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EFFECTS OF TILLAGE, CROPPING SYSTEM AND NPK FERTILIZER RATE ON PERFORMANCE OF MAIZE (*Zea mays* L.)/SOYBEAN (*Glycine max* L. (Merill)) INTERCROP IN THE GUINEA SAVANNAH AGROECOLOGICAL ZONE OF GHANA

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KARL ANYETIN-NYA ASEKABTA

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EFFECTS OF TILLAGE, CROPPING SYSTEM AND NPK FERTILIZER RATE ON PERFORMANCE OF MAIZE (*Zea mays* L.)/SOYBEAN (*Glycine max* L. (Merill)) INTERCROP IN THE GUINEA SAVANNAH AGROECOLOGICAL ZONE OF GHANA

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(B.Sc. AGRICULTURAL TECHNOLOGY)

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THESIS SUBMITTED TO THE DEPARTMENT OF AGRONOMY, FACULTY OF AGRICULTURE, UNIVERSITY FOR DEVELOPMENT STUDIES IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTER OF PHILOSOPHY DEGREE IN CROP SCIENCE

2018

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DECLARATION

I hereby declare that this is the result of my own research and that no previous submission has been made in this University or elsewhere for a Degree. References made herein are duly acknowledged.

KARL ANYETIN-NYA ASEKABTA (STUDENT)

……………………………… ……………………………

SIGNATURE **DATE**

I hereby declare that the preparation and presentation of the Thesis was supervised in accordance with the guidelines on supervision of Thesis laid down by the University for Development Studies.

DR. JOSEPH XORSE KUGBE (PRINCIPAL SUPERVISOR)

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ABSTRACT

The study was conducted on the research field of Integrated Water and Agriculture Development (IWAD) located in the Mamprugu Moagduri District, Yagaba, during the 2015 cropping season. The study sought to determine the effect of tillage system, and NPK fertilizer on productivity and yield of maize-soybean intercrop system. The experimental design consisted of three factors: tillage system at three levels (plough, ripping and direct-seeding), cropping system at two levels (sole maize and intercrop) and NPK fertilizer rate at three levels (0 kg/ha, half the recommended rate of 30-15-15 kg/ha and the full rate of 60-30-30 kg/ha). The treatments were laid out in a split-split plot design replicated three times. The tillage system was assigned to the main plot, cropping system to sub-plot and the NPK fertilizer rate being the sub-sub plot. Each sub-sub plot measured 5 x 5 m. A representative soil sample was taken before land preparation and after harvest. Two seeds of the maize variety (Pannar 35) were planted at a spacing of 80 cm x 20 cm. Soybean seeds were hand drilled at a spacing of 80 x 10 cm. Grain yield of maize was significantly influenced by sole fertilizer rate with highest yield occurring under the full rate (3.4 t/ha) compared to the half rate (2.7 t/ha), amounting to yield difference of 700 kg/ha. Yield of soybean under the integrated production was affected by interaction of tillage system and fertilizer rate. Highest yield was recorded under the ploughed condition at the full rate of fertilizer application, giving that production system the highest profit (3410 GHS/ha). Though sole maize, ploughed and with full rate of fertilizer application, gave similar benefit/cost ratio to the integrated production with half rate of fertilizer application, the intercropped system with half fertilizer rate resulted in 45% more increases in profit compared to the sole production with full fertilizer rate.

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DEDICATION

This work is dedicated to my children, Scholastica Anaam-lie, Lucious Ayieta-naam and Theophanes Awensuik-lie.

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CHAPTER ONE

INTRODUCTION

1.1 Background

Tillage is the agricultural preparation of soil by mechanical agitation of various types, such as digging, stirring, and overturning. Tillage is one of the important processes in agriculture. It is carried out mainly to loosen the upper layer of the soil, to mix the soil with fertilizer and organic residues, to control weeds, and to create a suitable seedbed for germination and plant growth (Rasmussen, 1999). Tillage is crucial for crop establishment, growth and ultimately, yield (Alkinson *et al*., 2007). Tillage practices influence soil physical, chemical and biological characteristics, which in turn may alter plant growth and yield (Carman, 1997; Ozpinar and Cay, 2006; Rashidi and Keshavarzpour, 2009). Appropriate tillage systems are site specific and depend on crop, soil type and the climate (Rasmussen, 1999). According to Srivastava *et al*. (2006), the objective of tillage is to develop a desirable soil structure or suitable tilth for a seedbed.

Intercropping system involves cultivating one main crop with one or more added crops where the main crop is of primary importance due to economic or food production reasons (Brintha and Seran, 2009). Thole (2007) reported that intercropping increases total yield per given piece of land and resulted in higher land equivalent ratio. Furthermore, if grain-legumes are involved, the legumes help to maintain and improve soil fertility due to their ability to biologically fix atmospheric nitrogen (SangingaWoomer, 2009; Jarenyama *et al*., 2000).

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Maize (*Zea mays* L.) is an important cereal crop worldwide. It is the most important cereal crop in Ghana and is an important component of sustainable cropping systems in the country contributing significantly to household security. The crop is consumed by people with varying food preferences and socioeconomic backgrounds in Ghana (Badu Apraku *et al*., 2011). Maize is a versatile crop, allowing it to grow across a range of agro-ecological zones in Ghana except for the Sudan Savannah (Morris *et al*., 1999).

Soybean is a legume which fixes nitrogen through a symbiotic relationship with nitrogen fixing bacteria of the species *Bradyrhizobium japonicum* (Sarkodie-Addo *et al*., 2006; Nastasija *et al*., 2008). Soybean can positively contribute to soil health, human nutrition and health, livestock nutrition, household income, poverty reduction and overall improvements in livelihoods and ecosystem services more than many other leguminous grain crops (Raji, 2007; Rakasi, 2011). Soybean is also beneficial in the management of *Striga hemonthica*, an endemic parasitic weed of cereal crops in the Savannah zone of Ghana (Carsky *et al*., 2000).

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NPK fertilizer is a complex fertilizer comprised primarily of the three primary nutrients (Nitrogen, Phosphorus and Potassium) required for healthy plant growth. The agriculture industry relies heavily on the use of NPK fertilizer to meet global food supply and ensure healthy crops. In Ghana fertilizer application rates are relatively low for all crops, but the average rates are slightly higher on maize fields with application rates averaging 14 kg/ha on maize fields, accounting for about 64% of total fertilizer use (Heisey and Mwangi, 1997).Onasanya *et al*. (2009), observed that applying 120 kg/ha of nitrogen fertilizer or 60

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kg/ha of nitrogen with 40 kg/ha of phosphorus fertilizer significantly increases maize yield. Morris *et al*. (2007), mentioned that fertilizer tends to be profitable for maize farmers in West Africa, yet less than half of maize farmers in Ghana apply fertilizer. Aflakpui *et al*. (1993), observed that greater grain yields are achieved in both maize and soybean with fertilizer application than with no fertilizer input. Poor kernel formation, increased abortion and ultimately lower grain yield of maize under N stress have been reported widely by Ngwira *et al*, (2012).

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1.2 Problem statement

Yield of maize (1.7 t/ha) is below achievable yield of 6 t/ha. The low maize yield is attributed, among other factors, to soil compaction, low and declining soil fertility, and periodic drought caused by erratic rainfall distribution patterns (Kugbe *et al*., 2015).The Guinea savannah zone of Ghana experiences annual bush burning (Kugbe *et al*., 2012) which most often is carried out for several reasons including clearing of land for cultivation, stimulating new shoots for fodder production and exposing wild game for hunting (NRI, 1996). This burning usually results in a marked, but short-lived rise in nutrient availability (normally referred to as N flush). However, it raises the soil pH to such high levels that deficiency of iron and other micro-nutrients could be induced (Oelsligle *et al*., 1976; Kugbe *et al*., 2015). Also, the ever-increasing human population together with practices such as slash and burn, and the recent proliferation of surface mining has endangered shifting cultivation as practiced in the past by most farmers, as a means of conserving the soil and maintaining productivity (Ekboir *et al*., 2007). As such, farmers in rural areas continue to grow maize on the same piece of land season after

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season, in addition to practicing the slash and burn method that had contributed to the increasing land degradation. This has affected crop production significantly, since the evolving systems are incapable of conserving soils against wind and water erosion and in restoring soil fertility, thus resulting in deterioration of the resource base of the soil (Kugbe *et al*., 2015; Mensah *et al*., 2015).

In Ghana, maize is largely grown by resource-poor smallholder farmers under rainfed conditions. Constraints to maize production in Northern Ghana include declining soil fertility, limited use of nitrogenous fertilizers (Kugbe *et al*., 2015), and periodic drought caused by erratic rainfall distribution patterns. These could reduce maize yields by an average of 15% each year (IITA, 2007). Though small-holder farmers may have access to different grades of fertilizers, there is lack of knowledge on the productivity of each fertilizer grade to maize production.

Tillage operations are also performed by most resource-poor farmers who lack supporting finances for hiring tillage services and have insufficient knowledge on the effect of these operations on soil physical properties and crop responses (Ozpinar and Isik, 2004). These farmers employ different tillage practices in the production of the crop. While some farmers plant maize after disc ploughing without disc harrowing, other farmers disc plough and disc harrow before planting (Aikins *et al*., 2012).

Soybean planted in fields with different soil types and drainage properties respond differently to tillage practices. No-tillage production of soybean is often less successful in

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poorly-drained soils (Dick and Van Doren, 1985) partly because of cooler and wetter soil conditions at planting (Meese *et al*., 1991). These soil conditions can lead to slower soybean germination and emergence which make the seedlings more vulnerable to seedling diseases.

Consequently, there is the need to identify sustainable tillage and cropping systems that allow continuous cultivation on the same piece of land.

1.3 Justification

The sustainable production of food, fibre and bioenergy depend on appropriate tillage and cropping systems that provide high yields and preserve soil, water and biodiversity (Franchini *et al*., 2012). The importance of continuous use of soil-conserving tillage methods, such as the no-tillage, is widely recognized for the sustainability of farming systems, particularly in tropical and subtropical regions (Erenstein, 2003). Conversely, no-tillage may increase topsoil compaction into levels in which the growth of roots is limited, especially on clayey soils and, or in soils with low organic matter content (Secco *et al*., 2009). On the other hand, no-tillage may not affect root growth, especially on sandy soils in which maize is mostly produced. Also, a good soil management programme, which is recommended for maize production in northern Ghana, protects the soil from water and wind erosion, provides a good weed-free seedbed for planting, destroys hardpans or compacted layers that may limit root development, and allows maintenance or even an increase of organic matter (Wright *et al*., 2008).

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Cereal-grain legume intercropping has the potential to address the soil nutrient depletion on smallholder farms (Sanginga and Woomer, 2009). The legumes play an important role in nitrogen fixation (Peoples and Craswell, 1992), and are important source of nutrition for both humans and livestock (Nandwa *et al*., 2011).

Soil quality is one of the most important determinants of maize yield in Northern Ghana (Braimoh*et al*., 2006). Inorganic fertilizer is necessary to correct the depleting soil quality, because organic techniques and inputs alone cannot restore depleted soils rapidly and can only sustain crop yields at limited levels (Moro *et al*., 2008). Resource-poor farmers growing food crops in sub-saharan Africa (SSA) relied on the extensive bush fallow system for maintaining the productivity of their farmlands. This system allowed nitrogen (N) and phosphorus (P), the most limiting nutrients, to be restored (Szott *et al*., 1991). However, with the current pressure on arable land, the practice of using shifting cultivation and natural fallows to regenerate the productivity of farmlands could no longer be sustained (Ekboir *et al*., 2007). Addition of organic sources of plant nutrients, especially manure to build soil organic matter (SOM) and rectify multiple nutrient deficiencies, is one option recommended for rehabilitating degraded soils (Bationo *et al*., 2007). However, most smallholder farmers cannot obtain sufficient manure due to low livestock numbers and are therefore unable to maintain critical levels of soil organic carbon required to sustain soil productivity (Muhereza *et al*., 2014). It is therefore necessary to identify complementary options to rehabilitate degraded soils.

In West Africa, mineral fertilizer has been found to increase crop yields substantially (Aflakpui *et al.*, 1993; Bationo *et al.*, 2007; Buah *et al.*, 2010). Annual nutrient losses in sub-Saharan African (SSA) ranged from 14-136 kg/ha NPK with majority of countries showing nutrient losses greater than 24 kg/ha NPK (Stoorvogel and Smaling, 1990; Henao and Baanante, 1999).Ghana is estimated to have annual nutrient losses of about 60 kg/ha NPK, which is among the highest rate in sub-Saharan Africa (SSA) (Henao and Baanante, 1999; Stoorvogel *et al.*, 1993).The most effective method to combat soil nutrient losses is to apply nutrient fertilizer (Vitousek *et al.*, 2009). Fertilizer application could decrease yield variability by replenishing soil nutrients. Several studies have suggested that large increases in fertilizer usage are necessary to correct the massive nutrient losses of much of the arable land in sub-Saharan Africa (SSA) (Heisey and Mwangi, 1997; Wallace and Knausenberger, 1997; Crawford *et al.*, 2005; Morris *et al.*, 2007). However, current fertilizer use in Ghana averages 6 kg/ha, representing one of the lowest rates in sub-Saharan Africa (SSA) (Banful, 2009). Increasing these fertilizer-use rate in Ghana could increase availability of nutrients and serve as a mechanism to increase agricultural yields (Wallace and Knausenberger, 1997).

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Application of inorganic fertilizer in the right quantities and at the right time might increase crop yields (Ortiz *et al.*, 2008). Ghana is estimated to have annual nutrient losses around 60 kg/ha NPK, among the highest rate in sub-Saharan Africa (SSA) (Stoorvogel *et al.*, 1993; Henao and Baanante, 1999). Across Northern Ghana, a recommended rate of NPK fertilizer of 60-30-30 kg/ha is required to increase maize yields (Salako *et al.*, 2007). This recommended rate poses a limitation to the resource-poor farmer, as they are expensive in terms of cost and transport to farmers' field. A review of the rate to lower amounts may help fertilizer usage by reducing the associated cost of purchase and of transport to the resource-poor farms.

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In intercropping, the crops are so selected that they take advantage of the different root stratification, varying nutrient requirements and differences in plant architecture so as to maximize resource use (Andrews and Kassam, 1976). Intercropping offers potential advantages for N-fixation, resource utilization, decreased inputs, utilization for the resource-poor farmer and increased sustainability in crop production (Egbe, 2010). However, scientific knowledge on interactions among intercropping species, fertilizer use and tillage systems is still very limited, hindering the opportunity to use such knowledge to increase maize and soybean yield in the resource-poor communities of Northern Ghana.

1.4 Objectives

The study seeks to:

- Determine the effect of tillage system, intercrop and NPK fertilizer rate on productivity and yield of maize-soybean intercrop system.
- Determine the effect of tillage system x intercrop, tillage system x NPK fertilizer rate and intercrop x NPK fertilizer rate on productivity and yield of maize-soybean intercrop system.
- Determine the effect of tillage system x intercrop x NPK fertilizer rate on productivity and yield of maize-soybean intercrop system.

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CHAPTER TWO

LITERATURE REVIEW

2.1 Origin and distribution

2.1.1 Maize

Maize (*Zea mays* L.) belongs to the family of grasses (*Poaceae*). It is cultivated globally and is one of the most important cereal crops worldwide (IITA, 1991). Maize was domesticated in Central Mexico (Matsuoka *et al.*, 2002) about 6,000-9,000 years ago (Benz, 2000). Maize was introduced into Africa in the 16th century from its native Mesoamerica, and now is one of the most widely grown cereal crops in Africa. Its evolution in Mesoamerica led to diversification into approximately 55 races (Sanchez *et al.*, 2000).In 2000, North America accounted for nearly 50% of the world maize production. The USA produced approximately 42%, China 18% and Europe 10%, whereas Australia produced less than 0.1% (Farnham *et al.*, 2003). Total land area planted to maize in Africa is estimated at 21 million ha. Yields range between 800 and 1200 kg/ha, which is far below the world average of 3700 kg/ha.

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Maize is a versatile crop grown over a range of agro climatic zones. In fact, the suitability of maize to diverse environments is unmatched by any other crop. It is grown from 58°N to 40°S, from below sea level to altitudes higher than 3000 m, and in areas with 250 mm to more than 5000 mm of rainfall per year (Shaw, 1988; Dowswell *et al.*, 1996) and with a growing cycle ranging from 3 to 13 months (CIMMYT, 2000). However, the major maize production areas are located in temperate regions of the globe. The United States, China, Brazil and Mexico account for 70% of global production. India has 5% of corn acreage and

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contributes 2% of world production. The area harvested to maize in Ghana in 2009 was 954,400 ha (FAO Statistical Databases, 2011).

2.1.2 Soybean

Soybean is native to Eastern Asia, mainly China, Korea and Japan, from where it spread to Europe and America and other parts of the world in the 18th century (Ngeze, 1993). Evidence in Chinese history indicates its existence more than 5,000 year ago, being used as food and a component of drugs (Norman *et al*., 1995). Some researchers have suggested Australia and Eastern Africa as other possible centres of origin of the genus Glycine (Addo-Quaye *et al*., 1993). 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 (Evans, 1996).

Soybean was first introduced to Africa in the early 19th century, through Southern Africa (Ngeze, 1993) and is now widespread across the continent (Wikipedia, 2009). However, Shurtleff and Aoyagi (2007) have stated that it might have been introduced at an earlier date in East Africa, since that sector 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 were the first to introduce the soybean in 1909. This early introduction did not flourish because of the temperate origin of the crop (Mercer-Quarshie and Nsowah, 1975). However, serious attempts to establish the production of the crop in Ghana started in the early 1970s. This was as a result of collaborative breeding

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efforts of Ghana's Ministry of Food and Agriculture (MoFA) and the International Institute of Tropical Agriculture (IITA) (Tweneboah, 2000).

2.2 Economic importance

2.2.1 Maize

In sub-Saharan Africa, maize is a staple food for an estimated 50% of the population and provides 50% of the basic calories. It is an important source of carbohydrate, protein, iron, vitamin B, and minerals. Africans consume maize as a starchy based food in a wide variety of porridges, pastes, grits, and beer. Green maize (fresh on the cob) is eaten parched, baked, roasted or boiled and plays an important role in filling the hunger gap after the dry season. Maize grains have great nutritional value as they contain 72% starch, 10% protein, 4.8% oil, 8.5% fibre, 3.0% sugar and 1.7% ash (Chaudhary, 1983).

Maize is the most important cereal fodder and grain crop under both irrigated and rainfed agricultural systems in the semi-arid and arid tropics (Hussan *et al*., 2003). The per capital consumption of maize in Ghana in 2000 was estimated at 42.5 kg (MoFA, 2000) and an estimated national consumption of 943000 Mt in 2006 (SRID, 2007). According to Dugje *et al*. (2009) soybean is more protein-rich than any of the common vegetable or legume 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.

Soybean has various nutritional and medicinal properties as well as industrial and commercial uses; and agronomic values such as soil conservation, green manure, compost and nitrogen fixation. Soybean can be cooked and eaten as a vegetable as well as

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processed into soy oil, soy milk, soy yogurt, soy flour, tofu and tempeh (Rienke and Joke, 2005; MoFA and CSIR, 2005).

Rienke and Joke (2005) reported that soybean contains 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. Comparatively, the cost of buying one kilogram of soybean is much less than buying a similar quantity of meat or eggs (Ngeze, 1993). 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 afford.

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2.2.2 Soybean

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. It is also heavily used in industries, especially in the manufacture of paint, soap, typewriter ink, plastic products, glycerine and enamels (Rienke and Joke, 2005; Ngeze, 1993 and Wikipedia, 2009). The cake obtained from soybean after oil extraction is also an important source of protein feed for livestock and fish. The expansion of soybean production has led to significant growth of the poultry, pig and fish farming (Abbey *et al*., 2001).

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The haulms, after extraction of seed, also provide good feed for sheep and goats (Dugje *et al*., 2009). Soybean is said to contain some anti-nutritional substances that reduce the nutritional value of the beans and are dangerous to health and therefore, need to be removed before they can be eaten. This is not a problem since these substances can be removed by simply soaking and or 'wet' heating the beans; leaving a valuable product that is not harmful to humans (Rienke and Joke, 2005; Ngeze, 1993). Soybean is also reported to have many health benefits. It has been reported that, regular intake of soy foods may help to prevent hormone-related cancers such as breast cancer, prostate cancer and colon cancer (Wikipedia, 2009). It also relieves menopausal symptoms, due to the oestrogen like effect. Research also suggest that, regular ingestion of soy products reduces the rate of cardiovascular diseases by reducing total cholesterol, low density lipoprotein cholesterol and preventing plaque build-up in arteries which could lead to stroke or heart attack (The Mirror, 2008). The high quality protein, low cholesterol oil and other nutritional values are beneficial in the treatment of nutritional diseases in children (MoFA and CSIR, 2005), diabetes and also very important protein for vegans (Wikipedia, 2009).

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2.3 Botany

2.3.1 Maize

Maize is a coarse, annual grass. The root system consists of seminal, secondary or coronal or crown and aerial or prop roots. The seminal roots, usually 3-5 in number grow downwards at the time of germination. The secondary roots, which are about 15-20 times as numerous as the seminal roots, develop from the first few nodes at the base of the stem. The aerial roots grow from the nodes above the ground and help to anchor the plant firmly

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(Onwueme and Sinha, 1991). The maize stem ranges in height from 0.6-4.5 m and in diameter from 1.4-5.0 cm. The stem consists of 8-12 internodes and a leaf develops at each node (Onwueme and Sinha, 1991). Tindall (1988) stated that the stems grow up to 3 m in height and from 3-4 cm in diameter with several nodes and internodes. Raemaekers (2001) also stated that the maize stalk is herbaceous and sub-divided into internodes. The number of internodes ranges from 6-20. The stalk varies from 1.0-3.5 m in height. Most maize types form only one stalk but there are types that form a number of side stalk or tillers.

According to Onwueme and Sinha (1991), the number of leaves ranges from 8-14. A leaf may be 80 cm long and 9-10 cm wide. Raemaekers (2001) reported that the leaves arise from the nodes and they alternate on opposite sides of the stalk. The female flowers are borne on a receptacle, termed ear, which arises at leaf axils near the mid-point along the stem. Normally 1-3 or more such ears develop. The flower organs, and later the grain kennels are enclosed in several layers of papery tissue termed husks. Strands of "silk", or the stigmas from the flowers emerge from the terminals of the ears and husks at the same time the pollen from the terminal tassels is shed. The pollen is wind-blown and comes in contact with the emerged silk or stigma. The pollen then germinates and a pollen tube grows down through the silk to the egg cell of the female flower. The male gamete fuses with the egg and from the fertilized egg the corn seed or kernel develops.

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2.4 Growth and development

2.4.1 Maize

Maize is a tall, determinate, monoecious, annual plant. It produces large, narrow, opposite leaves, borne alternatively along the length of the stem (Zhang *et al.*, 2015). All maize varieties follow same general pattern of development, although specific time and interval between stages and total number of leaves developed may vary among hybrids, seasons, time of planting and location. The various stages of maize growth are broadly divided into the vegetative and reproductive stages as follows:

Seedling/sprouting stage comes about one week after sowing, and the plants have about 2-4 leaves at this stage. Grand growth stage also called knee height stage of plants arrives about 35-45 days after sowing. Tasseling/Flower initiation stage is the stage at which the tassels or male flowers appear (Çakir, 2004). Generally the maize plant would have attained its full height by this stage.

Silking stage involving the formation of female flowers. Appearance of cobs makes the first reproductive stage and occurs 2-3 days after tasseling. This stage begins when silks are visible outside the husk. These are auxillary flowers unlike tassels that are terminal ones. Pollination occurs when these new moist silks catch the falling pollen grains. Milky stage commences when pollination and fertilization are over (Lauer, 2012).Grains start developing but they do not become hard. This soft dough stage is noticed by the silks on the top of the cob which remain partially green at this stage. The covering of the cobs also

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remains green. At maturity stage, the leaves get dried and silks get dried completely and become very brittle. Harvesting is done at this stage.

2.4.2 Soybean

Soybean is an annual, erect hairy herbaceous plant, ranging in height of between 30 and 183 cm, depending on the genotype (Ngeze, 1993). Some genotypes have prostrate growth, not higher than 20 cm or grow up to two metres high (Wikipedia, 2009). There are two types of growth habit of the soybean: determinate and indeterminate types with a number of approved varieties grown in Ghana (Ngeze, 1993; CSIR and MoFA, 2005). 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 (Ngeze, 1993).

The stem, leaves and pods are covered with fine brown or gray hairs. The leaves are trifoliate, having three to four leaflets per leaf. The fruit is a hairy pod that grows in clusters of three to five each of which is five to eight centimetres long and usually contains two to four seeds (Rienke and Joke, 2005). 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 resistant and protects the cotyledons and hypocotyls from damage (Wikipedia, 2009; Borget, 1992).

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

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2.5 Climatic and edaphic requirements

2.5.1 Maize

Maize needs regular supply of water and suffers badly in times of drought. It requires rainfall of about 600-1,200 mm per annum and this must be well distributed throughout the year (Awuku *et al.*, 1991). According to these authors maize needs water particularly at the time of tasselling and silking. The best maize growing areas in West Africa have minimum rainfall of 1,000-1,300 mm per annum, well-distributed during the growth period. Certain growth periods are particularly important if severe reductions in yield are to be avoided. In particular, the tesselling-silking stage is critical because grain formation is initiated during this short period. Availability of soil moisture at the time of tasselling is therefore essential for the production of high yields (Tweneboah, 2000). Experiments from a number of countries have demonstrated that soil moisture deficiency that causes wilting for 1-2 days during tasselling can reduce yield up to 20%, and 6-8 days of wilting at this stage can reduce yield by 50% which cannot be made up by later availability of soil moisture either by precipitation or irrigation (Tweneboah, 2000).

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Maize has two periods in its growth when inadequate moisture availability can disastrously affect yield. The first is during establishment, when stand can be substantially reduced because of inability of seeds to imbibe water against the gradient of soil water potential. Studies conducted by Rouanet (1987) have shown that maize is particularly sensitive to a shortage of water 30-40 days either side of flowering. The stage of the plant growth is also a critical period. To obtain high yields, it is most important that water deficits do not occur just prior to tasselling till completion of grain filling. Of all the growth stages, tasselling is the most sensitive period to water shortage as far as grain yield is concerned (Adjetey, 1994).

Maize tolerates a wide range of environmental conditions but it is essentially suited for warm climates with adequate moisture. Temperatures of 21-30ºC are suitable. High temperature and low moisture result in pollen being shed before silk is receptive or death of tassel and drying of silk (Adjetey, 1994). Temperature strongly influences the development of maize. After seedling emergence, high soil and air temperatures accelerate leaf appearance (Tollenaar *et al.*, 1979; Strulk, 1983) and also advance tassel initiation. Maximum plant yields are obtained when temperatures of the late vegetative and reproductive phases are relatively lower than 30ºC (Adjetey, 1994). According to Awuku *et al*. (1991), maize requires an average temperature of 25ºC to 30ºC· Tweneboah (2000) however stated that the optimum temperature for maize ranges 18-21ºC and the minimum temperature for germination is 10ºC.

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Germination and especially emergence will be far more rapid and uniform at temperatures above 16ºC. At about 20ºC, maize usually emerges 5-6 days after sowing. The critical temperature affecting yield is around 32ºC (Raemaekers, 2001). The aspect of light that influences maize growth substantially is the amount of light (intensity) received during the growth period. Maize requires a lot of clear sunshine (Adjetey, 1994).

Maize grows satisfactorily in a variety of soils but requires well-drained, deep loams or silty loams with high to moderate organic matter and nutrient content and pH 5.5-8.0 for best production (Tweneboah, 2000). Adjetey (1994) stated that maize grows on a wide variety of soils but it prefers deep, fertile, well-drained loam and silty loam soil with the soil pH not less than 4.5.

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

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2.5.2 Soybean

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 (Hans *et al*., 1997; Addo-Quaye *et al*., 1993). Ngeze (1993) stated that, soybean does well in fertile sandy soils with pH of between 5.5 and 7.0, and that the crop can tolerate acidic soils more than other legumes but does not grow well in water logged, alkaline and saline soils. Maintaining soil pH between 5.5 and 7.0 enhances the availability of nutrients such as nitrogen and phosphorus, microbial breakdown of crop residues and symbiotic nitrogen fixation (Ferguson et *al*., 2006). Rienke and Joke (2005) reported that high yields in loamy textured soil are recorded and that if the seeds are able to germinate, they grow better in clayey soils.

Soybean is a legume species that grows well in the tropical, subtropical and temperate climates (IITA, 2007). Plant breeders have argued that within the soybean species, there are varieties which react differently to photoperiod, and classified them as long day, short day and day neutral plants (Borget, 1992).

Rienke and Joke (2005) described soybean as being typically a short day plant, physiologically adapted to temperate climatic conditions. However, some 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 (Osafo, 1997). The relatively short growth duration is primarily due to sensitivity to the day length.

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This affects the extent of vegetative growth, flower induction, production of viable pollen, length of flowering, pod filling and maturity characteristics (Norman *et al*. 1995).

