treatments using 2018 and 2019 annual market prices. The yields were adjusted by 10 % downwards due to management level variability between a researcher and a farmer (CIMMYT, 1988). Cost of farm services were taken at Mampong market in the Mampong Municipal of the Ashanti region of Ghana. This was due to the location of the study and also all inputs were obtained from Mampong Municipal. Capital cost such as land, water and management charges interest on operational capital, depreciation of machinery and equipment, and other overhead cost were not considered because of so many years of depreciation and insignificant values.

The economic indicators used were;

3.13.1 Gross benefit

This is the product of the adjusted yield (t/ha) and the sale prices. It was calculated by multiplying the yield in (t/ha) by the market price.

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3.13.2 Net benefit

It is the gross benefit less total variable cost. It was calculated by subtracting the total cost of production from the gross benefit

3.13.3 Marginal analysis

This compares the net benefits with the total variable cost. The total variable cost was determined for each treatment and was compared with the net benefit.

3.13.4 Dominance analysis

Treatments were arranged in terms of increasing variable costs. The corresponding net benefits were also indicated. A treatment is dominant when it has a higher cost but a lower net benefit than any preceding treatment.

3.13.5 Marginal rate of returns

It is the percentage change in benefit over change in total variable cost in moving from a lower cost treatment to a higher one. An 80 % minimum acceptance rate of returns is used to determine the acceptability of any particular treatment. All the treatments were arranged from the highest to the lowest in terms of profitability. This was achieved by dividing the total variable cost by the net benefit multiply by 100 %.

$$\text{MMR} = \frac{\text{Net benefit}}{\text{Total Variable Cost}} \times 100\ \%$$

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3.13.6 Value cost ratio (VCR)

The value cost ratio (VCR) defines the profitability of a document. This was determined as the value of yield increase due to input, divided by the cost of additional input to achieve this.

3.14 Data Analysis

All data collected were analyzed by Analysis of Variance (ANOVA) using the GenStat version 11.1 (2008). The Least Significant Difference (LSD) was used to compare the differences in the treatment means at 5 % probability level. Correlation and cost benefit analysis was carried out for the two seasons using SPSS version 18.0 statistical package and Microsoft excel, 2016 respectively. Soil data analysis was also carried out.

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CHAPTER FOUR

RESULTS

4.1 Climatic Conditions at the Experimental Site

All climatic data were recorded at the Mampong Meteorological Station. In 2018, the maximum average temperature during the experiment was 33.4 ^oC and the minimum was 22.8 ^oC (Appendix A). Total rainfall from August to December was 511.5 mm. The minimum average relative humidity in 2018 season from August to December recorded was of 63.2 % and maximum of 94.4 %.

In 2019 season, the total rainfall from March to July was 1064.2 mm and was higher than rainfall recorded in 2018 (Appendix B). The maximum average temperature was 31.1 ^oC and the minimum of 22.6 ^oC. The 2018 cropping season was drier than in 2019. The average minimum relative humidity in 2019 was 63.8 % and a maximum of 95.8 %. The relative humidity of 2019 was higher than the relative humidity in 2018.

4.2 Nutrient Levels of Organic Amendments used in the Experiment

Table 4.1 shows nutrient contents of cattle manure and rock phosphate used in the experiment. Cattle manure had the highest total N, K and Mg, with the rock phosphate having the highest levels of total P and Ca. The pH values of the cattle manure and the rock phosphate were above neutral.

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Table 4.1: Chemical properties of cattle and rock phosphate used in the experiment

	pH 1:1	Ca (%)	Mg (%)	K (%)	P (%)	N (%)
Cattle Manure	8.2	1.98	0.65	0.26	0.71	2.06
Rock Phosphate	9.3	46.82	0.03	0.02	11.04	0.04

4.3 Initial Soil Chemical Properties at Experimental Site

From Table 4.2, it can be seen that the soil was very acidic from the top soil (0 – 15 cm). Organic matter content and nitrogen levels were moderate under general situations. The levels of cations in the background soils recorded lower values per soil nutrient content of CSIR – Soil Research Institute nutrient levels in 2009. Available P and K were not high per the results obtained from the background soil. The cations recording low values (Ca, Mg, K, Na) and affected the Total Exchangeable Bases (TEB) and the Effective Cation Exchange Capacity (ECEC) which indicates low base saturation of 84.76 %.

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Table 4.2: Initial soil chemical properties at experimental site

Treatments (ha^{-1})	pH (H_2O 1:2:3)	Org.C %	Total N %	Org. M %	Exch. Cations (Cmol/kg)				T.E.B.	Exch. A(Al^{+} H) Cmol/kg	ECEC Cmol/kg	% Base sat.	Avail.Bray's	Total P Ppm
					Ca	Mg	K	Na					P ppm	
No amendment (Control)	4.98	0.41	0.07	1.49	2.56	1.40	0.19	0.17	4.77	0.70	5.52	84.76	28.13	299.64

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4.4 Effect of Amendments on Chemical Characteristics after Two Weeks of Treatments Application

Treated soils increased in pH (Table 4.3). The manure treated plots and their combinations recorded higher levels of organic carbon, % total nitrogen and organic matter than the control treatments. The amended plots showed an increase in all the nutrient levels after manure decomposition than the control (Table 4.3). The exchangeable cations, total exchangeable bases and effective cation exchange capacity in the amended soil were higher than in the control. The (5 t/ha CM + 25 kg/ha RP) and (10 t/ha CM + 25 kg/ha RP) treatments recorded higher Ca and Mg levels than the rest of the treatments.

The (5 t/ha CM + 25 kg/ha RP) and the (10 t/ha CM + 25 kg/ha RP) recorded higher total exchangeable bases (TEB) than the rest of the amended plots. Also, all the amended plots recorded higher levels of (TEB) than the control. The (5 t/ha CM + 25 kg/ha RP) treatment recorded greatest levels of effective cation exchange capacity (ECEC) followed by (10 t/ha CM + 25 kg/ha RP). All the amended plots had higher levels of base saturation than the control treatment. The (10 t/ha CM + 25 kg/ha RP) treatment had the highest level of available P and total P followed by (5 t/ha CM + 25 kg/ha RP). All the amended plots gained higher levels of available P and total P than the control.

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Table 4.3: Effects of amendments on chemical characteristics of soil after two weeks of application

Treatments	pH (H_2O 1:2:5)	Org.C %	Total N %	Org. M %	Exch. Cations (Cmol/kg)				T.E.B.	Exch. A (Al^+ H) Cmol/kg	ECEC Cmol/kg	% Base sat.	Avail.Bray's	Total P Ppm
					Ca	Mg	K	Na					P ppm	
No amendment (Control)	4.98	0.41	0.07	1.49	2.56	1.40	0.19	0.17	4.77	0.70	5.52	84.76	28.13	299.64
5 t/ha CM	5.42	0.81	0.08	1.92	2.98	1.49	0.34	0.36	5.29	0.75	6.24	86.41	29.27	348.92
5 t/ha CM + 25 kg/ha RP	5.85	1.08	0.10	3.83	10.65	1.68	0.46	0.40	15.63	0.95	16.48	94.84	37.93	376.52
10 t/ha CM	5.52	0.99	0.09	2.77	5.33	1.54	0.36	0.20	8.68	0.85	9.38	92.54	35.42	350.89
10 t/ha CM + 25 kg/ha RP	6.21	1.18	0.10	40.90	10.22	1.68	0.39	0.20	15.34	1.10	16.44	93.31	58.88	412.00
LSD (0.05)	0.02	0.07	0.03NS	0.06	0.03	0.07	0.03	0.13	0.03	0.16	0.05	0.77	1.58	3.26
CV (%)	4.00	9.80	19.70	14.80	16.50	19.70	26.60	15.80	4.75	19.60	25.80	4.60	6.30	10.60

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4.5 Vegetative Growth

4.5.1 Plant height

In 2018 season, differences in plant height of soybean was observed at 49 DAP to 77 DAP. The (5 t/ha CM + 25 kg/ha RP) treatment produced the tallest plant throughout the growing period followed by the (10 t/ha CM + 25 kg/ha RP) treatment (Figure 4.1a). There was no significant ($P \geq 0.05$) differences in plant height among the (5 t/ha CM + 25 kg/ha RP) treatment and (10 t/ha CM + 25 kg/ha RP) treatment at the growing period. The sole treatments had similar ($P \geq 0.05$) plant height. However, at 77 DAP the 10 t/ha CM plants were significantly ($P \leq 0.05$) taller than those of the 5 t/ha CM. The combined treatments showed significant ($P \leq 0.05$) differences from the control hieght, which produced the shortest plant height (Figure 4.1 a).

In the 2019, significant ($P \leq 0.05$) differences in plant height was also observed at 49 DAP to 77 DAP. The (5 t/ha CM + 25 kg/ha RP) treatment produced the tallest plants throughout the growing seasons followed by 10 t/ha CM + 25 kg/ha RP treatments. There was an increase in plant height in both seasons with sampling periods by the treatments.

