EFFECTS OF TILLAGE AND NPK 15-15-15 FERTILISER APPLICATION ON MAIZE PERFORMANCE AND SOIL PROPERTIES

by

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DECLARATION

I hereby declare that this submission is my own work towards the Master of Science in Environmental Resources Management and that, to the best of my knowledge, it contains no material previously published by another person nor material which has been accepted for the award of any other degree of the University, except where due acknowledgment has been made in the text.

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ABSTRACT

The effects of two tillage treatments and four NPK15-15-15 fertiliser application on *Akposoe* maize (*Zea mays*, L.) performance and soil properties were evaluated under rainfed conditions in Kumasi in the 2010 minor and the 2011 major cropping seasons. The experiment was arranged as a factorial in a randomised complete block design. Tillage consisted of disc-ploughing followed by disc-harrowing and No Tillage while fertiliser application included 0, 150, 250, and 350 kg ha^{-1}. Overall, in both 2010 and 2011, at 10 weeks after planting, the disc-ploughing followed by disc-harrowing presented plant height, stem girth, number of leaves per plant, leaf area, root length and dry matter yield significantly greater than that of No Tillage. In 2010, grain yield obtained under No Tillage was higher than that under disc-ploughing followed by disc-harrowing although there was no significant difference between the two treatments. In 2011, however, disc-ploughing followed by disc-harrowing resulted in a significantly higher grain yield compared with that of No Tillage. Generally, applying NPK 15-15-15 fertiliser gave statistically significant growth and yield parameters in comparison with that of the 0 kg ha^{-1} fertiliser application rate. In 2011, the 250 kg ha^{-1} fertiliser application rate gave significantly higher grain yield compared with that of the 0 kg ha^{-1} rate. Soil penetration resistance and dry bulk density values after harvest were lower in the disc-ploughing followed by disc-harrowing plots than in the No Tillage plots before ploughing. In contrast, moisture content and total porosity after harvest were higher in the disc-ploughing followed by disc-harrowing plots than in the No Tillage plots before ploughing. Disc-ploughing followed by disc-harrowing, and applying NPK15-15-15 fertiliser at 250 kg ha^{-1} increased maize growth and yield. Additionally, disc-ploughing followed by disc-harrowing reduced soil penetration resistance and bulk density while increasing soil moisture content and total porosity.

DEDICATION

I dedicate this work to the glory of Yehowa Yasha.

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Francis Kyeremateng Arthur

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1. INTRODUCTION

1.1 Background to the study

Poor maize (*Zea mays,* L.) performance is a major concern for farmers in West Africa, and in particular, Ghana. Over 1,023,108 hectares of maize was harvested in Ghana in 2011 (FAO Statistical Databases, 2013). Maize is the most important cereal crop produced in Ghana. The crop is consumed by people with varying food preferences and socio-economic backgrounds in the country (Badu-Apraku *et al*., 2011). Maize is grown by the vast majority of rural households in all parts of Ghana except for the Sudan savannah zone (Morris *et al*., 1999). In Ghana, maize is largely grown by resource poor smallholder farmers under rainfed conditions. 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. There are some farmers who disc harrow without disc ploughing before planting. Some farmers "slash and burn" while others use no tillage before planting maize (Aikins *et al*., 2012). Many farmers perform tillage operations without being aware of the effect of these operations on soil physical properties and crop responses (Ozpinar and Isik, 2004).

The production of maize in Ghana was not enough to meet the domestic demand of 42.5 kg/head/year (Asafo-Agyei *et. al*., 1995). In 2004, Ghana exported 48 Mt of maize for $7,000 and imported 50,000 Mt of maize at a cost of $10,000,000 (FAO Statistical Databases, 2006 cited by Aikins *et al*., 2011). Factors affecting maize production in Ghana include poor weed and pest control, declining soil fertility, little or inadequate use of chemical fertilisers and inappropriate tillage practices (Aikins *et al*., 2012). Tillage may be described as the practice of modifying the state of the soil in order to provide conditions favourable to crop growth (Culpin, 1981). Tillage plays an important role in the production of crops such as maize. Tillage can affect crop production positively or negatively. Tillage influences soil quality via its effects on soil physical, chemical and biological properties, which in turn affect crop productivity (Anikwe and Ubochi, 2007).

In the humid tropics where most of the farmers are smallholders and chemical fertiliser is scarce and expensive, soil working and tillage methods can be a suitable alternative to enhance nutrient availability to crops (Adekiya and Ojeniyi, 2002). Disc ploughing is one of the fundamental operations undertaken in conventional tillage. According to Rashidi and Keshavarzpour (2007), conventional tillage practices modify soil structure by changing its physical properties such as soil bulk density, soil penetration resistance, soil moisture content, soil porosity and soil air. Papworth (2010) has also indicated that tillage influences crop growth and yields by changing soil structure and moisture removal patterns over the growing season. Disc ploughing in Ghana is undertaken in many farming areas including Ejura, Afram Plains, Atebubu, Nkoranza, Techiman, Wenchi, Nyankpala and Tamale (Aikins *et al*., 2007). Ploughing may be beneficial because of its loosening effect on the soil (Arvidsson, 1998), has increased the yield of numerous crops (Barbosa *et al*., 1989; Mathers *et al*., 1971 cited by Wesley *et al*., 2001) and has proven to be a practical method of increasing soil water intake rates (Wesley *et al*., 2001). Ploughing, however, results in reduced amounts of residue present on the soil surface (Raper, 2002).

Conservation tillage plays an important role in reducing soil erosion and improving soil quality (Uri *et al*., 1999) and can be an attractive alternative to conventional tillage for farmers because it has the potential to minimize labour and fuel consumption and to lower total production cost (Uri, 2000). No tillage is a system where crops are grown in narrow slots or tilled strips in previously undisturbed soil. In no tillage, there is less soil compaction, lower fuel and labour costs. Moreover, no tillage has many other advantages such as controlling wind and water erosion, reducing soil moisture loss and greenhouse gas emissions (Lindstrom and Reicosky, 1997 cited by Chen *et al*., 2005). No tillage has been noted to improve the soil structure compared with mouldboard ploughed soil, for example by increasing the organic matter content close to the soil surface (Rydberg, 1987). A major disadvantage of no tillage, however, is soil compaction which may increase mechanical resistance, thus hampering root growth (Comia *et al*., 1994; Rydberg, 1987 cited by Arvidsson, 1998).

The continuous cultivation of soils leads to low yields in maize due to the mining of the soil nutrients. This calls for the use of external inputs in order to reverse the loss of nutrients and maintain productivity (Mbah, 2006 cited by Agbede, 2010). The replenishment of nutrient and enhanced quality of tropical soils could be achieved through the addition of fertilizers (Shangakkara *et al*., 2004). Fertiliser is a component of sustainable crop production systems. Maize requires adequate supply of nutrients particularly nitrogen, phosphorus and potassium (NPK) for good growth and high yield. The quantity required of these nutrients depends on the pre-clearing vegetation, soil organic matter content, tillage method and light intensity (Kang, 1981).

The use of fertilizers will be critical to increasing food supply to support a growing population during the 21st century. However, an understanding of the underlying concepts of fertilizer use and the technologies that are available to deliver them will be critical in ensuring that increased use of fertilizers is not associated with further environmental degradation. Thus, it is important for the right amount of fertiliser to be applied onto crops.

Fertiliser application is one major farming operation needed to correct deficiencies in the soil in order to ensure proper growth and functioning of crops with the aim of increasing yield (Brady, 1990; Srivastava *et al*., 2006; Webster and Wilson, 1992). However, for effective soil fertility management, the right quantity of fertiliser needs to be applied. Inadequate fertiliser application rates lead to poor crop growth and yield. On the other hand, over application of fertiliser leads to low crop yield and environmental pollution. Adekayode and Ogunkoya (2010) observed improved maize growth parameters with corresponding higher yield in plots treated with fertilisers at 300 and 250 kg per hectare in Nigeria. In Ghana, while some farmers do not apply fertiliser on maize plants at all, others apply at varying rates unaware of its effects on the crop and on the environment.

1.2 Justification for the study

The environment of many agricultural systems in Ghana is highly deteriorated because of soil erosion and decreased fertility. Fertilization has the potential to dramatically increase maize production (Stewart *et al*., 2005), yet increased nutrient application is rarely managed by recommendations derived from soil testing and consequently this leads to misuse and associated economic (Chase *et al*., 1991) and environmental risks (Bundy *et al*., 2001; Cox and Lins, 1984). Further, inappropriate rate of fertiliser application and poor soil management worsen the soil degradation, adversely affecting the environment and jeopardizing the soil's productivity (Wienhold *et al*., 2004). With increasing fertiliser costs and declining soil fertility in many production areas in Ghana, knowledge of mineral fertiliser application rate and appropriate tillage requirements is vital to optimising maize production. Information on tillage requirements of maize and the implications of tillage-fertilizer types combination on maize performance is scarce in Ghana. It was appropriate, therefore, that this research be conducted since there is insufficient information on the effect of tillage and optimum NPK fertiliser application rates on maize performance and soil properties in Ghana.

1.3 Aim and objectives

The aim of the study was to determine the effects of tillage and NPK-15-15-15 fertiliser application rates on *Akposoe* maize variety and soil performance. The specific objectives of the study were to:

1. determine the effects of tillage and NPK15-15-15 fertiliser application rates, and their interaction on maize growth, dry matter yield and yield.
2. determine the effects of tillage and NPK15-15-15 fertiliser application rates and their interaction on soil penetration resistance, dry bulk density, moisture content and total porosity.

2. LITERATURE REVIEW

2.1 Origin, Classification and Botany of Maize

Maize (*Zea mays* L.), is an annual monocotyledon that belongs to the family Poaceae and the Maydeae tribe of which eight different genera have been recognised by taxonomists (Raemaekers, 2001).It is generally agreed that teosinte (*Z. mexicana*) is an ancestor of maize, although opinions vary as to whether maize is a domesticated version of teosinte (Galinat, 1988). *Zea* is a genus of the family Graminae (Poaceae), commonly known as the grass family.

Maize is a tall, monoecious annual grass with overlapping sheaths and broad conspicuously distichous blades. Plants have staminate spikelets in long spike-like racemes that form large spreading terminal panicles (tassels) and pistillate inflorescences in the leaf axils, in which the spikelets occur in 8 to 16 rows, approximately 30 cm long, on a thickened, almost woody axis (cob). The whole structure (cob) is enclosed in numerous large foliaceous bracts and a mass of long styles (silks) protrude from the tip as a mass of silky threads (Hitchcock and Chase, 1971). Pollen is produced entirely in the staminate inflorescence and cob, entirely in the pistillate inflorescence. Maize is wind pollinated and both self and cross pollination is usually possible. Maize is cultivated worldwide and represents a staple food for a significant proportion of the world's population. No significant native toxins are reported to be associated with the genus Zea (International Food Biotechnology Council, 1990).

2.1.1 The physiology of maize

The maize stems look like bamboo cane and the joints (nodes) are about 40–50 cm apart. The stems are erect and the height varies from 1–3 m. Maize has a very distinct growth form, the lower leaves being like broad flags, 50–100 cm long and 5–10 cm wide. The leaves consist of a leave sheath which grasps the stem and a long slender tapering leaf blade and a ligule. The ligule marks the point where the leaf blade extends from the stem. A leaf occurs at each node.

The leaves are opposite ranked. A mature maize plant produces 20-23 leaves depending on its period of maturity and development (Twumasi-Afriyie and Sallah, 1994). The leaf is supported by a prominent mid-rib along its entire length. Under the leaves and close to the stem grow the cobs. There are female inflorescences, tightly covered over by several layers of leaves, and so closed in by them to the stem, that they do not show themselves easily until the emergence of the pale yellow silks from the leaf whorl at the end of the cob. The silks are elongated stigmas that look like tufts of hair, at first green and later red or yellow. The apex of the stem ends in a male flower, the tassel. For each silk on which pollen from the tassel lands, one kernel of maize is produced. As the plant matures the cob becomes tougher and the silk dries to inedibility. The kernels dry out and become difficult to chew without cooking them tender first in boiling water. The grains are about the size of peas, and adhere in regular rows round a white pithy substance, which forms the cob. The root system is fibrous, spreading in all directions. The primary roots develop from the seed at germination and supply most nutrition during the first weeks. The permanent or coronal roots arise from the crown just below the soil surface once the seedling is growing well. Later on, more adventitious roots develop from above ground nodes and grow into the soil, their function being to anchor the plant and support it in upright position (Raemaekers, 2001).

2.1.2 Importance and uses of maize

Maize is a staple food for an estimated 50% of the population of sub-Sahara Africa and provides 50% of the basic calories (Ofori and Kyei-Baffour, 2006). It is an important source of carbohydrate, protein, iron, vitamin B, and minerals. Maize grains have great nutritional value as they may 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 the year 2000 was estimated at 42.5 kg (MoFA, 2000) and an estimated national consumption of 943,000 Mt in 2006 (SRID & MoFA, 2007).

Maize has numerous uses and ranks second only to wheat among the world's cereal crops in terms of total production. Also, because of its worldwide distribution and lower prices relative to other cereals, maize has a wider range of uses than any other cereals. It is the staple food crop and the base of most rural diets, as well as a cash crop. In poor communities, it is the main source of calories and protein, as well as the primary weaning food for babies (Mashingaidze, 2004). In developed countries, maize is consumed mainly as second-cycle produce, in the form of meat, eggs and dairy products.