Most legumes require an optimum temperature of between 17.5ºC and 27.5ºC for development (Ngeze, 1993). For soybean, the minimum temperature at which it develops is 10ºC, the optimum being 22ºC and the maximum about 40ºC. The seeds germinate well at temperatures between 15ºC and 40ºC, but the optimum is about 30ºC (Rienke and Joke, 2005). Addo-Quaye *et al*. (1993), have suggested the optimum temperature for growth as 23-25ºC.

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Soybean requires optimum moisture for seeds to germinate and grow well. The optimum rainfall amount is between 350 and 750 mm, well distributed throughout the growth cycle (Ngeze, 1993). Rienke and Joke (2005), and Addo-Quaye *et al*. (1993), have described two periods as being critical for soybean moisture requirement; from sowing to germination and flowering, and pod filling periods. During germination, the soil needs to be between 50% and 85% saturated with water, as the seed absorbs 50% of its weight in water before it can germinate. The amount of water required increases, and peaks up at the vegetative stage, and then decreases to reproductive maturity. Large variation in the amount and distribution of soil water limits soybean yield. According to Bohnert *et al*. (1995), there are two major roles of water in plants, as a solvent and transport medium of plant nutrients, and as an electron donor in the photosynthetic reaction processes. Troedson *et al*. (1985) reported that, soybean is quite susceptible to water stress, and usually respond to frequent watering by substantially increasing vegetative growth and

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yield. Jones and Jones (1989) defined water stress as the lack of the amount of soil water needed for plant growth and development, and which in certain cells of the plant may affect various metabolic processes. Direct impacts of drought stress to the physiological development of soybean depend on its water use efficiency (Earl, 2002).

In soybean management, water use efficiency is an important physiological characteristic related to the ability of plants to cope with water stress. According to Passioura (1997), grain yield is a function of the amount of water transpired, water use efficiency and harvest index. Soybean as a C_3 plant is little efficient in water use due to high evapotranspiration and low photosynthetic rates.

Pandy *et al*. (1984) found that increasing drought stress progressively reduced leaf area, leaf area duration, crop growth rate and shoot dry mater; hence, limits soybean yield. Drought stress, during flowering and early pod formation causes greatest reduction in number of pods and seeds at harvest (Sionit and Kramer, 1977). Low soil moisture with high plant population may cause yield to decrease because of drought stress (Gary and Dale, 1997).

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2.6 Management practices of maize

Maize seeds need soil that is warm, moist, well aerated and fine enough to give contact between the seed and the soil. Therefore, the ideal field for maize should be ploughed. Under traditional farming in tropical Africa, maize is grown in ridges, but it does better also on flat land (Raemaekers, 2001).

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Minimum tillage for field preparations has been more extensively tested and adopted for maize than for any other crop. Minimum tillage for maize has generally given yields that were equal to or even greater than those obtained from conventional tillage. The time of sowing maize is the critical factor affecting yields. Timely sowing which costs the farmer little or nothing is the cheapest and most effective step towards ensuring satisfactory maize yields. As a general rule, maize should be sown as near the beginning of the rains as possible. If sowing is delayed, there is a decline in the yield of maize (Raemaekers, 2001). In parts of West Africa where there are two distinct rainfall peaks, two crop seasons of maize can be grown in a year. The sowing date for early maize (major season) is March-April and for the late (minor season) maize is August-September. In the Northern sector of Ghana, there is only one rainy season. Planting should therefore not be done too early or too late since either of these may lead to about 40-50% loss in yield (Baffour, 1990).

To obtain optimum yield, maize must be planted early in the season to take advantage of the early rains (Tweneboah, 2000). In Southern Ghana however, maize is grown twice yearly. When grown as a sole crop, it may be sown at a spacing of about 80-90 cm between rows and 40-60 cm within rows with two plants per hill to give stand population of 37,000-62,500 plants per hectare (Tweneboah, 2000). Baffour (1990) also stated that on commercial farms, the spacing should be about 90 cm between rows and 30 cm within rows with two seeds per hill. According to Awuku *et al.* (1991), the recommended spacing for maize cultivation is 90 cm apart and 40 cm between plants, and 75 cm x 40 cm depending on the variety. All plants require a certain amount of nutrients, water and space for growth, and when crowded they cannot thrive well. If the space needed for their development is to some extent occupied by weeds that rob the cultivated plants of nutrients, moisture and sunlight, then returns from the crop must be correspondingly less.

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Ghana Grain Development Project (GGDP) (1990), stated that weeds have a competitive advantage over young maize seedlings and therefore it is necessary to keep fields free from weeds at least in the first 4-6 weeks after sowing. Yield losses of 40-60% due to weeds have been reported (Raemaekers, 2001). Weeds must never be allowed to out-grow maize plants before being controlled. According to James *et al.* (2000), Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA) (2002) and Dogan *et al*. (2004), the best time to minimize the effect of weeds on maize yields is within 4-8 weeks after planting when maize is in the 2nd-8th leaf stage. Alternatively, application of a good contact or systemic herbicides prior to planting will ensure that maize field is free from weeds during the critical growth stage of the crop that is, up to four weeks after planting. There is the need to follow up with light slashing of weeds at 6 weeks after sowing (James *et al.*, 2000). Tweneboah (2000) also stated that weeds may be controlled by hoeing 3-4 weeks after sowing. Awuku *et al.* (1991), stated that a farmer can use organic or chemical fertilizer on continuously or previously used land in southern and central Ghana. They again, stated that 50 kg of nitrogen, 50 kg of phosphorous and 50 kg of potassium should be applied on one hectare of land at planting time or a week after planting. According to Awuku *et al.* (1991), forest land left unused for at least five years before planting does not need any fertilizer application. They further stated that nitrogen is required by maize in large quantities but because it easily leaches through the soil, it cannot be applied at planting time but it should rather be applied as a side dressing in a split application two weeks

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before tasselling or silking. GGDP (1990) indicated that if organic sources of nitrogen are not available in sufficient quantities, chemical fertilizers should be used in addition to whatever manure or compost is applied. The recommended rate, however, depends on the soil type and cropping history of the field.

2.7 Fertilizer nitrogen application

2.7.1 Maize

Nitrogen is the key element for increasing maize productivity. It is an integral component of many compounds essential for plant growth processes including chlorophyll and many enzymatic activities (Roth and Fox, 1990). Nitrogen is a component of a number of compounds (proteins, nucleic acids, chlorophyll) and has an important role in many plant physiological processes (Raven *et al*., 1999). In particular, it is important in the efficient capture and use of solar radiation and therefore affects yield (Lafitte 2000; Birch *et al*., 2003). Nitrogen also mediates the utilization of potassium, phosphorus and other elements in plants. The optimum amounts of these elements in the soil cannot be utilized efficiently if nitrogen is deficient in plants. Therefore, nitrogen deficiency or excess can result in reduced maize yields. Nitrogen requirements of maize can be as high as 150-200 kg per hectare.

However, nitrogen requirement and utilization in maize also depends on environmental factors like irrigation and varieties. Application of nitrogen fertilizer has also been reported to have significant effect on grain yield and quality of maize (Lucas, 1986). Hardas and

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Aragiaanne-Hrestous (1985) reported that N at 180 kg/ha was optimum for maize. Singh *et al.* (2000) also reported that application of N at 200 kg/ha increased grain yield of maize. However, a substantial percentage of applied nitrogen is lost through volatilization, leaching and denitrification. If water and temperature conditions are ideal then productivity can only be limited by non-availability of nitrogen (Lafitte 2000; Birch *et al.* 2003).

Maize begins to rapidly take up nitrogen and other nutrients during the middle vegetative growth period with the maximum rate of nitrogen uptake occurring near silking stage (Binder *et al.*, 2000). Nitrogen deficiency is indicated by leaf yellowing first in the lowest leaves that starts at the tip and then extends along the mid-rib, stunted plants, delayed flowering and short poorly filled ears (Hughes, 2006). Maize can utilize nitrogen in both the ammonium and nitrate forms but because of the ready conversion of ammonium to nitrate by soil microbes, most nitrogen is taken up as nitrate (Farnham *et al.*, 2003). If nitrogen is supplied via irrigation water, urea is the best source (Birch *et al.*, 2003).

Application of nitrogen had a significant effect on plant height, number of grains per cob, 1000-grain weight and harvest index (Mahmood et *al.,* 2001). Increases in yield due to nitrogen application are supported by the findings of many research workers who reported increases in grain yields of cereals with nitrogen (Buah *et al.*, 1998; Khosla *et al.*, 2000; Workayehu, 2000; Yamoah *et al*., 2002; Aflakpui *et al*., 2005; Conley *et al*., 2005). According to Lafitte (2000) and Birch *et al.* (2003), if water and temperature conditions are ideal then productivity can only be limited by non-availability of nitrogen. Eghball and Maranville (1993) found that the mean nitrogen influx of maize increased with increasing

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soil nitrogen supply. With good agronomic practices, improved maize varieties have the potential to produce 4-6 t/ha of grains (MOFA, 2002). Increase in maize grain yield following increases in the rates of nitrogen was also observed by Luschinger *et al*. (1999), Sabir *et al*. (2000), and Younas *et al*. (2002) in their investigations. Nunes *et al*. (1996) reported that biomass and grain yields of maize crop increased with increasing N rate. Fedotkin and Kravtsov (2001) reported that grain and stover yield increased significantly up to 240 kg N/ha. Shivay and Singh (2000) reported that the highest plant height, leaf area index (LAI) and dry matter accumulation were recorded with 120 kg N/ha. Increased application of N reduced barrenness and increased the shelling percentage. Gokmen *et al*. (2001)stated that plant height, 1000 grain weight and grain weight per cob increased significantly with application of 100 kg N/ha while tasseling period generally decreased with increasing N rate.

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2.7.2 Soybean

Soybean plant has a nutrient dense, high protein seed, and therefore, requires high amount of nutrients for its growth (Lamond and Wesley, 2001). It is a legume that can meet its nitrogen needs by symbiotic relationship with nitrogen fixing bacteria of the species *Bradyrhizobia japonicum* from atmospheric nitrogen (Sarkodie-Addo *et al*., 2006). Generally, the plant will not benefit from supplemental nitrogen fertilizer application, where there are indigenous populations of the appropriate *Bradyrhizobia* bacteria strains that cause effective nodulation of the roots and nitrogen fixation (Darryl *et al*., 2004).

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Gary and Dale (1997) stated that nitrogen fertilizer application circumvents the benefit of Rhizobia bacteria, as the bacteria will not convert atmospheric nitrogen when soil nitrogen is readily available to the plant. However, where soybean have not been grown recently, inoculation of the seed with specific *Bradyrhizobia* strains is essential for effective nitrogen fixation (Darryl *et al*., 2004).

Malik *et al*. (2006) reported that soybean seed inoculation with Rhizobium in combination with phosphorus application at 90 kg per hectare performed better in yield under irrigated conditions. Soybean can produce maximum seed yield with relatively low levels of available phosphorus in the soil. Phosphorus application is not likely to increase seed yield at soil phosphate concentrations above 12 ppm P (Bray-1 test). Also, most soils seldom need potassium fertilizer for soybean production, since K levels are generally high in both surface soil and subsoil. Potassium fertilizer is not required if soil test shows more than 124 ppm (Ferguson *et al*., 2006). Linderman and Glover (2003) stated that of the basic nutrients N, P and K, N is supplied by the symbiotic bacteria in the nodules, while the others come from the soil and will be taken into the plant as it takes up water.

Bacteria present in soybean root nodules will fix nitrogen from the atmosphere, normally supplying most or all nitrogen needed by the plant. Soybean grown on soil where well nodulated soybean has been grown in recent years will probably not require inoculation; however, if there is any question about the presence of Rhizobium bacteria, inoculation is recommended (Darryl *et al*., 2004; Nastasija *et al*., 2008).

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The amount of nitrogen that a plant can fix depends on the variety, the strain of Rhizobium bacteria, the soil and the climatic conditions. Soybean is capable of fixing between 60 kg and 168 kg of nitrogen per hectare per year under suitable conditions (Rienke and Joke, 2005).

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Soybean nitrogen requirements are met in a complex manner as it is capable of utilizing both soil nitrogen in the form of nitrate and atmospheric nitrogen through symbiotic nitrogen fixation. In the symbiotic relationship, carbohydrates and minerals are supplied to the bacteria by the plant, and the bacteria transform nitrogen gas from the atmosphere into ammonium and nitrate for use by the plant (Frazen, 1999). Plant population is one factor that may influence how much residual nitrogen from soybean is contributing to a cropping system. Estimated nitrogen fixation of determinate soybean was approximately increased from 200-280 kg/ha, when plant population was increased from 48,500-194,000 plants/ ha respectively (Ennin and Clegg, 2001).

The process of nitrogen fixation requires the presence of the right species of the nitrogen fixing bacteria in the soil, and they are often attracted to the roots by chemical signals from the soybean root (Rienke and Joke, 2005). Once in contact with the root hairs, a root compound binds the bacteria to the root hair cell wall. The bacteria release a chemical that causes curling and cracking of the root hair, allowing the bacteria to invade the interior of the cells, and begin to change the plant cell structure to form nodules.

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The bacteria live in compartments of up to 10,000 in a nodule, called bacteroids. The nitrogen fixation is aided by an enzyme, nitrogenase which takes place in an environment without oxygen, through a transfer compound, leghemoglobin. This results in a pink-red colour of nodule interiors, an indication of active fixation of nitrogen (Lindermann and Glover, 2003).

Ferguson *et al*. (2006) reported that soybean plant will effectively utilize soil residual nitrate and nitrogen mineralized from soil organic matter, obtaining 25-75% of plant nitrogen, with the balance supplied from symbiotic fixation. Legume nodules that are not fixing nitrogen usually turn white, grey or green and may actually be discarded by the plant. This may be as a result of inefficient Rhizobium strain, poor plant nutrition, pod filling or other plant stresses. Nastasija *et al*. (2008) have outlined the following as factors that influence N-fixation:

- A temperature of 16ºC-27ºC is ideal, while levels above or below this reduce bacterial activity and slow the establishment of the N-fixing relationship.
- When soil Nitrogen levels are too high, nodule number and activity decrease. Roots do not attract bacteria or allow infection; hence, nitrogen fixation is limited.
- Poor plant growth does not allow the plants to sustain nodules and plant growth, therefore sacrificing nodule activity.
- If soil pores are filled with water, and not air, there will be no nitrogen to be fixed.

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2.8 Tillage

In the Guinea savanna zone of Ghana, farmers prepare the land by using hand hoe or by ploughing with tractors or drought animals. However, cultivation with the hand hoe is more common. When the soil is subjected to intensive and repeated tillage, it becomes susceptible to high run-off and soil erosion rates, and soil deterioration. This results in progressive decline in soil productivity and low crop yields (Giller *et al*., 2009). Some of the degraded soils often exhibit a general lack of response to mineral fertilizer addition.

Conservation tillage practices that leave a protective amount of crop residue on the soil surface help to control soil erosion, minimize surface crusting, reduce soil water evaporation and increase the rate of water infiltration. Surface residues maintained with no-tillage also can cause soils to remain cool and wet. Nonetheless, crop residue is often used as a source of fuel-wood and an important dry season livestock feed in the Guinea savanna zone of Ghana. The soil therefore is mostly bare for about six months prior to the cropping season. This is even compounded by the occurrence of indiscriminate annual bush fires in the dry season. Baudron *et al*. (2012) observed that complete residue removal for fodder and fuel, and intensive and excessive tillage can deplete soil organic carbon stocks which often lead to the deterioration of soil fertility and soil water storage capacity, resulting in frequent crop failures. Even where some crop residues are left on the fields, the residues are often grazed freely by livestock during the dry season after harvest of the crops. Hence, their overall contribution to organic N on fields can be negligible.

No-tillage, as an aspect of conservation farming, is actively promoted by international research and development organizations to conserve soils and, by this, ensure food security, biodiversity and water conservation. Conservation tillage practices have the potential to stabilize or increase crop yields over time, but the uptake is very slow (Giller *et al*., 2009). Only a few farmers use some sort of no-tillage system in the Guinea savanna zone of Ghana (Peterson, 2014).

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Conservation tillage practices on soil degradation in West Africa shows that such practices often, but not always, produce a positive grain yield effect (Bayala *et al*., 2011). In addition, maize-based conservation systems have showed significantly higher and more stable grain yield trends compared to conventional tillage systems in several studies (Aflakpui *et al*., 1993; Buah *et al*., 2000; Ngwira *et al*., 2012; Thierfelder *et al*., 2013).

Improved crop yields can be translated into increased revenues, but a net gain in revenue is achieved only if the benefits exceed additional cost. The proponents of conservation agriculture practices argue that the economic benefits can only be realized in the medium to long term. Data from two years on-farm studies support cost savings of conservation agriculture practices due to reduced labour and machinery time despite an increase in agro-chemical usage (Ribera *et al*., 2004).

2.9 Intercropping

Seran and Brintha (2010) defined intercropping as a type of mixed cropping and the agricultural practice of cultivating two or more crops in the same space at the same time. The important reason to grow two or more crops together is the increase in productivity per unit of land. In intercropping system, all the environment resources are utilized to

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maximize crop production per unit area per unit time. Risk may be minimized in intercropping (Woolley and Davis, 1991). Biological efficiency of intercropping is due to exploration of large soil mass compared to mono-cropping (Francis, 1989). This advanced agro technique has been practiced in past decades and achieved the goal of agriculture. There are some socio-economic (Ofori and Stern, 1987), biological and ecological advantages (Aggarwal *et al*., 1992; Fininsa, 1996) in intercropping over mono-cropping. Several scientists have worked on intercropping (John and Mini, 2005; Suresha *et al*., 2007; Seran and Jeyakumaran, 2009; Brintha and Seran, 2009), and most studies on intercropping had focused on the cereal based intercropping (Ofori and Stern, 1987; Ali *et al*., 2000; Langat *et al*., 2006; Hugar and Palled, 2008) and proved the success of intercropping.

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Successful intercropping needs several considerations before and during cultivation. Silwana and Lucas (2002) found that intercropping affects vegetative growth of component crops. There is therefore the need to consider the spatial, temporal and physical resources (Willey and Rao, 1981). Economically viable intercropping largely depends on adaptation of planting pattern and selection of compatible crops (Seran and Brintha, 2009). Cereal-legume intercropping, which has the potential to provide nitrogen depends on densities of crop, light interception, crop species and nutrients (Francis, 1989).

Compatible crop selection is vital in intercropping. The choice of compatible crops for an intercropping system depends on plant growth habit, land, light, water and fertilizer utilization (Brintha and Seran, 2009). Hardarson and Atkins (2003) found legume-cereal

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intercropping increased the fixation of nitrogen by legumes. Silwana and Lucas (2002) reported different crop species in mixtures increased capture of growth limiting resources. Midmore (1993) stated that different planting time of component crops improved the resource utilization and reduced the competition.

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2.9.1 Crop maturity, compatibility, density and time of planting

When two or more crops are grown together, the peak period of growth of components do not coincide. The biggest complementary effects and thus biggest yield advantages are seen to occur when the component crops have different growing periods, hence make their major demands on resources at different times. Crops of varying maturity duration should be chosen. A rapidly maturing crop completes its life cycle before the major growth period of the other crop commences. Crops which mature at different times thereby separating their periods of maximum demand to nutrients, moisture, aerial space and light could be suitably intercropped (Fawusi, 1985).

In maize-green gram, peak light demand for maize is around 60 days after planting, whiles green gram is ready to harvest (Reddy and Reddi, 2007).

Soybean plants are sensitive to day length, but not all plants respond the same way (Ritchie *et al*. 1994). Some cultivars flower under relatively short days while others flower under longer days. Cultivars of soybean are adapted to a narrow band of latitude and this zone of adaptation is identified by number. The narrow adaptation zone of soybean is due primarily to dependence on day length (photoperiod). Phytochrome, which is a

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photoreceptor in soybean, responds to changes in red to far-red light (R: FR ratio) and induces a photoperiod response (Song 1984). Phytochrome exists in two forms, Pr and Pfr. The red-absorbing form of the photoreceptor is reversibly activated by light to the far-red absorbing form. This physiologically active far-red-absorbing form triggers flowering in soybean.

Soybean yield is dependent on a large number of variables including weather, soil, fertility, genotype and physiology. Once soybean is planted, several of these variables are set and yield will primarily be the result of the physiology of the crop interacting with the weather. Photosynthesis has long been assumed to be one of the key physiological processes in regards to soybean productivity (Christy and Williamson 1985). Christy and Porter (1982) reported that soybean grain yield is strongly dependent on seasonal photosynthesis. In these studies, yield was related to the total amount of photosynthesis carried on by the crop during the growing season.

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Choosing the crop combination plays a vital role in intercropping. Plant density, shading and nutrition competition between plants reduce the yield of monocrop. Plant competition could be minimized not only by spatial arrangement, but also by choosing those crops best able to exploit soil nutrients (Fawusi, 1985). Seran and Brintha (2010) reported groundnut to be usually intercropped with maize in South East Asia and Africa. They also reported that popondo (*Phaseolus lunatus*) and mucuna (*Mucuna utilis*) lowered maize yield, while calopo (*Calopogonium tnucunoides*), cowpea (*Vigna sinensis*) and green gram (*Phaseolus aureus*) had much less effect on maize and were themselves tolerant to maize shade. Seran

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and Brintha (2010) stated that increased yield from better use of space in mixture are complimentary to utilizing time with crops in sequences. Therefore, maximum cropping should be obtained with sequences of high yielding crops in compatible mixtures. Cereal-legume intercropping is commonly practiced in Asia, Africa and South America (Vandermeer, 1992; Maluleke *et al*., 2005). In the tropics, maize-cowpea intercropping is often practiced (Van Kessel and Roskoski, 1988; Mpangane *et al*., 2004). Krantz (1981) found maize to be easily managed in maize-pigeon pea intercropping. Singh *et al*. (1998) stated in Central and South America and parts of East Africa that, maize is intercropped with bean.

Low plant population per unit area leads to low yield (Jeyakumaran and Seran, 2007). The seedling rate of each crop in the mixture is adjusted below its full rate to optimize plant density. If full rates of each crop were planted, neither would yield well because of intense overcrowding. By reducing the seedling rates of each, the crops have a chance to yield well within the mixture. The challenge comes in knowing how much to reduce the seedling rates. Modification of planting pattern of capsicum in intercropping system is feasible for vegetable cowpea cultivation (Jeyakumaran and Seran, 2007). Planting of pearl millet in paired row may provide additional space for an intercropping (Sivaraman and Palaniappan, 1996). Keeping the plant population per unit area of the base crop constant, no deviation of its yield has been noted by altering the orientation of the rows (Sivaraman and Palaniappan, 1996). Brintha and Seran (2009) stated that in radish-vegetable *amaranthus* intercropping, yield of radish was not significantly affected due to constant plant density of radish in mono-cropping and intercropping. The planting pattern of the maize and legumes

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(intercropping or growing maize after the legume harvest) did not affect the yield of maize (Ullah *et al*., 2007). A reasonable Leaf Area Index (LAI) is critical to maintain high photosynthetic rates and yield (Xiaolei and Zhifeng, 2002). Prasad and Brook (2005) reported that increasing maize plant density had significant effect on LAI in maize-soybean intercropping. In maize-okra intercropping, high plant density reduced number of leaves due to competition for light and other resources (Muoneke and Asiegbu, 1997). It was agreed with Prashaanth *et al*. (2009) in brinja -groundnut intercropping.

Mongi *et al*. (1976) found planting cowpea simultaneously with maize gave better yield. Amede and Nigatu (2001) stated that simultaneously planting maize and sweet potato did not influenced maize grain yields, whereas late planting of sweet potato negatively affects maize yield. Several researches have been focused on bush bean and maize planted simultaneously in alternate rows (Frankis *et al*., 1978; Pilbeam, 1996; Santalla *et al*., 1999).

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2.9.2 Maize-based intercropping

Intercropping of legumes and cereals is an old practice in tropical agriculture that time back to ancient civilization. Intercropping with maize is a way to grow a staple crop while obtaining several benefits from the additional crop. Snaydon and Harris (1979) found legume-cereal to be the most popular intercropping system in the tropics. Systems that intercrop maize with a legume are able to reduce the amount of nutrients taken from the soil as compared to a maize monocrop. In the absence of nitrogen fertilizer, intercropped legumes will fix nitrogen from the atmosphere and not compete with maize for nitrogen

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resources (Adu-Gyamfi *et al*. 2007). The mixture of nitrogen fixing crop and non-fixing crop gives greater productivity than mono-cropping (Seran and Brintha, 2009). Banik and Sharma (2009) reported that cereal-legume intercropping systems were superior to mono-cropping. Maize-french bean gave high maize equivalent yield over sole maize yield (Hugar and Palled, 2008) and kernel yield of maize was unaffected in maize-french bean intercropping (Pandita, 2001). Akinnifesi *et al*. (2006) revealed that without nitrogen fertilizer application, gliricidia-maize intercropping system gave high maize yield. West and Griffith (1992) observed maize yield increased by 26% in maize-soybean strip intercropping. This was agreed with Ghaffarzadeh *et al*. (1994). Tsubo *et al*. (2005) found that in maize-bean intercropping, maize yield was not affected.

2.9.3 Benefits of intercropping

2.9.3.1 Resource utilization

The main reasons for higher yields in intercropping is that the component crops are able to use natural resources differently and make better overall use of natural resources than grown separately (Marer *et al*., 2007). The efficient use of basic resources in the cropping system depends partly on the inherent efficiency of the individual crops that make up the system and partly on complimentary effects between the crops (Willey and Reddy, 1981). Biological basis for intercropping involves complementarily of resources used by the two crops (Barhom, 2001).

One of the main yield advantages in intercropping those crops sown as intercrop combination may be able to make better overall use of resources than when growing

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separately (Seran and Brintha, 2010). The partitioning of limiting resources among crop plants occurs whenever plants are grown in association (Blade *et al*., 1997).

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Soil fertility problems are not only an agronomic issue, but also strongly related to economic and social issues. Poor farmers are typically risk adverse and cannot afford to make large investments in relation to fertility management. Number of pods per capsicum plant were lower in capsicum-vegetable cowpea intercropping compared to mono-cropping due to nutrition and light competition (Seran and Jeyakumaran, 2009). Integrated nutrient management adopts a holistic approach to plant nutrient management by considering the totality of the farm resources that can be used as plant nutrients. Vesterager *et al*. (2008) found maize and cowpea intercropping is beneficial on nitrogen poor soils. Maize-cowpea intercropping increases the amount of nitrogen, phosphorous and potassium contents compared to monocrop of maize (Dahmardeh *et al*., 2010). Seran and Brintha (2010) reported that nutrient uptake and utilization is more efficient in corn-rice and corn-soybean intercrops than in those crops as monocrop.

Different root and leaf systems are able to harness more light and make use of more water and nutrients than when the roots and leaves of only one species are present. When only one species is grown, all the roots tend to compete with each other since they are all similar in their orientation and below surface depth. Similarly, the leaves of plants of the same species are directly opposite and growing at the same rate as each other, whereas the leaves of a plant of another species do not compete directly for sunlight in space and time.

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In the tropics, multi-storey plants harvested in sequence can utilize the sun's energy on a year round basis. A combined leaf canopy might make better use of light (Waddington and Edward, 1989). Intercropping between high and low canopy crops is a common practice in tropical agriculture and to improve light interception and hence yields of the shorter crops requires that they be planted between sufficiently wider rows of the taller once.

Intercropping creates microclimate favour in the lower plant growth (Azam-Ali *et al*., 1990). Jiao *et al*. (2008) found maize-groundnut intercropping enhanced the efficient utilization of strong light by maize and weak light by groundnut. Soybean and maize intercropping has been attributed to better use of solar radiation (Keating and Carberry, 1993), nutrients (Willey, 1990) and water (Morris and Garrity, 1993) over the mono crop. When two morphologically dissimilar crops with different periods of maturity are intercropped, light is the vital factor that determines the yield (Ijoyah, 2012). Competition of light affected the plant height in capsicum-bushitao intercropping (Jeyakumaran and Seran, 2007).

Availability of water in cropping system is vital to determine the growth of plant. Improvement of water use efficiency in intercropping leads to increase uses of other resources (Hook and Gascho, 1988). Intercrops have been identified to conserve water largely because of early high leaf area index and higher leaf area (Ogindo and Walker, 2005). Under normal condition cereal-legume intercropping uses water equally (Ofori and Stern, 1987). Various root systems in the soil reduces water loss, increases water uptake and increases transpiration that leads to create microclimate cooler than surroundings

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(Innis, 1997). Morris and Garrity (1993) mentioned that water captured by intercrops is higher and about 7% compared to monocrop. Ryan *et al*. (2008) stated cereal-legume use water more efficiently than mono-cropping. Barhom (2001) reported that water use efficiency was the highest under soybean-maize intercropping compared with mono-cropping maize and mono-cropping soybean. Soybean-maize intercropping was the best combination system during water scarcity periods (Tsubo *et al*., 2005). In areas of water scarcity, intercropping is a suitable method (Lynam *et al*., 1986). Biological efficiency of intercropping due to exploration of large soil mass compared to mono-cropping (Francis, 1989).