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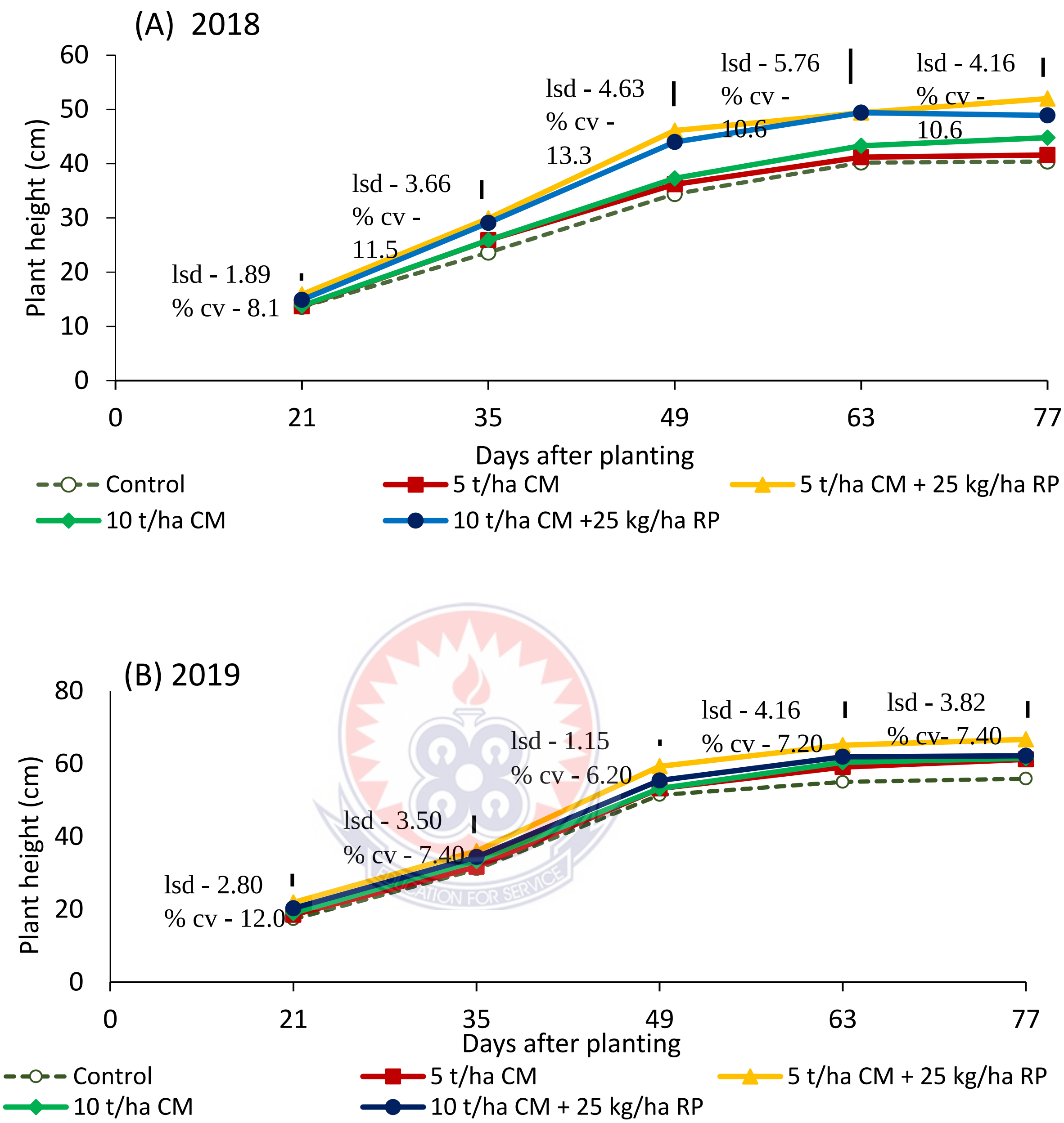
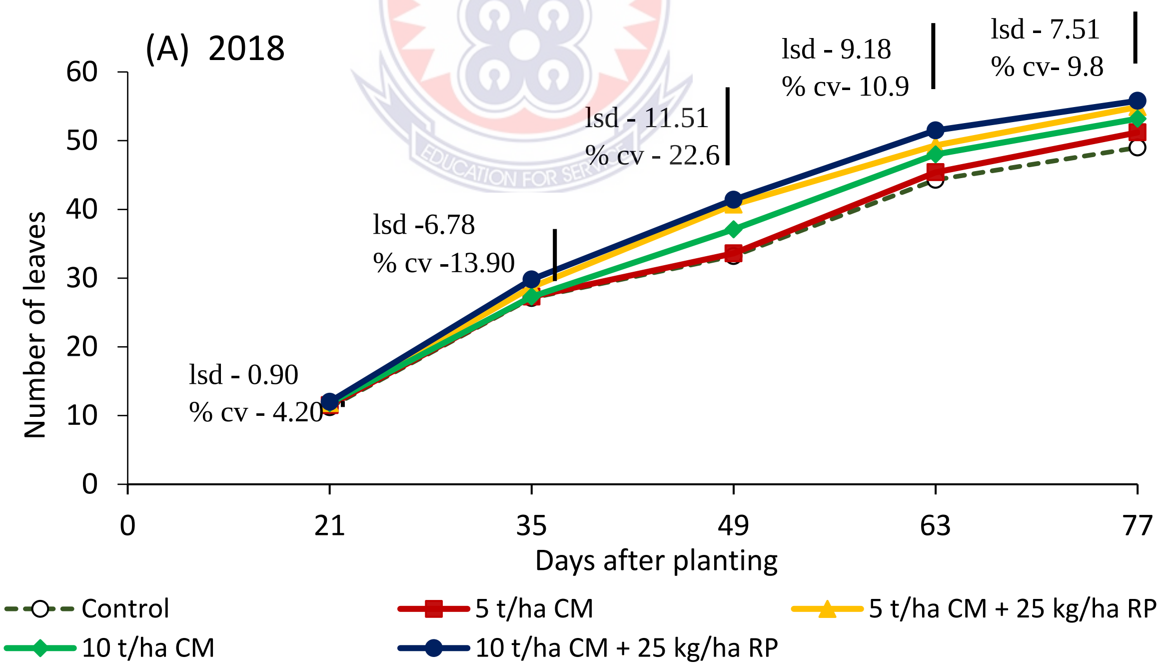


Figure 4.1: Plant height as influenced by cattle manure with rock phosphate in (A) 2018 and (B) 2019 seasons

4.5.2 Number of leaves

From Figure 4.2a, there was significant ($P \leq 0.05$) increase in soybean number of leaves at 49 DAP to 77 DAP in 2018 season. The combined treatments (10 t/ha CM + 25 kg/ha RP) and (5 t/ha CM + 25 kg/ha RP) treatment produced more leaf growth at 49 DAP to 77 DAP significantly ($P \leq 0.05$) higher than the control treatment (Figure 4.2a).

In 2019 growing season, the combined treatments produced significantly ($P \leq 0.05$) higer number of leaves at 49 DAP to 63 DAP than the sole treatments. The amended treatments had higher number of leaves than the control (Figure 4.2b). In 2018 and 2019 cropping seasons, there was linear and sequential increase in soybean number of leaves throughout their growing period.



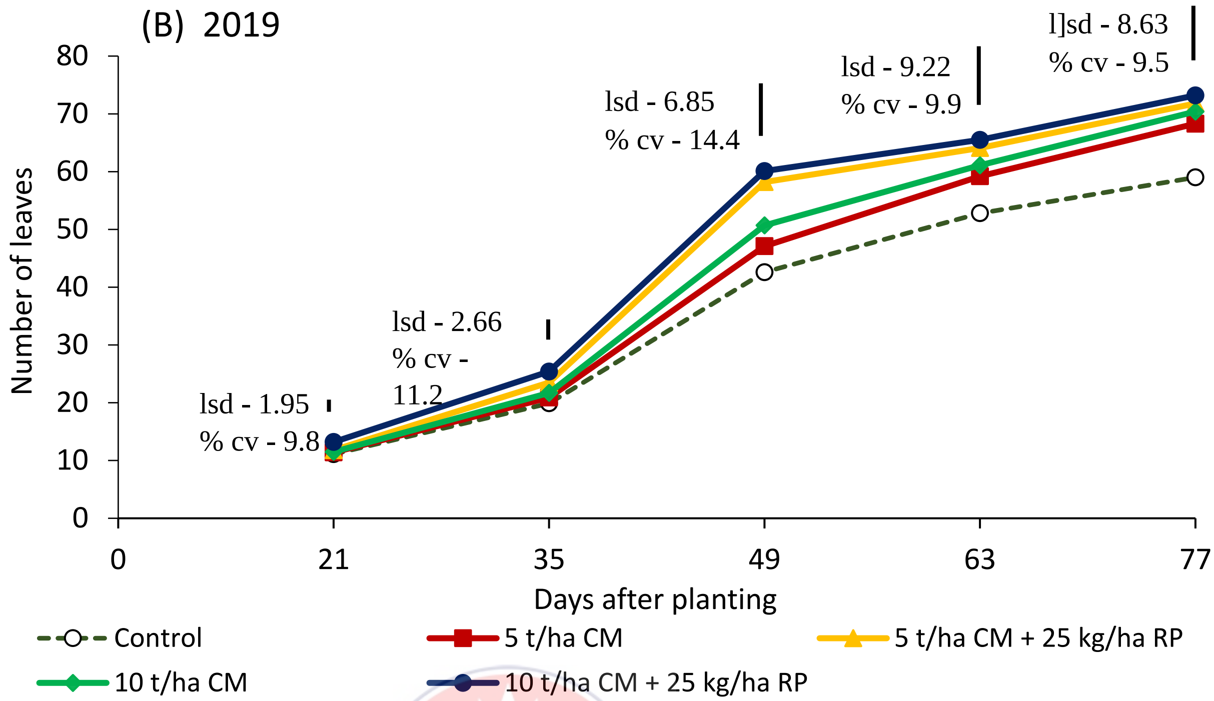
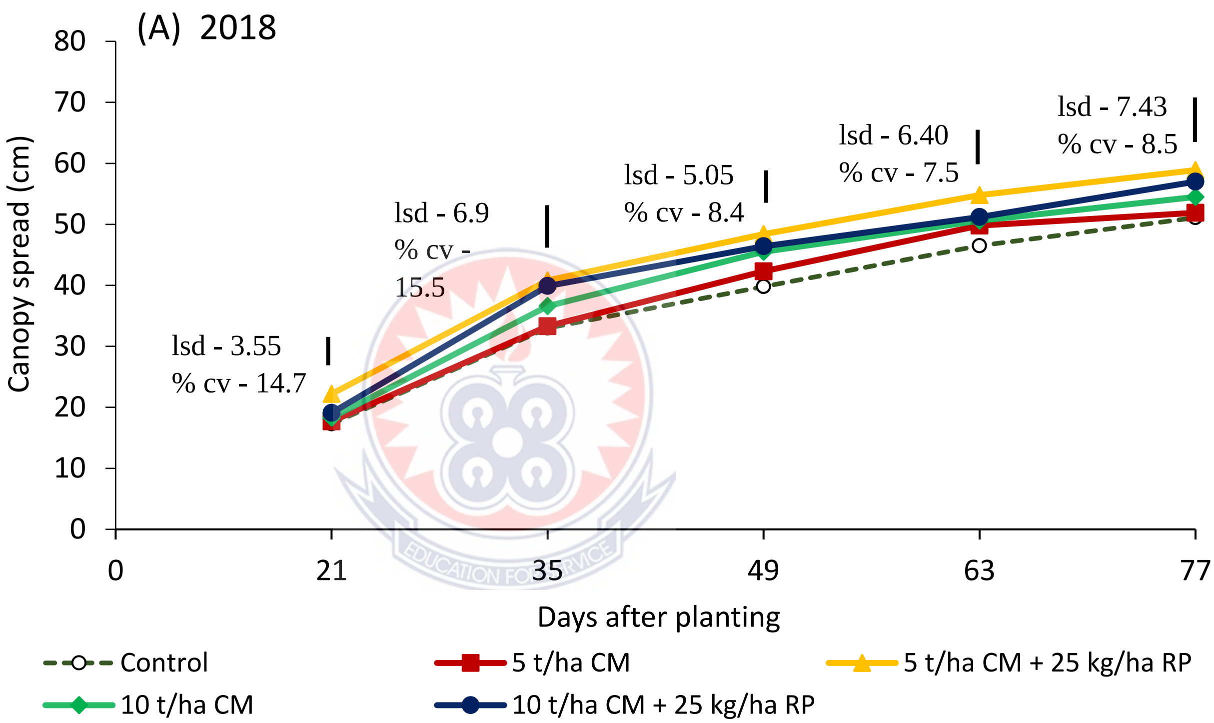


Figure 4.2: Number of leaves as influenced by cattle manure with rock phosphate in (A) 2018 and (B) 2019 seasons

4.5.3 Canopy spread

The canopy width of soybean plants for (5 t/ha CM + 25 kg/ha RP) and (10 t/ha CM + 25 kg/ha RP) treatments were higher than the control in 2018 season at 35 to 77 DAP. The 5 t/ha CM produced similar canopy spread as the control at 21, 35 and 77 DAP (Figure 4.3a).