In developing countries, maize is consumed directly and serves as staple diet for so many people. Africans consume maize as a starchy base 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 (Ofori and Kyei-Baffour, 2006). Each country has one or more maize dishes that are unique to its culture. Examples are *Ogi* (Nigeria), *Kenkey* (Ghana), *Koga* (Cameroon), *Tô* (Mali), *Injera* (Ethiopia), *Ugali* (Kenya). Most of these products are still traditionally processed (Okoruwa, 1997). Every part of the maize plant has economic value - the grain, leaves, stalk, tassel and cob can all be used to produce a large variety of food and non-food products (Raemaekers, 2001) cited by Gomez (2010). The husk is used to wrap food while the cobs and stalks are used as bio-fuels (Sallah *et al*., 2002).

2.1.3 Varieties of Maize

There are four general types of corn, the vegetable sweet corn, pop corn, flint corn (also known as Indian corn) and dent corn. While sweet corn is mainly meant for human consumption, i.e. primarily eaten on the cob and can be canned or frozen for future consumption, it is seldom used for feed or flour. Dent corn is the most widely grown maize variety. It is often used as livestock feed, in industrial products, or to make processed foods. Either white or yellow, dent kernels contain both hard and soft starch that become indented at maturity. Flint corn is used for similar purposes as the dent corn. Varieties of maize grown in Ghana include; '*Obaatanpa, Aburotia, Dobidi, Mamaba, Dadaba* and *Okomasa*'. In addition, extra-early maturing and Quality Protein Maize varieties tolerant of drought and resistant to weeds have been released to farmers. They are Golden Jubilee, "*Aziga*" (meaning big egg in Ewe), "*Etuto-Pibi*" (meaning father's child in Gonja) and "*Akposoe*". '*Akposoe*' is a white flint or dent open pollinated variety. It has a potential yield of 3.5t/ha and matures in 80 to 85 days. It is useful for planting either early or late in the season. It contains lysine and tryptophan, the two essential amino acids necessary for the normal growth and development of humans and other monogastric animals such as poultry and pigs (GNA, 2007; IITA, 2010).

2.1.4 Cultivation of maize

For maize to be produced successfully, there is the need to correctly apply production inputs that will sustain the environment as well as agricultural production. These include the use of adapted cultivars, appropriate soil tillage practices, application of fertilizers at the correct rates, management of plant population, proper weed, insect and disease control and harvesting.

2.1.5 Climatic requirements for maize production

Maize thrives well on a wide range of environmental conditions, but grows well in warm sunny climates with adequate moisture (Purseglove, 1992).The crop is grown in climates ranging from temperate to tropic during the period when mean daily temperatures are above 15°C. Minimum temperature for germination is about 10^{o}C. Germination and especially emergence will be far more rapid and uniform at soil temperatures above 16 ^{o}C. At about 20^{o}C, maize usually emerges 5-6 days after sowing (Raemaekers, 2001). Temperatures of 21 – 30^{o}C are suitable for maize cultivation (Adjetey, 1994). However, the critical temperature detrimental to maize yield is approximately 32 ºC (du Plessis, 2003).

2.1.6 Water requirements for maize production

Maize is an efficient user of water in terms of total dry matter production. The crop needs a regular supply of water and suffers badly in times of drought. Depending on the climate, maize requires between 600 and 1200 mm of water per annum and this must be well distributed throughout the growing season (Awuku *et al.*, 1991). Maize demands maximum moisture during tasselling and silking periods. Availability of soil moisture at the time of tasselling is therefore essential for the production of high yields (Tweneboah, 2000). In drought conditions, the rate of growth decreases, the silking period is retarded and grain filling and formation is significantly reduced resulting in yield reduction (Raemaekers, 2001).

2.1.7 Soil requirements for maize cultivation

Maize does well on most soils and can be grown continuously as long as soil fertility is maintained. Soils with good effective depth, favourable morphological properties, good internal drainage, an optimal moisture regime, sufficient and balanced quantities of plant nutrients and chemical properties are most favourable purposely for maize production (du Plessis, 2003). Maize is adapted to a wide variety of soils in the tropics, ranging from sandy to heavy clay soils. However, most maize is grown on well structured soils of intermediate texture (sandy loam to clay loams) because they provide adequate soil water, aeration and penetrability. In the tropics as a whole, Oxisols, Ultisols, Alfisols and Inceptisols have the greatest potential for maize production. Vertisols and Mollisols are excellent cereal soils but are limited in extent in the tropics (Norman *et al.*, 1995). Very heavy dense clay and very sandy soils are not good for maize cultivation. As the crop is susceptible to water logging, soils for maize cultivation should preferably be well-aerated and well-drained. The fertility demands for grain maize are relatively high in amount. For high-producing varieties, up to about 200 kg/ha N, 50 to 80 kg/ha P and 60 to 100 kg/ha K may be required (UNEP, 2007).

2.1.8 Land preparation

Primarily, land preparation prior to planting is carried out to create a soil structure suitable for crop growth, to incorporate residues, and to control weeds and diseases. The land preparation method chosen greatly influences growth and yield parameters of maize and soil properties. The choice of a method depends on the vegetation cover and the density of weeds. The prime land preparation methods for maize production are conventional tillage (plough and harrow) and conservation tillage (no tillage). In areas where the soil structure is adequate to allow for good growth without cultivation, weeds are controlled by one of several conservation tillage methods such as the use of herbicides. On the other hand, conventional tillage may be employed in which the land may be scraped off the weeds and stubble of previous crop and ploughed. The common tools used on subsistence farms for land preparation include machetes (cutlasses) and hoes. On commercial farms, the land is prepared by tractor-drawn implements in which early ploughing before the onset of the rain is followed by one or two harrowings. This practice is increasingly becoming unpopular because of the high cost of operating machinery and the difficulty in obtaining spare parts to experiment with reduced-tillage and zero tillage (Raemaekers, 2001).

2.1.9 Sowing

Maize seeds are sown at stake usually in rows for maximum plant population density. A good sowing is one that allow seeds to be placed at the correct depth, firming the soil around the seed at planting to assist in providing good contact between seed and soil, and to assist the seed in imbibing water from the soil. Sowing can be accomplished by machine or manual labour. In the normal case, seeds are dropped by hand using a machete or hoe or dibbled into the soil. Inter-row spacing range from 60-90 cm while intra-row spacing ranges from 30 – 60 cm depending on the variety. The seeds are sown at 2 seeds per hill but could be sown up to 3 or 4 and later thinned to 2 seedlings per hill. To obtain uniform germination, sowing depth of maize varies from 5 to 10 cm, depending on the soil type (du Plessis, 2003).

2.1.10 Weed control

Weeds are plants which are not cultivated and grow out of place among cultivated crops (Akobundu and Agyakwa, 1998) and whose virtues have not yet been discovered (Kazi *et al*., 2007). Among other things, weeds are exceptionally successful because they have highly efficient reproductive capacity, effective competitive behaviour for light, nutrient, space and water, grow in undesirable locations, resist control, disperse effectively and show high dormancy. Weed control is an important management practice for maize production that should be carried out to ensure optimum grain and forage yield. The methods employed to manage weeds vary, depending on the situation, available research information, tools, economics and experience (Monaco *et al*., 2002). Weed control in maize can be carried out by mechanical and/or chemical methods. Weeds between plant rows are removed generally by mechanical cultivation, while weeds on the rows are controlled by hand hoeing or by herbicides. Good weed control usually involves a combination of the available methods plus timeliness and good cultural practices (Abu-Hamdeh, 2003). According to James *et al*. (2000) and Doğan *et al.* (2004), the best time to minimize the effect of weeds on maize yield is within 4-8 weeks after planting when maize is in the 2-8 leaf stage.

2.1.11 Fertiliser Application in Maize Cultivation

Maize is a heavy feeder of nitrogen and phosphorus for vegetative growth and depletes soil of both macro and micro mineral nutrients. Fertiliser application is one major farming operation needed to correct deficiencies in the soil in order to ensure proper growth and functioning of crops with the aim of increasing yield (Srivastava *et al*., 2006; Webster and Wilson, 1992 cited by Aikins *et al*., 2010). Maize is particularly sensitive to soil nutrient deficiencies of both the major and minor nutrients. The deficiency of a particular nutrient can only be replenished by the application of that particular nutrient only. To achieve quick results, synthetic fertilizers such as NPK, nitrate (NO_3^-), ammonium (NH_4^+) and Urea ($CO(NH_2)_2$) are used by farmers despite their residual effect in the soil through acidic medium deposits. Amounts and types of fertiliser required will depend on soil type, cropping history and geographical location (Price, 1997).

Maize requires adequate supply of nutrients particularly nitrogen, phosphorus and potassium for good growth and high yield. Nitrogen and phosphorus are very essential for good vegetative growth and grain development in maize production. The quantity required of these nutrients particularly nitrogen depends on the pre-clearing vegetation, organic matter content, tillage method and light intensity (Kang, 1981) cited by Onasanya *et al.*, 2009). In general, the fertiliser requirements of maize in tropical conditions are about 100-120 kg N, 40 kg P and 50 kg K per hectare (Yayock *et al.* 1988). The recommended application rates of fertilizers in maize production in Ghana are; NPK 15-15-15 fertilizer at 250 kg ha^{-1}, NPK 19-19-19 fertilizer at 197 kg ha^{-1}, NPK 20-20-20 fertilizer at 187 kg ha^{-1}, and Ammonium Sulphate fertilizer at 125 kg ha^{-1} (Aikins *et al*., 2010). Fertiliser is normally placed 5 cm below the depth of the seed or seedling and about 5 cm to the side at the time of planting (Katinila *et al.*, 1998). This is accomplished by digging a single hole beside each seed, placing fertiliser in the hole, and covering it with soil. Alternatively, a continuous furrow is made along the length of the planting row. Fertiliser is placed in the furrow and covered with soil. The seed is planted on top of this soil and covered properly.

2.1.12 Fertiliser use in Ghana

Over the last 30 years, fertiliser consumption in sub-Saharan Africa has increased. In recent years, growth in fertiliser on cereals, particularly maize has contributed substantially to this increase. Nonetheless, current application rates remain low. Fertilization in tropical agriculture has the potential to dramatically increase production due to the highly weathered soils and the limited reserves of nutrients (Stewart *et al*., 2005), yet increased nutrient application is rarely managed by recommendations derived from soil testing and consequently this leads to misuse and associated economic (Chase *et al*., 1991) and environmental risks (Bundy *et al*., 2001; Cox and Lins, 1984). In Ghana currently, the importers of fertilisers to the various sectors of food production and other uses are numerous with a growing interest in the fertiliser import business. Between 2004 and 2007, Ghana imported 674,000.55 metric tonnes of fertiliser (MoFA, 2008).

The largest importer of bulk fertiliser in Ghana is YARA (estimated to account for around 70,000-80,000 tonnes in 2008). Other importers include CHEMICO, and Dizengoff (around 20,000-30,000 tonnes), and Golden Stock as well as a number of large agribusinesses/parastatals who import using tender systems for the main importers (e.g. Ghana Oil Palm Development Corporation; Unilever; Ghana Cotton Company). The importers coordinate imports to share shipping but do so on their own account. Dizengoff increasingly focuses on the foliate fertiliser market. In 2007, it brought in two consignments of 13,000 metric tonnes each. Fertiliser imports data over a nine year period from 1997 to 2001 (60,000-80,000 metric tonnes) and from 2004 to 2007 (110,000-190,000 metric tonnes) presents a rising trend.

The end users of fertilisers in the food production sector of Ghana, consists of a large number of small scale farmers in units of large households especially in the Northern, Brong Ahafo and parts of the Ashanti Region. With proper education, affordable price, timely availability and accessibility, demand for fertilisers in Ghana is enormous.

2.1.12.1 Fertiliser use and Maize production in sub-Saharan Africa

As is well known, food production in sub-Saharan Africa continues to lag behind population growth. Soil fertility must be managed more efficiently if Africa is to overcome its food-production problems. Mineral fertilisers and improved nutrient management strategies are crucial to such efficiency. New nutrient sources and more responsive crop varieties are also important. Maize combines widespread importance as a staple food with relatively high fertiliser responsiveness. As a result, maize production and fertiliser use are likely to become even more closely linked than they have been in the immediate past.

Though the appropriateness of seed-fertiliser technology for sub-Saharan Africa will continue to be debated, the continent can no longer be regarded as land-abundant. That characterization has been one of the major arguments against relying on a seed-fertiliser strategy for agricultural development. Though conditions vary widely, many African countries can now be classified as land-scarce (Binswanger and Pingali, 1988). Yield increases, rather than area expansion, will thus become progressively more important as a means of increasing crop production.

Mineral fertilisers must be included in any agricultural development strategy with a hope of reversing Africa's unfavourable food – production trends. Since the mid-1960s, 50-75 % of the crop yield increases in non-African developing countries have been attributed to fertilisers (Viyas, 1983). Fertilisers also complement other major inputs and practices (e.g., improved seeds, better water control) that have had the greatest impact on yield. Soil nutrient depletion is a common consequence of most African agriculture (Smaling, 1993). For the foreseeable future, "the environmental consequences of continued low use of fertilisers" through nutrient mining and increased use of marginal lands "are more inevitable and devastating than those anticipated from increased fertiliser use" (Dudal and Byrnes 1993; Matlon and Spencer, 1984).

2.1.12.2 Factors Influencing Farmers' Adoption and Intensity of Fertiliser Use

Demand and supply factors are hard to separate when evaluating farmers' decisions to adopt fertiliser and their subsequent decisions about application rates. Key influences such as farm size, access to credit, membership in cooperatives, contact with extension, access to outside information, availability of inputs, and distance to markets may be related at least as much to supply side constraints as to farmer demand factors (Mwangi, 1995).

2.1.12.3 Basic Price Factors

Theoretically, the decision to adopt fertiliser is determined by the interaction between agronomic response and the nutrient-grain price ratio. Agronomic response, in turn, is determined by soil characteristics and climatic factors. If the marginal agronomic response at a level of 0 kg/ha of applied nutrient is greater than the nutrient-grain price ratio, in theory the farmer should adopt fertiliser. In practice, other factors often prove important: the cost of operating capital for the cropping season; information and learning costs; and, perhaps, the effects of risk aversion (CIMMYT, 1988). Many observers contend that marginal agronomic response must be at least twice the nutrient-grain price ratio (i.e., the marginal rate of return on working capital invested in fertiliser must be at least 100 %) for significant adoption to occur.