2.9.3.2 Weed, pest, disease and erosion control

Intercropping might better control weeds, pests and diseases. Evidence of better weed control is reasonably clear where intercropping provides a more competitive effect against weeds either in time or space than does mono-cropping. Weed population was reduced in brinjal-groundnut intercropping (Srikrishnah *et al*., 2008). The nature and magnitude of crop-weed competition differs considerably between mono and intercrop combinations. The crop species, population density, sowing geometry, duration, growth rhythm of the component crop, the moisture and fertility status and tillage influenced weed flora in cropping system.

Crop-weed competition is determined by growth habit of crop. Increased leaf cover in intercropping systems helps to reduce weed populations once the crops are established (Beets, 1990). Shading showed considerable potential as a means of reducing the spread of

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Cyperus rotundus (Patterson, 1982). This re-emphasizes the possible importance of growing more than two crops on the same land at the same time. Mixed cropping reduces weed incidence (Altieri and Liebman, 1986; Zuofa *et al*., 1992). Makindea *et al*. (2009) found leafy greens can be intercropped with maize to control weeds in the tropics and increase productivity. Weed suppression in maize-groundnut intercropping was reported by Steiner (1984). Intercropping maize and legumes considerably reduced the weed density compared with the mono-cropping maize by decrease in available light for weeds compared to monocrops (Dimitrios *et al.*, 2010). Maize-cowpea intercropping suppresses weeds and ensures against total crop failure when one crop fails. Maize-pumpkin and maize-bean intercropping reduced weed biomass by 50-66% when established at a density of 12,300 and 222,000 plants ha^{-1} for beans (Mashingaidze, 2004). Mugabe *et al*. (1982) noted intercropping controlled weed effectively and reduce the harvestable biomass. Advantages from intercropping in weed control under low input conditions and increases in components of crop yields leads to improved weed control (Liebman and Dyck, 1993). Maize-rye intercropping reduces weed biomass by 50% (Samson, 1991).

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Maize is susceptible to many insects (Drinwater *et al*., 2002) and diseases (Flett *et al*., 1996). Intercropping appears to be a very promising cultural practice for this purpose. It is generally believed that one component crop of an intercropping system may act as a barrier or buffer against the spread of pests and pathogen. Intercropping maize-cowpea reduces the stem borer (Henrik and Peeter, 1997). Maize leafhopper (*Dalbus maindis* L.) was reduced under intercropping reported by Power (1990). Seran and Brintha (2010) found that maize-groundnut and maize-soybean mixed crop reduced the number of corn borer in

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maize. Insect problems are less on crops grown in mixture, especially with cowpea, pigeon pea, maize and some legumes (Hayward, 1975). Trenbath (1993) noted that pest and diseases were high in mono-cropping compared to intercropping. In chilli-maize intercropping, the incidence of *Anthonomus eugenii* was lower and yield was greater compared to chilli alone (Gutierrez, 1999). Pino *et al*. (1994) found pest and disease were less in tomato-maize intercropping. Soybean and groundnut are more effective in suppressing termite attack than common beans (Sekamatte *et al*., 2003). Umarajini and Seran (2008) stated incidence of white fly and leaf hopper were lower in brinjal-groundnut intercropping compared to mono-cropping. Singh and Adjeigbe (2002) stated mono-cropping needs more chemical to control pest and disease than intercropping.

Intercropping controls soil erosion by preventing rain drops from hitting the bare soil where they tend to seal surface pores, prevent water from entering the soil and increase surface erosion. Maize-cowpea intercropping, cowpea act as best cover crop and reduced soil erosion (Kariaga, 2004). Reddy and Reddi (2007) mentioned taller crops act as wind barrier for short crops. In brinjal-groundnut intercropping, pod weight of brinjal in mono-cropping was low due to absence of intercrop which leads to high water evaporation in soil surface (Prashaanth *et al*., 2009).

Rows of maize in a field with a shorter crop will reduce the wind speed above the shorter crops and thus reduce desiccation (Beets, 1990). Anil *et al*. (1998) suggested that multiple cropping systems increase the soil protection by increased vegetative growth during critical erosion periods.

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2.9.3.3 Crop yield and productivity of intercropping

Yield is taken as primary consideration in the assessment of the potential of intercropping practices (Anil *et al*., 1998). In legume and cereal intercropping, yield of cereal increased in intercropping as compared with mono-cropping (Brintha and Seran, 2008). Mashingaidze (2004) found that by intercropping, land was effectively utilized and yield was improved. The crops are grown together because of higher yields and greater biological and economic stability in the system (Francis, 1986). Land Equivalent Ratio (LER) is the most common index adopted in intercropping to measure the land productivity. It is often used as an indicator to determine the efficacy of intercropping (Seran and Brintha, 2009). LER greater than one indicates greater efficiency of land utilization in intercropping system. It is due to greater efficiency of resource utilization in intercropping or by increased plant density (Hashemi-Dezfouli and Herbert, 1992). Mandal *et al*. (1990) stated that LER shows advantages of cereal-legume intercropping. Tsubo *et al*. (2005) stated legume-cereal intercropping is generally more productive than monocrop. When two crops are grown together yield advantages occurs because of differences in their use of resources (Willey *et al*., 1983). Intercropping gives a greater stability of yield over monoculture (Willey and Reddy, 1981) and intercropping was more productive than sole crop grown on the same area of land (Anil *et al*., 1998). LER value exceeding unity in radish-vegetable amaranthus intercropping indicates yield advantages from intercropping compared to mono-cropping (Seran and Brintha, 2009). Legume and non-legume intercropping increases total grain and nitrogen yield (Barker and Blamey, 1985; Singh *et al*., 1986).

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In intercropping, higher yield and greater yield stability over mono-cropping was reported by Ofori and Stern (1987). Seran and Brintha (2010) reported that in intercropping, shading and reduced assimilate production have least effect on yield, while competition prevails during vegetative periods. Amede and Nigatu (2001) consistently received LER of 1.5 or greater when using the early maturing variety of maize. Maize-Kenaf-African Yam bean gave LER of 1.12 (Adeniyan *et al*., 2007). Mohta and De (1980) stated that LER increased to a maximum of about 48% by intercropping maize with soybeans compared with the cereal sole crops.

Intercropping often provides higher cash return than growing one crop alone (Grimes *et al*., 1983; Kurata, 1986). Intercropping occupies greater land use and thereby provides higher net returns (Seran and Brintha, 2009). Kalra and Gangwar (1980) reported that intercropping helps in increasing farm income on sustained basis. Intercropping commonly gave greater combined yields and monetary returns than obtained from either crop grown alone (Ahmad and Rao, 1982). Intercropping capsicum and vegetable cowpea gave higher net return compared to mono-cropping (Seran and Brintha, 2009).

One of the most important reasons for intercropping is to ensure that an increased and diverse productivity per unit area is obtained compared to sole cropping (Sullivan, 2003). For instance, using LER in a maize-soybean intercropping system, Kipkemoi *et al*. (2002) reported that it is greater than one under intercrop. Muoneke *et al.* (2007) found that the productivity of the intercropping system indicates yield advantage of 2-63% showing efficient utilization of land resource by growing the crops together. Raji (2007) had also reported higher production efficiency in maize-soybean intercropping systems. Addo-Quaye *et al*. (2011) found that LER was greater than unity, implying that it will be more productive to intercrop maize and soybean than grow them in monoculture. Allen and Obura (1983) observed LER of 1.22 and 1.10 for maize-soybean intercrop in two consecutive years. Prasad and Brook (2005) reported that Land equivalent ratios of all maize-soybean intercrops were greater than unity (1.30-1.45), indicating higher efficiency of intercropping compared to sole crops.

2.9.4 Biological Nitrogen Fixation

One promising alternative that can substantially reduce investment in fertilizers is the inclusion of legumes in the various cereals farming systems (Osunde *et al*., 2004), due to the fact that legumes have the ability to biologically fix nitrogen from the atmosphere, which is the major source of N in legume-cereal mixed cropping systems (Fujita *et al*., 1992). Osunde *et al*. (2004) found that without the addition of fertilizer the proportion of N derived from N-fixation was about 40% in the intercropped soybean and 30% in the sole crop, and with application of 40 kgNha^{-1}. Yusuf *et al*. (2007) found that maize grain yield was 46% significantly higher when grown after soybean than after maize and natural fallow.

Evidence suggests that associated non-legumes may benefit through N-transfer from legumes (Fujita *et al*., 1992). This N-transfer is considered to occur through root excretion, N leached from leaves, leaf fall, and animal excreta if present in the system (Fujita *et al*., 1992). Eaglesham *et al.* (1981) showed that 24.9% of N fixed by cowpea was transferred

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to maize. However, Ofori and Stern (1987) and Danso *et al*. (1993) reported that there is little or no current N transfer in cereal-legume intercropping system. In addition, Fujita *et al*.(1992) reported that benefits associated to non-leguminous crop in intercropping systems is influenced by component crop densities, which determine the closeness of legume and non-legume crops, and legume growth stages. Despite claims for substantial N-transfer from grain legumes to the associated cereal crops, the evidence indicate that benefits are limited (Giller *et al*., 1991). Benefits are more likely to occur to subsequent crops as the main transfer path-way is due to root and nodules senescence and fallen leaves (Ledgard and Giller, 1995).

The intercrop legume may accrue N to the soil and this may not become available until after the growing season, improving soil fertility to benefit a subsequent crop (Ofori and Stern 1987; Ledgard and Giller, 1995). Kumwenda *et al*. (1998) reported that sun hemp (*Crotalaria juncea*), Tephrosia (*Tephrosia vogelii*) and velvet bean (*Mucuna pruriens*) green manure often resulted in maize yields of 3-6 tha^{-1} even with no addition of mineral N fertilizer. Moreover, Chibudu (1998) found that maize yields were increased about 25% and 88% after maize-mucuna and maize-cowpea intercropping systems, respectively. Phiri *et al*., (1999) found that maize yields were increased about 244% after maize-*Sesbania sesban* intercropping system.

Kureh and Kamara (2005) found that maize grain yield was 28% higher after one year of soybean and 21% higher after one year of cowpea than in the continuously cropped maize. Maize grain yield was 85% higher after two years of soybean, and 66% higher after two

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years of cowpea than in the continuously cropped maize. Furthermore, Akinnifesi *et al*. (2007) found that over 4 consecutive cropping seasons, grain yields of maize increased by 340% in gliricidia-maize intercropping, when compared to unfertilized sole maize. Bationo *et al*. (1995) reported that intercropping of cowpea with millet may enhance millet grain yields by 30% above the control.

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2.9.5 Limitations

Despite the benefits of cereal-legumes intercropping systems in Integrated Soil Fertility Management (ISFM), there are some constraints that need to be curbed so as to attain progress (Mugendi *et al*., 2011; Odendo *et al*., 2011). For instance, within the regions of some countries the soils are acidic with limited phosphorus availability (Sanchez *et al*., 1997), which is harmful for Biological Nitrogen Fixation process and therefore lessen the N contribution of the legume component to system (Giller, 2001; Fujita and Ofosu-Budu, 1996). This is worsened by the current use of mineral fertilizers that is still low among smallholder farmers (Palm *et al*.,1997), which is associated to accessibility and affordability of appropriate fertilizer due to financial and infrastructure problems (Jama *et al*.,2000).

Lack of access to improved seed on time to these farmers, which is associated to poor market and policy are also contributing negatively to the successful contribution of these systems (Mugendi *et al*., 2011). Moreover, legume trees and legume cover crops have been repeatedly demonstrated to improve and maintain soil fertility under different environmental conditions, compared to grain legumes intercropping systems (Mugendi,

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1997; Mugendi *et al*., 1999; Kumwenda *et al*., 1998; Mugwe *et al*., 2011; Bationo *et al*., 2011). However, they have increasingly emerged as the least prioritized by smallholder farmers under their prevailing circumstances, which can be largely attributed to their lack of short-term benefits of both food and income (Mugendi *et al*., 2011; Bationo *et al*., 2011).

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Furthermore, there is lack of information and knowledge about fertility management technologies because most of the research that has been done related to cereal-legumes intercropping system in the past decades had less involvement of farmers, particularly the resource-constrained farmers (Mugendi *et al*., 2011; Maphumo, 2011), which is worsened by low technical knowhow of extension services on legume-based ISFM technologies (Maphumo, 2011).

Consequently, there are misconceptions among smallholder farmers about the role of legumes in the soil fertility management (Mtambanegwe and Maphumo, 2009). As consequence of these, the optimum productivity of cereal-legume systems is still a big challenge to the stakeholders involved in this sector.

Intercropping can lead to reduction in yield of one or more of component crops due to adverse competitive effects (Willey and Rao, 1980). Competition between component crops for growth limiting factor is regulated by basic morpho–physiological differences and agronomic factors such as proportion of crops in the mixture, fertilizer applications and relative sowing time (Willey and Rao, 1980). Where component crops are arranged in

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definite rows, the degree of competition is determined by the relative growth rates, growth duration and proximity of roots of the different crops (Willey and Rao, 1980).

In cereal-legume intercrops, cereal component with relatively higher growth rate and a more extensive rooting system is favored in the competition with associated legume (Ofori and Stern, 1987). Ofori and Stern (1987), showed that the yield of the legume component declined on average by about 52% of the sole crop yield whereas the cereal yield reduced by only 11%. The general observations from these are that, yields of the legume components are significantly depressed by cereal components in intercropping, which is attributed to reduced photosynthetically active radiation (PAR) that reaches the lower parts of the maize canopy occupied by the soybean crop.

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Another limitation of intercropping is often thought to be difficulties concerned with practical management of intercropping especially where there is a high degree of mechanization or where the component crops have different requirements for fertilizer and pesticides (Willey *et al*., 1980).

2.9.6 Intercropping and shading

Intensity and quality of solar radiation intercepted by a soybean canopy during the reproductive period is an important environmental factor determining soybean yield and yield components (Liu *et al*., 2010; Mathew *et al*., 2000). Mathew *et al*. (2000) stated that the yield of soybean is controlled by the availability of photosynthesis during post-flowering stage of development. Schou *et al.* (1978) reported that light levels during late

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flowering to mid-pod formation stages of growth are more critical than during vegetative and late reproductive periods in determining the yield of soybean. Taylor *et al*. (1982) concluded that pod abortion caused by lack of photosynthate supplied late in the growing period is a major factor limiting yield of soybean. Duncan (1986) suggested that light intercepted during and after seed initiation is a major determinant of yield.

In an experiment by Jiang and Egli (1993), shade imposed from first flower to early pod-fill reduced flower production and increased flower and pod abscission, resulting in reduced pod number and yield. They also found canopy photosynthesis during flowering and pod set to be an important determinant of seeds, and that the impact of shading on seeds depends on duration of shading. Furthermore, Herbert and Litchfield (1982) observed that pod number per plant was the most important component responsible for differences in soybean yield between different row widths and densities within a particular year, while a change in seed size resulted in the yield difference between two consecutive years. Thus, there is a differential response of yield components to changes in environmental conditions.

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Shading (49-20% of ambient light) resulted in lengthening of internodes and increased lodging in soybean plants (Ephrath *et al*., 1993). Light enrichment initiated at late vegetative or early flowering stages increased seed yield from 144-252%, mainly by increasing pod number. While light enrichment beginning at early pod formation increased seed size 8-23%, resulting in a 32-115% increase in seed yield (Mathew *et al*., 2000).

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2.10 Soil quality and fertilizer use in Ghana

Soil quality in sub-Saharan Africa has long been deteriorating, and the soil in Ghana is no exception. Significant soil multi-nutrient (NPK) deficiencies have been found throughout Ghana and appear to be at least partially due to poor cultivation practices. In the North, significantly lower chemical and nutrient properties have been found in permanently cultivated soils compared to soils under natural vegetation (Braimoh and Vlek, 2004).

In the South, rice yields were shown to increase significantly with the application of mineral fertilizer to correct these deficiencies (Moro *et al*., 2008). Overall, Ghana is estimated to have annual nutrient losses around 60 kgha^{-1} NPK, among the highest rates in sub-Saharan Africa (Henao and Baanante, 1999; Stoorvogel *et al*., 1993).

Several studies have suggested that large increases in fertilizer usage are necessary to correct the massive nutrient losses of much of the arable land in Sub-Saharan Africa (Morris *et al*., 2007; Crawford *et al*., 2005; Heisey and Mwangi, 1997; Wallace and Knausenberger, 1997). Currently, sub-Saharan Africa has the lowest fertilizer application rates of any region, with application rates around 10 kgha^{-1}. Africa contains 25% of the world’s arable land, yet represents less than 1 percent of global fertilizer consumption (Kariuki, 2011; Morris *et al*., 2007).

In Ghana, fertilizer use as of 2010 was well below the average in Sub-Saharan Africa and less than 6 kgha^{-1} (FAOstat, 2014). Historically, Ghana has seen some fluctuations in fertilizer usage, but the rates have always remained relatively low (FAO, 2005). Average

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fertilizer use on maize fields is higher than on all fields in Ghana, but the application rates are still low. Numerous studies have shown that increasing these fertilizer-use rates and the efficiency of its application can significantly increase agricultural yields, hence in an effort to increase yields through increasing fertilizer use in 2008, Ghana launched the fertilizer and seed subsidy program (Ersado *et al*., 2003; Kherallah *et al*., 2002; Weight and Kelly, 1999; Yanggen *et al*., 1998).

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CHAPTER THREE

MATERIALS AND METHODS

3.1 Description of the study area

The study was conducted during the 2015 cropping season at the research field of Integrated Water and Agriculture Development (IWAD) at Yagaba in the Mamprugu Moagduri District of Ghana (Figure 1). The area lies on an altitude of 183 m and longitudes 0^{o}35’W and 1^{o} 45’W and latitude 9^{o} 55’N and 10^{o} 35’N.

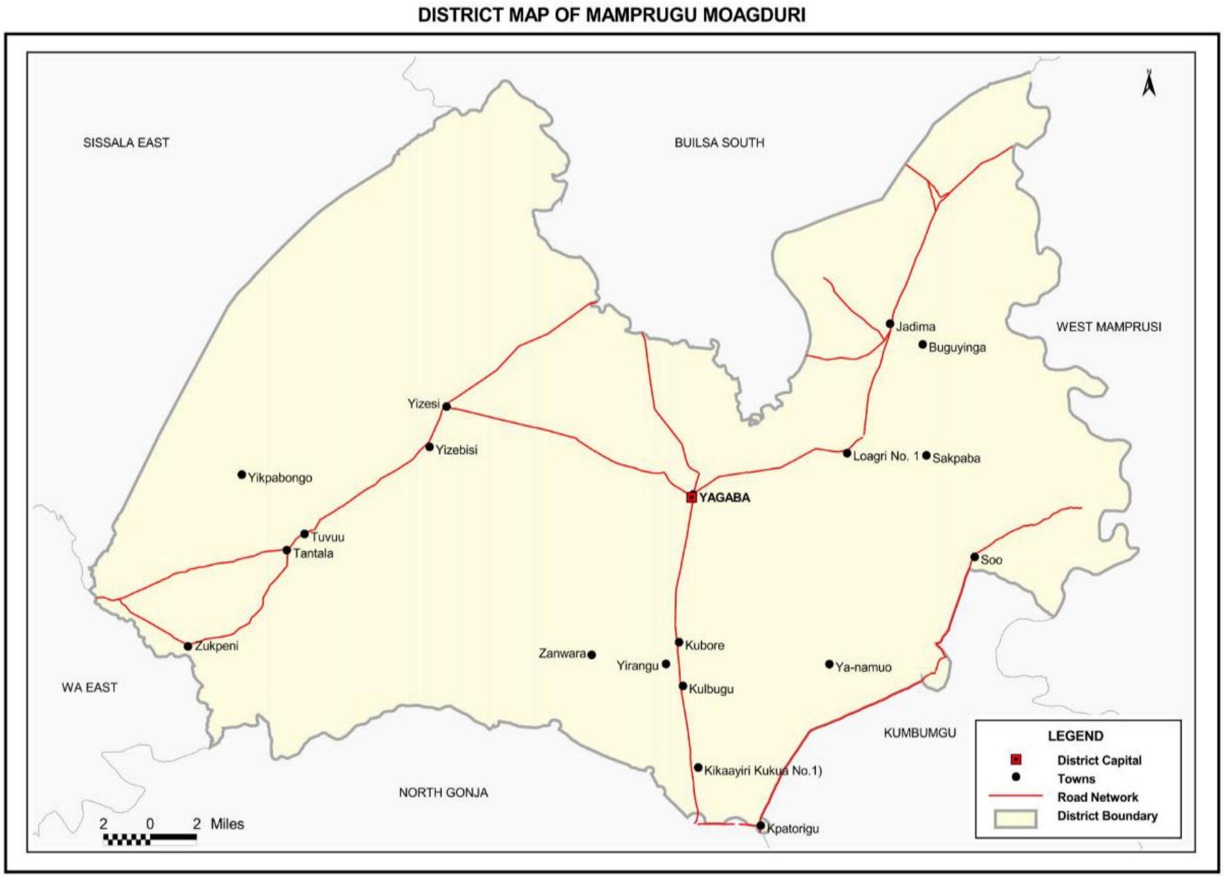

Figure 1: Map of Mamprugu Moagduri district showing location of IWAD. Source: Ghana Statistical Service, (GIS).

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The district lies within the Guinea savannah agroecological belt with single maxima rainfall regime. Average annual rainfall is between 1000 mm and 1400 mm with rains occurring between May and October (Armah *et al.*, 2011).July to September is normally the peak period for rainfall. Floods occur during the peak period after which there is a prolonged dry season from November to April. Temperatures are generally high all year round with the hottest month being March. Average monthly temperature is between 25^{o} and 30^{o}C. In the rainy season, there is high humidity and sunshine with heavy thunder storms. The dry season is characterized by dry harmattan winds from November to February and high sunshine from March to May. The vegetation of the site is savanna grassland, characterized by shrubs and few scattered trees (Nanang, 1998).

The district geology is made up of middle voltain rocks normally suitable for rural water supply. It is largely covered by a flat and undulating terrain. The most significant river in the district is the White Volta and its tributaries include Sissili and the Kulpawn rivers. Along the valleys of these rivers are large arable lands good for the cultivation of rice and other cereals. Soils in the district were developed under the Guinea Savannah vegetation. The soils are rich in nutrients especially along the valleys. Alluvial soils are quite extensive around the valleys which are also suitable for rice production. There is considerable soil erosion in the district due to bad farming practices and rampant burning of the bush.

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3.2 Land preparation

1. Ploughing: It essentially consists of opening the upper crust of the soil, breaking the clods and making the soil suitable for sowing seeds. A single plough operation, followed by a single harrowing to break clods and remove weeds was carried out using a tractor prior to lining and pegging.
2. Direct seeding: All pre-planting mechanical seed bed preparation was eliminated except for the creation of a narrow (2-3 cm wide) strip in the ground for seed placement to ensure adequate soil contact.
3. Ripping: The implement was adjusted to create ripped lines at a spacing of 80 x 40 cm after slashing the vegetation.

3.3 Experimental design

A split-split plot design was used comprising tillage system at three levels (plough, ripping and direct seeding), cropping system at two levels (sole maize, intercrop) and NPK fertilizer application rate at three levels (0 kg/ha, half the recommended rate of 30-15-15 kg/ha and the recommended optimum rate of 60-30-30 kg/ha).The tillage system was assigned to the main plot, cropping system to the sub-plot and the NPK fertilizer rate to the sub-sub plot. Each plot measured 5 x 5 m.

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3.4 Cultural practices

3.4.1 Planting

Two seeds of the maize variety (Pannar 35) was planted at a spacing of 80 cm x 20 cm. Soybean (Jenguma variety) seeds was hand drilled at a spacing of 80 x 10 cm. The planting pattern was 2:1 between rows.

3.4.2 Rate of Fertilizer application

NPK fertilizer was applied at recommended full rate of NPK (60-30-30 kg/ha), half the recommended rate (30-15-15 kg/ha) and zero (0 kg/ha). The fertilizer was banded on both sides of the plant and buried 3 weeks after planting (WAP).

3.4.3 Weed control

Weed control was carried out at 2 and 5 weeks after planting (WAP). Weeds in the ploughed and ripped plots were controlled using hand hoe, whiles those in the direct seeded plots were controlled using pre-emergence herbicide, Atrazine 80 WP(80g a.i./ha), applied at a rate of 1 litre per hectare.

3.5 Data collection

Soil physico-chemical properties and plant growth and yield parameters were collected. Total nitrogen, available phosphorus, exchangeable potassium, soil pH, organic matter and carbon were the chemical properties determined. Sand, silt and clay content were the soil physical properties determined before and after planting. Growth and yield parameters

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measured included plant height, leaf number, cob length, hundred seed weight, number of pods per plant, pod length and grain yield.

3.5.1 Soil sampling

A representative soil sample was taken at different parts of the field before ploughing and ripping. The soil augur was used to sample soil at randomly selected sites on each treatment plot. The samples were taken at a depth of 0-15 cm and 15-30 cm. They were then mixed thoroughly, air-dried and made to pass through a 2 mm, and 0.5 mm sieves for soil texture and chemical analysis. The soil samples were analyzed for both physical and chemical properties of the soil.

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3.5.1.1 Analysis of Soil physical properties

3.5.1.2 Particle size distribution

Particle size analysis estimates percentage of sand, silt and clay and is often reported as percentage by weight of oven-dry and organic matter-free soil. The particle size analysis was done by the hydrometer method as outlined by Anderson and Ingram (1993).A 50 g air-dried soil was weighed into a conical flask and a dispersing agent (sodium hexametaphosphate) added. After shaking on a reciprocal shaker at 400 rpm overnight (18 hours), the samples were transferred to 1 L sedimentation cylinders and made up to the mark with distilled water. A hydrometer was used to measure the density of the suspension of soil and water at various times using the formular below:

% Sand = 100 – [H1 + 0.2 (T1 - 20) – 2] x 2

% Clay = [H2 + 0. 2 (T2 – 20) – 2] x 2

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% Silt = 100 – (% Sand + % clay)

Where

WT= Total Weight of air-dried soil

H1 = 1st Hydrometer reading at 40 seconds

T1 = 1st Temperature reading at 40 seconds

H2 = 2nd Hydrometer reading at 3 hours

T2 = 2nd Temperature reading at 3 hours

– 2 = Salt correction to be added to hydrometer reading

0.2 (T – 20) = Temperature correction to be added to hydrometer reading, and T = Degree celsius.

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3.5.1.3 Analysis of Soil Chemical properties

3.5.1.4 Soil pH

A 10 g air- dried soil was weighed into a 100 ml beaker and 25 ml distilled water added (Fening *et al*., 2005). The suspension was stirred vigorously for 20 minutes. The suspension was allowed to stand for about 30 minutes by which time most of the suspended clay would have settled out from the suspension. The pH value was read using HT 9017 pH meter and the values recorded.

3.5.1.5 Total nitrogen (N)

Total N was determined by the Kjeldahl procedure modified to include the mineral nitrates in the soil by the use of salicylic acid to convert all the nitrates into ammonium salts (Tel and Hegatey, 1984). An amount of 10 g soil was weighed into a 250 ml Kjeldahl digestion

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flask and 10 ml of distilled water added to it. Ten (10) ml of concentrated H_2SO_4 was added followed by one tablet of selenium and potassium sulphate mixture and 0.10 g salicylic acid. The mixture was made to stand for 30 minutes and heated mildly to convert any nitrates and nitrites into ammonium compounds. The mixture was then heated more strongly (300-350^{o}C) to digest the soil to a permanent clear colour. The digest was cooled and transferred to a 100 ml volumetric flask and made up to the mark with distilled water. An amount of 20 ml aliquot of the solution was transferred into a tecator distillation flask and 10 ml of 40% NaOH solution was added and steam from the tecator apparatus allowed to flow into flask. The ammonium distilled was collected into 10 ml boric acid/ bromocresol green and methyl red solution. The distillate was titrated with 0.01 M HCl solution. Blank digestion, distillation and titration were also carried out as checks against traces of nitrogen in the reagents and water used. The percentage of total Nitrogen in the sample was calculated using the formular below:

$$\%\ \text{N in sample} = \frac{\text{Titre value} \times 0.01 \times 0.014 \times \text{volume of extract} \times 100}{\text{Weight of sample (g)} \times \text{volume of aliquot (ml)}} = \quad \text{Eqn (1)}$$

Where 0.01 = Molarity of HCl, 0.014 = Miliequivalent of nitrogen

3.5.1.6 Available phosphorus (P)

The Bray 1 extraction solution procedure (Bray and Kurtz, 1945) was used for available P. Phosphorus in the extract was determined on a Pye-Unicam spectrophotometer at a wavelength of 660 nm with blue ammonium molybdate as reducing agent. An amount of 2 g soil sample was extracted with 20 ml of Bray 1 solution (0.03 M NH_4F and 0.025 M HCl). The suspension was shaken by hand for one minute and immediately filtered through

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Whatman No. 42 filter paper. Standard series of 0, 1.2, 2.4, 3.6, 4.8 and 6.0 were prepared by respectively measuring 0, 10, 20, 30, 40, 50 ml of 12.0 mg P/L into a 100 ml volumetric flask and made up to the mark with distilled water. The measurement was then done on the spectrophotometer (Bray and Kurtz, 1945).