In 2019, the (5 t/ha CM + 25 kg/ha RP) treatment recorded the highest canopy width among the amended plots at 49 to 77 DAP while the control recorded the least canopy width (Figure 4.3b). The (5 t/ha CM + 25 kg/ha RP) treatment recorded the highest canopy spread followed by (10 t/ha CM + 25 kg/ha RP) treatment. The sole treatments had similar mean values as the control treatments at 49 DAP to 77 DAP (Figure 4.3b). However, the control plots had the lowest canopy spread. In the seasons there was a linear growth in canopy width. In both seasons the (5 t/ha CM + 25 kg/ha RP) treatment recorded the highest canopy width but not significantly (P≥0.05) different from (10 t/ha CM + 25 kg/ha RP) treatment.



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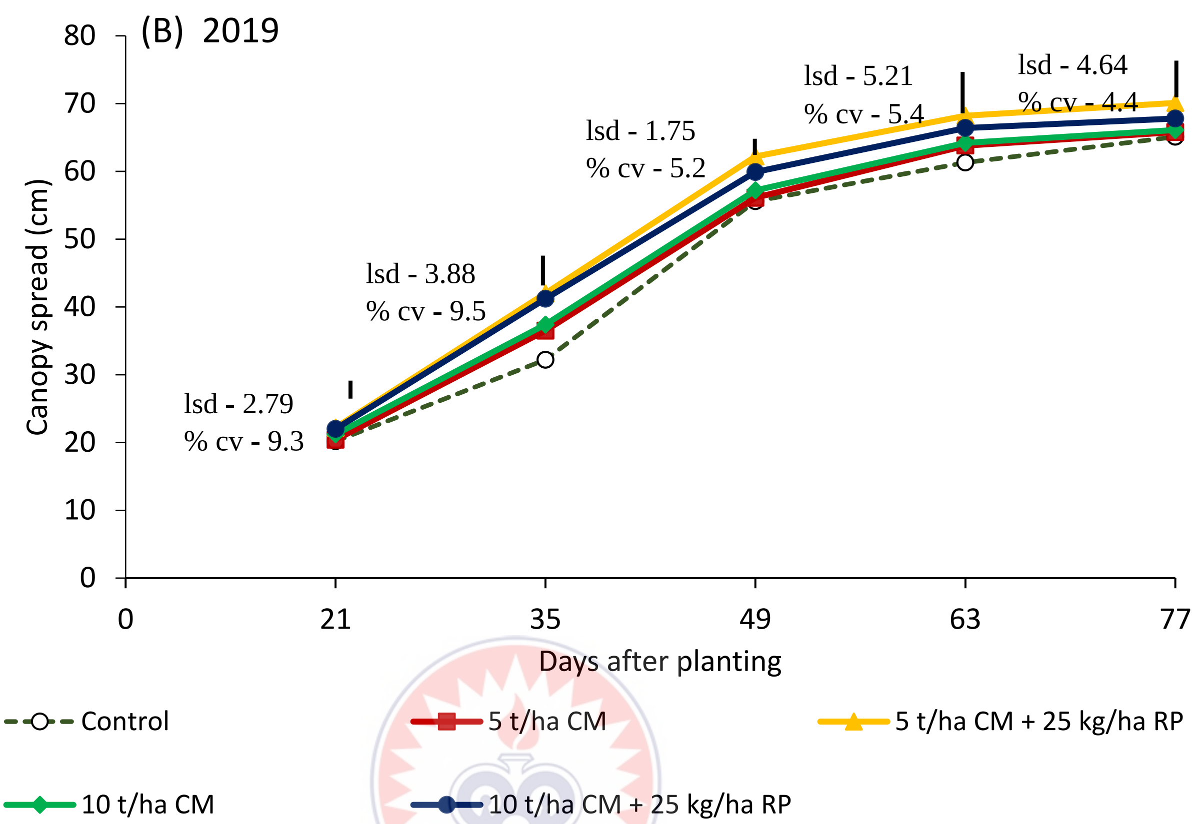

Figure 4.3: Canopy spread as influenced by cattle manure with rock phosphate in (A) 2018 and (B) 2019 seasons

4.5.4 Fresh shoot weight

From Figure 4.4a, the (10 t/ha CM + 25 kg/ha RP) had greater fresh shoot weight than other amended plots followed by (5 t/ha CM + 25 kg/ha RP) treatment in 2018. There were no clear differences among the sole treatments for the fresh shoot weight at the various DAPs. All the amended plots produced fresh shoot weight higher than the control during the 2018 minor rainy season.

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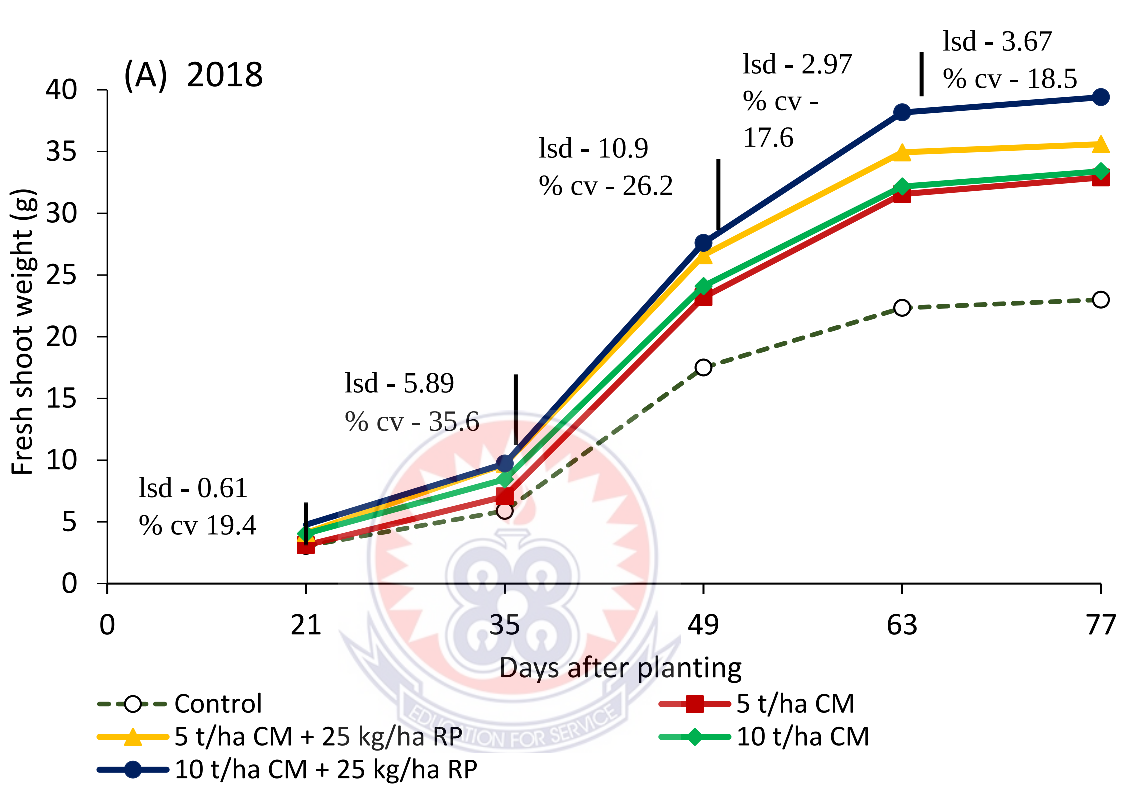
During the 2019 season, the (10 t/ha CM + 25 kg/ha RP) treatments produced greater fresh shoot weight of soybean than the other amended plots and the control at only 63 and 77 DAP (Figure 4.4b).



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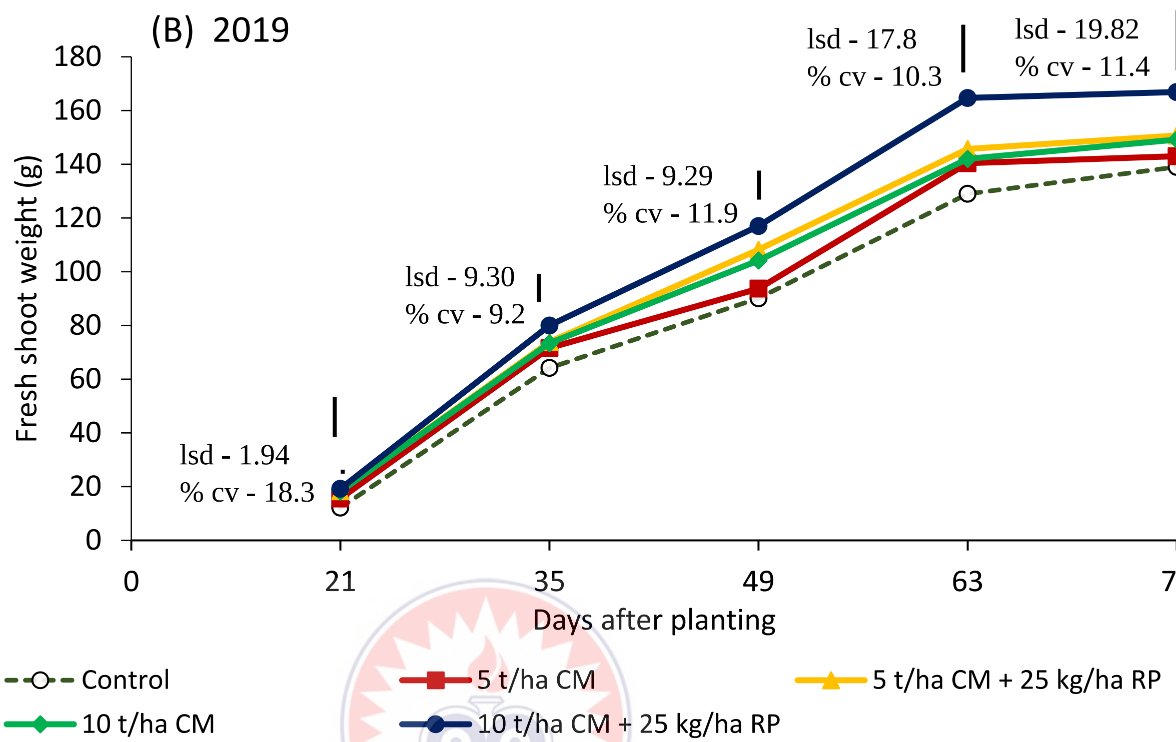

Figure 4.4 Fresh shoot weight as influenced by cattle manure with rock phosphate in (A) 2018 and (B) 2019 seasons

4.5.5 Dry shoot weight

The mean dry shoot weight of soybean for all amended plots were greater than the control at 49, 63 and 77 DAP in 2018. But at 77 DAP the control treatment effect was similar to the 5 t/ha CM treatment. The (10 t/ha CM + 25 kg/ha) RP treatment produced the greater dry shoot weight than all other treatments at 63 and 77 DAP. In 2019, (Figure 4.5b) the greatest dry shoot weight of soybean was recorded by (10 t/ha CM + 25 kg/ha RP) treatment followed by (5 t/ha CM + 25 kg/ha RP) treatment at 49, 63 and 77 DAP.