2.1.12.4 Risk Aversion and Credit Constraints

Risk aversion is commonly assumed to play an important part in technology adoption decisions. Many observers conclude, however, that after adoption, risk aversion can reduce fertiliser applications by no more than 20 % of the "optimal" rates (Binswanger and Sillers, 1983; Shalit and Binswanger, 1985). Production risk is apt to be considerably more important in marginal areas, than in more suitable maize growing areas (McCown *et al*., 1992).

Certainly output price instability constitutes a risk for fertiliser users in western Africa (Vlek, 1990). In eastern and southern Africa, maize prices are probably more stable than prices for certain other cereals (e.g. sorghum and millet), but less stable than maize prices in other developing regions of the world. These details suggest the need for more careful risk assessment in Africa as compared to those other regions. Constraints on cash or credit availability often cause farmer behaviour that looks like risk aversion (Masson, 1972; Binswanger and Sillers, 1983). For many African smallholder farmers, fertiliser expenditures can represent a considerable proportion of the total cash expense for crop production.

2.1.12.5 Availability of fertiliser

Despite differences of opinion on other issues, many analysts of fertiliser use and policy in Africa and the rest of the developing world contend that basic problems of availability (i.e. getting the right fertiliser to the right place at the right time) are at least as important as price-response interactions in determining fertiliser use (Fontaine & Sindzingre, 1991; Pinstrup-Andersen, 1993; Blackie, 1995). Often referred to as non-price factors, these problems can be accommodated within a pricing framework by noting that, in effect, they raise the shadow price of fertilisers to farmers. Although the features of the African fertiliser economy that lead to high prices are often intertwined with those that constrain availability, policy makers have often focused solely on the one effect (high prices) rather than on availability, and ignored the underlying causes completely.

Ghana currently has no fertiliser manufacturing plants. Fertiliser is imported into the country through the port at Tema which has limited capacity and can accommodate 10 m draft vessels of up to 20,000 metric tons. Fertiliser importers complain that the port is operating inefficiently with delays leading to high rent charges.

2.1.13 Harvesting and storage of maize

The time of harvesting of maize is obviously dictated by the time of planting. The early maturity varieties require between 75-80 days to reach maturity while others may go up to 120 days. Maize may be harvested either as soft dough or hard dough (Kling, 1991) depending on the stage of maturity. Generally, the soft dough is best harvested when the cobs are fresh, as soon as the stigmas dry out or turn brown (Yayock *et al*., 1988). The hard dough is usually harvested immediately the grain is dry mostly at a moisture content of about 15-20% when cobs have reached the physiological maturity. Typically, maize is harvested manually by hand or mechanically by use of combine harvesters or mechanical pickers. Manually, the hand or cutlass is used to split cobs from stalk, dehusked and later shelled manually or mechanically. With the use of the combine harvester, the entire cob is harvested which then requires a separate operation of a maize sheller to remove the kernels from the cob. The combine with a maize head cuts the stalk near the base and then separates the cob of maize from the stalk so that only the cob and husk enter the machinery. The husk and the cob are separated keeping only the kernels. To avoid postharvest grain deterioration and germination of grain on the cob, it is necessary that the harvest of dry maize coincides with the dry periods. Harvested maize is usually left out for further drying to the required moisture content of at most 13%. Dried maize grains are stored in open cribs, sacks, bins or silos to prevent moulding (Katinila *et al*., 1998).

2.1.14 Pests and diseases control in maize production

Maize cultivation is bedevilled with the incidence of several pests, notable among them being stalk borers and armyworms. Economic losses caused by stalk borers may be very severe because damages caused are hard to see at first, and by the time a severe attack is noticed, many plants may already have been killed and many others damaged beyond recovery. Infected plants have spotted, speckled or white leaves, retarded shoot growth, stunted plant and gradual death (Fröhlich and Rodrwald, 1970). Several insecticides, e.g. Endosulfan, can be used to effectively control stalk borers. Other cultural control measures including early planting, the use of resistant varieties and the burning of stalks after harvest are proven to be effective in the control of stalk borers.

Many species of grasshoppers are known to feed on the foliage of the maize plant. They attack and devour large plants leaving only the bare stalks or, sometimes, only stubs in the field. Grasshoppers can be controlled with insecticides, preferably applied to the hatching areas when the nymphs are young (Martin *et al*., 2006).

Birds, cane rats, squirrels, rats, monkeys and insects often cause various damages to the maize plant, particularly the husks, creating room for secondary infections by pathogens. The squirrels and crows remove seeds and seedlings from the soil; the cane rats chew the stalks and cobs; while the monkeys and birds destroy cobs and grains. Birds and animals can be controlled by scaring, trapping or use of scarecrows. These can be human-like figures, noise-making structures, shiny objects or bright colours that scare animals away from the field. Moreover, sheets of paper can be rolled into cones or cups which are used to cover cobs to prevent bird damage. Insect pests can be sprayed using insecticides such as Kilsect 2.5 EC.

Diseases common to maize include smuts, rust, bacterial blight, and streak. These diseases can be controlled by the use of chemicals, seed selection, crop rotation, use of resistance varieties and the removal of alternative hosts. Also, at harvest, all diseased plants, husks and or cobs should be destroyed by burning to prevent the pathogens from being carried over to the next year's crop.

To minimize yield reduction due to pests and diseases, it is important to incorporate pest and disease-tolerant features as a high objective in maize breeding programme. Crop rotation, aimed at breaking the life cycle of vectors and pathogens, can be practiced to control pests and diseases (Brust and King, 1994).

2.1.15 Maize production and use in Ghana

Maize was introduced into Ghana by the Portuguese in the 16th century (Sallah, 1992). It has since become an integral part of the traditional system of agriculture in the country with the area under maize production increasing every year.

Maize is the most important cereal crop produced in Ghana and currently the most widely consumed staple food with increasing production since 1965 (FAO, 2008; Morris *et al.,* 1999). Maize is produced predominantly by smallholder resource-poor farmers under rain-fed conditions. Two major reasons that account for low productivity in maize include low soil fertility and low application of external inputs. The crop has been successfully cultivated in the southern part of the Interior Savannah Zone where it is preferred to sorghum, either for consumption or as a crop for the growing season (Sallah, 1992).

In Ghana, maize is commonly grown in an intercropped system involving legumes (groundnut, cowpea) and/or other cereals (sorghum, millet) (Sallah, 1992). It is produced in all five agro-ecologies, namely, the coastal savannah, forest savannah, transition, Guinea and Sudan savannah (Obeng-Antwi *et al*., 2002).

The bulk of maize produced in Ghana is processed into indigenous dishes and consumed directly by humans (Sallah *et al*., 2002). It serves as an important source of infant nutrition and is widely fed to weaning children without any protein supplement such as egg, milk or beans. Maize in Ghana is consumed in a variety of forms. It is eaten in the raw state as cooked or roasted corn. It may be ground or pounded when dried to prepare various food items such as *Kenkey, tuo-saafi, koko* (porridge), *banku* and *Akpele* (Morris *et al*., 1999). It features prominently in animal feed and as industrial raw material (NARP, 1993). It is a major source of feed ingredient for poultry and pigs (Twumasi-Afriyie *et al.*, 1997).

2.2 Soil Tillage

Soil tillage is the physical, chemical or biological manipulation of the soil to optimize conditions for germination, seedling establishment and crop growth (Lal, 1979; 1983). Ahn and Hintze (1990), however, defined it as any physical loosening of the soil carried out in a range of cultivation operations, either by hand or mechanized. For any given location, the choice of a tillage practice will depend on one or more of the following factors (Lal 1980; Unger 1984):

(i) Soil factors, which include relief, erodibility, erosivity, rooting depth, texture and structure, organic-matter content and mineralogy;

(ii) Climatic factors, which include rainfall amount and distribution, water balance, length of growing season, temperature (ambient and soil), length of rainless period;

(iii) Crop factors, which include growing duration, rooting characteristics, water requirements, seed, and

(iv) Socio-economic factors, which include farm size, availability of a power source, family structure and composition, labour situation.

Tillage is a labour-intensive activity in low-resource agriculture practiced by small landholders, and a capital and energy-intensive activity in large-scale mechanized farming (Lal, 1991). Continual soil inversion can in some situations lead to a degradation of soil structure leading to a compacted soil composed of fine particles with low levels of soil organic matter (SOM). Such soils are more prone to soil loss through water and wind erosion eventually resulting in desertification, as experienced in USA in the 1930s (Biswas, 1984).

This process can directly and indirectly cause a wide range of environmental problems. The conventional soil management practices resulted in losses of soil, water and nutrients in the field, and degraded the soil with low organic matter content and a fragile physical structure, which in turn led to low crop yields and low water and fertiliser use efficiency (Wang *et al*., 2007). Therefore, scientists and policy makers put emphasis on conservation tillage systems.

Compared to conventional tillage, there are several benefits from conservation tillage such as economic benefits to labour, cost and time saved, erosion protection, soil and water conservation, and increases of soil fertility (Uri *et al*., 1998; Wang and Gao, 2004). Conservation tillage (reduced tillage) can lead to important improvements in the water storage in the soil profile (Pelegrín *et al.*, 1990). Tillage operations generally loosen the soil, decrease soil bulk density and penetration resistance by increasing soil macro porosity. Under conventional tillage conditions, improvements were also obtained in crop development and yield, especially in very dry years (Pelegrín *et al*., 1990; Murillo *et al*., 1998, 2001). Mahboubi *et al.* (1993) in a 28-year long term experiment found that no-tillage resulted in higher saturated hydraulic conductivity compared with conventional tillage on a silt loam soil in Ohio whereas Chang and Landwell (1989) did not observe any changes in saturated hydraulic conductivity after 20 years of tillage in a clay loam soil in Alberta. Saturated hydraulic conductivity of silty clay loam soil was higher when subject to 10 years of tillage than no-tillage in Indiana (Heard *et al*., 1988). They attributed the higher hydraulic conductivity of tilled soil to greater number of voids and abundant soil macro pores caused by the tillage implementation.

Studies comparing no-tillage with conventional tillage systems have given different results for soil bulk density. Osunbitan *et al.* (2005) found that soil bulk density was greater in no-till in the 5 to 10 cm soil depth, but Logsdon *et al*., (1999) reported no differences in bulk density between tillage systems. The ambiguous nature of these research findings call for additional studies of the effect of long-term tillage on soil properties under various tillage practices in order to optimize productivity and maintain sustainability of soils.

Tillage strongly influences soil health. It is therefore important to apply that type of technology that will make it possible to sustain soil productivity at a level feasible for normal crop growth. Appropriate tillage practices are those that avoid the degradation of soil properties but maintain crop yields as well as ecosystem stability (Lal, 1981, 1984, 1985). The best management practices usually involve the least amount of tillage necessary to grow the desired crop. This not only involves a substantial saving in energy costs, but also ensures that a resource base, namely the soil, is maintained to produce on a sustainable basis.

2.2.1 Importance of Tillage

Effective tillage systems create an ideal seedbed condition (i.e. soil moisture, temperature and penetration resistance) for plant emergence, plant development, and unimpeded root growth (Licht and Al-Kaisi, 2005). Soil manipulation can also change fertility status markedly and the changes may be manifested in good or poor performance of crops (Ohiri and Ezumah, 1991).Tillage aims to create a soil environment favourable to plant growth (Klute, 1982). It is carried out with the objective of changing the soil physical properties and to enable the plants to show their full potential. Soil ploughing techniques are used in order to provide a good seedbed and root development, to control weeds, to manage crop residues, reduce erosion and level the soil surface for planting, irrigation, drainage, incorporation of fertiliser or pesticides and harvest operations. Subsoil compaction may reduce the availability and uptake of water and plant nutrients thereby, lowering crop yield (Khurshid *et al*., (2006).

2.2.2 Tillage Treatment for Maize Production

Tillage treatment is known to affect growth and yield parameters of maize and soil properties. It has been reported that among the crop production factors, tillage contributes up to about 20% (Khurshid *et al*., 2006). The tillage method chosen depends on the vegetation cover and the manner in which the soil surface is to be exposed for sowing of seeds, which in turn is dependent on the density of weeds. The primary tillage treatments for maize production are conventional tillage (plough and harrow) and conservation or no tillage.

Conventional tillage involves intensive working of the soil to produce a fine tilth. In mechanized cultivation, the field is ploughed to break up the soil and harrowed to break up large clods of soil resulting from ploughing before the ridges are made. In this type of tillage, usually, the vegetation may be cleared and allowed to decompose partially or burnt to facilitate digging during which any residues are worked into the soil (Youdeowei *et al.*, 1986).

Conservation tillage is an operation that is designed to maintain the roughness of a field surface and leave most of the previous crop residues on the surface while providing a suitable seed-bed and weed control for the next crop. This roughness reduces water runoff and soil erosion (Ikisan, 2000). It involves the use of cutlass, hoe, pickaxe, herbicide application or mulch tillage. Mulch tillage leaves crop residue on the soil surface for quick germination and satisfactory yield. The use of conventional tillage operations is harmful to soil, hence, there is a significant interest and emphasis on the shift to conservation tillage and no-tillage methods for the purpose of controlling soil erosion

(Iqbal *et al*., 2005). Conservation agriculture has led to maize crop yield increases and greater profitability as production costs are reduced (CKB, 2009).