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3.5.1.7 Exchangeable potassium (K^+)

The exchangeable K^+ was extracted with 1.0 M neutral NH_4OAc solution (Black, 1965). After the extraction, K^+ was determined using a Perkin-Elmer atomic absorption spectrophotometer at wavelength of 766.5 nm.

3.5.2 Data collected on maize

Five plants were randomly selected and tagged per plot for measurements of growth, dry matter yield and yield components. Plant height, number of leaves per plant and leaf area were measured at weekly intervals for twelve weeks beginning from three weeks after planting. Dry matter yield, cob weight and 100-seed weight were determined at harvest.

3.5.2.1 Plant height

The height of five randomly selected and tagged plants were measured every three weeks from the ground level to the tip of the terminal leaf with the aid of a metre rule. The mean height was then computed. The plant height measurements were taken from 4 WASE to the 12 WAPG.

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3.5.2.2 Number of leaves

Number of leaves per plant was determined by counting all the leaves on each tagged plant. The mean of the five plants was used as the number of leaves per plant.

3.5.2.3 Leaf area

In order to measure the leaf area, the length and width of the leaves of five tagged plants were measured with a ruler at 6 WAP. The mean of the five plants was calculated and Leaf area was calculated as maximum length x maximum width x 0.747, where 0.747 is a constant.

3.5.2.4 Height of cob attachment

This was determined by measuring the five tagged plants on each plot with a metre rule from their bases to the point of cob attachment and the mean of the five plants were computed.

3.5.2.5 Cob length

This was measured in centimetres by considering de-husked cobs of the five tagged plants from each plot and measuring from the point of cob attachment to the end of the silk. The mean of the five plants were computed.

3.5.2.6 Cob weight

At harvest, the cobs of the five tagged plants were manually harvested, washed and cleaned to remove traces of soil. Cob weight was then measured using an electronic balance.

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3.5.2.7 100 Seed weight

Five cobs of the tagged plants were shelled and 100 grains per each cob was weighed. The mean weight of grains per cob for each treatment was then computed.

3.5.2.8 Grain yield

Grain yield was measured after threshing the harvested plants from the central one square metre of each plot. These were put in labelled envelopes and oven dried to a constant weight at 60ºC for 48 hours. The resulting weights, in grams (g) per metre square were then scaled up to tons per hectare.

3.5.3 Data collected on soybeans

Five plants were tagged per plot for the measurement of number of leaves per plant, number of nodules per plant, dry matter yield at 50% flowering, % active nodules, number of pods per plant, number of seeds per plant and 100 seed weight.

3.5.3.1 Plant height

Five plants of soybean were tagged per plot for the measurement of plant height from the ground level to the highest tip of the stem. The average plant height was calculated for each treatment.

3.5.3.2 Nodule count and effectiveness

The number of nodules was taken at 35 days after sowing to assess nodulation using the method suggested by Herridge *et al*. (1984). The samples from the five tagged plants were

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carefully dug out with adequate soil moisture to retrieve detached nodules. The nodules were kept in labelled polythene bags and sent to the laboratory and washed, counted and the fresh weight taken after which the nodules were cut opened to determine apparent effectiveness using a knife and hand lens. Nodules with pink or reddish colour were considered effective and fixing nitrogen, while those that were green or colourless were considered as ineffective. The percentage effective nodules were calculated according to the methods of Singleton *et al*. (1983).

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3.5.3.3 Number of pods per plant

All the pods of the five tagged plants in each plot were plucked. These were then counted manually and the average pod number calculated.

3.5.3.4 Number of seeds per pod

The number of seeds per pod was measured by taking five random plants from the harvested plants. All pods were plucked and counted. Pods were shelled and counted. Average number of seeds per pod was then estimated for each treatment.

3.5.3.5 100 Seed weight

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

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3.5.3.6 Grain yield

Grain yield per hectare was measured by threshing the harvested plants from the 5 x 5 m of each plot. These were put in labelled envelopes and oven dried to a constant weight at 60ºC for 48 hours. The resulting weight in grams (g) per metre square were then scaled up to tons per hectare.

3.6 Benefit/cost ratio

Economic (profit, benefit/cost) analysis of maize and soybean production based on tillage, cropping systems, and NPK fertilizer application was done using the formula;

$$\mathbf{BCR} = \frac{\textbf{Discounted value of income}}{\textbf{Discounted value of costs}} \quad \textbf{= Eqn. (2)}$$

3.7 Data Analysis

A split-split plot analysis of variance (ANOVA) in SPSS statistical package was used to analyse data collected. Treatment differences were compared using the Least Significant Difference (LSD) procedure at 5% level of probability. The results are presented in Figures and Tables.

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CHAPTER FOUR

RESULTS

4.1 Initial and post harvest soil physico-chemical properties

The result of soil physico-chemical property showed that the soil used for the study was sandy-loam in texture, low in total nitrogen and available phosphorus (Table 1).The soil had a pH of 5.02-5.21. The soil available P was low and the exchangeable cations (K, Ca and Mg) were not also high. The percentage nitrogen, organic matter and organic carbon were moderate. Generally initial CEC, available N, exchangeable Ca and Mg were statistically higher ($P<0.05$) than the post harvest condition (Table 1).

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Table 1: Physico-chemical properties of the soil used for the study

Soil parameter	**Initial soil analysis**	**Post harvest soil analysis**	***F pr.***
pH	5.21	5.02	$P < 0.05$
Organic carbon (%)	0.05	0.04	$P > 0.05$
CEC (Cmol $^{+}$ /kg)	2.15	2.22	$P < 0.05$
Available Nitrogen (%)	0.06	0.05	$P > 0.05$
Available Phosphorus (mg/kg)	8.90	8.40	$P < 0.05$
Exchangeable Bases			
Potassium (Cmol/kg)	8.06	7.98	$P > 0.05$
Calcium (Cmol/kg)	1.39	1.25	$P < 0.05$
Magnesium (Cmol/kg)	0.45	0.41	$P > 0.05$
Particle size distribution (%)			
Sand	52.05	53.01	$P < 0.001$
Clay	0.32	0.28	$P > 0.05$
Silt	47.63	46.71	$P < 0.001$
Texture	Sandy loam	Sandy loam	

For detailed analysis of the soil physico-chemical properties see appendices 21-31

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4.2 Growth and yield of maize

4.2.1 Number of leaves, plant height and leaf area

The interaction of tillage systems with NPK fertilizer rate and cropping systems, tillage system with NPK fertilizer rate, cropping systems with NPK fertilizer rate, and tillage system with cropping systems, did not significantly *($P>0.05$)* affect leaf number of maize at 3 WAP. Similarly, tillage system and cropping system as sole factors did not significantly *($P>0.05$)* affect leaf number of maize at 3 WAP. Leaf number of maize was however affected by NPK fertilizer rate ($P<0.001$) at 3 WAP (Table 2). At 6 WAP, leaf number of maize was affected by NPK fertilizer rate ($P<0.001$) and Cropping system ($P<0.05$) as sole factors. Also, at 9 WAP, leaf number of maize was enhanced by NPK fertilizer rate ($P<0.001$) only. However, leaf number of maize was not affected by any of the treatments at 12 WAP (Table 2). There was a general trend of increase in leaf number during the period of maize growth with maximum leaf number recorded at 9-12 (WAP) (Figure 2).

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Table 2: Summary of Anova and post hoc test for leaf number of maize at different weeks after planting

Anova

Week	Three way	Two way			One way		
		TS x FR	CS x FR	TS x CS	TS	CS	FR
3							√
6						√	√
9							√
12							

LSD at 0.05

Week	Three way	Two way			One way		
		TS x FR	CS x FR	TS x CS	TS	CS	FR
3							0.3175
6						0.256	0.53
9							0.517
12							

√= *statistically significant*

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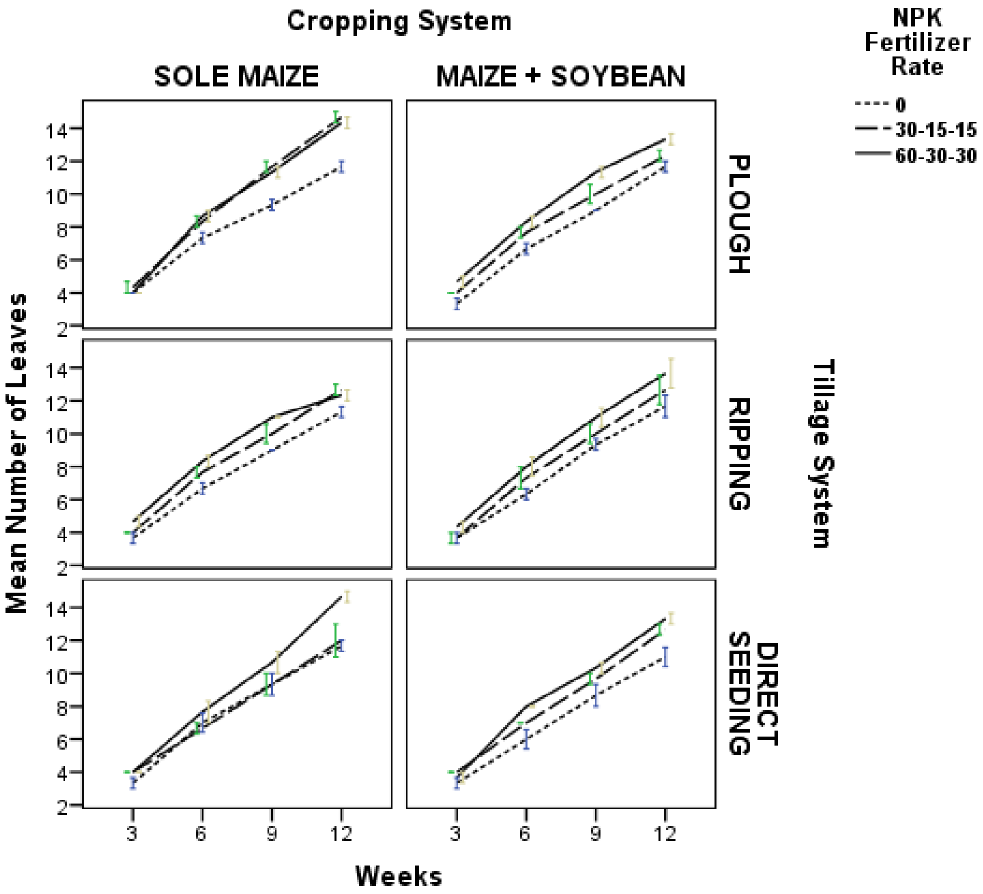

Figure 2: Effect of tillage system, fertilizer rate and cropping system on leaf number of maize, grown in Yagaba, in the Guinea savanna zone of Ghana, during the 2015 cropping season. Error bars: +/- SE.

Plant height of maize was affected by tillage system (*P<0.05*) and NPK fertilizer rate (*P<0.05*) as sole factors at 3 WAP (Table 3). There was a three way interaction effect among tillage system, NPK fertilizer rate, and cropping system *(P<0.01)* for plant height at 6 WAP (Table 3). Also, tillage system (*P<0.001*), NPK fertilizer rate (*P<0.001*), and cropping system (*P<0.05*) as sole factors significantly affected plant height at 6 WAP. At 9 WAP, plant height was significantly affected by the interaction between tillage system x

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NPK fertilizer rate ($P<0.001$), tillage system x cropping system ($P<0.05$), and cropping system and NPK fertilizer rate ($P<0.05$) (Table 3). Also, tillage system ($P<0.05$) and NPK fertilizer rate ($P<0.001$) as sole factors affected plant height at 9 WAP. At 12 WAP, plant height was significantly affected by the interaction between tillage system x NPK fertilizer rate ($P<0.05$).Also tillage system ($P<0.05$), cropping system ($P<0.05$) and NPK fertilizer rate ($P<0.001$) as sole factors significantly affected plant height at 12 WAP (Table 3). There was a general trend of increase in maize height during the period of growth (Figure 3). Greater height of maize was recorded at 9-12 WAP.

Table 3: Summary of Anova and post hoc test for plant height of maize at different weeks after planting

Anova

Week	Three way	Two way			One way		
		TS x FR	CS x FR	TS x CS	TS	CS	FR
3					√		√
6	√				√	√	√
9		√	√	√	√		√
12		√			√	√	√

LSD at 0.05

Week	Three way	Two way			One way		
		TS x FR	CS x FR	TS x CS	TS	CS	FR
3	3.2456				1.908		1.01
6					1.573	1.365	1.37
9		5.081	3.958	5.481	4.84		2.23
12		6.799			6.331	3.288	3.148

√= *statistically significant*

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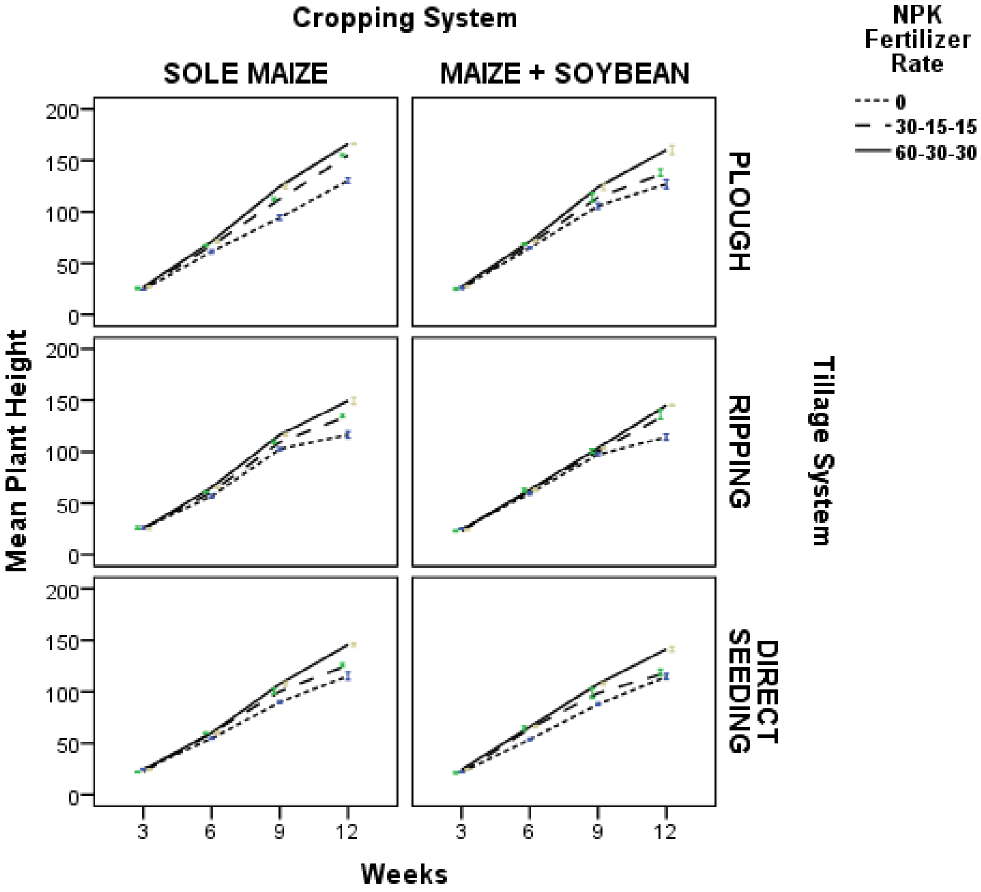

Figure 3: Effect of tillage system, fertilizer rate and cropping system on plant height of maize, grown in Yagaba, in the Guinea savanna zone of Ghana, during the 2015 cropping season. Error bars: +/- SE.

There was a three way interaction effect among tillage system, NPK fertilizer rate, and cropping system *(P<0.05)* for leaf area at 6 WAP (Table 4). Also tillage system x NPK fertilizer rate *(P<0.001)* affected leaf area of maize at 6 WAP. Tillage system *(P<0.001)* and NPK fertilizer rate *(P<0.001)* also affected leaf area of maize at 6 WAP. Among the treatments, ploughing and a fertilizer application rate of 60-30-30 kg/ha on sole maize

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recorded the largest leaf area (Figure 4). Direct seeding, in an integration of maize and soybean produced the lowest leaf area at zero NPK fertilizer rate.

Table 4: Summary of Anova and post hoc test for leaf area of maize at 6 weeks after planting

Anova							
	Three way	Two way			One way		
		TS x FR	CS x FR	TS x CS	TS	CS	FR
	√	√			√		√
LSD at 0.05							
	Three way	Two way			One way		
		TS x FR	CS x FR	TS x CS	TS	CS	FR
	23.75	17.31			12.74		10.22

√= *statistically significant*

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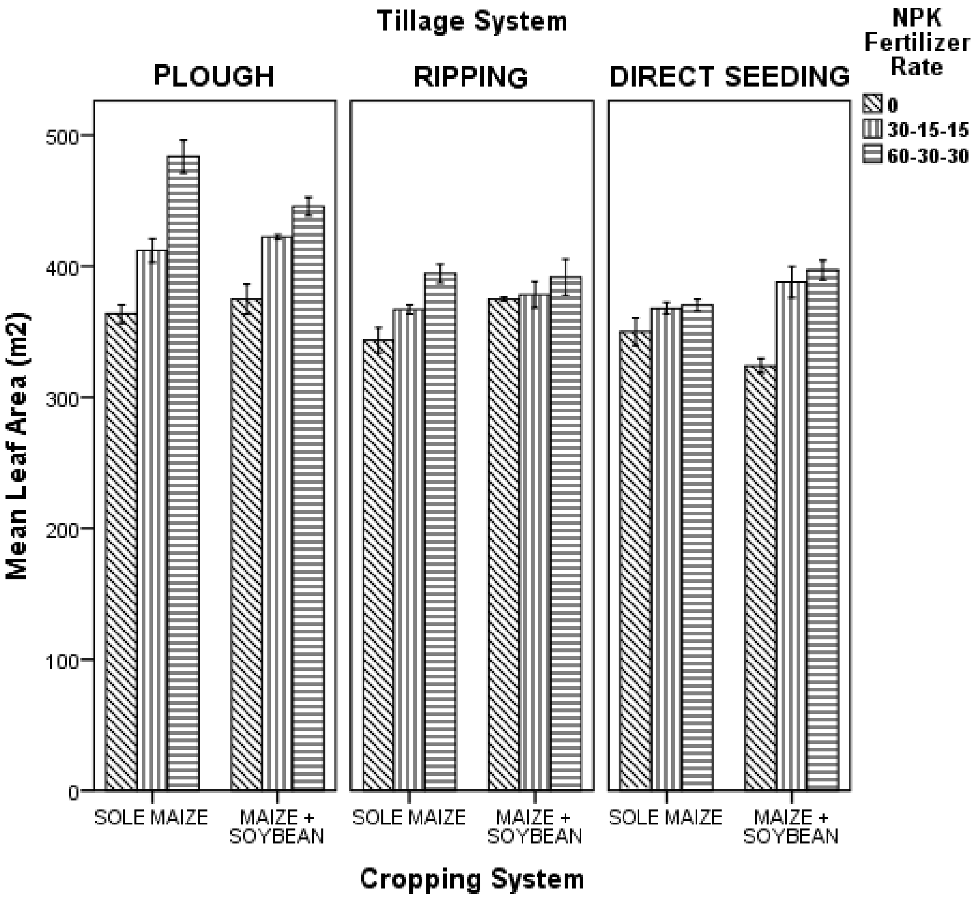

Figure 4: Effect of tillage system, fertilizer rate and cropping system on leaf area of maize, grown in Yagaba, in the Guinea savanna zone of Ghana, during the 2015 cropping season. Error bars: +/- SE.

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4.2.2 Height of cob attachment

The tillage systems x cropping systems x NPK fertilizer rate, tillage systems x NPK fertilizer rate, cropping system x NPK fertilizer rate, and tillage systems x cropping systems did not significantly *(P>0.05)* affect the height of cob attachment. However, tillage system *(P<0.05)* and NPK fertilizer rate *(P<0.001)* significantly affected the height of cob attachment (Table 5). Height of cob attachment was highest for the ploughed field but similar to ripping, while direct seeding resulted in lowest height of cob attachment

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(Figure 5). Statistically, there was no difference in cob height of direct seeded and ripped entries.

Table 5: Summary of Anova and post hoc test for height of cob attachment of maize

	Three way	Two way			One way		
Anova		TS x FR	CS x FR	TS x CS	TS	CS	FR
					√		√

	Three way	Two way			One way		
LSD at 0.05		TS x FR	CS x FR	TS x CS	TS	CS	FR
					3.54		2.513

√= *statistically significant*

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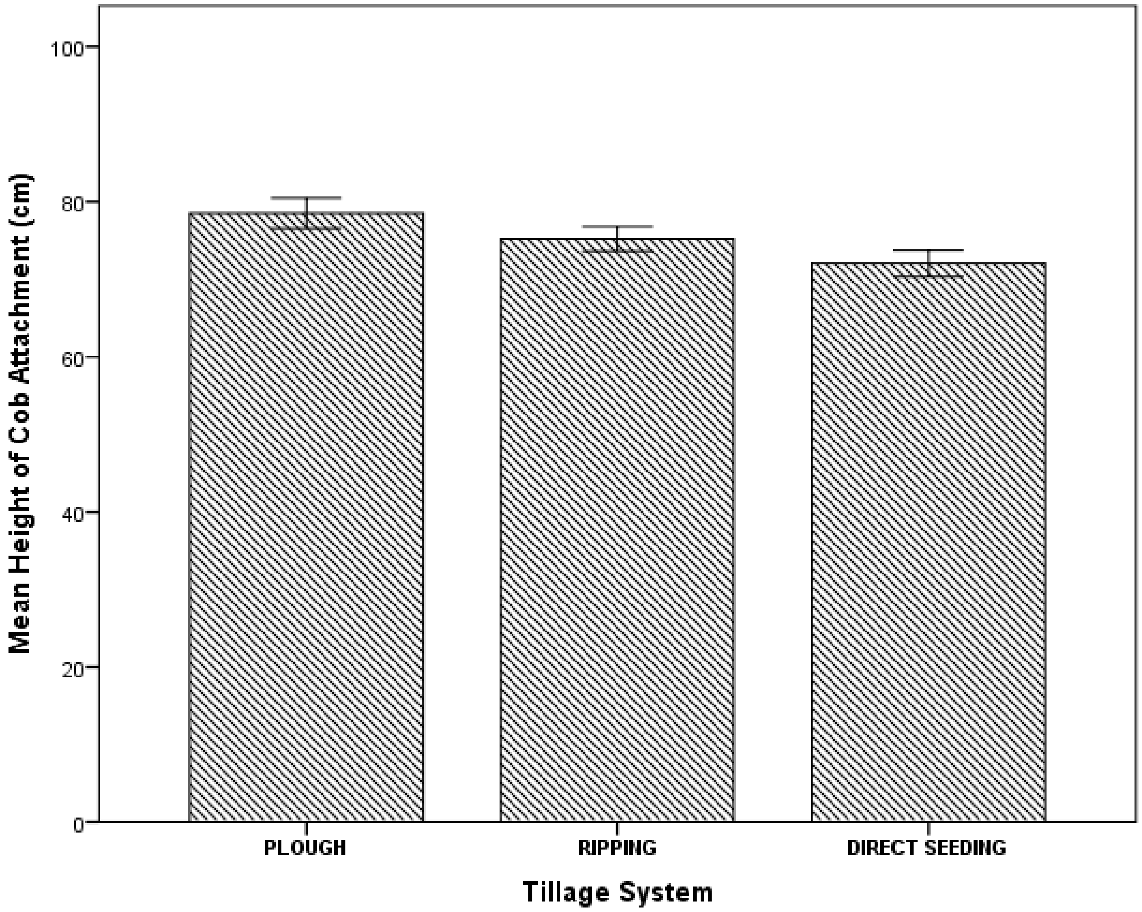

Figure 5: Effect of tillage system on height of cob attachment of maize, grown in Yagaba, in the Guinea savanna zone of Ghana, during the 2015 cropping season. Error bars: +/- SE.

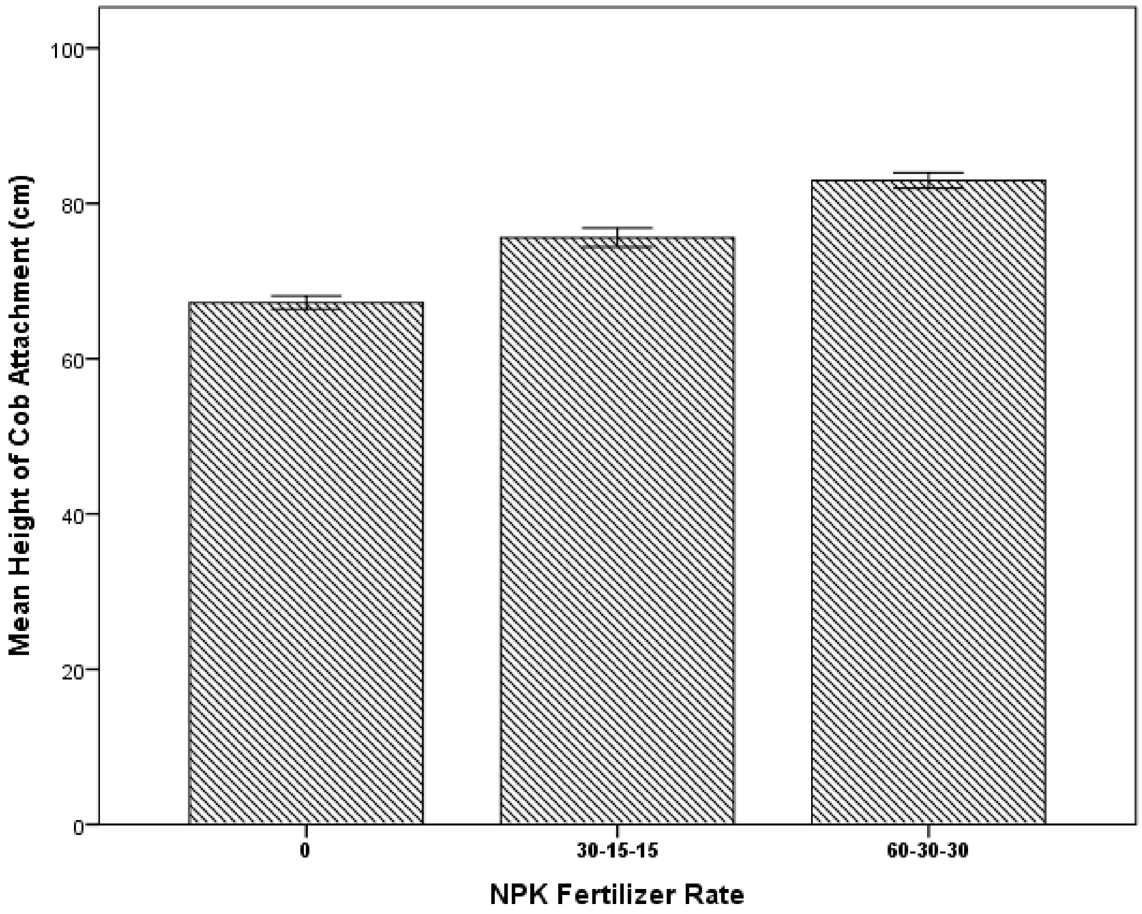

Figure 6: Effect of NPK fertilizer rate on height of cob attachment of maize, grown in Yagaba, in the Guinea savanna zone of Ghana, during the 2015 cropping season. Error bars: +/- SE.

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4.2.3 Cob length

There was no two way nor three way interaction effect between tillage system, NPK fertilizer rate and cropping system for cob length of maize *($P>0.05$)*. However, tillage system *($P<0.05$)* and NPK fertilizer rate *($P<0.001$)* affected cob length of maize (Table 6). Analysis of variance portrayed that, the experimental plots subjected to ploughing recorded the greatest cob length (Figure 7). Although, plants from ripped plots recorded higher

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values than those from directly seeded plots, there was no statistically significant differences among them.