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The 5 t/ha CM treatment and control produced similar dry shoot weight. Generally, the 2019 dry shoot weight were greater than the 2018 season.

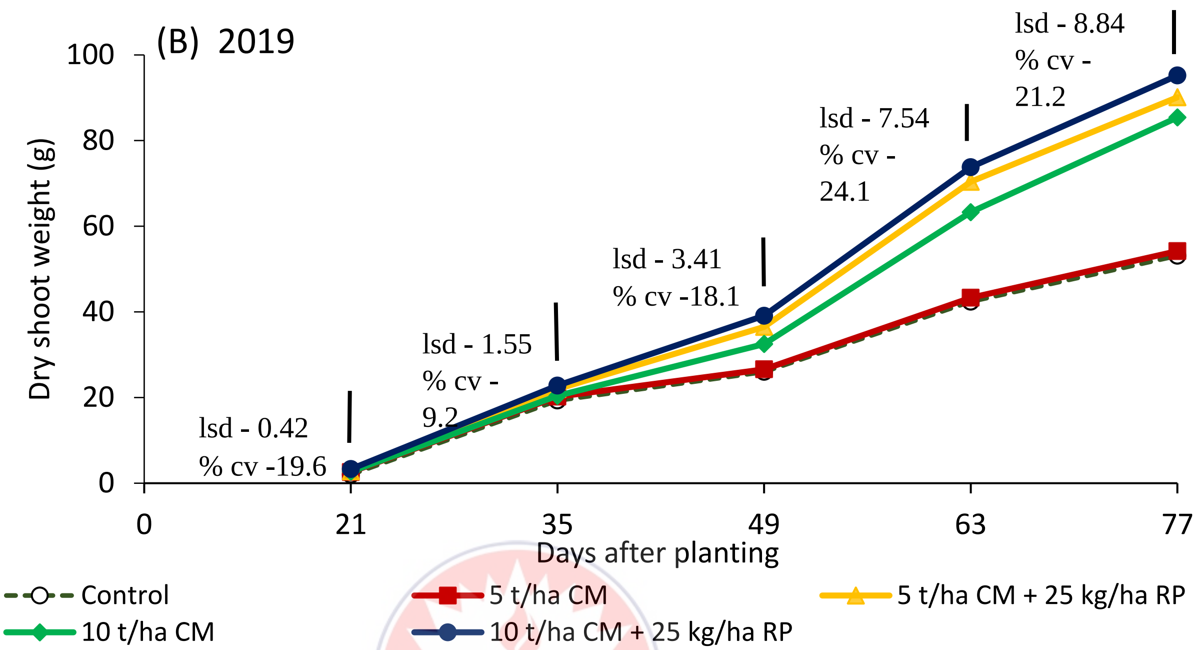

Figure 4.5: Dry shoot weight as infuenced by cattle manure with rock phosphate in (A) 2018 and (B) 2019 seasons

4.5.6 Fresh root weight

In 2018 season, there was significant differences (P ≤ 0.05) observed in soybean fresh root weight among the amended plots and the controls (Figure 4.6a) on all days except 21 DAP. The (5 t/ha CM + 25 kg/ha RP) treatment produced the highest root weight followed by (10 t/ha CM + 25 kg/ha RP) and 10 t/ha CM treatment. The (10 t/ha CM + 25 kg/ha RP) and 10 t/ha CM produced the same root weight at the 21 DAP. The 5t/ha CM treatment and the control also obtained the same lowest root weight on the 21 DAP (Figure 4.6a). At the 77 DAP, the (5 t/ha CM + 25 kg/ha RP) treatment produced the

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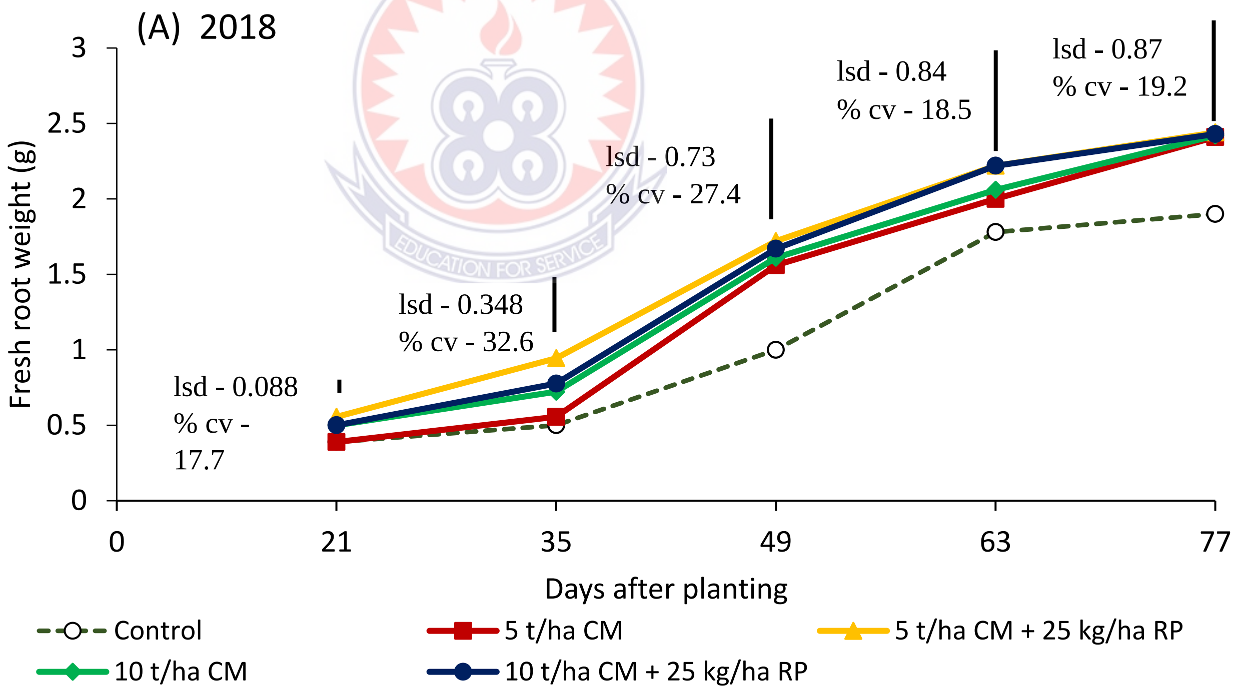
greatest fresh root weight followed by the (10 t/ha CM + 25 kg/ha RP) treatment. However, all the amended treatments influenced the fresh root weight positively at 77 DAP than the control plots in 2018 cropping season.

In 2019 season, fresh root weight showed significant variation ($P \leq 0.05$) among treatment means. The (5 t/ha CM + 25 kg/ha RP) treatment produced the greatest root biomass followed by (10 t/ha CM + 25 kg/ha RP) and 10 t/ha CM treatment whiles the control produced the least root weight. At the 77 DAP, there was no significant ($P \geq 0.05$) differences observed among amended plots. Fresh root weights in 2019 cropping season was greater than in 2018 growing season.



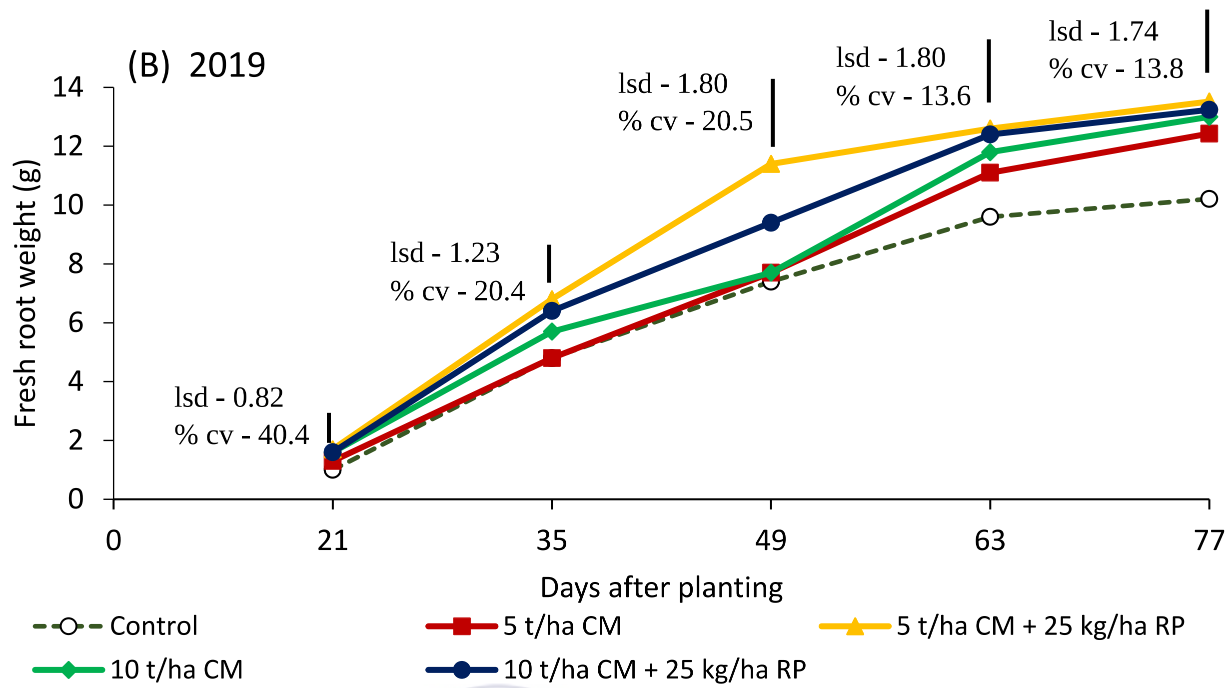


Figure 4.6 Fresh root weight as influenced by cattle manure with rock phosphate in (A) 2018 and (B) 2019 seasons

4.5.7 Dry root weight

From Figure 4.7a, all the amended plots exhibited no significant (P≥0.05) differences in dry root weight produced at 21 to 49 DAP in 2018 seasons. The control treatment produced the least dry root weight at 63 to 77 DAP. During the 2019 season, there was no significant (P≥0.05) differences in soybean dry root weight was observed at 21 DAP. At 45, 63 and 77 DAP, the (5 t/ha CM + 25 kg/ha RP) produced the greatest dry root which was significantly higher than all treatments, except (10 t/ha CM + 25 kg/ha RP). The control treatment effect was lower than all other treatments at 63 and 77 DAP in 2019.