2.3 Soil Properties

2.3.1 Soil texture

Soil texture describes the proportion of the three primary sizes of soil particles- sand, silt and clay. It is the most fundamental soil property which affects water-holding capacity and aeration (Plaster, 2002). Soil texture can be determined by mechanical analysis of a sample in the laboratory and also by a "feel" test (Lockhart and Wisemans, 1988). The soil particles are divided into three groups. Sand particles are 0.2 – 0.05 mm in diameter. Silt has particles that range in diameter from 0.05 – 0.002 mm, and clay particles have diameters smaller than 0.002 mm. Most soils contain some material from each size group and soil texture is determined by the relative proportion of these types of particles. Soil texture is of agricultural importance because texture influences water and air movement in the soil and also determines energy required for soil cultivation (Walton, 1988).

2.3.2 Soil structure

Soil structure describes the arrangement and organization of the particles in the soil (Hillel, 1982). This can be altered by weather conditions, penetration of plant roots, cultivation, etc (Lockhart and Wisemans, 1988). Structure directly affects many properties of the soil. Water retention and conductance are dependent on pore space and pore sizes. It influences ploughing operations because of the properties of individual particles are more or less masked in stable aggregates which can thus give a favourable physical condition to soil that would otherwise be intractable. It also affects the environment for roots through its effects on water and oxygen supply and soil strength. Growth of plants can be severely retarded or wholly prevented by structure that is grossly unfavourable to water or air movement or resistant to seedling emergence or root growth (Marshall and Holmes, 1988).

2.4. Soil Physical Properties

2.4.1. Porosity

Total pore space is a measure of the soil volume that holds air and water. The value is usually expressed as a percentage and is known as porosity. Soil porosity is part of the property known as soil structure which includes the arrangement of particles in aggregates, and the size, shape and distribution of the pores both within and between the aggregates. If the particles lie close together as in sandy soils or compact subsoil, the total porosity is low. If they are arranged in porous aggregates, as is often the case in medium-textured soil high in organic matter, the pore spaces per unit volume will be high (Brady and Weil, 1999). Porosity depends on the water content of the soil, since the volume of pores and the total volume of an initially dry soil may change differently due to swelling as clay surface hydrates or shrinks as the soil dries (White, 2006).

2.4.2 Bulk Density

Bulk density is defined as the mass of oven-dry soil per unit volume, and depends on the densities of the constituent soil particles (clay, organic matter, etc.) and other packing and arrangement into peds (White, 2006). The volume includes both solids and pores. The bulk densities of soils depend mostly on the amount of pore space in the soil, since particle weight is fairly constant. Bulk densities of mineral soils usually range from 1.0 g cm^{-3} for “fluffed-up” clay soils to 1.8 g cm^{-3} for some sandy soils. Organic soils are much lighter, with values of 0.1 to 0.6 g cm^{-3} being common (Plaster, 2002). Bulk density is inversely related to total porosity (Carter and Ball, 1993), which gives an idea of the porous space left in the soil for air and water movement. The optimal bulk density for plant growth is different for each soil. In general, less than optimal bulk density (high porosity) leads to poor water relations, and high bulk density (low porosity) reduces aeration and increases penetration resistance, limiting root growth (Cassel, 1982).

2.5 Tillage effects on soil properties

2.5.1 Tillage effects on soil degradation

Soil erosion has conventionally been perceived as one of the main causes of land degradation and the main reason for declining yields in tropical regions. Intensive or inappropriate tillage practices have been a major contributor to land degradation. The last four decades have seen a major increase in intensive agriculture in the bid to feed the world population more efficiently than ever before. In many countries, particularly the more developed countries, this intensification of agriculture has led to the use of more and heavier machinery, deforestation and land use changes in favour of cultivation. This has led to several problems including loss of organic matter, soil compaction and damage to soil physical properties.

Soil tillage breaks down aggregates, decomposes soil organic matter, pulverizes the soil, breaks pore continuity and forms hard pans which restrict water and air movement and root growth. On the soil surface, the powdered soil is more prone to sealing, crusting and erosion. Improving soil physical fertility involves reducing soil tillage to a minimum and increasing soil organic matter.

Tillage-induced soil erosion in developing countries can entail soil losses exceeding 150 t/ha annually and soil erosion, accelerated by wind and water, is responsible for 40% of land degradation world-wide. Several more recent studies have shown that no tillage systems with crop residue mulch can increase nutrient use efficiency (Lal, 1979). The no-till system seems to have a broad application in humid and sub-humid regions, for which 4-6 t/ha of residue mulch appears optimal (Lal, 1975). The beneficial effect of conservation tillage systems on soil loss and runoff have been demonstrated in studies conducted by ICRISAT (1988) and Mensah Bonsu and Obeng (1979).

2.5.2 Tillage Effects on Soil Water Content

Tillage effects differ from one agro-ecological zone to the other. In semi-arid regions moisture conservation is one of the key factors to consider. Nicou and Chopart (1979) showed that tillage and residue management increased soil profile water content. Sharma *et al.* (2011) showed that the no-till soils retained the highest moisture followed by minimum tillage, raised bed and conventional tillage in inceptisols under semi arid regions of India. Tillage treatments influenced the water intake and infiltration rate. Several researchers also show the importance of tillage on soil moisture (Lal, 1977; Klute 1982; Norwood *et al*., 1990). Tillage enhances soil water storage by increasing soil surface roughness and controlling weeds during a fallow. This stored water may improve subsequent crop production by supplementing growing season precipitation (Unger and Baumhardt, 1999). Several studies have shown that deep tillage has immense potential for water storage and better crop production. Schillinger (2001) and Lampurlanes *et al*., (2002) observed no difference in water storage efficiency of reduced tillage compared with other tillage systems.

2.5.3 Tillage effects on porosity

Soil porosity characteristics are closely related to soil physical behaviour, root penetration and water movement (Pagliai and Vignozzi, 2002, Sasal *et al*., 2006) and differ among tillage systems (Benjamin, 1993). Lal *et al*. (1980) revealed that straw returning could increase the total porosity of soil while minimal and no tillage would decrease the soil porosity for aeration, but increase the capillary porosity; as a result, it enhances the water capacity of soil along with poor aeration of soil (Wang & Wen, 1994, Glab and Kulig, 2008). However, Borresen (1999) found that the effects of tillage and straw treatments on the total porosity and porosity size distribution were not significant. Allen *et al*. (1997) indicated that minimal tillage could increase the quantity of big porosity. Tangyuan *et al*. (2009) showed that the soil total porosity of the 0–10 cm soil depth layer was mostly affected; conventional tillage can increase the capillary porosity of soil and the porosities were C > H > S but the non-capillary porosity (S) was the highest. Returning of straw can increase the porosity of soil.

2.5.4 Tillage Effects on Soil Bulk Density

The most commonly measured soil physical properties affecting hydraulic conductivity are soil bulk density and effective porosity as these two properties are fundamental to soil compaction and related agricultural management issues (Strudley *et al*., 2008). The studies comparing no-tillage with conventional tillage systems have given different results for soil bulk density. Several studies showed that soil bulk density was greater in no-till in the 5 to 10 cm soil depth (Osunbitan *et al.*, 2005). No differences in bulk density were found between tillage systems (Logsdon *et al*., 1999). However, Tripathi *et al*., (2005) found increase in bulk density with conventional tillage in a silty loam soil. Moreover, there are few studies that have examined changes in soil physical properties in response to long term tillage and frequency management (> 20 y) in the northern Great Plains. Rashidi and Keshavarzpour (2008) observed that the highest soil bulk density of 1.52 g cm^{-3} was obtained for the No Tillage treatment and lowest (1.41 g cm^{-3}) for the conventional tillage treatment. The highest soil penetration resistance of 1250 kPa was obtained for the No Tillage treatment and lowest (560 kPa) for the conventional tillage treatment. The highest soil moisture content of 19.6% was obtained for the conventional tillage treatment and lowest (16.8%) for the No tillage treatment.

2.5.5 Tillage effects on water use efficiency

Water-use efficiency and maize grain yields were observed to be significantly higher under zero tillage than under other tillage treatments in Nigeria (Osuji,1984). Lal (1985) showed that soil physical properties and chemical fertility were substantially worse in ploughed watersheds after six years of continuous mechanized farming and twelve crops of maize, while the decline in the soil properties was decidedly less in the no-tillage watershed. The lower maize yields of the ploughed watershed are related to erosion, compaction, fall in organic matter content and fall in pH. After 10 years of continuous comparative no-tillage and conventional tillage trials in Southwest Nigeria, Opara-Nadi and Lal (1986) observed that total porosity, moisture retention, saturated and unsaturated hydraulic conductivity, and the maximum water-storage capacity increased under no-tillage with mulch.

2.5.6 Tillage effect on environment

Conservation tillage may affect the production of nitrous oxide through its effect on soil structural quality and water content (Ball *et al*., 1999). Conservation tillage can prevent nutrient loss (Jordan *et al*. 2000). Comparison of herbicide and nutrient emissions from 1991 to 1993 on a silty clay loam soil.

Plots 12 m wide were established and sown with winter oats in 1991 followed by winter wheat and winter beans. De-nitrification in anaerobic soil and nitrification in aerobic soil produce nitrous oxide, with the former being more important. As soil structure improves, the potential for creating anaerobic conditions and nitrous oxide emissions is reduced (Arah et al., 1991). Intensive soil cultivations break-down SOM producing CO_2 thereby lowering the total C sequestration held within the soil. Building SOM, the adoption of conservation tillage, especially if combined with the return of crop residues, can substantially reduce CO_2 emissions (West and Maryland, 2002). In the UK, where conservation tillage was used, soil C was 8% higher compared to conventional tillage, equivalent to 285g SOM m^{-2}. In the Netherlands, SOM was 0.5% higher using an integrated approach over 19 years, although this increase was also achieved because of higher inputs of organic matter (Kooistra *et al.*, 1989). Murillo *et al.*, (2004) in a long term experimentation, observed that in conservation tillage (0-10 cm depth) organic matter values have been reached close to the minimum content of 2% (1.1% organic C) considered necessary for most agricultural practices carried out in European Occidental soils (Bullock, 1997). These are indeed moderate values, and would not justify the implementation of conservation tillage systems (aimed at achieving high surface organic matter content).

2.5.7 Tillage effects on crop yield

The effect of tillage systems on crop yield is not uniform with all crop species, in the same manner as various soils may react differently to the same tillage practice. Murillo *et al.*, (2004) compared the traditional tillage, TT (the soil was ploughed by mould board, to a 30 cm depth, after burning the straw of the preceding crop) and conservation tillage, conservation tillage (the residues of the previous crop were left on the soil surface, as mulch, and a minimum vertical tillage (chiselling, 25 cm depth) and disc harrowing (5 cm depth) were carried out. Results revealed that crops yield was higher in conservation tillage. Results presented by Nicou and Charreau (1985) showed the effect of tillage on yields of various crops in the West African semi-arid tropics. Cotton showed the smallest yield increase with tillage within the range of crops tested. Tillage effects in semi-arid zones are closely linked to moisture conservation and hence the management of crop residues. Several authors (Unger *et al.*, 1991; Larson, 1979; Brown *et al.*, 1989; Thomas *et al.*, 1990, Sharma *et al.*, 2009) emphasize the link between crop residue management and tillage and recognize them as the two practices with major impact on soil conservation in the semi-arid zones. Residue retention in a cropping system in Burkina Faso significantly increased the yield of cowpeas (IITA/SAFGRAD, 1985).

2.5.8 Effects of tillage and NPK fertiliser on maize performance

Increased cropping intensity coupled with the adoption of inefficient crop management techniques has resulted in low crop productivity. The imbalanced use of chemical fertilisers and little or no use of organic manures have created soil health problems and drastically lower plant nutrients in the soil. The excessive use of heavy machinery for various crop production operations has caused the development of hard pan in the soil that has aggravated the issue of low crop productivity. The efficient crop management practices provide essential information to obtain the potential yield of rainfed maize fodder on sustainable basis. Studies conducted in the past have revealed the positive impact of deep tillage and fertiliser treatments on the yield and yield components of field crops. Ishaq *et al*. (2002) reported that concentration of NPK was greater in the plough layer than subsoil. Maize fodder yield was significantly negatively correlated with penetration resistance and was positively correlated with soil NPK concentration. Soon *et al*. (2001) reported that N uptake by wheat increased with deep tillage as compared with conventional tillage when following a legume crop. Abu-Kreshe *et al*. (1996) reporting similar results stated that alternate use of deep tillage in legume-based cropping system increases the plant nutrient uptake and grain yield of sorghum. Jin *et al*. (1996) investigated the effect of cattle manure application on yield of maize and soil characteristics. It was observed that cattle manure application resulted in higher maize yield than chemical fertilisers. Suri and Sarita (1996) concluded that addition of farm yard manure (FYM) reduces the requirement of NPK fertiliser. They reported that FYM lowered NPK fertiliser requirement for maize by 60, 50 and 40% when 10, 7.5 and 5 t/ha FYM were applied to maize plots, respectively. Sharma and Singh (1996) reported that the application of 10 t ha^{-1} of FYM in conjunction with fertiliser at nutrient levels of 90:45:20 resulted in higher grain production of maize than applying fertiliser and FYM alone. Similarly, Mahajan (1996) conducted an experiment to study the effect of phosphorus and FYM combinations on maize wheat sequence under rainfed conditions. The effect of FYM was useful in increasing the yield of maize and wheat by 27 and 20%, respectively. Suri *et al*. (1997) carried out a field experiment in India during 1991-92 to evaluate the role of FYM in NPK fertiliser economy in maize-wheat sequence. It was suggested that application of K can be omitted in maize as well as follow-wheat if FYM is applied. Similarly, Richards *et al*. (1999) reported that combined application of organic and inorganic fertilisers has positive effect on forage yield of maize. However, when the fertilisers were applied individually, these had negative effect on the crop yield. Mohamed and Aret (1999) conducted a fertiliser trial on maize in Egypt. They concluded that application of 20 kg N + 20 m FYM produced the highest grain yield, protein contents and 1000-grain weight. Richards *et al*. (1999) conducted 15 field trials in the UK to evaluate soil mineral N measurement as a means for quantifying the total N supply to forage maize and formed the basis for fertiliser recommendations on a crop specific basis. In every trial 4 rates of cattle manure, N and 4 rates of ammonium nitrate were factorially combined. Results proved to be useful for N recommendation. They also recommended that soil mineral nitrogen measurement should be taken 7 to 10 weeks after drilling and that if at this stage the amount of mineral nitrogen is less than the expected crop N off take, N fertiliser should be applied. Kagata *et al*. (1999) grew forage maize with two-rowed barley in rotation for 9 successive years with four fertiliser treatments i.e. control, FYM, FYM+NPK and NPK fertiliser. Dry matter yield and harvest index of forage maize were stable and high in FYM and FYM + NPK treatments, but gradually decreased with NPK or without fertiliser. Disease was frequently observed in the 3 years in NPK but not in FYM or FYM + NPK. Total nitrogen and carbon in soil increased over time in the treatments including FYM. Chemical fertiliser application together with FYM application has reportedly recorded positive effects on mineral composition of fodder in maize (Sahoo and Panda, 1999).