Table 6: Summary of Anova and post hoc test for cob length of maize

Anova							
	Three way	Two way			One way		
		TS x FR	CS x FR	TS x CS	TS	CS	FR
					√		√
LSD at 0.05							
	Three way	Two way			One way		
		TS x FR	CS xFR	TS x CS	TS	CS	FR
					1.031		0.866

√= *statistically significant*

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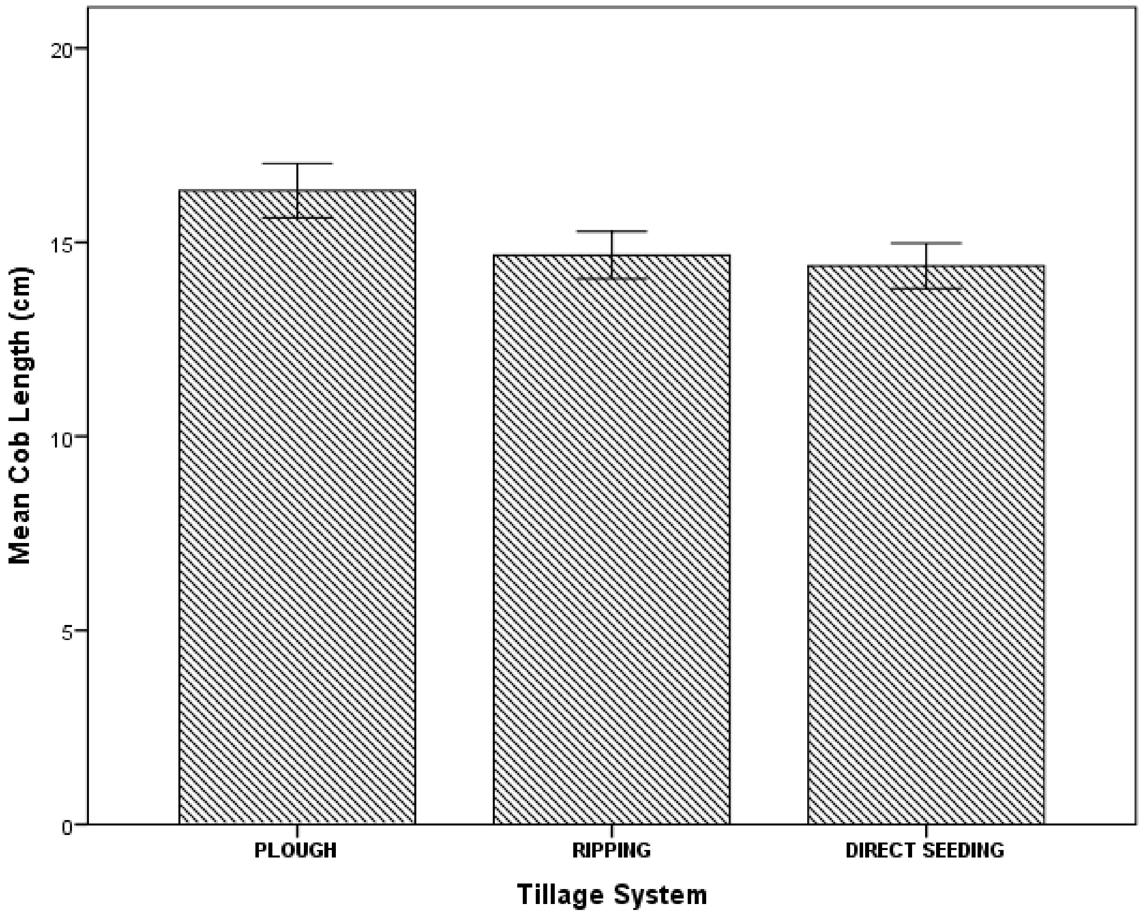

Figure 7: Effect of tillage system on cob length of maize, grown in Yagaba, in the Guinea savanna zone of Ghana, during the 2015 cropping season. Error bars: +/- SE.

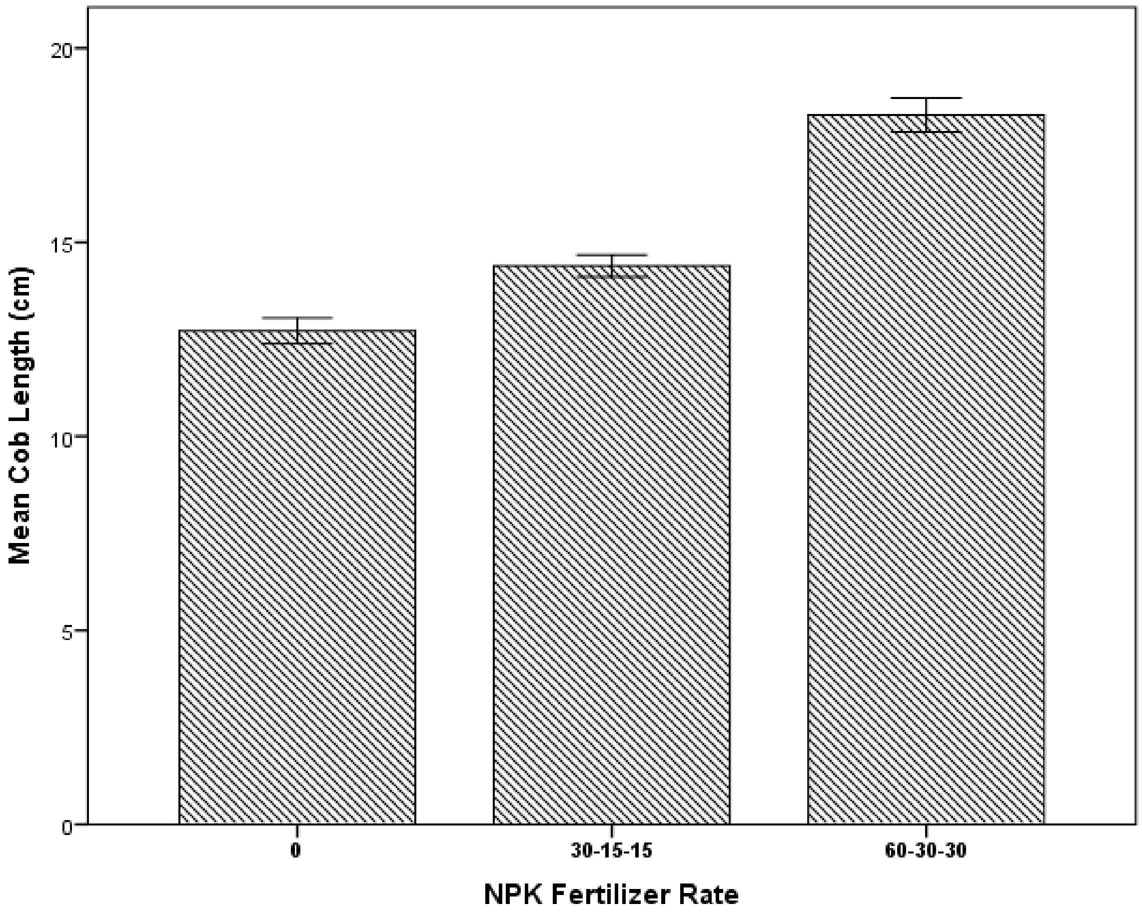

Figure 8: Effect of NPK fertilizer rate on cob length of maize, grown in Yagaba, in the Guinea savanna zone of Ghana, during the 2015 cropping season. Error bars: +/- SE.

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4.2.4 Cob weight

The tillage systems x NPK fertilizer rate x cropping systems, cropping systems x NPK fertilizer rate, and tillage systems x cropping systems did not impact significantly *($P>0.05$)* on cob weight. However, tillage system x NPK fertilizer rate *($P<0.05$)* showed significant impact on cob weight (Table 7). Also, cob weight was significantly *($P<0.001$)* affected by NPK fertilizer rate. Ploughing as a tillage system with NPK fertilizer application rate of 60-30-30 recorded the highest cob weight of 12.5 kg/ha followed by ripping at NPK

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fertilizer rate of 60-30-30 (11 kg/ha), which was at par with direct seeding at NPK fertilizer rate of 60-30-30 kg/ha (Figure 9). NPK fertilizer rate of 30-15-15 kg/ha gave lower but similar cob weights across the three tillage systems of ploughing, ripping and direct seeding. The lowest cob weights were taken at no application of NPK fertilizer across the three tillage systems.

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Table 7: Summary of Anova and post hoc test for cob weight of maize

Anova							
	Three way	Two way			One way		
		TS x FR	CS x FR	TS x CS	TS	CS	FR
		√					√
LSD at 0.05							
	Three way	Two way			One way		
		TS x FR	CS x FR	TS x CS	TS	CS	FR
		0.986					0.548

√= *statistically significant*

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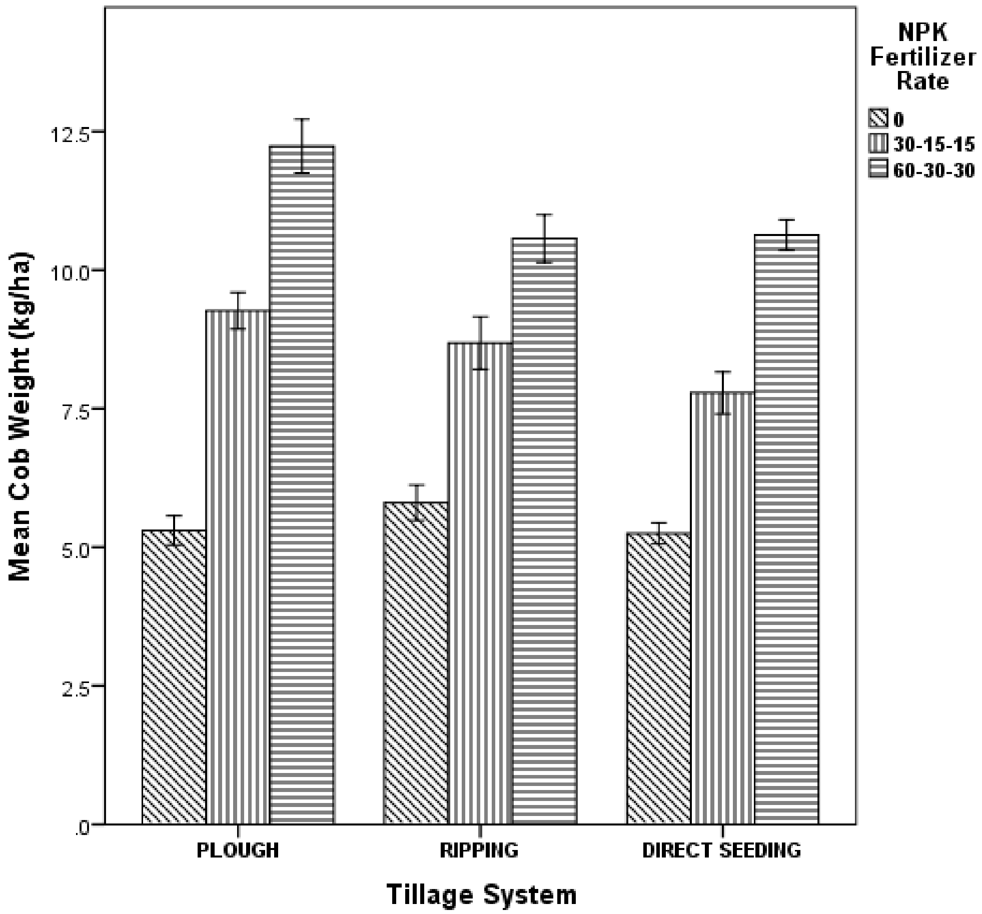

Figure 9: Effect of tillage system and NPK fertilizer rate on cob weight of maize grown in Yagaba, in the Guinea savanna zone of Ghana during the 2015 cropping season. Error bars: +/- SE.

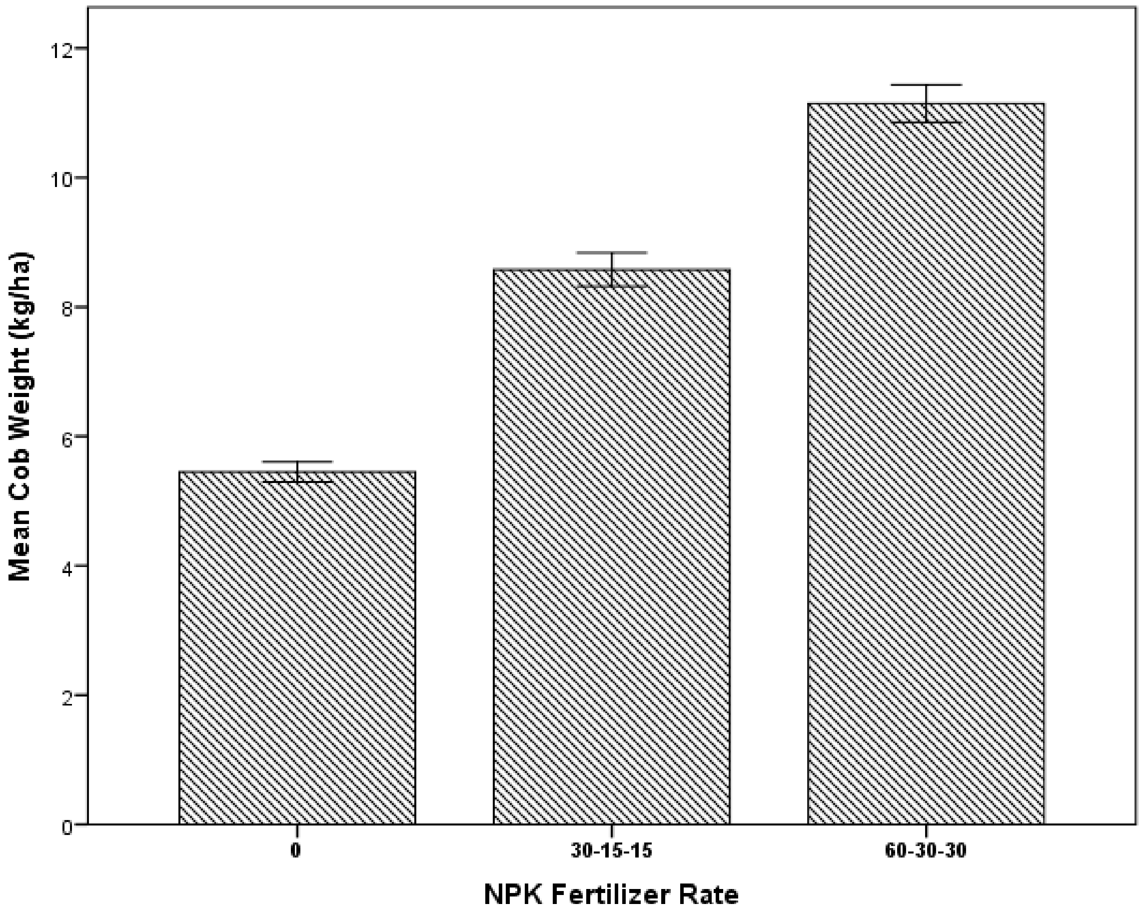

Figure 10: Effect NPK fertilizer rate on cob weight of maize grown in Yagaba, in the Guinea savanna zone of Ghana during the 2015 cropping season. Error bars: +/- SE.

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4.2.5 Hundred seed weight

There was no significant effect *(P>0.05)*for tillage systems x NPK fertilizer rate x cropping systems, tillage systems x NPK fertilizer rate, cropping systems x NPK fertilizer rate, and tillage systems x cropping systems for hundred seed weight. Also, tillage system and cropping system as sole factors, did not significantly *(P>0.05)* affect hundred seed weight. Hundred seed weight was however significantly *(P<0.001)* influenced by NPK fertilizer rate (Table 8).

Table 8: Summary of Anova and post hoc test for hundred seed weight of maize

Anova

Three way	Two way			One way		
	TS x FR	CS x FR	TS x CS	TS	CS	FR
						√

LSD at 0.05

Three way	Two way			One way		
	TS x FR	CS x FR	TS x CS	TS	CS	FR
						1.667

√= *statistically significant*

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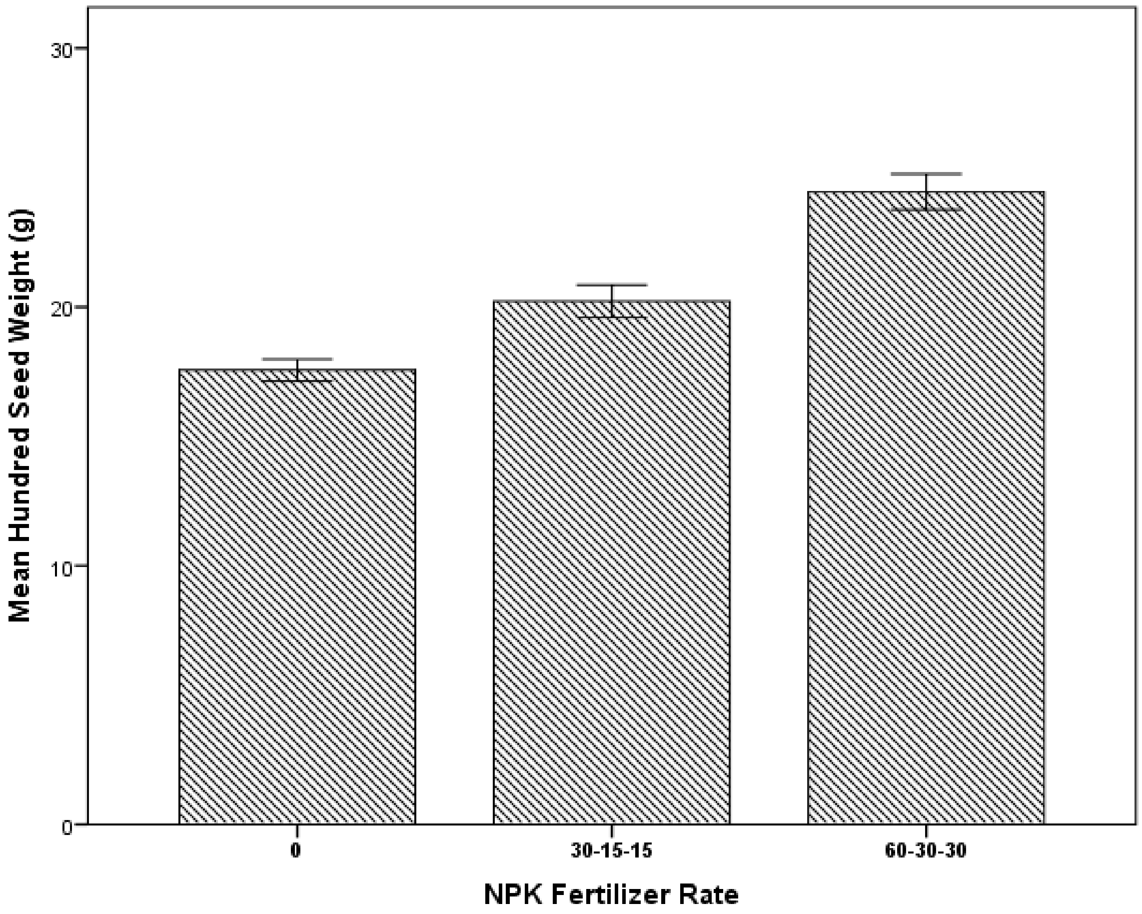

Figure 11: Effect of NPK fertilizer rate on hundred seed weight of maize, grown in Yagaba, in the Guinea savanna zone of Ghana, during the 2015 cropping season. Error bars: +/- SE.

Analysis of variance also indicated that, hundred seed weight was higher when experimental plots were applied with NPK fertilizer of 30-15-15 kg/ha and lowest from 0 kg/ha of NPK (Figure 11). Hundred seed weight among treatments ranged between 15 and 30 g.

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4.2.6 Grain yield

Tillage systems x NPK fertilizer rate x cropping systems, tillage systems x NPK fertilizer rate, cropping systems x NPK fertilizer rate, and tillage systems x cropping systems did not improve grain yield significantly *(P>0.05)*. In addition, tillage system and cropping system as sole factors did not impact grain yield significantly *(P>0.05).* Grain yield, however, significantly *(P<0.001)* varied with fertilizer rate (Table 9). Application of NPK fertilizer at a rate of 60-30-30 kg/ha NPK resulted in the highest grain yield of 3.4 t/ha (Figure 12). Plots that received no NPK fertilizer applicationrecorded lowest yield of 1.5 t/ha, whiles application of 30-15-15 kg/ha gave about 2.7 t/ha.

Table 9: Summary of Anova and post hoc test for grain yield of maize

Anova							
	Three way		Two way		One way		
		TS x FR	CS x FR	TS x CS	TS	CS	FR
							√
LSD at 0.05							
	Three way		Two way		One way		
		TS x FR	CS x FR	TS x CS	TS	CS	FR
							0.2049

√= statistically significant

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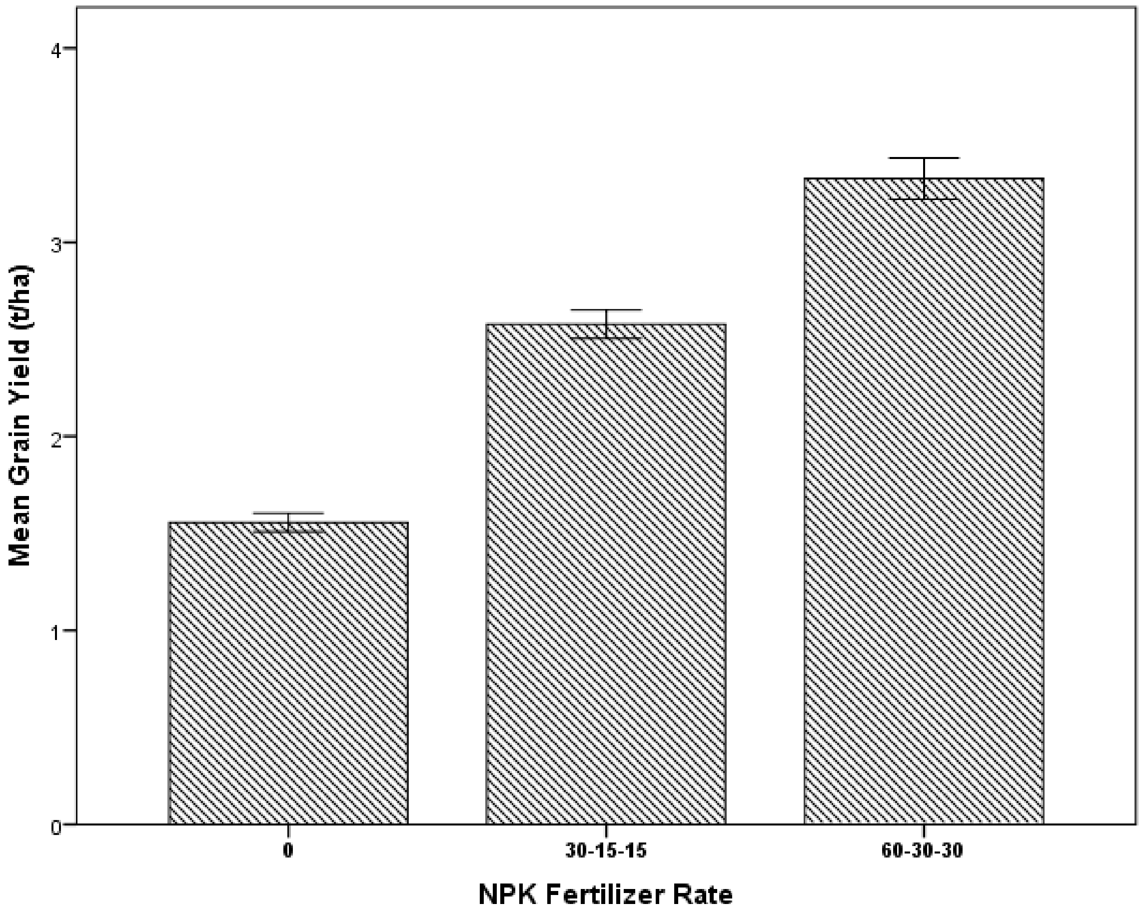

Figure 12: Effect of NPK fertilizer rate on grain yield of maize grown in Yagaba in the Guinea savanna zone of Ghana during the 2015 cropping season. Error bars: +/- SE.

4.3 Growth and yield of soybean intercrop

4.3.1 Plant height

There was no significant effect for tillage system x NPK fertilizer rate *($P>0.05$)* on plant height of soybean intercrop. However, tillage system *($P<0.05$)* and NPK fertilizer rate *($P<0.001$)* affected plant height of the soybean intercrop (Table 10). Among tillage systems used, the highest plant height was achieved under ploughing, followed by direct seeding and then ripping (Figure 13).

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Table 10: Summary of Anova and post hoc test for plant height of soybean

Anova				
	Three way	Two way	One way	
		TS x FR	TS	FR
			√	√
LSD at 0.05				
	Three way	Two way	One way	
		TS x FR	TS	FR
			2.683	2.161

√= *statistically significant*

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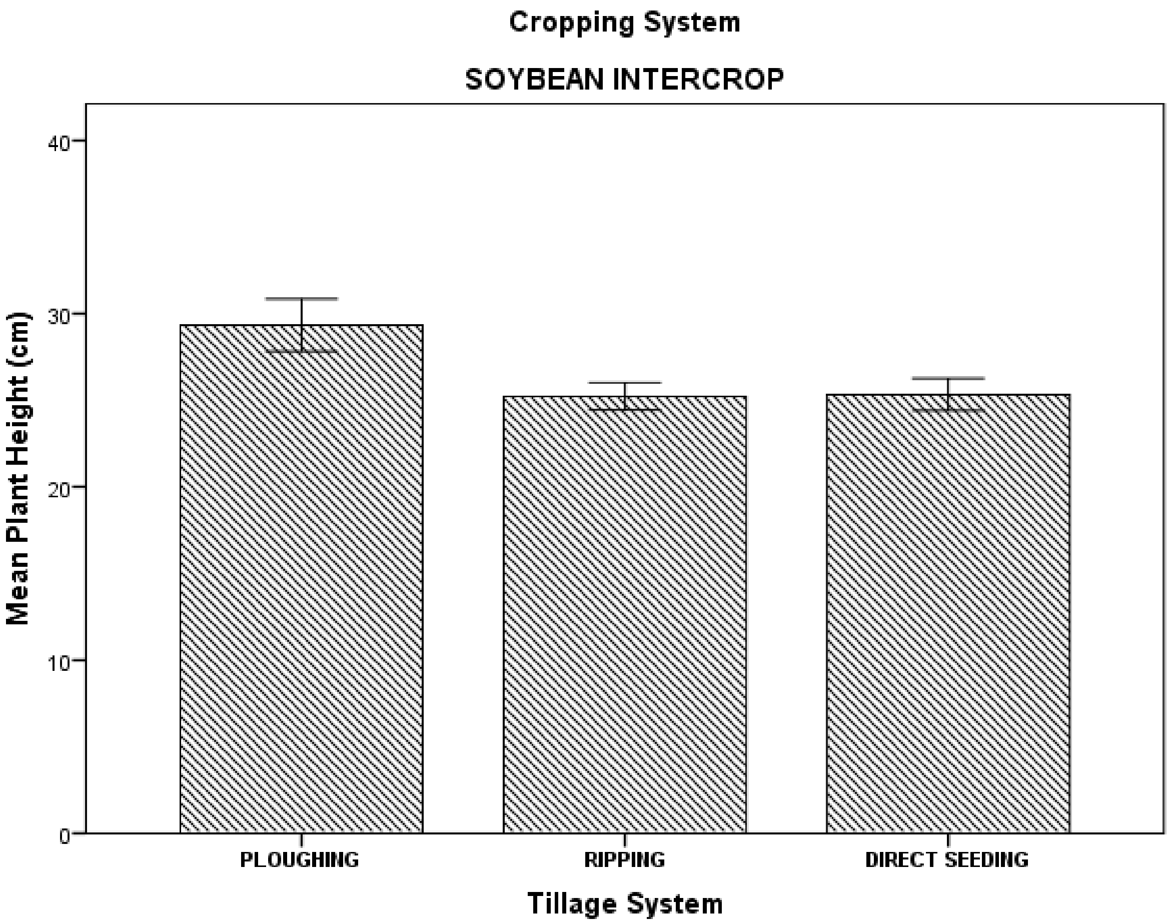

Figure 13: Effect of tillage system on plant height of soybean in a soybean–maize intercrop, at Yagaba in the Guinea savanna zone of Ghana, during the 2015 cropping season. Error bars: +/- SE.

Also, highest plant height was achieved with NPK fertilizer rate of 60-30-30 kg/ha (Figure 14). The lowest plant height was however achieved with NPK fertilizer rate of 0 kg/ha.