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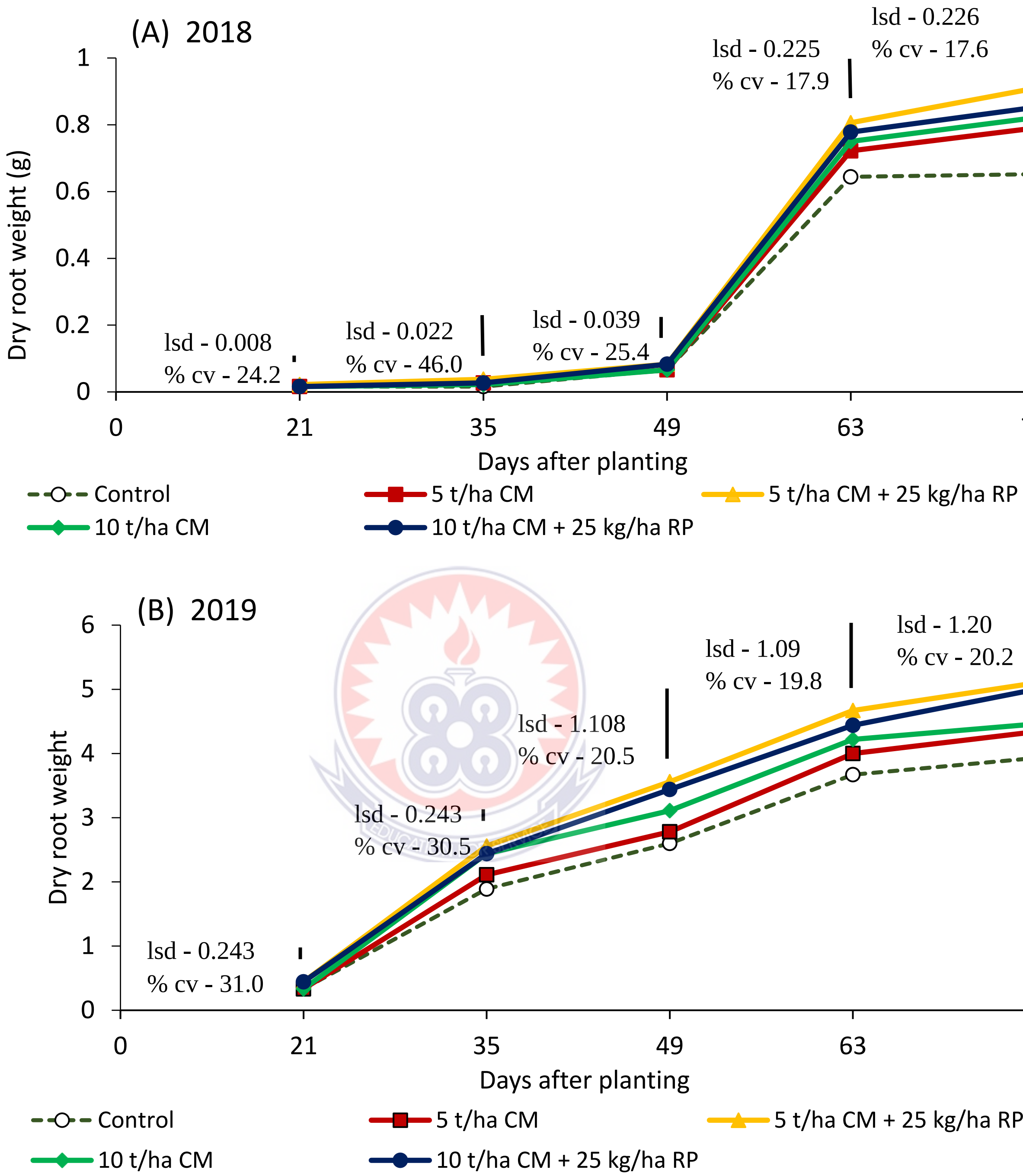

Figure 4. 7: Mean dry root weight per plant as influenced by cattle manure with rock phosphate in (A) 2018 and (B) 2019 seasons

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4.6 Yield and Yield Components

4.6.1 Quality seed and diseased seed weight per plant

Table 4.4 shows quality seed and diseased seed weight per plant during the 2018 and 2019 cropping seasons. In 2018 season, no significant ($P \geq 0.05$) difference was shown among treatment means. During the 2019 cropping season, the treatments showed significant ($P \leq 0.05$) differences among the treatment means. The heaviest quality seed weight was recorded by the (5 t/ha CM + 25 kg/ha RP) treatment with appreciable value (16.15 g) which was significantly higher than all other treatment effects, except that of (10 t/ha CM + 25 kg/ha RP). All other treatment differences were not significant ($P \geq 0.05$).

In 2018, the (5 t/ha CM + 25 kg/ha RP) treatment produced the lowest diseased seed weight 1.18 g followed by (10 t/ha CM + 25 kg/ha RP) treatment diseased seed weight 1.30 g (Table 4.4). There was significant difference between the diseased seed weight of (5 t/ha CM + 25 kg/ha RP) and 5 t/ha CM treatment values. The control treatment produced the highest diseased seed weight (2.03 g). During the 2019 growing season, there was a significant ($P < 0.05$) difference in diseased seed weight per plant. The control produced the heaviest diseased seed weight per plant which was significantly higher than that of (10 t/ha CM + 25 kg/ha RP) only. All other treatment differences were not significant.

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Table 4.4: Quality and diseased seed weight per plant as influenced by cattle manure with rock phosphate soil amendment in 2018 minor and 2019 major rainy seasons

Treatments	Quality seed weight per plant (g)		Diseased seed weight per plant (g)	
	2018	**2019**	**2018**	**2019**
Control/ No amendment	2.99	12.01	2.03	2.09
5 t/ha CM	3.46	13.06	2.01	1.90
5 t/ha CM + 25 kg/ha RP	4.79	16.15	1.18	1.26
10 t/ha CM	3.10	12.97	1.35	1.78
10 t/ha CM + 25 kg/ha RP	4.18	14.64	1.30	0.61
LSD ($P \leq 0.05$)	NS	1.80	0.33	1.00
CV (%)	31.40	13.50	25.80	19.40

**CM: Cattle Manure* **RP: Rock Phosphate* **NS: Non-Significant*

4.6.2 Pod weight and seed weight per plant

Table 4.5 shows mean pod weight and seed weight per plant during the 2018 and 2019 cropping season. In 2018, the (5 t/ha CM + 25 kg/ha RP) recorded the highest pod weight value (10.90 g) followed by (10 t/ha CM + 25 kg/ha RP) value (10.50 g). However, there was no significant differences ($P \geq 0.05$) observed among (5 t/ha CM + 25 kg/ha RP), (10 t/ha CM + 25 kg/ha RP) and 10 t/ha CM treatments in pod weight. In 2019, the (5 t/ha CM + 25 kg/ha RP) treatment producued the greatest pod yield which was significantly ($P \leq 0.05$) higher than those of the control and 5 t/ha CM treatment only. The latter two treatment effect were also lower than that of 10 t/ha CM and (10 t/ha CM + 25 kg/ha RP) treatment.

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In 2018, (5 t/ha CM + 25 kg/ha RP) treatment recorded the greatest seed weight per plant and was significantly ($P \leq 0.05$) heavier than all other treatments. The (10t/ha CM + 25 kg/ha RP) and the 10 t/ha CM produced similar seed weight which were greater than the control and 5 t/ha CM treatments.In 2019, treatment effect of 5 t/ha CM and (5 t/ha CM + 25 kg/ha RP) for seed weight was significantly ($P \leq 0.05$) higher than all treatments except 10 t/ha CM and (10 t/ha CM + 25 kg/ha RP). The control treatment was lower than that of (10 t/ha CM + 25 kg/ha) only. All other treatment effect were similar.

Table 4.5: Pod weight and seed weight per plant as influenced by Cattle Manure with Rock Phosphate soil amendment in 2018 minor and 2019 major rainy seasons

Treatments	Pod weight per plant (g)		Seed weight per plant (g)	
	2018	2019	2018	2019
Control/No amendment	7.5	18.7	4.0	12.8
5 t/ha CM	7.9	20.6	4.2	14.9
5 t/ha CM + 25 kg/ha RP	10.7	29.0	6.8	18.1
10 t/ha CM	9.3	20.9	5.4	15.1
10 t/ha CM + 25 kg/ha RP	10.5	22.5	5.5	16.0
LSD ($P \leq 0.05$)	1.9	4.0	1.0	2.6
CV (%)	17.2	18.6	21.6	14.8

4.6.3 Pods length and plant biomass at harvest

Table 4.6 shows pod length and pant biomass during the 2018 and 2019 cropping season. There was no significant ($P \geq 0.05$) difference in pod length among treatment means in both 2018 and 2019 cropping seasons.

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The plant biomass at harvest in 2018 showed significant ($P \leq 0.05$) differences among the treatment means (Table 4.6). The (5 t/ha CM + 25 kg/ha RP) produced the heaviest weight in plant biomass which was significantly higher than all treatment effects, except (10 t/ha CM + 25 kg/ha RP). The control treatment was lower than all other treatment effects. In 2019, there were significant ($P \leq 0.05$) differences among the treatments. The heaviest soybean biomass was produced by the combined treatments, (5 t/ha CM + 25 kg/ha RP), which was significantly ($P \leq 0.05$) higher than the control treatment only.

Table 4.6: Pod length and plant biomass as influenced by Cattle Manure with Rock Phosphate soil amendment in 2018 minor and 2019 major rainy seasons

Treatments	Pod length (cm)		Plant biomass at harvest (g)	
	2018	2019	2018	2019
Control / No amendment	3.4	3.5	24.3	84.1
5 t/ha CM	3.4	3.4	33.5	134.8
5 t/ha CM + 25 kg/ha RP	3.5	3.7	40.2	170.2
10 t/ha CM	3.4	3.5	33.9	135.1
10 t/ha CM + 25 kg/ha RP	3.5	3.5	37.8	159.0
LSD ($P \leq 0.05$)	NS	NS	3.2	70.27
CV (%)	3.4	6.3	16.9	38.9

**CM: Cattle Manure* **RP: Rock Phosphate* ** NS: Non-Significant*

4.6.4 Number of pods and number of seeds per plot

Table 4.7 shows number of pods and seeds produced during the 2018 and 2019 cropping season. In 2018, the greatest number of pods was recorded by the (10 t/ha CM + 25 kg/ha RP), but this was significantly ($P \leq 0.05$) higher than the control treatment only.