2.6 Strategies for mitigating challenges of tillage

Conservation agriculture is a concept for resource-saving agricultural production that strives to achieve acceptable profits together with high and sustained production levels while concurrently conserving the environment. Interventions such as mechanical soil tillage are reduced to an absolute minimum and the use of external inputs such as agrochemicals and nutrients of mineral or organic origin are applied at an optimum level and in a way and quantity that do not interfere with or disrupt the biological processes. One of the soil conservation techniques developed in USA is known as 'conservation tillage', which involves soil management practices that minimize the disruption of the soil's structure, composition and natural biodiversity, thereby minimizing erosion and degradation, but also water contamination.

2.6.1 Principles of conservation agriculture

Conservation agriculture systems utilize soils for the production of crops with the aim of reducing excessive mixing of the soil and maintaining crop residues on the soil surface in order to minimize damage to the environment. This is done with the objective to:

- Provide and maintain an optimum environment of the root-zone to maximum possible depth.
- Avoid physical or chemical damage to roots that disrupts their effective functioning.
- Ensure that water enters the soil so that

(a) plants never or for the shortest time possible, suffer water stress that will limit the expression of their potential growth; and so that

(b) residual water passes down to groundwater and stream flow, not over the surface as runoff.

- Favour beneficial biological activity in the soil.

Conservation tillage is now commonplace in areas where rainfall causes soil erosion or where preservation of soil moisture (because of low rainfall) is the objective. World-wide, conservation tillage was practiced on 45 million ha, most of which is in North and South America (FAO, 2001) but is increasingly being used in other semi-arid and tropical regions of the world (Lal, 2000). In USA, during the 1980s, it was recognized that substantial environmental benefits could be generated through soil conservation and to take advantage of this policy goals were changed. These were successful in reducing soil erosion; however, the social costs of erosion are still substantial, estimated at $37.6 billion annually (Lal, 2001). World-wide, soil degradation caused by erosion was estimated to reduce food productivity by 18 million Mg at the 1996 level of production (Lal, 2000). Because of the increasing population and rising standards of living, it is essential to develop those agricultural practices that maximize agricultural production while also enhancing ecosystem service. Eco-efficiency is related to both "ecology" and "economy," and denotes both efficient and sustainable use of resources in farm production and land management (Wilkins, 2008). Experience has shown that conservation agriculture systems achieve yield levels as high as comparable conventional agricultural systems but with less fluctuations due, for example, to natural disasters such as drought, storms, floods and landslides. Conservation agriculture therefore contributes to food security and reduces risks for communities (health, conditions of living, water supply), and also reduces costs for the State (less road and waterway maintenance).

3. MATERIALS AND METHODS

3.1 Experimental Site Description

The experiment was conducted during the 2010 minor and 2011 major cropping seasons under rainfed conditions. The experimental site was located at the arable field of the Department of Crop and Soil Sciences at the Kwame Nkrumah University of Science & Technology, Kumasi. The experimental site belongs to the semi-deciduous forest agro-ecological zone of Ghana with an average annual rainfall of about 1300 mm. The average daily temperature is about 26^{o}C with a range between 18 ^{o}C and 35^{o}C. Table 3.1 displays the maximum and minimum temperatures as well as rainfall data at the experimental site during the period of the experiment. The soil at the experimental site is sandy loam in texture and is classified as Ferric Acrisol (FAO, 1998).

Table 3.1: Air Temperature and rainfall data between August, 2010 and July, 2011

Month	T_{max} (°C)	T_{min} (°C)	T_{mean} (°C)	Rainfall (mm)
August	29.0	21.5	25.25	134.9
September	29.7	21.9	25.80	201.8
October	31.0	22.0	26.50	163.3
November	31.5	22.5	27.00	111.1
December	32.4	22.0	27.20	47.0
January	32.2	19.7	25.95	20.2
February	33.4	21.6	27.50	66.6
March	32.8	22.3	27.55	256.4
April	33.3	22.9	28.10	157.4
May	32.6	22.6	27.60	149.9
June	31.4	22.3	26.85	197.7
July	29.0	21.8	25.40	247.6

T_{max} (°C) - Maximum Air Temperature °C ;T_{min} (°C) - Minimum Air Temperature °C

3.2 Experimental Design

The experiment was designed as a two factor study arranged in a randomised complete block design in three replicate blocks. The two factors included tillage treatments and NPK 15-15-15 fertiliser application rates. The levels of the tillage treatments were "No tillage" and "disc ploughing followed by disc harrowing" while the NPK 15-15-15 fertiliser application rates were 0 kg ha^{-1}, 150 kg ha^{-1}, 250 kg ha^{-1} and 350 kg ha^{-1}. There were 24 experimental plots with each plot measuring 3.5 m long and 3.0 m wide. Buffer zones of 3.0 m were created between blocks and 1.5 m within plots on the same block. Field layout is presented in Appendix 1.

3.3 Crop Management practices

3.3.1 Sowing

Akposoe, an extra early maturing maize variety (85 Day) was obtained from the Crops Research Institute (CRI) of the Council for Scientific and Industrial Research (CSIR) at Fumesua, Kumasi. In the 2010 minor growing season, the crop was planted on the 10th of September. In the 2011 major growing season, the *Akposoe* maize variety was planted on the 14th of April. Sowing was done at two seeds per hill at a depth of 5 cm using a custom made depth controlled dibber (Aikins *et al*., 2006). *Akposoe* maize was planted at the recommended spacing of 75 cm x 35 cm resulting in a plant population of 76,190 plants/ha.

3.3.2 Weed Control

Weed control was undertaken at three and five weeks after planting. Weed control in the disc ploughing followed by disc harrowing tillage plots was carried out using a hand hoe. Weed control in the no tillage plots was accomplished using ANITRAZ 500 S.C. (a selective pre and early post emergence herbicide for the control of annual grasses and broadleaf weeds in maize) at 500g/l (i.e. in 400 litres of water /ha) using a weed wiper. In the 2010 minor season, weed control was carried out on 3rd and 17th October respectively. During the 2011 major season, weeding was done on the 5th and 19th of May respectively.

3.3.3 Insect Pest Control

The control of insect pests in maize is important for optimizing the growth and yield of the crop. Insect pests were controlled using KILSECT 2.5 EC containing 25 g of Lambda-cyhalothrin per litre at a rate of 800 ml ha^{-1} at three and five weeks after planting. The insecticide was applied in the 2010 minor season on the 4th and 18th of October, 2010 while that on the 2011 major season was done on the 6th and 20th of May, 2011.

3.3.4 Fertiliser Application

NPK 15-15-15 was applied at three weeks after planting on the respective plots at their respective rates (0 kg ha^{-1}, 150 kg ha^{-1}, 250 kg ha^{-1} and 350 kg ha^{-1}). NPK 15-15-15 was applied on 1st October and 7th May respectively in the 2010 minor and 2011 major growing seasons respectively. Ammonium sulphate fertiliser was also applied at 5 weeks after planting at a rate of 125 kg ha^{-1} on all treatments irrespective of NPK 15-15-15 application rate.

3.4 Data Collection

3.4.1 Seedling emergence

Seedling emergence was obtained as a count on a daily basis starting from the first day after emergence until emergence was deemed complete. The percentage seedling emergence was determined from the number of seedlings emerged divided by the total number of seeds planted and multiplied by 100.

3.4.2 Plant Height, Stem Girth, Number of Leaves per Plant and Leaf Area Index

Six plants were selected at random per plot and tagged for the measurement of plant height, stem girth, number of leaves per plant and leaf area. Data were taken on a weekly basis starting from one week after planting for ten weeks. Plant height was measured using a metre rule from the soil surface at the base of the plant to the top of the highest leaf. Stem girth was measured by a thread and a ruler. The number of leaves per plant was obtained as a count from the six tagged plants per plot. Leaf area was obtained from measuring the length and width of the broadest leaf on each of the six tagged plants. The leaf area was then determined using the linear regression analysis equation:

$$Leaf\ Area = k(LxW)$$

Where,

k = 0.75 which is constant for all cereals

L = Leaf length

W = Leaf width.

3.4.3 Root Length, Dry Matter and Grain Yield

The root lengths, dry matter and grain yields of the six tagged plants per plot were taken at harvest (90 days after planting for both seasons). Six *Akposoe* maize root lengths were measured per plot. Root length was measured as the length from the base of the shoot to the tip of the root of each plant using a ruler. The dry matter yields were determined by manually harvesting the six tagged *Akposoe* maize plants per plot. The plants were washed and cleaned to remove traces of soil before oven drying them at 70 ^{o}C for 48 hours. The fresh cob weights of the six tagged plants were recorded using an electronic balance at harvest. After sun drying for seven days, their dry weights were obtained. Grains obtained from the six selected plants per plot were threshed and weighed.

3.5 Soil Properties

Three sets of soil samples were taken in the course of the experiment and analysed for physical properties. The first set was taken before land preparation. The second set was taken at flowering while the third set was taken after harvest. Samples were taken from the 0–15 cm and 15–30 cm soil layers.

3.5.1 Penetration Resistance

Soil penetration resistance readings were recorded with a pocket penetrometer in kPal. Ten replications were taken at random from each plot per given day and the average of the ten represented the entire plot.

3.5.2 Dry Bulk Density

Soil dry bulk density was determined by the core sample method. It was determined by obtaining undisturbed soil cores of known volume and dividing the oven dry soil mass by the core volume of the sample. Precautions were taken to reduce the disturbance of soil within the metal cylinder during sampling. The collected soil cores were trimmed to the exact volume of the cylinder and oven dried at 105^{o}C for 24 hours.

3.5.3 Moisture Content

Soil moisture content was determined gravimetrically. Soil moisture content was found by dividing the mass of moisture by the oven dry mass of soil.

3.5.4 Air Content

The air content of the soil in the 0–15 cm and 15–30 cm layers was calculated from the values of the total porosity and moisture content.

3.5.5 Total Porosity

The total porosity of the soil in the 0–15 cm and 15–30 cm layers was calculated from the values of the dry bulk and particle densities using the following equation (Chancellor, 1994):

$$\text{Porosity} = \left(1 - \frac{\rho_b}{\rho_p}\right) \times 100$$

Where,

ρ_b = Dry bulk density (Mgm^{-3})

ρ_p = Particle density (Mgm^{-3}) = 2.65 Mg m^{-3} (Assumed).

3.6 Data Analyses

All data were subjected to analysis of variance (ANOVA) using the General Linear factorial Model in MINITAB Statistical Software Release 15 (MINITAB Inc., 2007). Treatment means were separated using least significant difference (LSD) comparisons at $p<0.05$.

4. RESULTS AND DISCUSSION

4.1 Introduction

This chapter deals with the presentation and discussion of results obtained in the field study conducted in the 2010 minor and 2011 major cropping seasons.

4.2 Maize growth and performance

4.2.1 Effect of tillage treatment on seedling emergence

Fig. 4.1 and Fig. 4.2 show the effect of tillage treatment on *Akposoe* maize seedling emergence over a period of 20 days after planting in the 2010 minor and 2011 major cropping seasons respectively. In the 2010 minor cropping season, mean seedling emergence in the disc ploughing followed by disc harrowing plots were higher (99.06%) as compared to that in then Tillage plots (98.85%). In the 2011 major season, the higher mean seedling emergence of 99.79% was found in the disc ploughing followed by disc harrowing plots while the lower seedling emergence of 98.13% was found in the No Tillage plots. The analysis of variance showed that over the 20-day period, tillage treatment did not have significant effect on seedling emergence. These results are in contrast with that of Thiagalingam *et al*. (1996) who reported that the emerged populations of soybean sown using no-tillage was significantly higher than those sown using conventional tillage on *Kandosols* in the semi-arid tropics of the Northern Territory and Far North Queensland in Australia.