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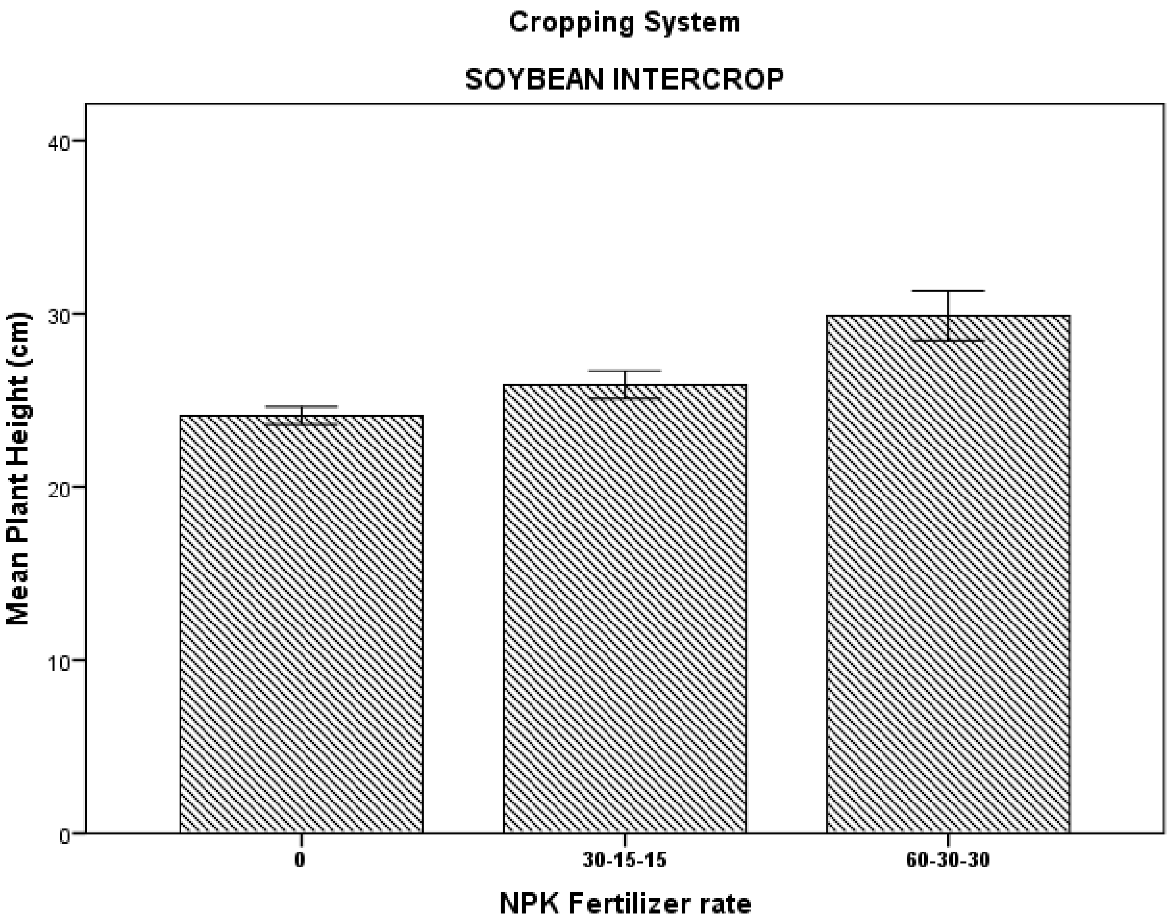

Figure 14: Effect of NPK fertilizer rate on plant height of soybean in a soybean–maize intercrop, at Yagaba in the Guinea savanna zone of Ghana, during the 2015 cropping season. Error bars: +/- SE.

4.3.2 Number of leaves

Tillage systems x NPK fertilizer rate (P>0.05) and tillage system (P>0.05) as sole factor did not affect leaf number of soybean intercrop. NPK fertilizer rate (P<0.05) however affected leaf number of soybean intercrop (Table 11).

Table 11: Summary of Anova and post hoc test for number of leaves of soybean

Anova	Three way	Two way	One way	
		TS x FR	TS	FR
				√

LSD at 0.05	Three way	Two way	One way	
		TS x FR	TS	FR
				4.228

√= *statistically significant*

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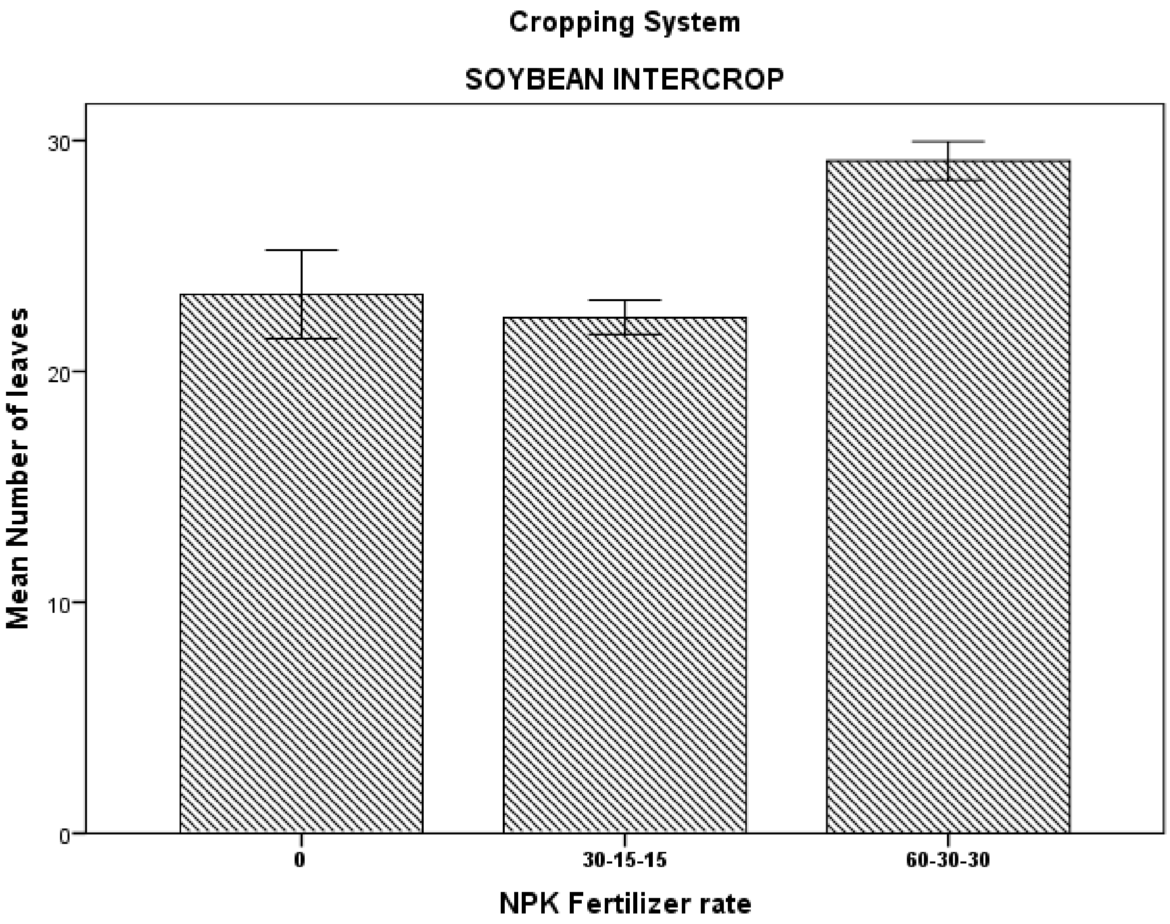

Figure 15: Effect of NPK fertilizer rate on number of leaves of soybean in a soybean-maize intercrop production system, grown in Yagaba, in the Guinea savanna zone of Ghana, during the 2015 cropping season. Error bars: +/- SE.

There was an increase in leaf number of soybean at a NPK fertilizer application rate of 60-30-30 kg/ha (Figure 15). Experimental plots that received 30-15-15 kg/ha of NPK fertilizer recorded least number of leaves among the soybean crops. The number of soybean plants leaves ranged between 20 and 30 among treatment combinations.

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4.3.3 Number of pods per plant at harvest

There was no significant effect for tillage system x NPK fertilizer rate *($P>0.05$)* and tillage system *($P>0.05$)* on pod number of soybean intercrop. However, number of pods was significantly affected by NPK fertilizer rate *($P<0.001$)* (Table 12). Pods harvested ranged from 28 to 39 per plant with respect to NPK fertilizer rate (Figure 16). Pod number at harvest was highest on 60-30-30 kg/ha NPK and least on 0 kg/ha NPK.

Table 12: Summary of Anova and post hoc test for pod number of soybean

Anova				
	Three way	Two way	One way	
		TS x FR	TS	FR
				√
LSD at 0.05				
	Three way	Two way	One way	
		TS x FR	TS	FR
			3.71	3.024

√= *statistically significant*

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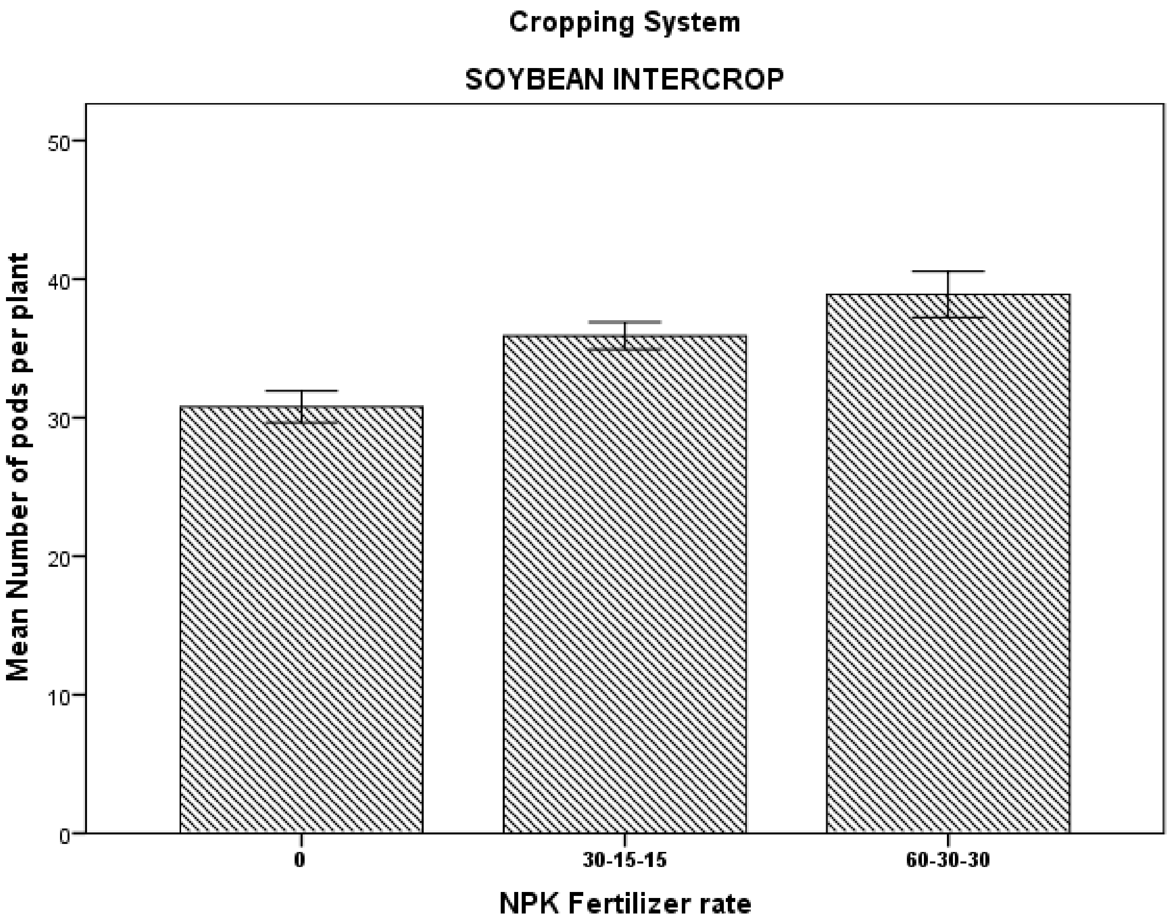

Figure 16: Effect of NPK fertilizer rate on pod number of soybean in a soybean –maize intercrop production system grown in Yagaba in the Guinea savanna zone of Ghana, during the 2015 cropping season. Error bars: +/- SE.

4.3.4 Number of seeds per pod

There was no significant effect for tillage system x NPK fertilizer rate *(P>0.05)* and tillage system *(P>0.05)* on number of seeds per pod of soybean intercrop. However, NPK fertilizer rate *(P<0.05)* as sole treatment significantly affected number of seeds per pod (Table 13). NPK Fertilizer application rate of 30-15-15 kg/ha recorded the highest seed count followed by 60-30-30 and 0 kg/ha respectively (Figure 17). Averagely, a pod of soybean contained three seeds.

Table 13: Summary of Anova and post hoc test for number of seeds per pod of soybean

Anova				
	Three way	Two way	One way	
		TS x FR	TS	FR
				√
LSD at 0.05				
	Three way	Two way	One way	
		TS x FR	TS	FR
				0.442

√= *statistically significant*

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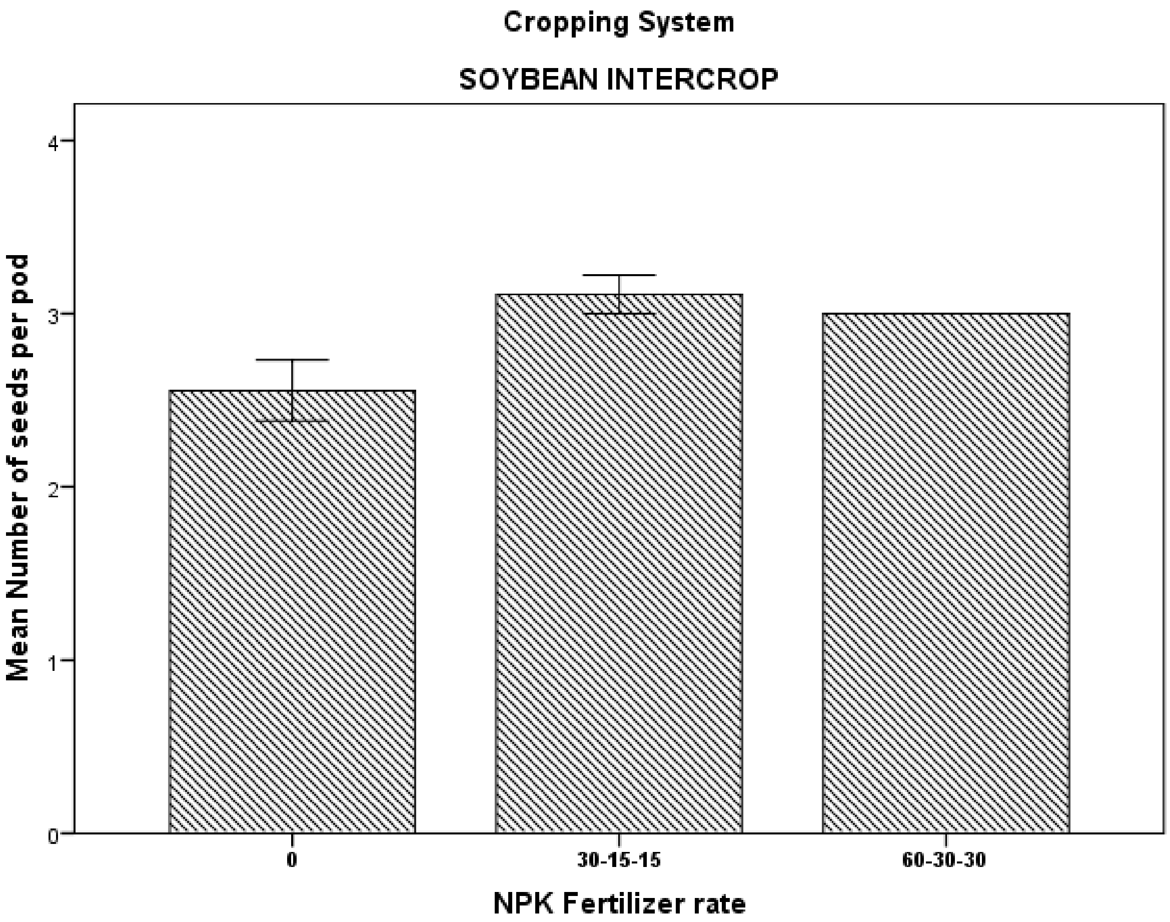

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Figure 17: Effect of NPK fertilizer rate on number of seeds per pod of soybean in a soybean –maize intercrop production system grown in Yagaba in the Guinea savanna zone of Ghana, during the 2015 cropping season. Error bars: +/- SE.

4.3.5 Hundred seed weight

There was no significant effect for tillage system x NPK fertilizer rate *(P>0.05)* and tillage system *(P>0.05)* on hundred seed weight of soybean intercrop. Hundred seed was however affected by NPK fertilizer rate *(P<0.001)* (Table 14). An application of 60-30-30 kg/ha NPK recorded maximum seed weight of soybean. Seed weight recorded least among 0 kg/ha NPK (Figure 18). Averagely, seed weight of 12.58 g, 11.7 g and 11.79 g were respectively recorded for the 60-30-30 kg/ha NPK, 30-15-15 kg/ha NPK and 0 kg/ha NPK.

Table 14: Summary of Anova and post hoc test for hundred seed weight of soybean

Anova				
	Three way	Two way	One way	
		TS x FR	TS	FR
				√
LSD at 0.05				
	Three way	Two way	One way	
		TS x FR	TS	FR
				0.661

√= *statistically significant*

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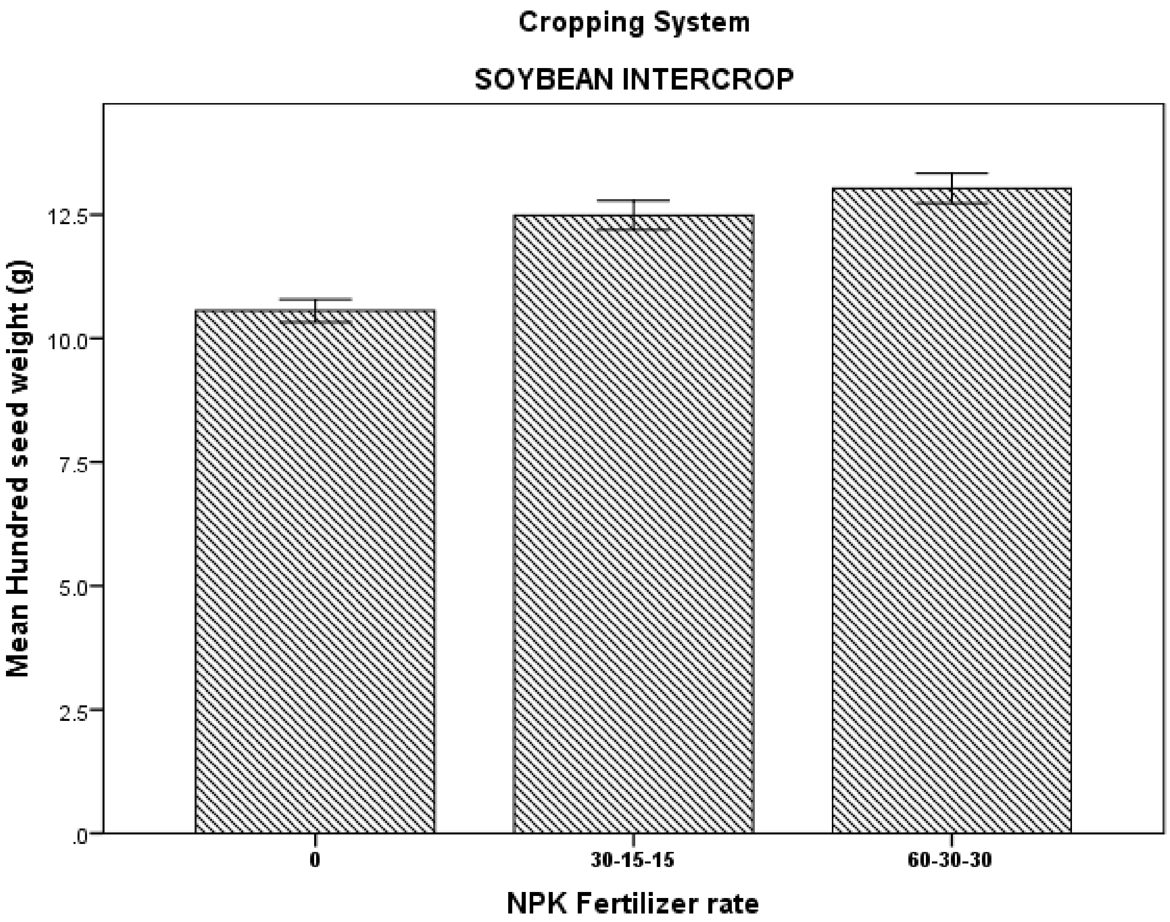

Figure 18: Effect of tillage system on hundred seed weight of soybean in a soybean – maize intercrop production system grown in Yagaba, in the Guinea savanna zone of Ghana during the 2015 cropping season. Error bars: +/- SE.

4.3.6 Grain yield

With the exception of the interaction of tillage system *($P<0.05$)* and NPK fertilizer rate *($P<0.001$)* (Table 15), yield of soybean was not affected by tillage system x NPK fertilizer rate *($P>0.05$)*. Highest grain yield was recorded on ploughed plots (Figure 19).Direct seeded treatment of the tillage system resulted in lower grain yield of soybean intercrop.

Table 15: Summary of Anova and post hoc test for grain yield of soybean

Anova				
	Three way	Two way	One way	
		TS x FR	TS	FR
			√	√
LSD at 0.05				
	Three way	Two way	One way	
		TS x FR	TS	FR
			0.1469	0.1677

√= *statistically significant*

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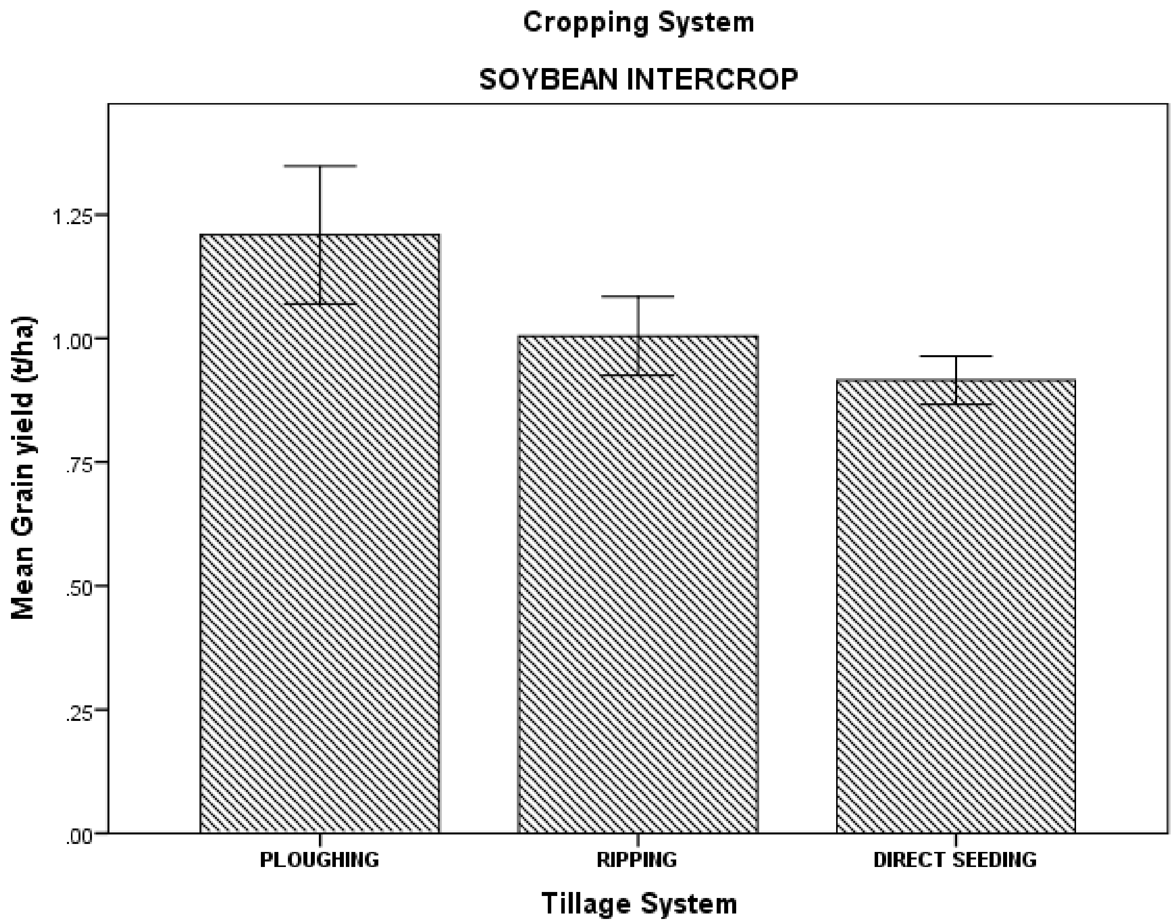

Figure 19: Effect of tillage system on grain yield (t/ha) of soybean in a soybean-maize intercrop production system grown in Yagaba in the Guinea savanna zone of Ghana during the 2015 cropping season. Error bars: +/- SE.

Soybean supplied with 60-30-30 kg/ha NPK (Figure 20) gave the highest grain yield (1.4 t/ha), whilst soybean supplied with 0 kg/ha NPK gave the lowest grain yield (0.7 t/ha).

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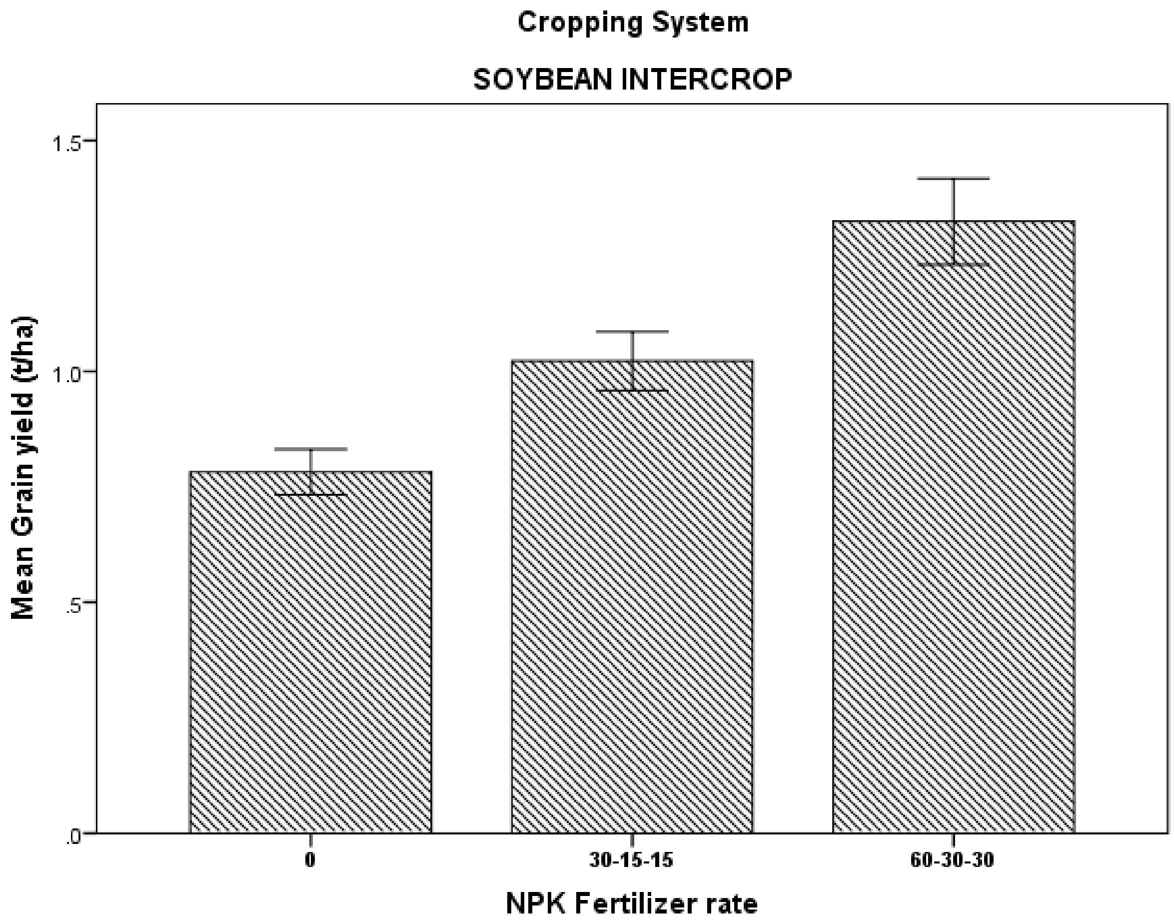

Figure 20: Effect of NPK fertilizer rate on grain yield (t/ha) of soybean in a soybean-maize intercrop production system grown in Yagaba in the Guinea savanna zone of Ghana during the 2015 cropping season. Error bars: +/- SE.

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4.3.7 Benefit/cost analysis for maize and soybean using different technologies

From the results on comparative analysis of the economic productivity of maize and soybean production techniques (Table 16), intercropped maize ploughed with a NPK fertilizer rate of 60-30-30 kg/ha gave the highest benefit/cost ratio. This was followed by intercropped maize ripped with a NPK fertilizer application rate of 60-30-30 kg/ha. The application of sole maize ploughed with zero rate of NPK fertilizer application gave the least benefit/cost ratio. Though sole maize ploughed with full rate of NPK fertilizer application, when compared with intercrop (maize-soybean) ploughed with half rate of NPK fertilizer application accrued the same benefit/cost ratio of 2.1; the intercropped system with half NPK fertilizer rate resulted in higher profit of 2233 GHS compared to the sole production system (GHS 1524) (Table 16).

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Table 16: Benefit/Cost analysis of maize and soybean production based on tillage, cropping systems, and NPK fertilizer application technologies in the Guinea savanna zone of Ghana.