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All other treatment effects were similar. In 2019, there were no significant (P ≥ 0.05) differences in the number of pods among treatment means. The (5 t/ha CM + 25 kg/ha RP) produced significantly (P ≤ 0.05) greater number of seeds than all other treatments in 2018. In the 2019, there was significant (P ≤ 0.05) variation in the number of seeds. The amended plots produced similar number of seeds (Table 4.7), which were all greater than the control effect.

Table 4.7: Number of pod and seed per plot as influenced by Cattle Manure with Rock Phosphate soil amendment in 2018 minor and 2019 major rainy seasons

Treatments	Number of pods per plot		Number of seeds per plot	
	2018	**2019**	**2018**	**2019**
Control / No amendment	381.0	906.0	850.0	1526.0
5 t/ha CM	480.0	921.0	945.0	1898.0
5 t/ha CM + 25 kg/ha RP	500.0	1044.0	1193.0	2064.0
10 t/ha CM	449.7	938.0	903.0	2004.0
10 t/ha CM + 25 kg/ha RP	502.0	1038.0	989.0	2036.0
LSD (P ≤ 0.05)	70.7	NS	165.6	245.6
CV (%)	11.9	10.1	16.9	12.2

**CM: Cattle Manure* **RP: Rock Phosphate* **NS: Non-Significant*

4.6.5 Number of pods and number of seeds per plant

Table 4.8 shows number of pods and number of seeds per plant during the 2018 and 2019 cropping seasons. In 2018, soybeans grown using (5 t/ha CM + 25 kg/ha RP) produced the greatest number of pods per plant, which was significantly (P ≤ 0.05) higher than from the control and 5 t/ha CM treatments only.

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In 2019, (5 t/ha CM + 25 kg/ha RP) produced the greatest number of pods per plant and was significantly ($P \leq 0.05$) higher than all other treatments (Table 4.8). The (10 t/ha CM + 25 kg/ha RP) treatment produced the next greatest effect which was greater than the control treatment effect only. All other treatment effects were similar. In 2019, (5 t/ha CM + 25 kg/ha RP) produced the greatest number of seeds per plant, but this was significantly ($P \leq 0.05$) higher than those of the control and 10 t/ha CM treatments only. The control treatment effect was lower than 5 t/ha CM and (10 t/ha CM + 25 kg/ha RP) treatments.

Table 4.8: Number of pods and number of seeds per plant as influenced by Cattle manure with Rock Phosphate soil amendment in 2018 and 2019 major rainy seasons

Treatments	Number of pods per plant		Number of seeds per plant	
	2018	2019	2018	2019
Control/ No amendment	24.0	44.0	45.0	92.0
5 t/ha CM	24.0	49.0	46.0	119.0
5 t/ha CM + 25 kg/ha RP	31.0	56.0	68.0	122.0
10 t/ha CM	28.0	49.0	54.0	101.0
10 t/ha CM + 25 kg/ha RP	29.0	51.0	55.0	119.0
LSD ($P < 0.05$)	1.13	3.91	5.15	11.09
CV (%)	10.4	9.0	17.1	12.2

**CM: Cattle Manure* **RP: Rock Phosphate*

4.6.6 Pods weight and seeds weight per plot

Table 4.9 indicates mean pods weight and seeds weight per plot during the 2018 and 2019 cropping seasons. In 2018, there was a significant ($P < 0.05$) treatment difference. The combined treatments, (5 t/ha CM + 25 kg/ha RP) and (10 t/ha CM + 25 kg/ha RP) produced similar pod weight, which was significantly ($P \leq 0.05$) than those of 10 t/ha CM

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and control treatments. The control treatment effect was the lowest. During 2019 growing season, the (5 t/ha CM + 25 kg/ha RP) treatment produced the heaviest pod weight per plot (g) and was significantly ($P \leq 0.05$) different from all the other treatments except the (10 t/ha CM + 25 kg/ha RP) treatment. The sole treatments, (5 t/ha CM and 10 t/ha CM) gave similar effect of 481.70 g and 476.70 g, respectively. The control had significantly the lowest pod weight of 375.00 g among the treatments means (Table 4.9).

In 2018, there was a significant ($P \leq 0.05$) difference among the treatment for seed weight per plot. The (5 t/ha CM + 25 kg/ha RP) treatment produced the heaviest seed weight per plot, which was significantly ($P \leq 0.05$) higher than all the treatment means except (10 t/ha CM + 25 kg/ha RP) treatment. The control recorded the lowest seed weight. In 2019, there was significantly ($P \leq 0.05$) difference among the treatment means in seed weight per plot. The (5 t/ha CM + 25 kg/ha RP) performed significantly ($P \leq 0.05$) better (277.20 g) than all treatments, except except (10 t/ha CM + 25 kg/ha RP). The control produced the lowest seed weight.

Table 4.9: Pod weight and seed weight per plot as influenced by Cattle Manure with Rock Phosphate soil amendment in 2018 and 2019 major rainy seasons

Treatments	Pod weight per plot (g)		Seed weight per plot (g)	
	2018	2019	2018	2019
Control/ No amendment	105.0	375.0	100.5	204.2
5 t/ha CM	220.3	481.7	119.4	240.8
5 t/ha CM + 25 kg/ha RP	234.7	554.3	141.0	277.2
10 t/ha CM	201.7	476.7	100.7	238.3
10 t/ha CM + 25 kg/ha RP	234.0	508.0	115.7	254.0
LSD ($P \leq 0.05$)	32.04	52.18	8.89	22.4
CV (%)	13.1	14.1	13.7	10.9

**CM: Cattle Manure* **RP: Rock Phosphate*

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4.6.7 100 – seed weight and number of seeds per pod

In 2018, there was significant (P $\leq$ 0.05) difference among treatment means in 100 – seed weight (Table 4.10). The treatment effect of (5 t/ha CM + 25 kg/ha RP) was the greatest, and this was significantly higher than all other treatment means. The (10 t/ha CM + 25 kg/ha RP) treatment effect was also greater than the rest. The control treatment effect was lower than all the other treatments. In 2019, treatment differences for 100 - seed weight was not significant (P $\geq$ 0.05). Number of seeds per pod was not significantly different among all treatments in both seasons (P $\geq$ 0.05).

Table 4.10: 100 – seed weight and number of seeds per pod as influenced by Cattle Manure with Rock Phosphate soil amendment in 2018 minor and 2019 major rainy seasons

Treatments	100 – Seed weight (g)		Number of seeds per pod	
	2018	2019	2018	2019
Control/No amendment	9.00	11.00	1.90	2.30
5 t/ha CM	10.00	12.30	1.90	2.30
5 t/ha CM + 25 kg/ha RP	10.50	14.00	2.10	2.70
10 t/ha CM	9.50	12.30	2.00	2.30
10 t/ha CM + 25 kg/ha RP	10.10	13.00	2.10	2.40
LSD (P < 0.05)	0.05	NS	NS	NS
CV (%)	20.50	15.60	13.70	14.60

**CM: Cattle Manure* **RP: Rock Phosphate* **NS: Non-Significant*

4.6.8 Harvest index and grain yield

There was no significant (P $\geq$ 0.05) difference in treatment means for harvest index during 2018 season (Table 4.11). In 2019, the harvest index from the (5 t/ha CM + 25

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kg/ha RP) treatment was significantly higher than the control treatment only. The harvest indices for the rest of the treatments did not show any significant (P $\geq$ 0.05) differences.

In 2018, (5 t/ha CM + 25 kg/ha RP) treatment obtained the greatest grain yield, which was significantly (P $\leq$ 0.05) higher than other treatments. The lowest effect was produced by the control treatment. In 2019, the (5 t/ha CM + 25 kg/ha RP) treatment recorded the greatest grain yield, and this was significantly (P $\leq$ 0.05) higher than other treatments except (10 t/ha CM + 25 kg/ha RP) treatment. All other treatment differences were not significant (P $\geq$ 0.05).

Table 4.11: Harvest index and grain yield as influenced by Cattle Manure with Rock Phosphate soil amendment in 2018 minor and 2019 major rainy seasons

Treatments	**Harvest index**		**Grain yield (t/ha)**	
	2018	**2019**	**2018**	**2019**
Control / No amendment	0.15	0.06	0.60	1.87
5 t/ha CM	0.11	0.10	1.04	2.00
5 t/ha CM + 25 kg/ha RP	0.11	0.15	1.80	2.31
10 t/ha CM	0.12	0.11	1.07	2.04
10 t/ha CM + 25 kg/ha RP	0.14	0.11	1.25	2.11
LSD (P$\leq$0.05)	NS	0.04	0.09	0.25
CV (%)	20.5	34.60	11.80	8.60

**CM: Cattle Manure* **RP: Rock Phosphate* **NS: Non-Significant*

4.7 Number of Effective Root Nodules 2018

The response of number of effective root nodules to the rates of cattle manure and combined application of cattle manure with rock phosphate is shown in Table 4.12 in the 2018 growing period. Effective nodules showed significant variation (P $\leq$ 0.05) among

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the treatments on all days sampling on all days of sampling. On all days of sampling, the treatment effect of (5 t/ha CM + 25 kg/ha RP) was the greatest. On all days there was no nodule production in the control treatment.

Table 4.12: Effective nodules per plant as influenced by Cattle Manure with Rock Phosphate soil amendment in 2018 minor rainy season

	Number of effective nodules per plant			
Treatment	**21DAP**	**35DAP**	**49DAP**	**63DAP**
Control/No amendment	0.00	0.00	0.00	0.00
5 t/ha CM	0.10	0.10	1.33	0.67
5 t/ha CM + 25 kg/ha RP	0.44	1.22	7.33	2.67
10 t/ha CM	0.11	0.11	1.40	1.64
10 t/ha CM + 25 kg/ha RP	0.22	0.22	7.10	1.33
LSD ($P \leq 0.05$)	0.41	0.43	5.62	2.47
CV (%)	27.10	31.40	35.04	31.30

**CM: Cattle Manure*   **RP: Rock Phosphate*

4.8 Number of Effective Nodules 2019

Table 4.13 shows the results of the influence of the levels cattle manure with combination of the levels of cattle manure and rock phosphate application of effective nodules. The number of effective nodules showed no significant variation ($P \geq 0.05$) among the treatments at 21 and 49 DAP. At 35 and 63 DAP, the treatment effect of (5 t/ha CM + 25 kg/ha RP) was the greatest, but this was greater than the control treatment only.