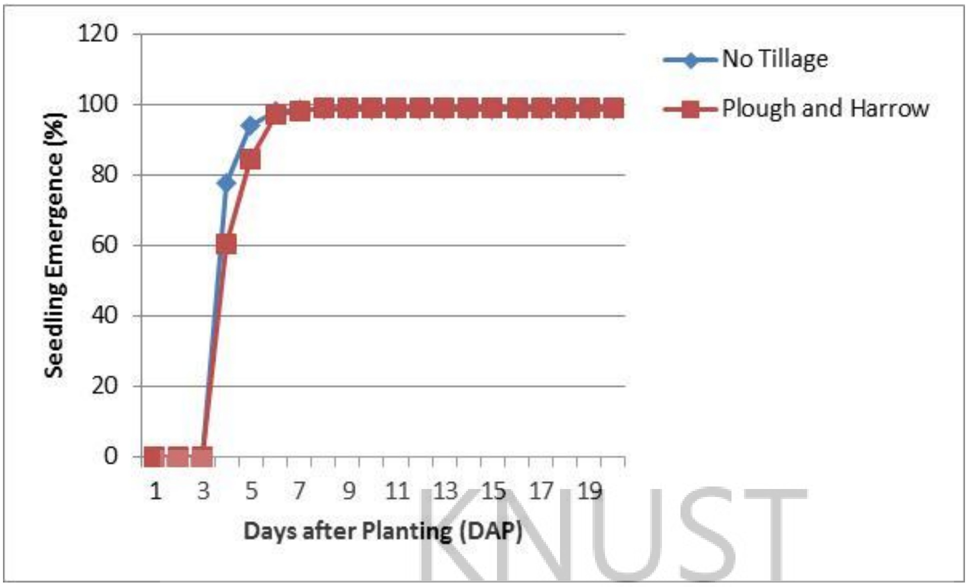

Fig. 4.1: Effect of tillage treatment on seedling emergence, 2010

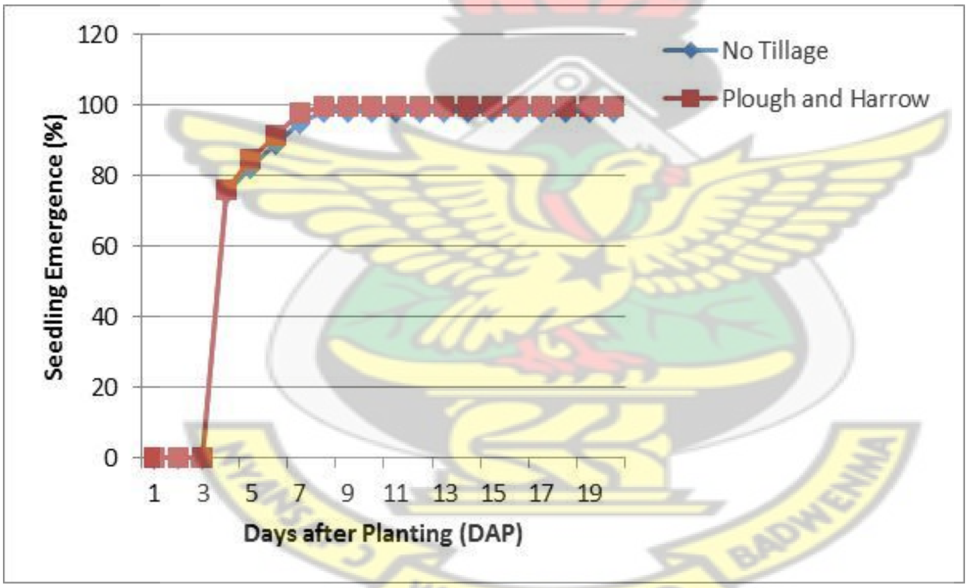

Fig. 4.2: Effect of tillage treatment on seedling emergence, 2011

4.2.2 Effect of tillage treatment on plant height

Plant height is an important parameter that determines the growth of maize plants. Plant height, according to Glenn and Daynard (1974), is associated with greater yields in maize. The results on *Akposoe* maize plant height over a period of 10 weeks after planting

(WAP) in the 2010 minor and 2011 major cropping seasons under the different tillage treatments are shown in Fig. 4.3 and Fig. 4.4 respectively. In the 2010 minor cropping season, the disc ploughing followed by disc harrowing treatment plots gave taller plants (193 cm) compared with the No Tillage treatment plots (181 cm). The analysis of variance showed that tillage did not have significant effect on plant height during the 2010 minor season. In the 2011 major season, however, tillage treatment had statistically significant effect on *Akposoe* maize plant height. The disc ploughing followed by disc harrowing plots recorded a mean plant height of 148 cm while the No Tillage plots recorded a mean plant height of 112 cm. This result is similar to the research conducted by Memon *et al.* (2012) who compared the effects of different tillage and fertilizer treatments on the growth and yield components of maize in Pakistan.

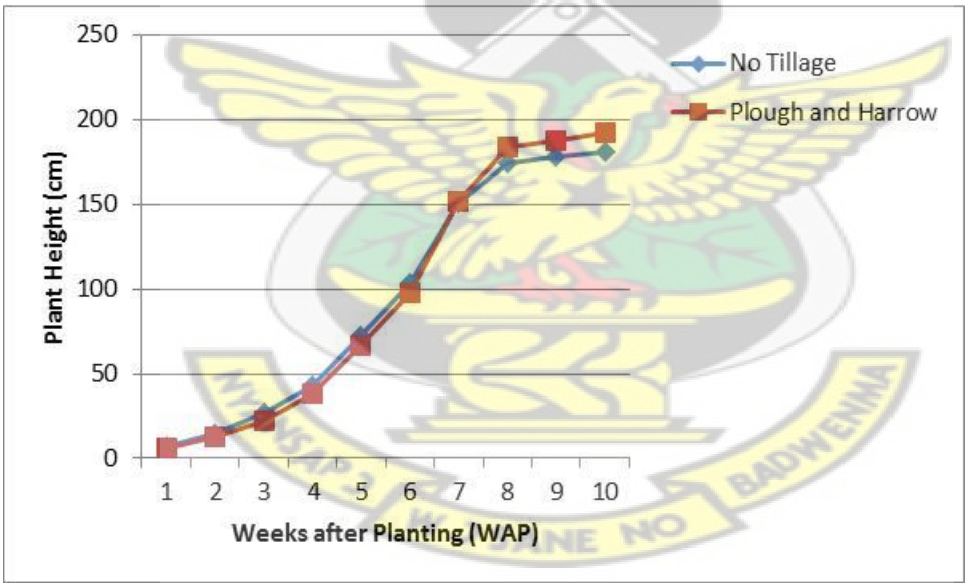

Fig. 4.3: Effect of tillage treatment on plant height, 2010

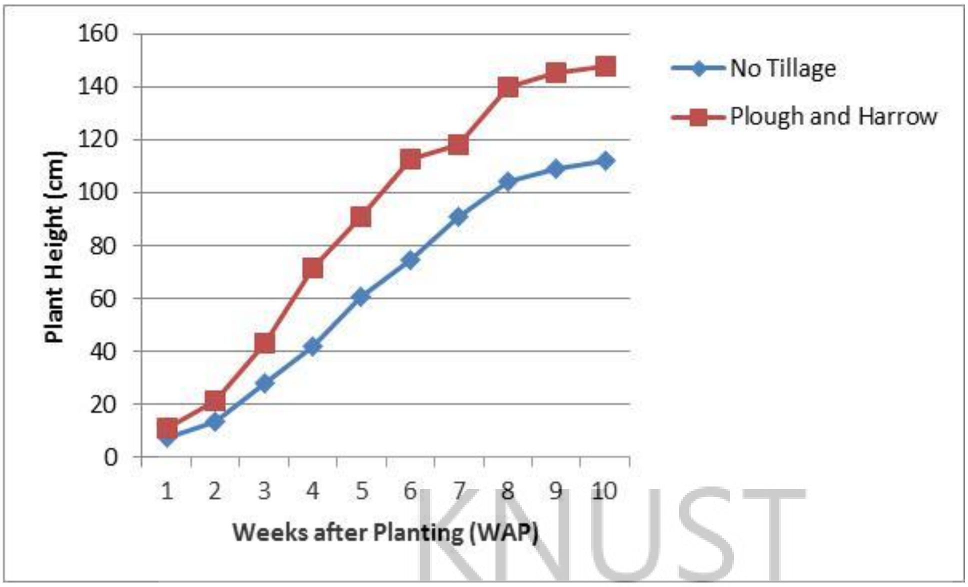

Fig. 4.4: Effect of tillage treatment on plant height, 2011

4.2.3 Effect of fertiliser application rates on plant height

Fig. 4.5 and Fig. 4.6 illustrate the effect of fertiliser application rates on *Akposoe* maize plant height over a period of 10 weeks after planting in the 2010 minor and 2011 major cropping seasons respectively. At 10 weeks after planting, analysis of variance showed statistically significant difference in plant height between the different fertiliser application rates. Plants in the 150 kg ha^{-1}, 250 kg ha^{-1} and 350 kg ha^{-1} fertiliser application plots were significantly taller than those in the no fertiliser application plots (0kg ha^{-1}) for both the 2010 minor and 2011 major cropping seasons. There was no significant difference in plant height between the 150kg ha^{-1}, 250kg ha^{-1} and 350kg ha^{-1} fertiliser application treatments. These results are similar to that of Memon *et al.* (2012) who observed significantly taller plants in plots applied with fertiliser compared with that of plots that did not receive fertiliser application.

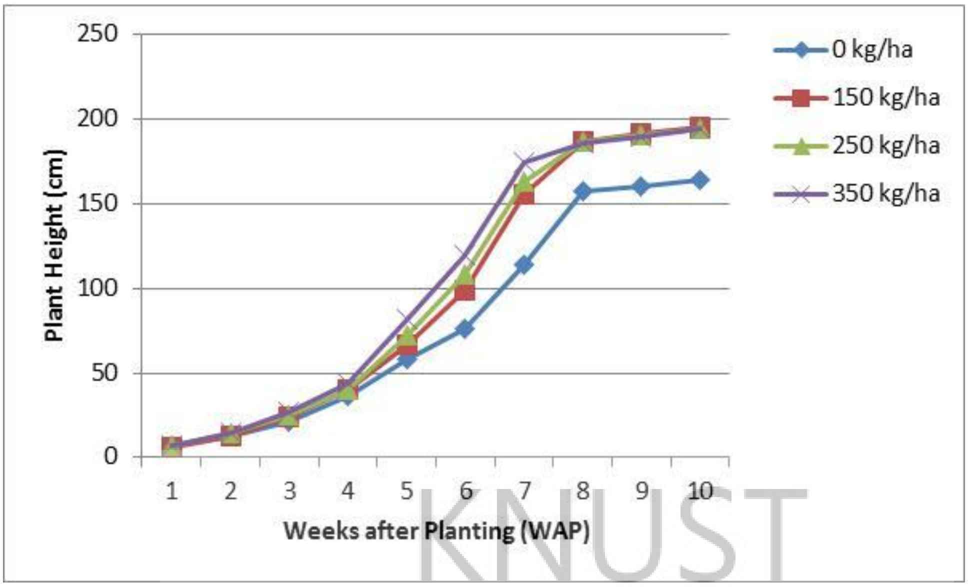

Fig. 4.5: Effect of fertiliser application on plant height, 2010

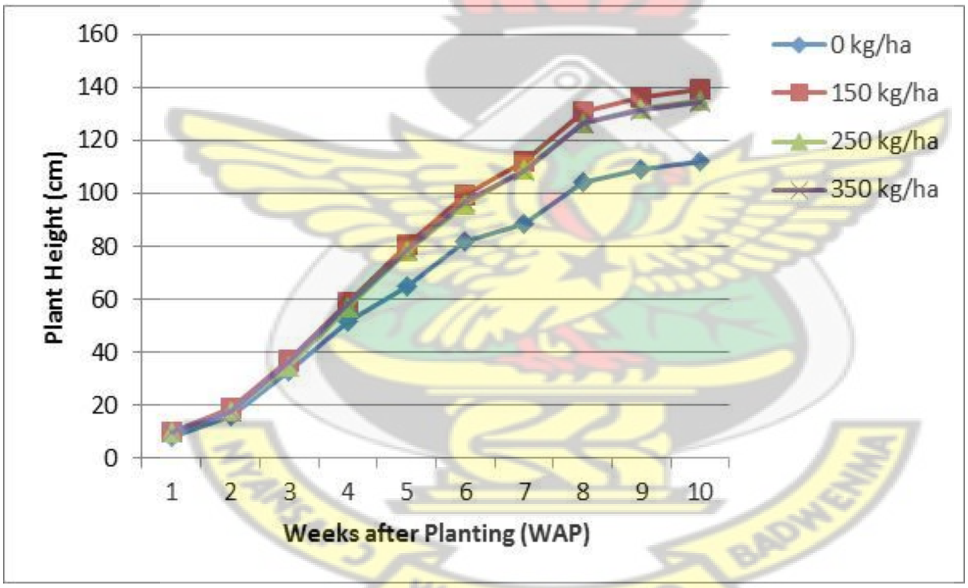

Fig. 4.6: Effect of fertiliser application on plant height, 2011

4.2.4 Effect of tillage treatment on stem girth

Fig. 4.7 and Fig. 4.8 illustrate the effect of tillage treatment on *Akposoe* maize stem girth for the first 10 weeks after planting in the 2010 minor and 2011 major cropping seasons. At 10 weeks after planting, analysis of variance showed statistically significant difference in stem girth between the different tillage treatments for both the 2010 minor and 2011 major cropping seasons. Plant stems in the disc ploughing followed by disc harrowing treatment plots were significantly bigger than those in the No Tillage treatment plots for both cropping seasons. In the 2010 minor season, the disc ploughing followed by disc harrowing tillage treatment recorded the bigger mean stem girth of 79 mm while the No tillage treatment plots recorded the smaller stem girth of 68 mm. In the 2011 major season, the disc ploughing followed by disc harrowing recorded the bigger stem girth (81 mm) while the No Tillage treatment plots gave the smaller mean stem girth (64 mm).