System/Technology	Cost of production (GH¢) per ha	Total income (GH¢) per ha	Profit (GH¢) per ha	Benefit/cost ratio
SMPZ	1130	1440	310	1.3
SMPH	1258	2610	1352	2.1
SMPF	1356	2880	1524	2.1
M+SPZ	1902	2604	702	1.4
M+SPH	2039	4272	2233	2.1
M+SPF	2196	5606	3410	2.6
SMRZ	1000	1710	710	1.7
SMRH	1203	2430	1227	2.0
SMRF	1281	2340	1059	1.8
M+SRZ	1752	2514	762	1.4
M+SRH	1955	3234	1279	1.7
M+SRF	2016	4696	2680	2.3
DsSMZ	915	1260	345	1.4
DsSMH	1128	2160	1032	1.9
DsSMF	1241	2700	1459	2.2
DsM+SZ	1691	2412	721	1.4
DsM+SH	1927	3838	1911	2.0
DsM+SF	1937	4158	2221	2.1

SMPZ= Sole maize ploughed with zero rate of fertilizer applicationSMPH= Sole maize ploughed with half rate of fertilizer application SMPF= Sole maize ploughed with full rate of fertilizer application M+SPZ= Maize+Soybean ploughed with zero rate of fertilizer application M+SPH= Maize+Soybean ploughed with half rate of fertilizer application M+SPF= Maize+Soybean ploughed with full rate of fertilizer application SMRZ= Sole maize ripped with zero rate of fertilizer application SMRH= Sole maize ripped with half rate of fertilizer application SMRF= Sole maize ripped with full rate of fertilizer application M+SRZ= Maize+Soybean ripped with zero rate of fertilizer application M+SRH= Maize+Soybean ripped with half rate of fertilizer application M+SRF= Maize+Soybean ripped with full rate of fertilizer application DsSMZ= Direct seeded Sole maize with zero rate of fertilizer application DsSMH= Direct seeded Sole maize with half rate of fertilizer application DsSMF= Direct seeded Sole maize with full rate of fertilizer application DsM+SZ= Direct seeded Maize+Soybean with zero rate of fertilizer application DsM+SH= Direct seeded Maize+Soybean with half rate of fertilizer

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application DsM+SF= Direct seeded Maize+Soybean with full rate of fertilizer application.

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CHAPTER FIVE

DISCUSSION

5.1 Soil physico-chemical properties

The observed decline in soil organic carbon (Table 1) may be attributed to the stimulatory effect of living roots on microbial activities that enhanced soil organic matter decomposition (Cheng and Coleman, 1990; Fan *et al.*, 2006).

The slight increase in pH after harvest could be attributed to addition high NPK fertilizer rate. This observation is consistent with the findings of Chuwku *et al.*, (2012) who reported that application of 300 kg/ha of NPK fertilizer could lead to increase in soil pH. There was decrease in total N after harvest. This could be attributed to nutrient up take by component crops and the absence of NPK fertilizer application on some of the fields. Similarly, the available P was depleted after harvest. The depletion may be attributed to uptake of the nutrients by component crops and probably due to fixation of the element which usually occurs at low soil pH (Brady and Weil, 2007). A similar trend was observed with the exchangeable bases.

Soil organic carbon content also showed slight increase in maize- soybean intercropped plots. These changes are considered favourable as it decreases the bulk density (Adams, 1973) and decrease in bulk density is known to favour aeration and water storage (Letey, 1958). It is also probable that deep root growth was more enhanced by planting on the ploughed and ripped fields than on the zero-tillage field (Merrill *et al.*, 1996).

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5.2 Growth response of maize

The observed higher variation in the growth response of maize to ploughing, application of fertilizer at the rate of 60-30-30 kg/ha NPK and absence of cover crop (soybean) is attributed to favorable conditions of growth under those conditions and is in line with (Ijoyah, 2012; Dankyi *et al.*, 2005) who mentioned that, maize is a common component in most intercropping systems in the tropics and fertilizer formulation remains the key element in the production of maize as poor soil nutrition remains key to the cause of low yield.

The observed shorter plant height recorded in maize-soybean intercropping might be attributed to competition of crops, over shading and climbing of the legumes to the main maize crop. This observation is also in line with Silwana *et al*. (2007) who observed longer maize height among maize mono crop than when maize was intercropped with legumes. Thobasti (2009) also mentioned that cowpea intercropped with maize recorded reduced plant height of maize compared to maize mono crop especially under water limiting conditions depending on the season when the legume intercropped restricted maize growth. This finding is supported by the result of Ofori and Stern (1987) who found that maize plant height was increased by nitrogen fertilizer application but reduced by intercropping with different legume species. In contrast to the findings of this study, Mohammed *et al*. (2006) reported a no significant difference on maize plant height from cowpea intercrop.

Taller maize plants provide a better advantage of trapping more solar radiation than intercropped legumes which is very critical for growth and development of crops. Also,

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taller plant height among sole maize may be attributed to spacing. In view of the soybean that was integrated among maize, the component crop (sole maize) received limited catchment area to explore nutrients in the soil and sunlight as a result of competition between the soybean and the maize. This observation is in line with Thwala and Ossum (2004), who observed low plant height among intercrops with respect to spacing. This study matches with the findings of Ibrahim (2008) who opined that intercropping maize with cowpea varieties leads to significant reduction in maize plant height.

The significant increase in plant height associated with increased NPK fertilizer rate of 60-30-30 kg/ha is a reflection of the effective role of fertilizer elements, N, P and K which has been increased. This result is in conformity with the assertion made by Babatola (2013). The observed increase in plant height under conventional tillage (ploughing) and ripping might have been due to the ability of the tillage systems to have loosen the soil horizon and providing suitable area for germination and development of the plants (Rasmussen, 1999).

Leaves serve as important site for photosynthetic activities (Flexas *et al*., 2002). Greater number of leaves on NPK fertilizer treated plots enhanced better canopy formation which suppressed weed growth to influence grain yield. The ability of maize to have responded positively to increased NPK fertilizer rate may be attributed to the essentiality of the elements N, P and K, which are responsible for plant growth and development (Havlin *et al*., 2007). The non-significance response in the number of leaves per plant in maize indicates that there was intra and interspecific competition for the available resources at the growth stages. This observation agrees with the reports by Ennin *et al.* (2002) on solar

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radiation capture and utilization in intercropping. During the stages of growth, competition ensued among intercrops, resulting in depression of the vegetative growth of the intercrops compared to sole crops. This resulted in the significant decrease in plant height due to shading effect and a reduction in number of leaves per plant. The increase in number of leaves per plant among sole maize plants might be due to readily available nutrients and favorable conditions during the growth period of the crop. An increase in number of leaves per plant with fertilizer application has also been reported by Ragheb *et al.* (1987).

Maize leaf area plays a role in photosynthesis and yield (Sinclair and Horie, 1989; Richards, 2000). The photosynthetic capacity of crops is a function of leaf area. Leaf area is important for crop light interception and therefore has a large influence on crop yield (Dwyer and Stewart, 1986). The effect of tillage systems and NPK fertilizer usage resulted in appreciable enlargement of the unit area covered by the leaves. The lowest leaf area obtained in the No-Tillage plots may be due to the lack of soil loosening for providing conditions favourable to crop growth and yield (Aikins *et al*., 2012). This result is in agreement with that of Videnović *et al*. (2011) who observed higher leaf area index in conventional tillage plots in comparison with that of the No-Tillage plots. The increase in leaf area in the fertilized plots (60-30-30 and 30-15-15 kg/ha rates of NPK fertilizer) can be attributed to higher availability of potassium which is known to stimulate the synthesis of carbohydrate for the development of the maize, as potassium usage has been reported to be accelerated by sufficient quantities of nitrogen (Hersshey, 2002). Leaf area is pertinent in determining crop growth due to its influence on photosynthesis. This confirms the fact that higher N, P, and K application rate enhance leaf growth in maize (Gobron, 2009) as

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reflected on grain yield in the present study. The higher total leaf area among sole maize treatments indicates greater interception of incoming solar radiation by monocrops than by maize/soybean intercrops, and this may also be the reason for increased grain yield in sole maize systems relative to their integrated counterparts. As postulated, nitrogen plays a key role in several physiological processes and increased N levels has been associated with greater photosynthetic rates (Li *et al*., 2012; Toth *et al*., 2002). Low N supply negatively affects the amount or activity of photosynthetic components (Li *et al.,* 2012) accordingly, it is postulated that biochemical limitations primarily constrain photosynthesis in N-deficient plants.

5.3 Yield and components of yield

The height to which cobs were attached to the maize plant is a good indicator of easiness with which matured cobs can be harvested (Ochieng and Tanga, 1995). Height of cob attachment was influenced by the application of NPK fertilizer and the practice of tillage. The fertilizer effect as an influencing factor to height of cob attachment was facilitated by 60-30-30 and 30-15-15 kg/ha rates of N, P and K. Research indicates that nitrogen is a peculiar element for plant growth and development (Havlin *et al.,* 2007) and hence this reflection in the vegetative growth and yield components. Inferences to tillage systems however indicate that ploughing and ripping supported the height of cob attachment in maize as way of making seedbed suitable and available for maize plant to exploit water and nutrient resources in the soil horizon (Rasmussen, 1999).

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The negative influence emanating from the effect of direct seeding condition may have been caused by compactness of the soil which is noted to impede the acquisition of both water and nutrients and growth of roots (Hamza and Anderson, 2005). Soil disturbance caused by ploughing might have increased porosity and penetrability by allowing roots to have better access to water and nutrients. This statement is in line with the observation of Fan *et al.* (2006) who opined that tillage practice modifies the state of the soil in order to provide conditions favourable for crop growth. Findings by Carlesso *et al.* (2002) also indicated that maize and soybean yield components was high when cultivated under conventional tillage as a result of improved access to soil moisture than under a no-tillage system.

The observed lowest yields of the intercrop under the direct-seeded fields may be adduced to higher competition among maize and soybean for resources despite the nutrient supply and it is probable that deep root growth was more enhanced on ploughed and ripped experimental plots than on direct-seeded plots. Assertions made by Liu *et al.* (2008), and (Husnjack *et al*., 2002) emphasized that tillage had a multipurpose functionality, including preparation of seedbeds, placing seeds, reducing soil compaction, incorporating crop residues and controlling weeds. The increase in cob weight and length, hundred seed weight and grain yield of maize in relation to the NPK fertilizer rate may be attributed to the increase in NPK fertilizer levels which might have contributed to nutrient supply and in return improved the yield characters. The NPK fertilizer rate supplied nutrient elements N, P and K. The higher rates resulted in increase amount of these elements in the soil as also observed by Whitbread *et al.* (2004). Increase in seed weight with increased NPK rate

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might be due to the increases in leaf area that promoted interception of more sunlight for the production of carbohydrate, and translated into grain yield as reported by Ayoola and Makinde (2009).

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This reflected in the production of increased seed weight which is in relation to the observation made by Raja (2003). The observed low yield and yield components recorded by the absence of NPK fertilizer treatment might be adduced in part to the deficiency of nutrients as revealed by the low nutrient status of the soil. This observation agrees with the statement by FAO (2003) that increased maize production occurs with higher levels of nutrient application.

Tillage effect played critical role in maize growth and development. Conventional tillage (ploughing) might have provided suitable environment for initial radical and plumule development as also observed by Memon *et al*. (2013). It also helped to maintain adequate soil moisture, creating ideal seedbed conditions for seedling emergence, development and unimpeded root growth. This observation confirms the inferences made by Licht and Kaisi (2005). Also, ploughing as a conventional manipulation of the soil might have permitted plant roots development, allowing maintenance and even an increase in soil organic matter (Wright *et al*., 2008) which is often impeded by no-till soils as shown by the soil physio-chemical properties. The practice of direct seeding technique, integration of leguminous cover crop and the absence of NPK fertilizer least promoted the parameters under this study.

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The decrease in parameters among maize-soybean intercrop was mainly attributed to intra and interspecific competition for nutrients, light, and space.

5.4 Benefit/Cost analysis

According to Adegye and Dittoh (1985), the higher the benefit/cost ratio, the higher the profit derived from the use of the given production system. However, it would be inappropriate to judge the economic performance of the various treatments based on only the benefit/cost. This is attributed to the fact that, sole maize ploughed with a full rate of NPK fertilizer application, and intercrop (maize-soybean) ploughed with a half rate of NPK fertilizer application accrued the same benefit/cost ratios of 2.1 but resulted in a profit of 1524 and 2233, respectively (Table 2).

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CHAPTER SIX

CONCLUSION AND RECOMMENDATION

6.1 Conclusion

The type of tillage system, NPK fertilizer rate and maize/soybean integration have impact on yield and productivity of maize.

Ploughing and NPK fertilizer rate promoted the growth of maize and soybean in an intercropped system. However, only NPK fertilizer rate of 60-30-30 kg/ha increased yield of maize (3.4 t/ha) and soybean (1.4 t/ha).

Intercropped maize with soybean under ploughed condition and with NPK fertilizer rate of 60-30-30 gave the highest Benefit/cost ratio (2.6) and profit (3410 GHS).

Sole maize and intercropped maize (under ploughed condition) with NPK fertilizer rates of 60-30-30 and 30-15-15 kg/ha respectively, accrued the same benefit/cost ratio of 2.1 but resulted in profit of 1524 GHS and 2233 GHS, respectively. The latter stand to be more beneficial to the resource-poor farmer.

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6.2 Recommendations

At the end of the experiment, the following recommendations have been made:

1. The absence of leguminous cover crop and adoption of 60-30-30 kg/ha rate of NPK fertilizer will improve the yield of maize. This technology should be promoted in the Guinea savannah zone.
2. Though the absence of leguminous cover crop and adoption of 60-30-30 kg/ha rate of NPK fertilizer will improve the yield of maize compared to the integration system, the integration with soybean increases the benefit and profits and is therefore recommended to the resource constrained farmer.
3. There is the need to determine the long-term effect of tillage and NPK fertilizer application rate on maize growth, yield and on soil properties.

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APPENDICES

Appendix 1: Soil pH before and after cultivation

Source of variation	d.f	s.s.	m.s.	v.r.	F pr.
Reps stratum	2	0.0028000	0.0014000	2.33	
Reps.*Units* stratum					
Initial_Post	1	0.0541500	0.0541500	90.25	0.011
Residual	2	0.0012000	0.0006000		
Total	5	0.0581500			

Appendix 2: Soil Organic Carbon (%) before and after cultivation

Source of variation	d.f	s.s.	m.s.	v.r.	F pr.
Reps stratum	2	0.00030000	0.00015000	3.00	
Reps.*Units* stratum					
Initial_Post	1	0.00015000	0.00015000	3.00	0.225
Residual	2	0.00010000	0.00005000		
Total	5	0.00055000			

Appendix 3: Soil CEC (Cmol$^+$/kg) before and after cultivation

Source of variation	d.f.	s.s.	m.s	v.r	F pr.
Reps stratum	2	0.00030000	0.00015000	3.00	
Reps.*Units* stratum					
Initial_Post	1	0.00735000	0.00735000	147.00	0.007
Residual	2	0.00010000	0.00005000		
Total	5	0.00775000			

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Appendix 4: Soil Available Nitrogen (%) before and after cultivation

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	2	0.00040000	0.00020000		
Reps.*Units* stratum					
Initial_Post	1	0.00015000	0.00015000	11.00	0.059
Residual	2	0.00000000	0.00000000		
Total	5	0.00055000			

Appendoix 5: Soil Available Phosphorus (mg/kg) before and after cultivation

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	2	0.006100	0.003050	0.67	
Reps.*Units* stratum					
Initial_Post	1	0.360150	0.360150	79.15	0.012
Residual	2	0.009100	0.004550		
Total	5	0.375350			

Appendix 6: Soil Potassium (Cmol$^+$/kg) before and after cultivation

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	2	0.0004000	0.0002000	0.33	
Reps.*Units* stratum					
Initial_Post	1	0.0096000	0.0096000	16.00	0.057
Residual	2	0.0012000	0.0006000		
Total	5	0.0112000			

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Appendix 7: Soil Calcium (Cmol$^+$/kg) before and after cultivation

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	2	0.00030000	0.00015000	3.00	
Reps.*Units* stratum					
Initial_Post	1	0.02940000	0.02940000	588.00	0.002
Residual	2	0.00010000	0.00005000		
Total	5	0.02980000			

Appendix 8: Soil Magnesium (Cmol$^+$/kg) before and after cultivation

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	2	0.0007000	0.0003500	2.33	
Reps.*Units* stratum					
Initial_Post	1	0.0024000	0.0024000	16.00	0.057
Residual	2	0.0003000	0.0001500		
Total	5	0.0034000			

Appendix 9: Particle size distribution ofSand (%) before and after cultivation

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	2	0.0036000	0.0018000	2.25	
Reps.*Units* stratum					
Initial_Post	1	1.3824000	1.3824000	1728.00	<.001
Residual	2	0.0016000	0.0008000		
Total	5	1.387600			

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Appendix 10: Particle size distribution of Clay (%) before and after cultivation

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	2	0.0001000	0.0000500	0.33	
Reps.*Units* stratum					
Initial_Post	1	0.0024000	0.0024000	16.00	0.057
Residual	2	0.0003000	0.0001500		
Total	5	0.0028000			

Appendix 11: Particle size distribution of Silt (%) before and after cultivation

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	2	0.0001000	0.0000500	0.11	
Reps.*Units* stratum					
Initial_Post	1	1.2696000	1.2696000	2821.33	<.001
Residual	2	0.0009000	0.0004500		
Total	5	1.2706000			

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Appendix 12: Effect of tillage system, fertilizer rate and cropping system on leaf number of maize (3 WAP) grown in Yagaba, in the Guinea savanna zone of Ghana, during the 2015 cropping season

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	2	0.4815	0.2407	1.30	
REP.TILLAGE_SYSTEM stratum					
TILLAGE_SYSTEM	2	1.1481	0.5741	3.10	0.154
Residual	4	0.7407	0.1852	1.11	
REP.TILLAGE_SYSTEM.CROPPING_SYSTEM stratum					
CROPPING_SYSTEM	1	0.2963	0.2963	1.78	0.231
TILLAGE_SYSTEM.CROPPING_SYSTEM	2	0.0370	0.0185	0.11	0.897
Residual	6	1.0000	0.1667	0.78	
REP.TILLAGE_SYSTEM.CROPPING_SYSTEM.FERTILIZER_APPLICATION stratum					
FERTILIZER_APPLICATION	2	4.1481	2.0741	9.74	<.001
TILLAGE_SYSTEM.FERTILIZER_APPLICATION	4	1.0741	0.2685	1.26	0.313
CROPPING_SYSTEM.FERTILIZER_APPLICATION	2	0.1481	0.0741	0.35	0.710
TILLAGE_SYSTEM.CROPPING_SYSTEM.FERTILIZER_APPLICATION	4	1.5185	0.3796	1.78	0.165
Residual	24	5.1111	0.2130		
Total	53	15.7037			

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Appendix 13: Effect of tillage system, fertilizer rate and cropping system on leaf number of maize (6 WAP) grown in Yagaba, in the Guinea savanna zone of Ghana, during the 2015 cropping season

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	2	1.0370	0.5185	0.82	
REP.TILLAGE_SYSTEM stratum					
TILLAGE_SYSTEM	2	5.4815	2.7407	4.35	0.099
Residual	4	2.5185	0.6296	4.25	
REP.TILLAGE_SYSTEM.CROPPING_SYSTEM stratum					
CROPPING_SYSTEM	1	1.5000	1.5000	10.12	0.019
TILLAGE_SYSTEM.CROPPING_SYSTEM	2	0.4444	0.2222	1.50	0.296
Residual	6	0.8889	0.1481	0.25	
REP.TILLAGE_SYSTEM.CROPPING_SYSTEM.FERTILIZER_APPLICATION stratum					
FERTILIZER_APPLICATION	2	20.2593	10.1296	17.09	<.001
TILLAGE_SYSTEM.FERTILIZER_APPLICATION	4	0.9630	0.2407	0.41	0.802
CROPPING_SYSTEM.FERTILIZER_APPLICATION	2	0.7778	0.3889	0.66	0.528
TILLAGE_SYSTEM.CROPPING_SYSTEM.FERTILIZER_APPLICATION	4	1.1111	0.2778	0.47	0.758
Residual	24	14.2222	0.5926		
Total	53	49.2037			

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Appendix 14: Effect of tillage system, fertilizer rate and cropping system on leaf number of maize (9 WAP) grown in Yagaba, in the Guinea savanna zone of Ghana, during the 2015 cropping season

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	2	1.4444	0.7222	1.37	
REP.TILLAGE_SYSTEM stratum					
TILLAGE_SYSTEM	2	5.4444	2.7222	5.16	0.078
Residual	4	2.1111	0.5278	0.51	
REP.TILLAGE_SYSTEM.CROPPING_SYSTEM stratum					
CROPPING_SYSTEM	1	0.9074	0.9074	0.88	0.386
TILLAGE_SYSTEM.CROPPING_SYSTEM	2	1.3704	0.6852	0.66	0.550
Residual	6	6.2222	1.0370	1.84	
REP.TILLAGE_SYSTEM.CROPPING_SYSTEM.FERTILIZER_APPLICATION stratum					
FERTILIZER_APPLICATION	2	30.3333	15.1667	26.85	<.001
TILLAGE_SYSTEM.FERTILIZER_APPLICATION	4	2.2222	0.5556	0.98	0.435
CROPPING_SYSTEM.FERTILIZER_APPLICATION	2	0.2593	0.1296	0.23	0.797
TILLAGE_SYSTEM.CROPPING_SYSTEM.FERTILIZER_APPLICATION	4	2.9630	0.7407	1.31	0.294
Residual	24	13.5556	0.5648		
Total	53	66.8333			

Appendix 15: Effect of tillage system, fertilizer rate and cropping system on leaf number of maize (12 WAP) grown in Yagaba, in the Guinea savanna zone of Ghana, during the 2015 cropping season

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	2	421.4	210.7	1.13	
REP.TILLAGE_SYSTEM stratum					
TILLAGE_SYSTEM	2	355.4	177.7	0.95	0.460
Residual	4	749.1	187.3	0.96	
REP.TILLAGE_SYSTEM.CROPPING_SYSTEM stratum					
CROPPING_SYSTEM	1	220.0	220.0	1.13	0.329
TILLAGE_SYSTEM.CROPPING_SYSTEM	2	387.8	193.9	0.99	0.424
Residual	6	1171.7	195.3	1.06	
REP.TILLAGE_SYSTEM.CROPPING_SYSTEM.FERTILIZER_APPLICATION stratum					
FERTILIZER_APPLICATION	2	604.0	302.0	1.64	0.215
TILLAGE_SYSTEM.FERTILIZER_APPLICATION	4	841.6	210.4	1.14	0.361
CROPPING_SYSTEM.FERTILIZER_APPLICATION	2	370.8	185.4	1.01	0.380
TILLAGE_SYSTEM.CROPPING_SYSTEM.FERTILIZER_APPLICATION	4	837.9	209.5	1.14	0.363
Residual	24	4419.8	184.2		
Total	53	10379.5			

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Appendix 16: Effect of tillage system, fertilizer rate and cropping system on plant height of maize (3 WAP) grown in Yagaba, in the Guinea savanna zone of Ghana, during the 2015 cropping season

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	2	10.333	5.167	1.22	
REP.TILLAGE_SYSTEM stratum					
TILLAGE_SYSTEM	2	74.333	37.167	8.75	0.035
Residual	4	17.000	4.250	3.38	
REP.TILLAGE_SYSTEM.CROPPING_SYSTEM stratum					
CROPPING_SYSTEM	1	6.685	6.685	5.31	0.061
TILLAGE_SYSTEM.CROPPING_SYSTEM	2	9.593	4.796	3.81	0.086
Residual	6	7.556	1.259	0.58	
REP.TILLAGE_SYSTEM.CROPPING_SYSTEM.FERTILIZER_APPLICATION stratum					
FERTILIZER_APPLICATION	2	19.111	9.556	4.43	0.023
TILLAGE_SYSTEM.FERTILIZER_APPLICATION	4	20.556	5.139	2.38	0.080
CROPPING_SYSTEM.FERTILIZER_APPLICATION	2	4.148	2.074	0.96	0.397
TILLAGE_SYSTEM.CROPPING_SYSTEM.FERTILIZER_APPLICATION	4	11.741	2.935	1.36	0.277
Residual	24	51.778	2.157		
Total	53	232.833			

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Appendix 17: Effect of tillage system, fertilizer rate and cropping system on plant height of maize (6 WAP) grown in Yagaba, in the Guinea savanna zone of Ghana, during the 2015 cropping season

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	2	2.778	1.389	0.48	
REP.TILLAGE_SYSTEM stratum					
TILLAGE_SYSTEM	2	585.333	292.667	101.31	<.001
Residual	4	11.556	2.889	0.69	
REP.TILLAGE_SYSTEM.CROPPING_SYSTEM stratum					
CROPPING_SYSTEM	1	46.296	46.296	11.01	0.016
TILLAGE_SYSTEM.CROPPING_SYSTEM	2	13.481	6.741	1.60	0.277
Residual	6	25.222	4.204	1.06	
REP.TILLAGE_SYSTEM.CROPPING_SYSTEM.FERTILIZER_APPLICATION stratum					
FERTILIZER_APPLICATION	2	547.111	273.556	69.03	<.001
TILLAGE_SYSTEM.FERTILIZER_APPLICATION	4	36.556	9.139	2.31	0.087
CROPPING_SYSTEM.FERTILIZER_APPLICATION	2	2.815	1.407	0.36	0.705
TILLAGE_SYSTEM.CROPPING_SYSTEM.FERTILIZER_APPLICATION	4	67.074	16.769	4.23	0.010
Residual	24	95.111	3.963		
Total	53	1433.333			

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Appendix 18: Effect of tillage system, fertilizer rate and cropping system on plant height of maize (9 WAP) grown in Yagaba, in the Guinea savanna zone of Ghana, during the 2015 cropping season

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	2	45.48	22.74	0.83	
REP.TILLAGE_SYSTEM stratum					
TILLAGE_SYSTEM	2	1712.15	856.07	31.30	0.004
Residual	4	109.41	27.35	1.04	
REP.TILLAGE_SYSTEM.CROPPING_SYSTEM stratum					
CROPPING_SYSTEM	1	56.02	56.02	2.12	0.195
TILLAGE_SYSTEM.CROPPING_SYSTEM	2	391.26	195.63	7.42	0.024
Residual	6	158.22	26.37	2.51	
REP.TILLAGE_SYSTEM.CROPPING_SYSTEM.FERTILIZER_APPLICATION stratum					
FERTILIZER_APPLICATION	2	2832.48	1416.24	134.76	<.001
TILLAGE_SYSTEM.FERTILIZER_APPLICATION	4	308.74	77.19	7.34	<.001
CROPPING_SYSTEM.FERTILIZER_APPLICATION	2	82.93	41.46	3.95	0.033
TILLAGE_SYSTEM.CROPPING_SYSTEM.FERTILIZER_APPLICATION	4	86.30	21.57	2.05	0.119
Residual	24	252.22	10.51		
Total	53	6035.20			

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Appendix 19: Effect of tillage system, fertilizer rate and cropping system on plant height of maize (12 WAP) grown in Yagaba, in the Guinea savanna zone of Ghana, during the 2015 cropping season

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Source of variation                 d.f.        s.s.        m.s.     v.r.   F pr.