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Table 4.13: Number of effective nodules per plant as influenced by cattle manure with rock phosphate soil amendment in 2019 major rainy season

	Number of effective nodules per plant			
Treatment	**21DAP**	**35DAP**	**49DAP**	**63DAP**
Control/No amendment	0.40	0.20	2.70	1.30
5 t/ha CM	0.40	1.10	6.70	3.60
5 t/ha CM + 25 kg/ha RP	1.70	2.00	12.30	10.30
10 t/ha CM	1.10	1.40	8.70	7.00
10 t/ha CM + 25 kg/ha RP	1.40	1.50	9.00	8.60
LSD ($P \leq 0.05$)	NS	1.08	NS	6.49
CV (%)	25.10	32.10	26.20	31.43

**CM: Cattle Manure* **RP: Rock Phosphate* **NS: Non-Significant*

4.9 Correlation Matrix Analysis of Yield and Yield Components of Soybean

During the 2018 season, the grain yield observed highly positive correlation with average number of seeds per plant ($r = 0.886$, $P \leq 0.01$), quality seeds ($r = 0.752$, $P \leq 0.05$) and plant biomass at harvest ($r = 0.870$, $P \leq 0.05$). This implies that, increase in number of seeds harvested results in increase in the grain yield obtained per tonne. However, the result indicates that, a decline in seeds results in the reduction in the grain yield. Again, Table 4.14 shows a moderate correlation between grain yield and harvest index ($r = 0.600$, $P \leq 0.05$). The results also indicate that there is strong positive correlation between grain yield and root nodules ($r = 0.732$, $P \leq 0.05$). This relationship was statistically significant at 1 % level. This implies that, increase in the root nodules contribute positively to the soybean grain yield harvested (Table 4.14).

Again, Table 4.15 presents the results from the correlation analysis between yield and yield components during the 2019 major rainy seasons. There is a strong correlation

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between grain yield and average number of pods per plant (r = 0.734, P $\leq$ 0.05). The results also indicates that, grain yield has positive and significant correlation between mean number of seeds per plant (r = 0.707, P $\leq$ 0.05), pod weight per plant (r = 0.895, P $\leq$ 0.05), harvest index (r = 0.724, P $\leq$ 0.05) and root nodules (r = 0.891, P $\leq$ 0.05). Further, the findings show that grain yield has a positive and significant correlation with quality seeds per plant which also measured the marketable of seeds harvested (r = .598 P $\leq$ 0.05) as shown in (Table 4.15).

Table 4.14: Correlation matrix for 2018 minor rainy season

Variables	1	2	3	4	5	6	7	8	9
1.Yield t/ha	1								
2. Mean Number of pods per Plant	.799**	1							
3. Mean Number of seeds per plant	.886***	.887**	1						
4.Pod weight per plant	.514	.633**	.701*	1					
5.Seed weight per plant	.421	.196	.188	.354	1				
6.Quality seeds per plant	.752**	.328	.649**	.441	.061	1			
7.Plant biomass at harvest	.870**	.321	.741***	.705*	.405	.496	1		
8.Harvest Index	.600**	.513	.558	.556	.233	.134	.116	1	
9.Root Nodules	.731***	.640**	.827***	.705**	.636*	.643**	.620**	.730*	1

*Note: *, ** and *** denote statistically significant at 10%, 5% and 1% respectively*

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Table 4.15: Correlation matrix for 2019 harvest season

Variables	1	2	3	4	5	6	7	8	9
1.Yield t/ha	1								
2.Mean Number of pods per Plant	.734***	1					.		
3. Mean Number of seeds per Plant	.707*	.749***	1						
4. Pod weight per plant	.595**	.472	.024	1					
5.Seed weight per plant	.213	.285	.741***	.547*	1				
6.Quality seeds per plant	.598*	.177	.500	.098	.376	1			
7.Plant biomass at harvest	.420	.718***	.411	.215	.497	.267	1		
8.Harvest Index	.724**	.552*	.520**	.114	.126	.026	.221	1	
9. Root Nodules	891***	.850***	.762**	.881**	.460*	632*	.730	.667*	1

*Note: *, ** and *** denote statistically significant at 10%, 5% and 1% respectively*

4.10 Cost Benefit Analysis for 2018 and 2019 Rainy Seasons

Appendix C and D, present the results from the cost and benefits for the 2018 and 2019 rainy seasons. The results from (Appendix C) show that in the 2018 planting season, the combined treatment of cattle manure and Togo rock phosphate (5 t/ha CM + 25 kg/ha RP) recorded the highest net benefits (GH₵ 18,130.68/ ha) while the control recorded the lowest net benefit of (GH₵ 1899.52/ ha). Among the treatment plot, the highest cost recorded was accumulated from (10 t/ha CM + 25 kg/ha RP) compared to the control plots but obtained hghier net benefit than the sole treatments and the control.

In the 2019 major season (Appendix D), the combined treatment (5 t/ha CM + 25 kg/ha RP) produced the highest net benefit of (GH₵ 32,877.93/ ha) compared with sole treatment and the control plots. In terms of cost, the results revealed that, the control obtained the lowest cost (GH₵ 200.00/ ha) compared to the amended plots yet obtained

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the lowest net benefit. However, comparatively, the major cropping season in 2019 yielded highest net benefits in the case of the treatment plots compared to that of 2018 cropping season. In both cropping seasons, the marginal rate of return was higher among the combined treatments compared to the sole treatments and the control plots (Appendix D).

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CHAPTER FIVE

DISCUSSION

5.1 Effects of Amendments on Soil Chemical Properties

The study examined the role of cattle manure, Togo rock phosphate and integrated nutrient management for improvement and maintenance of soil fertility particularly the chemical properties of the soil. The results showed that the soil fertility was improved following the application of the cattle manure, and the combination rock phosphate and cattle manure to the soil amended. The findings indicate that the combined application of cattle manure and rock phosphate to the soil produced highest amounts of Ca, Mg, K and Na (Table 4.3) compared to the the sole treatment and controls. The results show that, the combination of rock phosphate and cattle manure might have increased the exchangeable cations in the top soil which were essential to improve the soil fertility.

This finding agrees with the results by Butterly et *al.* (2013) who reported that the application of organic manure tend to increase the fertility of the soil by providing supplemental cations such as Ca, Mg and organic matter in the soil. Similarly, this present study supports findings from Goldberg *et al.* (2020) who concluded that, applying organic material to amend the soil possibly increase the cation exchange capacity (CEC) which is a measure of the retention of positively charged ions in the top soil. The provision of the supplemental nutrients through the application of cattle manure tends to have high prospects to support the growth and development of crops.

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The application of the cattle manure further significantly affected the soil pH as shown in Table 4.3. The results indicate that the application of the cattle organic manure increased the pH range from 4.98 to 5.52 in the amended plots. This implies that, the cattle manure contributed to reducing the soil acidity to improve the soil nutrients for the growth and development of the crop. The results further suggest that, the combined application of Togo rock phosphate and cattle manure yields a greater impact on the soil pH than the other amendments and the control. To support the growth and development of a crop, the soil pH plays a key role hence, the results suggest that, applying the cattle manure has a greater potential to amend the acidity of the soil.

The results show further that, the soils amended with the cattle manure and their combinations with the Togo rock phosphate recorded higher levels of organic carbons percentage, total nitrogen and organic matter than the control soil (without any amendment) (Table 4.3). The results confirm that all the amended soils improved the nutrient levels, after the decomposition of the cattle manure. The findings from the present study indicate that, the combination of cattle manure and the rock phosphate provided higher soil nutrients, Organic Carbon, N and organic matter content than the sole application of the cattle manure.

The findings support the study by Guo *et al*. (2017) who conducted a study on the effect of organic manure on soil organic carbon, amount of N and organic matter. They reported that application of manure increased the amount of organic Carbon, N and organic matter in the soil to support growth and yield of crops. Again, the results are in line with a study

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by Biratu *et al*. (2019) who found high soil organic carbon, soil nutrients such as N and organic matter in the soil amended with manure. This supports the growth and crop yield which has an advantage over the application of the inorganic fertilizer. Providing another treatment of RP alone could have shown the effect of CM on P availability in RP.

5.2 Effects of Soil Amendments on Growth of Soybean

The results from the study indicate that, the application of the combination of cattle manure and rock phosphate shows significant contribution to the growth of plant height, plant leaves, and canopy spread (Figures 4.1, 4.2 and 4.3). Increase in the number of leaves and plant height is associated with better growth of the plant as it helps the plant to undergo photosynthesis. The leaves contain the chlorophyll which are all significant factors for the growth of the plant. Results from the study revealed that, the amended plots produced increased plant height of soybean compared to the control plots (Figure 4.1A and 4.1B). For instance, (5 t/ha CM + 25 kg/ha RP) treatment recorded the tallest plant height.

The results from the two different planting seasons conclusively indicated that, the combination of cattle manure and Rock phosphates produced more leaves, plant height and canopy spread than the control plots for all the two seasons. Due to the increasing number of leaves as a result of the application of the cattle manure and the rock phosphate combined, the canopy spread of the soybean plant also increased (Figure 4.3). The canopy spread depends on the number of leaves produced hence increasing number

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of leaves also increased the canopy spread. The canopy spread has significant influence of the crop yield as reported by previous scholars.

The results agree with the findings from Jennifer (2014), who concluded that the application of phosphorus significantly improved total leaf area in soybean and other vegetative parts of the plant, hence the increase in canopy width, plant leaves, plant height with combination of cattle manure and Rock phosphate. Phosphorus is an important nutrient for plant growth and their development (Van Slyke, 2001). The author confirmed an increase in leaf area also resulted in an increase in photosynthetic organ (leaves) area as well as the number of pods per plant in soybean. Habib *et al*. (2012), also confirms that high crop growth rate contributed to high grain yield.

The results from the two cropping seasons indicated that, the application of the cattle manure and the rock phosphate combined yielded the greatest shoot fresh weight (Figure 4.4) as it was greater than that of the control plots. In the same vein, the findings confirm that, the shoot dry weight was highest when the cattle manure with rock phosphate combination was applied compared to the sole application of cattle manure. The results agree with Tsvetkova and Geogiev (2003), who stated that phosphorus deficiency affected the whole plant fresh and dry mass at the harvesting stage.

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5.3 Effect of Soil Amendment on Yield and Yield Components of Soybean

The study examined the effect of soil amendment on soybean yield and yield components. The results showed significant differences in the yield and yield components due to the application of cattle manure applied alone and the combination of cattle manure and rock phosphate. Seed yield increased from the plots where the soil was amended with the cattle manure and rock phosphate.

Results from Tables 4.7 and 4.8 showed an increased number of pods and number of seeds during the 2018 and 2019 cropping seasons. The findings showed a clear significant difference between soybeans grown in the soil amended plots and the control plots. The results showed that the combined application of cattle manure and rock phosphate produced the greatest number of pods per plant as compared to the control plots. The results show that, the application of the cattle manure and the rock phosphate provided soil nutrients such as N, Ca, P and Na, and other micro nutrients which improved the seed yield. The results further showed that, from the 100 – seed weight, pod yield and the grain yield increased as a result of the application of the cattle manure with rock phosphate. The seed yield weight increased significantly due to the application of the cattle manure. The least soybean grain yield was recorded from the control which was significantly lower than the amended treatments.