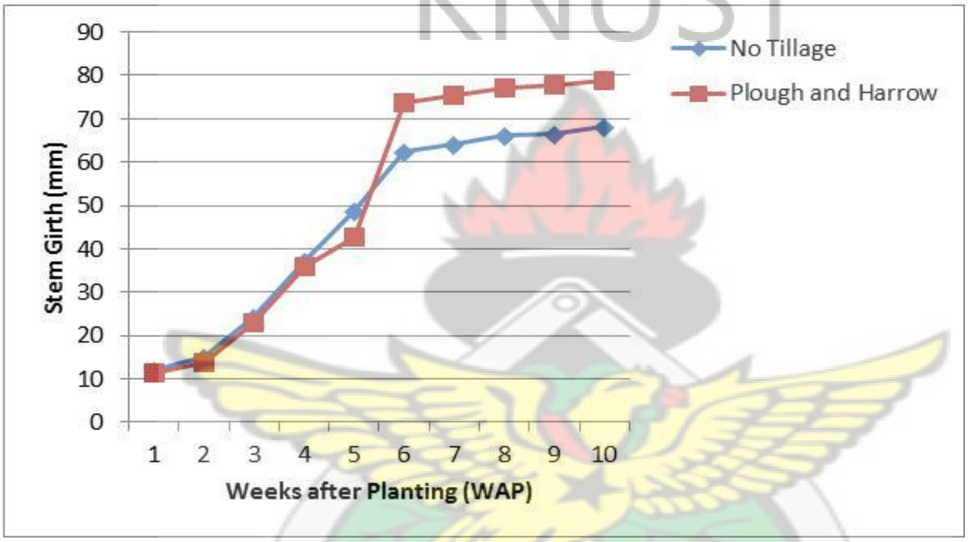

Fig. 4.7: Effect of tillage treatment on stem girth, 2010

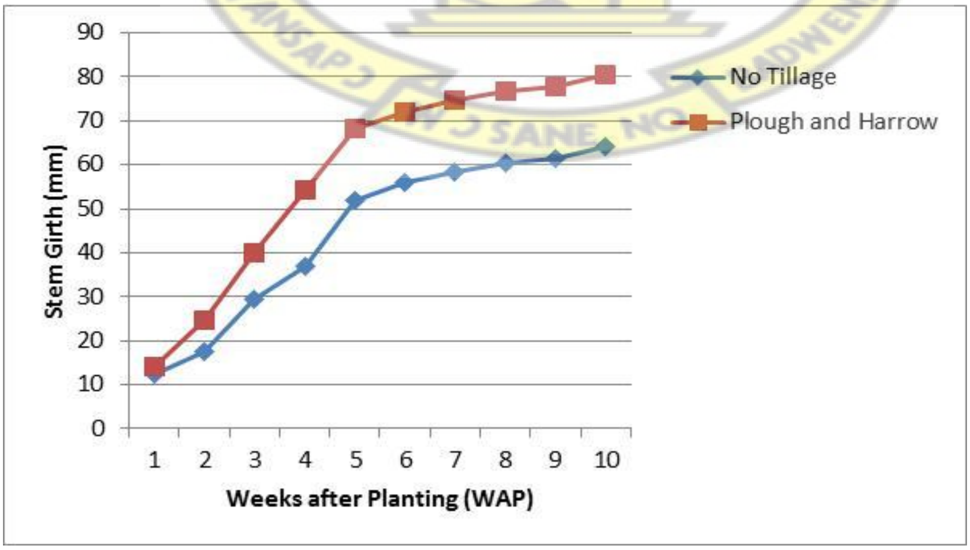

Fig. 4.8: Effect of tillage treatment on stem girth, 2011

4.2.5 Effect of fertiliser application rates on stem girth

Fig. 4.9 and Fig. 4.10 illustrate the effect of different fertiliser application rates on *Akposoe* maize stem girth in the 2010 minor and 2011 major cropping seasons. At 10 weeks after planting in both seasons, analysis of variance showed statistically significant difference in stem girth between the different fertiliser application rates. Maize plant stems in the 150 kg ha^{-1}, 250 kg ha^{-1} and 350 kg ha^{-1} fertiliser application plots were significantly bigger than those in the no fertiliser application plots (0kg ha^{-1}) for both the 2010 minor and 2011 major cropping seasons. Again, in both seasons, the 350 kg ha^{-1} fertiliser application rate produced maize plants with the biggest stem. In the 2010 minor cropping season, the 350 kg ha^{-1} fertiliser treatment produced maize plants significantly bigger than the 150kg ha^{-1} fertiliser treatment. There was, however, no significant difference in stem girth between the 350kg ha^{-1} and 250kg ha^{-1} fertiliser application rates in 2010. In the 2011 major cropping season, there was no significant difference in stem girth between the 150kg ha^{-1}, 250kg ha^{-1} and 350kg ha^{-1} fertiliser application treatments.

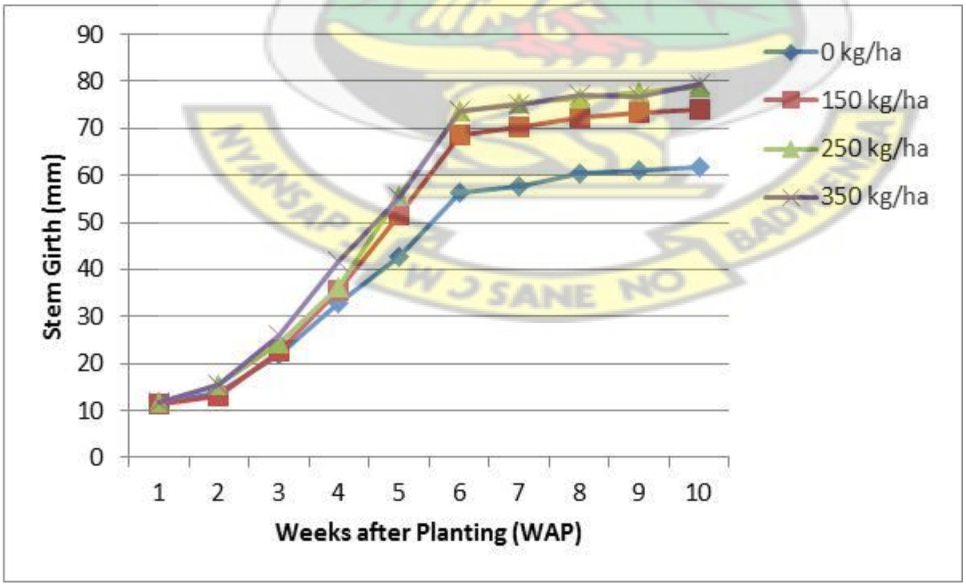

Fig. 4.9: Effect of fertiliser application on stem girth, 2010

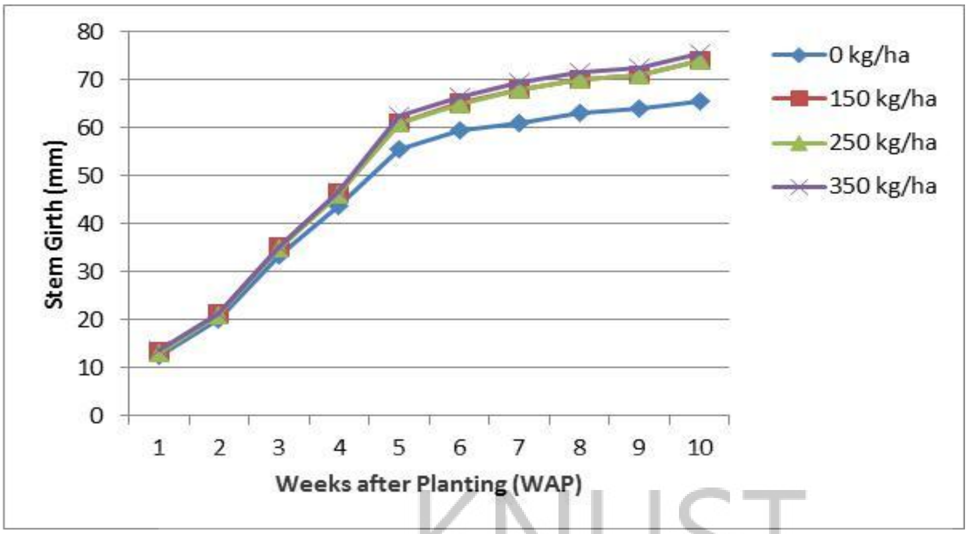

Fig. 4.10: Effect of fertiliser application on stem girth, 2011

4.2.6 Effect of tillage treatment on number of leaves per plant

The effect of tillage treatment on the number of leaves per plant for *Akposoe* maize under the various tillage treatments are depicted in Fig. 4.11 and Fig. 4.12. Analysis of variance showed statistically significant effect of tillage treatment on the number of leaves per plant in both the 2010 minor and 2011 major cropping seasons. At 10 weeks after planting in both cropping seasons, the disc ploughing followed by disc harrowing treatment plots produced higher number of leaves per plant compared with that in the No tillage treatment plots.

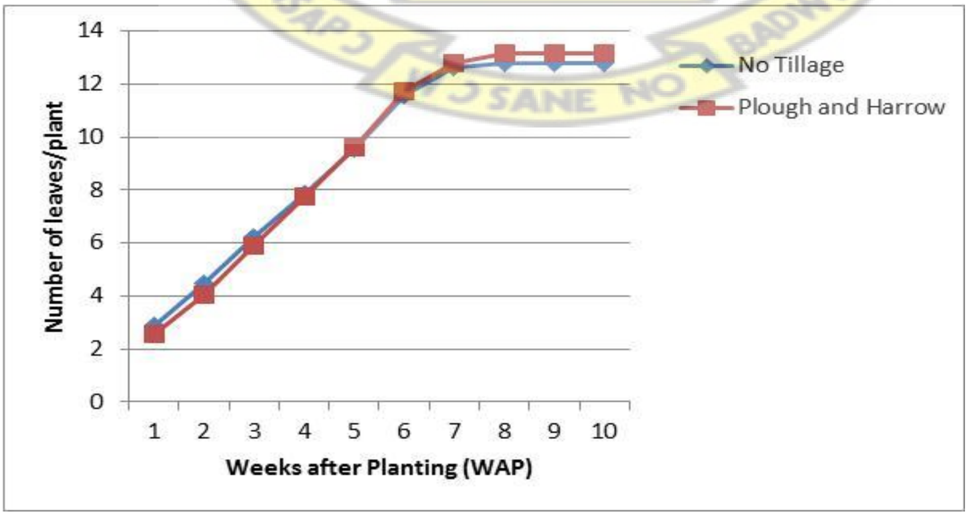

Fig. 4.11: Effect of tillage treatment on number of leaves per plant, 2010

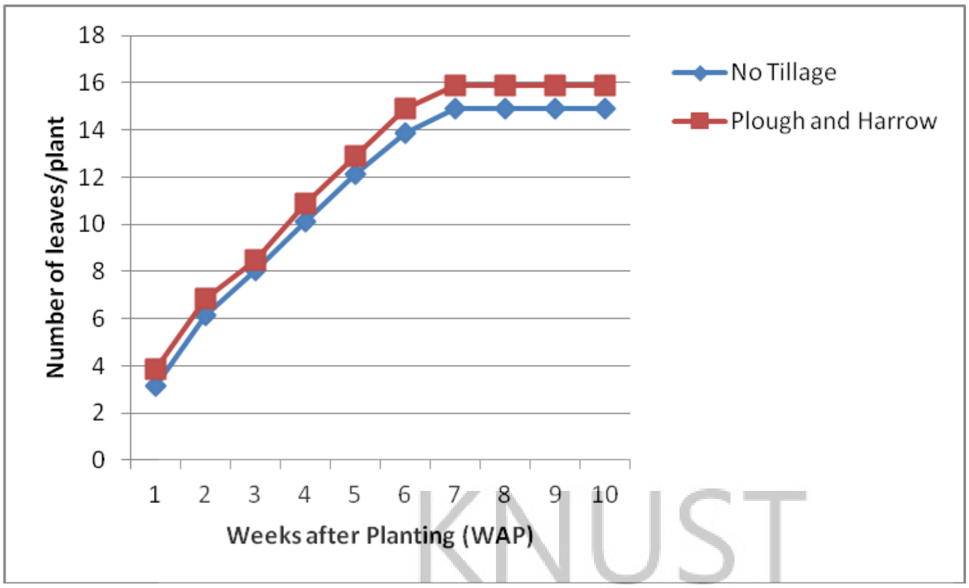

Fig. 4.12: Effect of tillage treatment on number of leaves per plant, 2011

4.2.7 Effect of fertiliser application on number of leaves per plant

The ability of a plant to intercept sunlight and its photosynthetic capability depends on the number of leaves produced by the plant. The effect of fertiliser application treatment on the number of leaves per maize plant for the 2010 minor and 2011 major season are presented in Fig. 4.13 and Fig. 4.14 respectively. At 10 weeks after planting, analysis of variance showed statistically significant difference in the number of leaves per plant between the different fertiliser application rates. Plants in the 150 kg ha^{-1}, 250 kg ha^{-1} and 350 kg ha^{-1} fertiliser application plots had significantly higher number of leaves per plant compared with those in the no fertiliser application plots (0kg ha^{-1}) for both the 2010 minor and 2011 major cropping seasons. There was no significant difference in the number of leaves per plant between the 150kg ha^{-1}, 250kg ha^{-1} and 350kg ha^{-1} fertiliser application treatments in both cropping seasons.