REP stratum                            2       65.44       32.72     0.70

REP.TILLAGE_SYSTEM stratum
TILLAGE_SYSTEM                         2     3475.00     1737.50    37.12   0.003
Residual                               4      187.22       46.81     1.92

REP.TILLAGE_SYSTEM.CROPPING_SYSTEM stratum
CROPPING_SYSTEM                        1      317.80      317.80    13.04   0.011
TILLAGE_SYSTEM.CROPPING_SYSTEM
                                       2      110.48       55.24     2.27   0.185
Residual                               6      146.22       24.37     1.16

REP.TILLAGE_SYSTEM.CROPPING_SYSTEM.FERTILIZER_APPLICATION stratum
FERTILIZER_APPLICATION                 2     8934.33     4467.17   213.38  <.001
TILLAGE_SYSTEM.FERTILIZER_APPLICATION
                                       4      316.33       79.08     3.78   0.016
CROPPING_SYSTEM.FERTILIZER_APPLICATION
                                       2       66.70       33.35     1.59   0.224
TILLAGE_SYSTEM.CROPPING_SYSTEM.FERTILIZER_APPLICATION
                                       4      140.85       35.21     1.68   0.187
Residual                              24      502.44       20.94

Total                                 53    14262.83
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Appendix 20: **Effect of tillage system, fertilizer rate and cropping system on leaf area of maize (6 WAP) grown in Yagaba, in the Guinea savanna zone of Ghana, during the 2015 cropping season**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	2	800.6	400.3	2.11	
REP.TILLAGE_SYSTEM stratum					
TILLAGE_SYSTEM	2	26600.7	13300.4	70.14	<.001
Residual	4	758.5	189.6	1.23	
REP.TILLAGE_SYSTEM.CROPPING_SYSTEM stratum					
CROPPING_SYSTEM	1	317.8	317.8	2.06	0.201
TILLAGE_SYSTEM.CROPPING_SYSTEM	2	827.8	413.9	2.68	0.147
Residual	6	925.6	154.3	0.70	
REP.TILLAGE_SYSTEM.CROPPING_SYSTEM.FERTILIZER_APPLICATION stratum					
FERTILIZER_APPLICATION	2	31311.8	15655.9	70.96	<.001
TILLAGE_SYSTEM.FERTILIZER_APPLICATION	4	7320.0	1830.0	8.29	<.001
CROPPING_SYSTEM.FERTILIZER_APPLICATION	2	767.8	383.9	1.74	0.197
TILLAGE_SYSTEM.CROPPING_SYSTEM.FERTILIZER_APPLICATION	4	4931.1	1232.8	5.59	0.003
Residual	24	5295.3	220.6		
Total	53	79857.0			

Appendix 21: Effect of tillage system, fertilizer rate and cropping system on height of cob attachment of maize, grown in Yagaba, in the Guinea savanna zone of Ghana, during the 2015 cropping season

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	2	45.37	22.69	1.55	
REP.TILLAGE_SYSTEM stratum					
TILLAGE_SYSTEM	2	373.81	186.91	12.78	0.018
Residual	4	58.52	14.63	1.48	
REP.TILLAGE_SYSTEM.CROPPING_SYSTEM stratum					
CROPPING_SYSTEM	1	7.41	7.41	0.75	0.420
TILLAGE_SYSTEM.CROPPING_SYSTEM	2	1.37	0.69	0.07	0.934
Residual	6	59.22	9.87	0.74	
REP.TILLAGE_SYSTEM.CROPPING_SYSTEM.FERTILIZER_APPLICATION stratum					
FERTILIZER_APPLICATION	2	2228.04	1114.02	83.49	<.001
TILLAGE_SYSTEM.FERTILIZER_APPLICATION	4	70.19	17.55	1.32	0.293
CROPPING_SYSTEM.FERTILIZER_APPLICATION	2	6.04	3.02	0.23	0.799
TILLAGE_SYSTEM.CROPPING_SYSTEM.FERTILIZER_APPLICATION	4	44.19	11.05	0.83	0.521
Residual	24	320.22	13.34		
Total	53	3214.37			

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Appendix 22: Effect of tillage system, fertilizer rate and cropping system on cob length of maize, grown in Yagaba, in the Guinea savanna zone of Ghana, during the 2015 cropping season

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	2	8.481	4.241	3.42	
REP.TILLAGE_SYSTEM stratum					
TILLAGE_SYSTEM	2	39.815	19.907	16.04	0.012
Residual	4	4.963	1.241	0.56	
REP.TILLAGE_SYSTEM.CROPPING_SYSTEM stratum					
CROPPING_SYSTEM	1	1.500	1.500	0.68	0.441
TILLAGE_SYSTEM.CROPPING_SYSTEM	2	0.778	0.389	0.18	0.842
Residual	6	13.222	2.204	1.39	
REP.TILLAGE_SYSTEM.CROPPING_SYSTEM.FERTILIZER_APPLICATION stratum					
FERTILIZER_APPLICATION	2	292.593	146.296	92.40	<.001
TILLAGE_SYSTEM.FERTILIZER_APPLICATION	4	3.852	0.963	0.61	0.661
CROPPING_SYSTEM.FERTILIZER_APPLICATION	2	3.111	1.556	0.98	0.389
TILLAGE_SYSTEM.CROPPING_SYSTEM.FERTILIZER_APPLICATION	4	1.778	0.444	0.28	0.888
Residual	24	38.000	1.583		
Total	53	408.093			

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Appendix 23: Effect of tillage system, fertilizer rate and cropping system on cob weight of maize, grown in Yagaba, in the Guinea savanna zone of Ghana, during the 2015 cropping season

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	2	1.1659	0.5830	0.79	
REP.TILLAGE_SYSTEM stratum					
TILLAGE_SYSTEM	2	9.8626	4.9313	6.70	0.053
Residual	4	2.9452	0.7363	0.57	
REP.TILLAGE_SYSTEM.CROPPING_SYSTEM stratum					
CROPPING_SYSTEM	1	1.0980	1.0980	0.86	0.390
TILLAGE_SYSTEM.CROPPING_SYSTEM	2	5.6493	2.8246	2.21	0.191
Residual	6	7.6844	1.2807	2.02	
REP.TILLAGE_SYSTEM.CROPPING_SYSTEM.FERTILIZER_APPLICATION stratum					
FERTILIZER_APPLICATION	2	292.7848	146.3924	230.37	<.001
TILLAGE_SYSTEM.FERTILIZER_APPLICATION	4	8.6330	2.1582	3.40	0.025
CROPPING_SYSTEM.FERTILIZER_APPLICATION	2	0.1781	0.0891	0.14	0.870
TILLAGE_SYSTEM.CROPPING_SYSTEM.FERTILIZER_APPLICATION	4	1.4930	0.3732	0.59	0.675
Residual	24	15.2511	0.6355		
Total	53	346.7454			

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Appendix 24: Effect of tillage system, fertilizer rate and cropping system on hundred seed weight of maize, grown in Yagaba, in the Guinea savanna zone of Ghana, during the 2015 cropping season

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	2	0.593	0.296	0.04	
REP.TILLAGE_SYSTEM stratum					
TILLAGE_SYSTEM	2	87.259	43.630	6.05	0.062
Residual	4	28.852	7.213	3.17	
REP.TILLAGE_SYSTEM.CROPPING_SYSTEM stratum					
CROPPING_SYSTEM	1	0.296	0.296	0.13	0.731
TILLAGE_SYSTEM.CROPPING_SYSTEM	2	7.704	3.852	1.69	0.262
Residual	6	13.667	2.278	0.39	
REP.TILLAGE_SYSTEM.CROPPING_SYSTEM.FERTILIZER_APPLICATION stratum					
FERTILIZER_APPLICATION	2	434.370	217.185	37.00	<.001
TILLAGE_SYSTEM.FERTILIZER_APPLICATION	4	33.074	8.269	1.41	0.261
CROPPING_SYSTEM.FERTILIZER_APPLICATION	2	7.704	3.852	0.66	0.528
TILLAGE_SYSTEM.CROPPING_SYSTEM.FERTILIZER_APPLICATION	4	1.963	0.491	0.08	0.987
Residual	24	140.889	5.870		
Total	53	756.370			

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Appendix 25: Effect of tillage system, fertilizer rate and cropping system on grain yield of maize, grown in Yagaba, in the Guinea savanna zone of Ghana, during the 2015 cropping season

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	2	0.39370	0.19685	1.90	
REP.TILLAGE_SYSTEM stratum					
TILLAGE_SYSTEM	2	0.34481	0.17241	1.67	0.298
Residual	4	0.41407	0.10352	0.64	
REP.TILLAGE_SYSTEM.CROPPING_SYSTEM stratum					
CROPPING_SYSTEM	1	0.11574	0.11574	0.71	0.431
TILLAGE_SYSTEM.CROPPING_SYSTEM	2	0.42259	0.21130	1.30	0.340
Residual	6	0.97667	0.16278	1.84	
REP.TILLAGE_SYSTEM.CROPPING_SYSTEM.FERTILIZER_APPLICATION stratum					
FERTILIZER_APPLICATION	2	28.48926	14.24463	160.59	<.001
TILLAGE_SYSTEM.FERTILIZER_APPLICATION	4	0.71519	0.17880	2.02	0.124
CROPPING_SYSTEM.FERTILIZER_APPLICATION	2	0.02704	0.01352	0.15	0.859
TILLAGE_SYSTEM.CROPPING_SYSTEM.FERTILIZER_APPLICATION	4	0.25296	0.06324	0.71	0.591
Residual	24	2.12889	0.08870		
Total	53	34.28093			

Appendix 26: Effect of tillage system and fertilizer rate on plant height of soybean in a soybean –maize intercrop, grown in Yagaba, in the Guinea savanna zone of Ghana, during the 2015 cropping season

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	2.741	1.370	0.33	
Rep.TILLAGE_SYSTEM stratum					
TILLAGE_SYSTEM	2	98.741	49.370	11.74	0.021
Residual	4	16.815	4.204	0.95	
Rep.TILLAGE_SYSTEM.FERTILIZER_APPLICATION stratum					
FERTILIZER_APPLICATION	2	157.630	78.815	17.81	<.001
TILLAGE_SYSTEM.FERTILIZER_APPLICATION	4	43.259	10.815	2.44	0.103
Residual	12	53.111	4.426		
Total	26	372.296			

Appendix 27:Effect of tillage system and fertilizer rate on number of leaves of soybean in a soybean –maize intercrop production system, grown in Yagaba, in the Guinea savanna zone of Ghana, during the 2015 cropping season

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	4.74	2.37	0.22	
Rep.TILLAGE_SYSTEM stratum					
TILLAGE_SYSTEM	2	64.30	32.15	3.02	0.159
Residual	4	42.59	10.65	0.65	
Rep.TILLAGE_SYSTEM.FERTILIZER_APPLICATION stratum					
FERTILIZER_APPLICATION	2	266.74	133.37	8.08	0.006
TILLAGE_SYSTEM.FERTILIZER_APPLICATION	4	52.59	13.15	0.80	0.550
Residual	12	198.00	16.50		
Total	26	628.96			

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Appendix 28: Effect of tillage system and fertilizer rate on pod number of soybean in a soybean –maize intercrop production system, grown in Yagaba, in the Guinea savanna zone of Ghana, during the 2015 cropping season

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	20.519	10.259	1.28	
Rep.TILLAGE_SYSTEM stratum					
TILLAGE_SYSTEM	2	169.407	84.704	10.54	0.025
Residual	4	32.148	8.037	0.93	
Rep.TILLAGE_SYSTEM.CROPPING_SYSTEM.FERTILIZER_APPLICATION stratum					
FERTILIZER_APPLICATION	2	302.741	151.370	17.47	<.001
TILLAGE_SYSTEM.FERTILIZER_APPLICATION	4	35.259	8.815	1.02	0.437
Residual	12	104.000	8.667		
Total	26	664.074			

Appendix 29:Effect of tillage system and fertilizer rate on number of seeds per pod of soybean in a soybean – maize intercrop production system, grown in Yagaba, in the Guinea savanna zone of Ghana, during the 2015 cropping season

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	0.2222	0.1111	2.00	
Rep.TILLAGE_SYSTEM stratum					
TILLAGE_SYSTEM	2	0.2222	0.1111	2.00	0.250
Residual	4	0.2222	0.0556	0.30	
Rep.TILLAGE_SYSTEM.FERTILIZER_APPLICATION stratum					
FERTILIZER_APPLICATION	2	1.5556	0.7778	4.20	0.041
TILLAGE_SYSTEM.FERTILIZER_APPLICATION	4	0.2222	0.0556	0.30	0.872
Residual	12	2.2222	0.1852		
Total	26	4.6667			

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Appendix 30:Effect of tillage system and fertilizer rate on hundred seed weight of soybean in a soybean –maize intercrop production system, grown in Yagaba, in the Guinea savanna zone of Ghana, during the 2015 cropping season

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	2.6763	1.3381	2.25	
Rep.TILLAGE_SYSTEM stratum					
TILLAGE_SYSTEM	2	4.1385	2.0693	3.47	0.134
Residual	4	2.3837	0.5959	1.44	
Rep.TILLAGE_SYSTEM.FERTILIZER_APPLICATION stratum					
FERTILIZER_APPLICATION	2	30.5207	15.2604	36.87	<.001
TILLAGE_SYSTEM.FERTILIZER_APPLICATION	4	2.4659	0.6165	1.49	0.266
Residual	12	4.9667	0.4139		
Total	26	47.1519			

Appendix 31:Effect of tillage system and fertilizer rate on grain yield of soybean in a soybean –maize intercrop production system, grown in Yagaba, in the Guinea savanna zone of Ghana, during the 2015 cropping season

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	0.00616	0.00308	0.24	
Rep.TILLAGE_SYSTEM stratum					
TILLAGE_SYSTEM	2	0.40723	0.20361	16.17	0.012
Residual	4	0.05037	0.01259	0.47	
Rep.TILLAGE_SYSTEM.FERTILIZER_APPLICATION stratum					
FERTILIZER_APPLICATION	2	1.32883	0.66441	24.92	<.001
TILLAGE_SYSTEM.FERTILIZER_APPLICATION	4	0.30957	0.07739	2.90	0.068
Residual	12	0.32000	0.02667		
Total	26	2.42216			

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Appendix 32: Cost of production for Sole maize ploughed with zero rate of fertilizer application

Item/Activity	**Quantity**	**Unit price (GH ¢)**	**Total (GH ¢)**
Land preparation	1 hectare	125.00	125.00
Planting material:			
Maize seeds	25 kg	5	125.00
Planting	1 hectare	110	110.00
Weeding	3 times	120	360.00
Harvesting	1 hectare	120	120.00
Threshing and Bagging		210	210.00
Transportation	16 bags	5	80.00
			= 1130.00

Appendix 33: Benefit from the production of Sole maize, ploughed with zero rate of fertilizer application

Quantity	**Unit price (GH ¢)**	**Total (GH ¢)**
16 bags	90	**1440.00**

Appendix 34: Cost of production for Sole maize ploughed with half rate of fertilizer application

Item/Activity	**Quantity**	**Unit price (GH ¢)**	**Total (GH ¢)**
Land preparation	1 hectare	125	125.00
Planting material:			
Maize seeds	25 kg	5	125.00
Fertilizer	50 kg (1bag)	83	83.00
Planting	1 hectare	110	110.00
Weeding	3 times	120	360.00
Fertilizer application	2 times	40	80.00
Harvesting	1 hectare	120	120.00
Threshing and Bagging		210	210.00
Transportation	29 bags	5	145.00
			=1258.00

Appendix 35: Benefit from the production of Sole maize, ploughed with half rate of fertilizer application

Quantity	Unit price (GH ¢)	Total (GH ¢)
29 bags	90	**2610.00**

Appendix 36: Cost of production for Sole maize ploughed with full rate of fertilizer application

Item/Activity	Quantity	Unit price (GH ¢)	Total (GH ¢)
Land preparation	1 hectare	125	125.00
Planting material:			
Maize seeds	25 kg	5	125.00
Fertilizer	100 kg (2bags)	83	166.00
Planting	1 hectare	110	110.00
Weeding	3 times	120	360.00
Fertilizer application	2 times	40	80.00
Harvesting	1 hectare	120	120.00
Threshing and Bagging		210	210.00
Transportation	32 bags	5	160.00
			= **1356.00**

Appendix 37: Benefit from the production of Sole maize, ploughed with full rate of fertilizer application

Quantity	Unit price (GH ¢)	Total (GH ¢)
32 bags	90	**2880.00**

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Appendix 38: Cost of production for intercrop (maize+soybean) ploughed with zero rate of fertilizer application

Item/Activity	Quantity	Unit price (GH ¢)	Total (GH ¢)
Land preparation	1 hectare	125	125.00
Planting material:			
• Maize seeds	25 kg	5	125.00
• Soybean seeds	30 kg	8	240.00
Planting:			
• Maize	1 hectare	110	110.00
• Soybean	1 hectare	120	120.00
Weeding	3 times	120	360.00
Harvesting:			
• Maize	1 hectare	120	120.00
• Soybean	1 hectare	140	140.00
Threshing and Bagging:			
• Maize			
• Soybean		210	210.00
		240	240.00
Transportation:			
• Maize	14 bags	5	70.00
• Soybean	8.4 bags	5	42.00
			= 1902.00

Appendix 39: Benefit from the production of intercrop (maize+soybean), ploughed with zero rate of fertilizer application

Quantity	Unit price (GH ¢)	Total (GH ¢)
Maize: 14 bags	90	1260.00
Soybean: 8.4 bags	160	1344.00
		= 2604.00

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Appendix 40: Cost of production for intercrop (maize+soybean) ploughed with half rate of fertilizer application

Item/Activity	Quantity	Unit price (GH ¢)	Total (GH ¢)
Land preparation	1 hectare	125	125.00
Planting material:			
• Maize seeds	25 kg	5	125.00
• Soybean seeds	30 kg	8	240.00
Fertilizer	50 kg (1 bag)	83	83.00
Planting:			
• Maize	1 hectare	110	110.00
• Soybean	1 hectare	120	120.00
Weeding	3 times	120	360.00
Fertilizer application	2 times	40	80.00
Harvesting:			
• Maize	1 hectare	120	120.00
• Soybean	1 hectare	140	140.00
Threshing and Bagging:			
• Maize			
• Soybean		210	210.00
		240	240.00
Transportation:			
• Maize	24 bags	5	120.00
• Soybean	13.2 bags	5	66.00
			= 2039.00

Appendix 41: Benefit from the production of intercrop (maize+soybean), ploughed with half rate of fertilizer application

Quantity	Unit price (GH ¢)	Total (GH ¢)
Maize: 24 bags	90	2160.00
Soybean: 13.2 bags	160	2112.00
		= 4272.00

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Appendix 42: Cost of production for intercrop (maize+soybean) ploughed with full rate of fertilizer application

Item/Activity	**Quantity**	**Unit price (GH ¢)**	**Total (GH ¢)**
Land preparation	1 hectare	125	125.00
Planting material:			
• Maize seeds	25 kg	5	125.00
• Soybean seeds	30 kg	8	240.00
Fertilizer	100 kg (2 bags)	83	83.00
Planting:			
• Maize	1 hectare	110	110.00
• Soybean	1 hectare	120	120.00
Weeding	3 times	120	360.00
Fertilizer application	2 times	40	80.00
Harvesting:			
• Maize	1 hectare	120	120.00
• Soybean	1 hectare	140	140.00
Threshing and Bagging:			
• Maize			
• Soybean		210	210.00
		240	240.00
Transportation:			
• Maize	31 bags	5	155.00
• Soybean	17.6 bags	5	88.00
			= 2196.00

Appendix 43: Benefit from the production of intercrop (maize+soybean), ploughed with full rate of fertilizer application

Quantity	**Unit price (GH ¢)**	**Total (GH ¢)**
Maize: 31 bags	90	2790.00
Soybean: 17.6 bags	160	2816.00
		= 5606.00

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Appendix 44: Cost of production for Sole maize ripped with zero rate of fertilizer application

Item/Activity	Quantity	Unit price (GH ¢)	Total (GH ¢)
Land preparation	1 hectare	100	100.00
Planting material:			
Maize seeds	25 kg	5	125.00
Planting	1 hectare	110	110.00
Weeding	2 times	120	240.00
Harvesting	1 hectare	120	120.00
Threshing and Bagging		210	210.00
Transportation	19 bags	5	95.00
			= **1000.00**

Appendix 45: Benefit from the production of Sole maize, ripped with zero rate of fertilizer application

Quantity	Unit price (GH ¢)	Total (GH ¢)
19 bags	90	**1710.00**

Appendix 46: Cost of production for Sole maize ripped with half rate of fertilizer application

Item/Activity	Quantity	Unit price (GH ¢)	Total (GH ¢)
Land preparation	1 hectare	100	100.00
Planting material:			
Maize seeds	25 kg	5	125.00
Fertilizer	50 kg (1bag)	83	83.00
Planting	1 hectare	110	110.00
Weeding	2 times	120	240.00
Fertilizer application			
	2 times	40	80.00
Harvesting	1 hectare	120	120.00
Threshing and Bagging		210	210.00
Transportation	27 bags	5	135.00
			= **1203.00**

Appendix 47: Benefit from the production of Sole maize, ripped with half rate of fertilizer application

Quantity	Unit price (GH ¢)	Total (GH ¢)
27 bags	90	**2430.00**

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Appendix 48: Cost of production for Sole maize ripped with full rate of fertilizer application

Item/Activity	Quantity	Unit price (GH ¢)	Total (GH ¢)
Land preparation	1 hectare	100	100.00
Planting material:			
Maize seeds	25 kg	5	125.00
Fertilizer	100 kg (2bags)	83	166.00
Planting	1 hectare	110	110.00
Weeding	2 times	120	240.00
Fertilizer application			
	2 times	40	80.00
Harvesting	1 hectare	120	120.00
Threshing and Bagging			
		210	210.00
Transportation	26 bags	5	130.00
			= **1281.00**

Appendix 49: Benefit from the production of Sole maize, ripped with full rate of fertilizer application

Quantity	Unit price (GH ¢)	Total (GH ¢)
26 bags	90	**2340.00**

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Appendix 50: Cost of production for intercrop (maize+soybean) ripped with zero rate of fertilizer application

Item/Activity	**Quantity**	**Unit price (GH ¢)**	**Total (GH ¢)**
Land preparation	1 hectare	100	100.00
Planting material:			
• Maize seeds	25 kg	5	125.00
• Soybean seeds	30 kg	8	240.00
Planting:			
• Maize	1 hectare	110	110.00
• Soybean	1 hectare	120	120.00
Weeding	2 times	120	240.00
Harvesting:			
• Maize	1 hectare	120	120.00
• Soybean	1 hectare	140	140.00
Threshing and Bagging:			
• Maize			
• Soybean		210	210.00
		240	240.00
Transportation:			
• Maize	13 bags	5	65.00
• Soybean	8.4 bags	5	42.00
			= 1752.00

Appendix 51: Benefit from the production of intercrop (maize+soybean), ripped with zero rate of fertilizer application

Quantity	**Unit price (GH ¢)**	**Total (GH ¢)**
Maize: 13 bags	90	1170.00
Soybean: 8.4 bags	160	1344.00
		= 2514.00

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Appendix 52: Cost of production for intercrop (maize+soybean) ripped with half rate of fertilizer application

Item/Activity	Quantity	Unit price (GH ¢)	Total (GH ¢)
Land preparation	1 hectare	100	100.00
Planting material:			
• Maize seeds	25 kg	5	125.00
• Soybean seeds	30 kg	8	240.00
Fertilizer	50 kg (1 bag)	83	83.00
Planting:			
• Maize	1 hectare	110	110.00
• Soybean	1 hectare	120	120.00
Weeding	2 times	120	240.00
Fertilizer application	2 times	40	80.00
Harvesting:			
• Maize	1 hectare	120	120.00
• Soybean	1 hectare	140	140.00
Threshing and Bagging:			
• Maize			
• Soybean		210	210.00
		240	240.00
Transportation:			
• Maize	21 bags	5	105.00
• Soybean	8.4 bags	5	42.00
			= 1955.00

Appendix 53: Benefit from the production of intercrop (maize+soybean), ripped with half rate of fertilizer application

Quantity	Unit price (GH ¢)	Total (GH ¢)
Maize: 21 bags	90	1890.00
Soybean: 8.4 bags	160	1344.00
		= 3234.00

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Appendix 54: Cost of production for intercrop (maize+soybean) ripped with full rate of fertilizer application

Item/Activity	**Quantity**	**Unit price (GH ¢)**	**Total (GH ¢)**
Land preparation	1 hectare	100	100.00
Planting material:			
• Maize seeds	25 kg	5	125.00
• Soybean seeds	30 kg	8	240.00
Fertilizer	100 kg (2 bags)	83	83.00
Planting:			
• Maize	1 hectare	110	110.00
• Soybean	1 hectare	120	120.00
Weeding	2 times	120	240.00
Fertilizer application	2 times	40	80.00
Harvesting:			
• Maize	1 hectare	120	120.00
• Soybean	1 hectare	140	140.00
Threshing and Bagging:			
• Maize			
• Soybean		210	210.00
		240	240.00
Transportation:			
• Maize	28 bags	5	140.00
• Soybean	13.6 bags	5	68.00
			= **2016.00**

Appendix 55: Benefit from the production of intercrop (maize+soybean), ploughed with full rate of fertilizer application

Quantity	**Unit price (GH ¢)**	**Total (GH ¢)**
Maize: 28 bags	90	2520.00
Soybean: 13.6 bags	160	2176.00
		= **4696.00**

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Appendix 56: Cost of production for Direct seeded Sole maize with zero rate of fertilizer application

Item/Activity	Quantity	Unit price (GH ¢)	Total (GH ¢)
Planting material:			
Maize seeds	25 kg	5	125.00
Atrazine (a.i WP 80 g/l/ha)			
	4 (80 g/l/ha)	25	100.00
Planting	1 hectare	110	110.00
Weed control	2 times	90	180.00
Harvesting	1 hectare	120	120.00
Threshing and Bagging		210	210.00
Transportation	14 bags	5	70.00
			= 915.00

Appendix 57: Benefit from the production of Direct seeded Sole maize, with zero rate of fertilizer application

Quantity	Unit price (GH ¢)	Total (GH ¢)
14 bags	90	**1260.00**

Appendix 58: Cost of production for Direct seeded Sole maize with half rate of fertilizer application

Item/Activity	Quantity	Unit price (GH ¢)	Total (GH ¢)
Planting material:			
Maize seeds	25 kg	5	125.00
Fertilizer	50 kg (1bag)	83	83.00
Atrazine (a.i WP 80 g/l/ha)			
	4 (80 g/l/ha)	25	100.00
Planting	1 hectare	110	110.00
Weed control	2 times	90	180.00
Fertilizer application	2 times	40	80.00
Harvesting	1 hectare	120	120.00
Threshing and Bagging		210	210.00
Transportation	24 bags	5	120.00
			= 1128.00

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Appendix 59: Benefit from the production of Direct seeded Sole maize, with half rate of fertilizer application

Quantity	Unit price (GH ¢)	Total (GH ¢)
24 bags	90	**2160.00**

Appendix 60: Cost of production for Direct seeded Sole maize with full rate of fertilizer application

Item/Activity	Quantity	Unit price (GH ¢)	Total (GH ¢)
Planting material:			
Maize seeds	25 kg	5	125.00
Fertilizer	100 kg (2bags)	83	166.00
Atrazine (a.i WP 80 g/l/ha)	4 (80 g/l/ha)	25	100.00
Planting	1 hectare	110	110.00
Weed control	2 times	90	180.00
Fertilizer application	2 times	40	80.00
Harvesting	1 hectare	120	120.00
Threshing and Bagging		210	210.00
Transportation	30 bags	5	150.00
			= **1241.00**

Appendix 61: Benefit from the production of Direct seeded Sole maize, with full rate of fertilizer application

Quantity	Unit price (GH ¢)	Total (GH ¢)
30 bags	90	**2700.00**

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Appendix 62: Cost of production for Direct seeded intercrop (maize+soybean) with zero rate of fertilizer application

Item/Activity	Quantity	Unit price (GH ¢)	Total (GH ¢)
Planting material:			
• Maize seeds	25 kg	5	125.00
• Soybean seeds	30 kg	8	240.00
Atrazine (a.i WP 80 g/l/ha)			
	4 (80 g/l/ha)	25	100.00
Planting:			
• Maize	1 hectare	110	110.00
• Soybean	1 hectare	120	120.00
Weed control	2 times	90	180.00
Harvesting:			
• Maize	1 hectare	120	120.00
• Soybean	1 hectare	140	140.00
Threshing and Bagging:			
• Maize			
• Soybean		210	210.00
		240	240.00
Transportation:			
• Maize	14 bags	5	70.00
• Soybean	7.2 bags	5	36.00
			= 1691.00

Appendix 63: Benefit from the production of Direct seeded intercrop (maize+soybean) with zero rate of fertilizer application

Quantity	Unit price (GH ¢)	Total (GH ¢)
Maize: 14 bags	90	1260.00
Soybean: 7.2 bags	160	1152.00
		= 2412.00

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Appendix 64: Cost of production for Direct seeded intercrop (maize+soybean) with half rate of fertilizer application

Item/Activity	Quantity	Unit price (GH ¢)	Total (GH ¢)
Planting material:			
• Maize seeds	25 kg	5	125.00
• Soybean seeds	30 kg	8	240.00
Atrazine (a.i WP 80 g/l/ha)			
	4 (80 g/l/ha)	25	100.00
Fertilizer	50 kg (1bag)	83	83.00
Planting:			
• Maize	1 hectare	110	110.00
• Soybean	1 hectare	120	120.00
Weed control	2 times	90	180.00
Fertilizer application	2 times	40	80.00
Harvesting:			
• Maize	1 hectare	120	120.00
• Soybean	1 hectare	140	140.00
Threshing and Bagging:			
• Maize			
• Soybean		210	210.00
		240	240.00
Transportation:			
• Maize	27 bags	5	135.00
• Soybean	8.8 bags	5	44.00
			= 1927.00

Appendix 65: Benefit from the production of Direct seeded intercrop (maize+soybean) with half rate of fertilizer application

Quantity	Unit price (GH ¢)	Total (GH ¢)
Maize: 27 bags	90	2430.00
Soybean: 8.8 bags	160	1408.00
		= 3838.00

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Appendix 66: Cost of production for Direct seeded intercrop (maize+soybean) with full rate of fertilizer application

Item/Activity	Quantity	Unit price (GH ¢)	Total (GH ¢)
Planting material:			
• Maize seeds	25 kg	5	125.00
• Soybean seeds	30 kg	8	240.00
Atrazine (a.i WP 80 g/l/ha)			
	4 (80 g/l/ha)	25	100.00
Fertilizer	100 kg (2bags)	83	83.00
Planting:			
• Maize	1 hectare	110	110
• Soybean	1 hectare	120	120
Weed control	2 times	90	180
Fertilizer application	2 times	40	80
Harvesting:			
• Maize	1 hectare	120	120
• Soybean	1 hectare	140	140
Threshing and Bagging:			
• Maize			
• Soybean		210	210
		240	240
Transportation:			
• Maize	27 bags	5	135
• Soybean	10.8 bags	5	54
			= 1937

Appendix 67: Benefit from the production of Direct seeded intercrop (maize+soybean) with full rate of fertilizer application

Quantity	Unit price (GH ¢)	Total (GH ¢)
Maize: 27 bags	90	2430
Soybean: 10.8 bags	160	1728
		= 4158