The findings from the study are in line with Hati *et al.* (2018) who reported that the greatest number of pods per plant was recorded with 30 kg P application ha^{-1}. However, the lowest number of pods per plant was recorded from the control. This is further

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supported by Houben *et al.* (2013). Who reported that greater number of pods per plot was produced when higher doses of phosphorus were applied. According to Piraveena and Thayamini (2010) there was a higher number of pods when 50 kg/ha rock phosphate with cattle manure was applied in their experiment. The combined treatments with the cattle manure and rock phosphate gave greater quality seed weight than the sole treatments. However, the control treatment produced the highest diseased seed weight per plant.

Again, the result showed that, the combined treatment of cattle manure and rock phosphate treatment gave the highest yield, and pod weight per plant which was significantly ($P \leq 0.05$) heavier than the control plots or sole treatment with cattle manure. Results from Table 4.6 shows mean pod length and plant biomass during the 2018 and 2019 cropping seasons. The mean pod lengths obtained from the combined treatment with cattle manure and rock phosphate were the highest compared to those obtained from the control plots and the sole application of cattle manure treatment. The combined treatment with the cattle manure with the phosphates produced the heaviest weight in plant biomass while the lowest value of the plant biomass was recorded by the control treatment.

Arega *et al.* (2018) reported that cattle manure had crucial effect on number of branches per plant, pod length and other grain yield. The results showed that, during the two cropping seasons, the harvest indices increased in the present study as a result of the combined application of cattle manure and rock phosphate to the soybeans. According to

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Mahama (2011) water is required at its peak during vegetative stage of crops growth and as a result helped improved better plant biomass and other parameters in 2019 than 2018 growing season. Pod length is highly influenced by rainfall according to Roriz *et al*. (2014). Pod length is affected by drought according to Soybeans Production Guide (2002). The findings support Bakal *et al.* 2019 who reported that different soybean varieties are sensitive to changes in environmental conditions where the crop is being grown.

5.4 Number of Effective Nodules

Table 4.12 and 4.13, shows the response of number of effective root nodules to the rates of cattle manure and combined application of cattle manure with rock phosphate during the 2018 and 2019 growing periods. The number of effective nodules showed no significant variation ($P \geq 0.05$) among the treatments at early stages in both 2018 and 2019 seasons. However, significant ($P \leq 0.05$) differences were observed after 49 DAP. The combined treatments made up of cattle manure and rock phosphate, (5 t/ha CM + 25 kg/ha RP) and (10 t/ha CM + 25 kg/ha RP), produced significant variation ($P \leq 0.05$) in number of effective nodules in both 2018 and 2019 seasons. The recent study confirms the findings of Van Slyke (2001) that P promotes root development and induces nodulation in legumes. Also, significant ($P \leq 0.05$) differences was observed between control treatment and cattle manure with or without rock phosphate and this agree with the work done by Piraveena and Thayamini (2010) that application of cattle manure and rock phosphate increased number of effective nodules than the control.

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Cattle manure is a good source of organic matter which does not only supply the food material for the growth of microorganisms but also provides favourable conditions for increasing activity of some desirable soil organisms (Van Slyke, 2001). As a result, microbial activity is generally more in cattle manure that was applied to the soil. This may be the reason for the variation of nodule numbers between the control treatment and the other amended plots. Also, cattle manure might release micronutrients for the nodulation. Sole application of cattle manure in present study did not indicate highest value at any growing period and this might be as a result of low P availability when cattle manure is applied solely. Van Slyke (2001) confirms that, farm manure including cattle manure are generally deficient in P which is an important nutrient for plant growth and development.

5.5 Economic Analysis

The results from the cost benefit analysis revealed that the net benefits accrued from the two growing seasons as a result of the combined treatment of cattle manure with rock phosphate ranged from GH¢14,076.90 to GH¢32,877.93 per hectare as presented in the Appendix E and F. This was greater than the net benefits accrued from the control plots. The sole application of cattle manure accrued a net benefit raging from GH¢5,327.61 to GH¢25,127.17 per hectare which was far greater than the control plots. This indicates that the application of the cattle manure improved the soil fertility and contributed more to the yield and total output.

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The results also revealed that, the combined treatments (5 t/ha CM + 25 kg/ha RP) accrued the highest net benefits and marginal rate of returns was the highest while the control obtained the lowest. Further, the results showed that, the marginal rate of return reported during the 2019 harvest, cost and benefit analysis was above 90 % acceptable level as shown in Appendix D. Among the treatment plots, the highest cost recorded was (10 t/ha CM + 25 kg/ha RP) treatment plots compared to the control plots. Sun *et al.* (2013) confirms that organic matter is associated with increased yields and higher economic returns. Increase in number of seeds harvested results in increase in the grain yield obtained per ton.

The findings showed that, there is a strong correlation between grain yield and average number of pods per plant. The result also indicates that, grain yield has positive and significant correlation with average number of seeds per plant. The findings showed that grain yield has a positive and significant correlation with quality seeds per plant which also measured the marketable seeds harvested.

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CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

From the results of the study, the following conclusions were drawn:

- It was observed that, the addition of cattle manure and naturally occurring rock phosphate used as amendments increased soil organic matter content as well as increases in soil nutrient such as available P, total P, K, Ca, ECEC and total N.
- The (5 t/ha CM + 25 kg/ha RP) produced the highest grain yield in both cropping seasons, this is an indication that soybean yield cannot be fully met through sole cattle manure incorporation, rather in combination with rock phosphate.
- The (10 t/ha CM + 25 kg/ha RP) produced the highest shoot fresh weight whilst the (5 t/ha CM + 25 kg/ha RP) had a positive influence on virtually all the parameters measured.
- The soybean grain yield had a strong positive and statistically significant association with plant biomass at harvest, root nodules, mean number of pods and mean number of seeds per plant. This implies that as these yield components increases, grain yield turns to increase.
- In the same way, as the soybean crop parameters decline in growth, there will be a positive reduction in yield. This further highlight that, any intervention that seeks to improve these soybean crop parameters (plant biomass at harvest, root nodules, mean number of pods and mean number of seeds per plant) should have significant positive impact on soybean grain yield.

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- The (5 t/ha CM + 25 kg/ha RP) accrued the highest net benefits and marginal cost of returns.
- Parameters measured in this experiment gave higher (good) response to treatments in 2019 major rainy season as compared to 2018 minor cropping season.

6.2 Recommendatons for Future Research

1. Soybean farmers are encouraged to use cattle manure at a rate of 5 t/ha either applied alone or in combination with rock phosphate to improve soil fertility as well as soil physical properties.

2. The incorporation of (5 t/ha CM + 25 kg/ha RP) treatment are recommended for soybean growers for higher yield and better plant growth.

3. The treatments considered in this study should be assessed under different ecological zone to ascertain some of the conclusions outlined and to compare costs and benefits to influence the adoption and use.

4. Further study should include RP alone at 25 kg/ha RP and should include a range of RP to assess the effect of CM on phosphorus release in RP.

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APPENDICES

Appendix A: Climatic conditions during the 2018 minor season

Month	Total Monthly Rainfall (mm)	Mean Monthly Humidity % (Hours GMT)		Mean Monthly Max & Min Temperatures (°C)	
		06: 00	15:00	Min.	Max
August	192.60	95.00	69.00	22.00	29.00
September	170.70	95.00	76.00	22.00	30.00
October	75.10	95.00	63.00	22.00	33.00
November	18.30	94.00	55.00	23.00	33.00
December	54.80	93.00	53.00	23.00	33.00
	511.50	94.40	63.20	22.80	33.40

Source: Meteorological Service Department, Mampong – Ashanti, 2018

Appendix B: Climatic conditions during the 2019 major season

Month	Total Monthly Rainfall (mm)	Mean Monthly Humidity % (Hours GMT)		Mean Monthly Max & Min Temperatures (°C)	
		06: 00	15:00	Min.	Max
March	110.60	93.00	57.00	23.00	33.00
April	138.80	95.00	61.00	23.00	33.00
May	164.60	96.00	61.00	23.00	32.00
June	376.60	98.00	67.00	22.00	29.00
July	273.50	97.00	73.00	22.00	28.00
	1064.20	95.80	63.80	22.60	31.10

Source: Meteorological Service Department, Mampong – Ashanti, 2019

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Appendix C: Cost benefit analysis for soybean as influence by cattle manure with rock phosphate soil amendment in 2018 minor season

Treatment	Control	5 t/ha CM	5 t/ha CM + 25 kg/ha RP	10 t/ha CM	10 t/ha CM + 25 kg/ha RP
Gross Yield (ton)/ha	0.60	1.02	1.80	1.07	1.25
Adjusted Yield (10 % downwards)	0.54	0.918	1.62	0.963	1.125
Gross benefits (GH¢)/ha	2099.52	6067.61	18895.68	9277.16	15381.90
Total Variable Cost (TVC) GH¢)/ha	200.00	740.00	765.00	1280.00	1305.00
Net Benefit (GH¢)/ha	1899.52	5327.61	18130.68	7997.16	14076.90
MRR $= \frac{\Delta \text{ Net Benefit}}{\Delta TVC} \times 100$		634.83	51212.28	D -1967.67	24318.98

Appendix D: Cost benefit analysis for soybean as influenced by cattle manure with rock phosphate soil amendment in 2019 major season

Treatment	Controls	5 t/ha CM	5 t/ha CM + 25 kg/ha RP	10 t/ha CM	10 t/ha CM + 25 kg/ha RP
Gross Yield (ton)/ha	1.57	2	2.31	2.04	2.11
Adjusted Yield (10 % downwards)	1.413	1.8	2.079	1.836	1.899
Gross benefits (GH¢)/ha	10173.60	12960.00	14968.8	13672.8	13672.80
Total Variable Cost (TVC) GH¢)/ha	200.00	740.00	765.00	1280.00	1305.00
Net Benefit (GH¢)/ha	21159.91	24320.00	32877.93	25127.17	26909.61
MRR $= \frac{\Delta \text{ Net Benefit}}{\Delta TVC} \times 100$ %		585.20	34231.72	D -1505.00	7129.76

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Appendix E: Guide to interpretation of soil analytical data by CSIR, Soil Research Institute (2009)

Soil nutrient (mineral) content

Nutrient	Rank / Grade
Soil pH (Distilled Water Method)	
<5.0	Very Acidic
5.0– 5.5	Acidic
5.6 – 6.0	Moderately Acidic
6.1 – 6.5	Slightly Acidic
6.6 – 7.0	Neutral
7.1 – 7.5	Slightly Alkaline
7.6 – 8.5	Alkaline
>8.5	Very Alkaline
Organic matter (%)	
<1.5	Low
1.6 – 3.0	Moderate
>3.0	High
Nitrogen (%)	
<0.1	Low
0.1 – 0.2	Moderate
>0.2	High

Soil Research Institute - (CSIR).