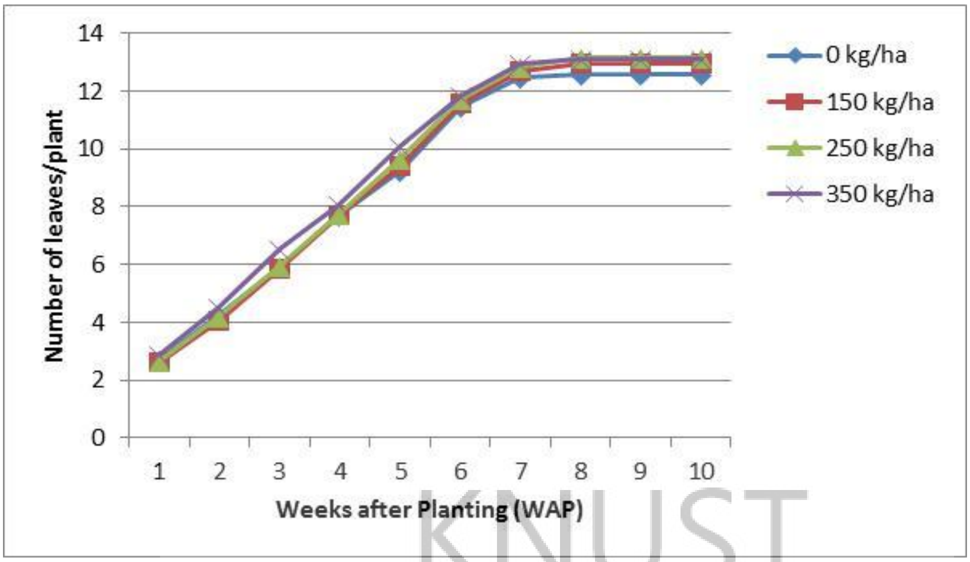

Fig. 4.13: Effect of fertiliser application on number of leaves per plant, 2010

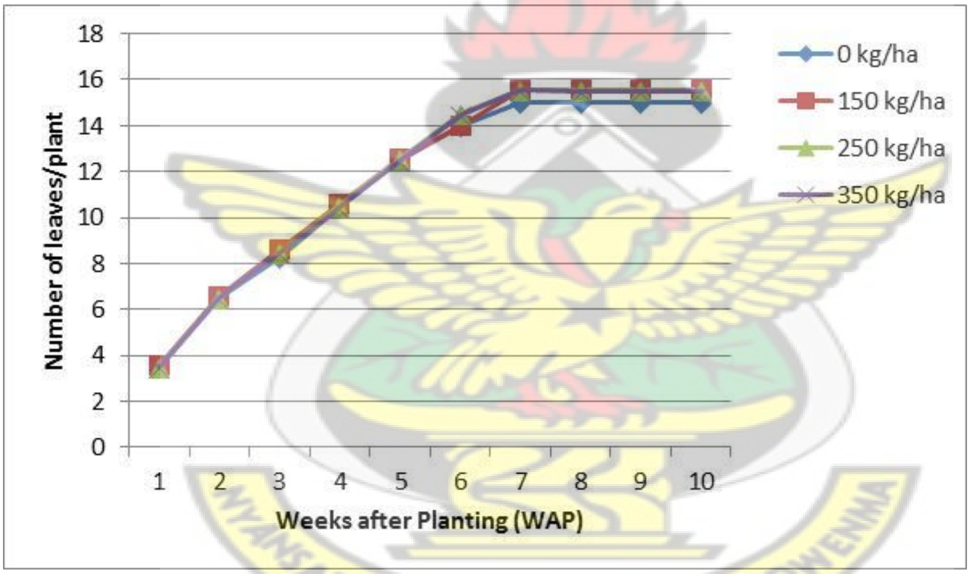

Fig. 4.14: Effect of fertiliser application on number of leaves per plant, 2011

4.2.8 Effect of tillage treatment on leaf area

Fig. 4.15 and Fig. 4.16 show the effect of tillage treatment on *Akposoe* maize leaf area obtained over 10 weeks after planting for the 2010 minor and 2011 major cropping seasons respectively.

Analysis of variance showed statistically significant effect of tillage treatment on leaf area in both the 2010 minor and 2011 major cropping seasons. At 10 weeks after planting in both cropping seasons, the disc ploughing followed by disc harrowing treatment plots produced plants with bigger leaf area compared with the No tillage treatment plots.

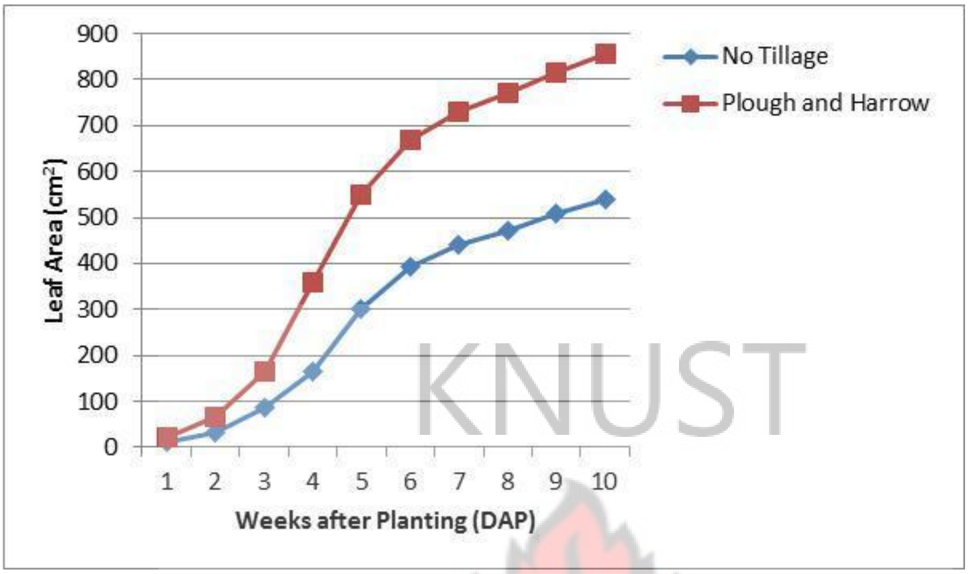

Fig. 4.15: Effect of tillage treatment on leaf area, 2010

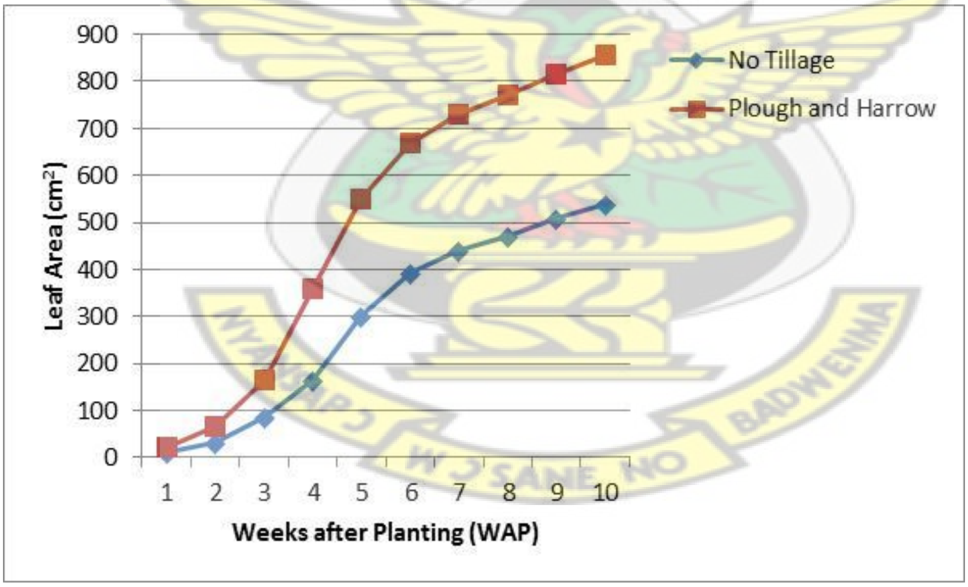

Fig. 4.16: Effect of tillage treatment on leaf area, 2011

4.2.9 Effect of fertiliser application on leaf area

Fig. 4.17 and Fig 4.18 present the effect of fertiliser application rate on *Akposoe* maize leaf area obtained over 10 weeks in the 2010 minor and 2011 major cropping seasons. At 10 weeks after planting, analysis of variance showed statistically significant difference in leaf area between the different fertiliser application rates. At 10 WAP in the 2010 minor season, leaf area had increased with fertiliser increments: thus, 350 kg ha^{-1}, 250 kg ha^{-1} and 150 kg ha^{-1} gave leaf areas of 560.8 cm^2, 544.2 cm^2, and 516.3 cm^2 respectively. In the 2011 major season, the 150 kg ha^{-1} fertiliser treatment presented the broadest leaf area (757.2 cm^2) followed by the 350 kg ha^{-1} (735.9 cm^2) and then the 250 kg ha^{-1} (722.5 cm^2). Thus, plants in the 150 kg ha^{-1}, 250 kg ha^{-1} and 350 kg ha^{-1} fertiliser application plots had significantly bigger leaf area compared with those in the no fertiliser application plots for both the 2010 minor (367.3 cm^2) and 2011 major (571.6 cm^2) cropping seasons. There was no significant difference in the leaf area between the 150kg ha^{-1}, 250kg ha^{-1} and 350kg ha^{-1} fertiliser application treatments in both cropping seasons.

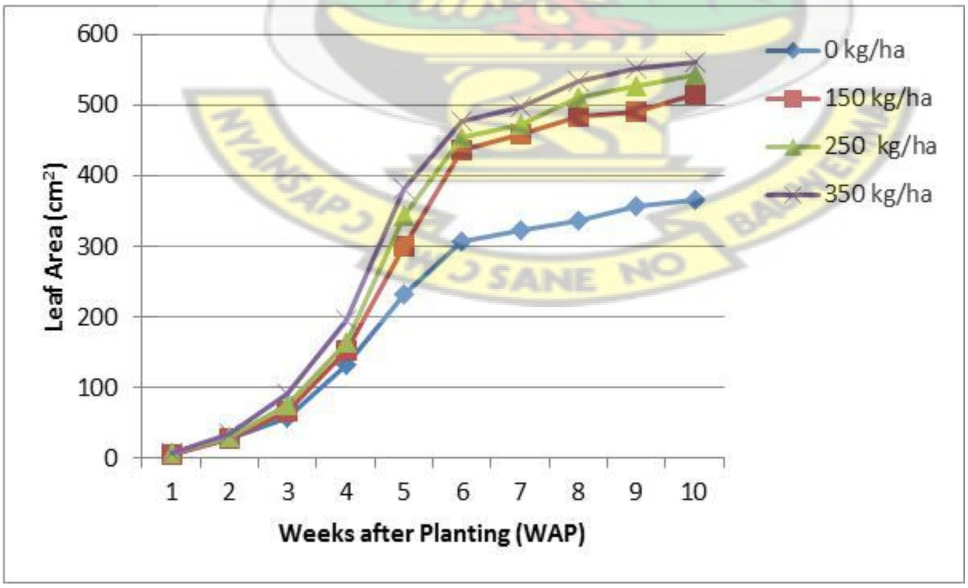

Fig. 4.17: Effect of fertiliser application on leaf area, 2010

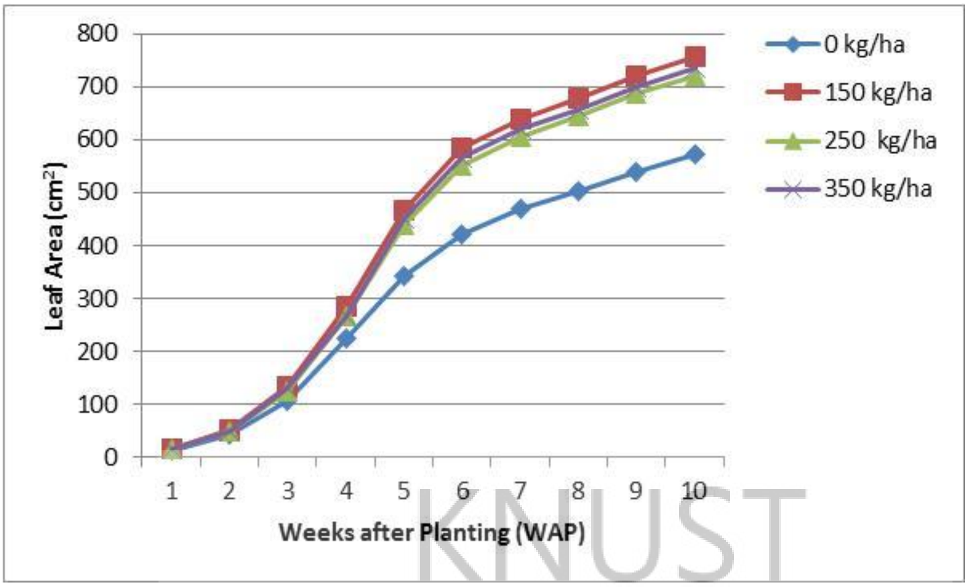

Fig. 4.18: Effect of fertiliser application on leaf area, 2011

4.2.10 Effect of Tillage Treatment on Root Length and Dry Matter Yield

The root is the main organ of the plant which has to make contact with the soil to absorb nutrients and water. The ability of plants to obtain such is related to their capacity to develop extensive root systems (Chen and Weil, 2011). Table 4.1 shows results of the effect of tillage treatment on *Akposoe* maize root length and dry matter yield at harvest in the 2010 minor and 2011 major cropping seasons. At harvest, analysis of variance showed statistically significant difference in root length between the different tillage treatments. *Akposoe* maize plant roots in the disc ploughing followed by disc harrowing plots were significantly longer than those in the No Tillage plots in both the 2010 minor and 2011 major seasons. The longer roots obtained by maize plants in the disc ploughing followed by disc harrowing plots may be ascribed to the loosening effect of the operation on the impeding soil layer at the site. These results are similar to that of Rashidi and Keshavarzpour (2008) who investigated the effect of different tillage methods on soil properties and crop yield of melon (*Cucumis melo*).

Table 4.1: Effect of Tillage Treatment on Root Length and Dry Matter Yield

Treatment	Minor Season 2010 Root Length (cm)	Minor Season 2010 Dry Matter Yield (kg ha^{-1})	Major Season 2011 Root Length (cm)	Major Season 2011 Dry Matter Yield (kg ha^{-1})
No Tillage	27.4	2853	29.9	2705
Plough + Harrow	32.8	4208	56.3	5750
Average	30.1	3531	43.1	4228
LSD ($p<0.05$)	4.0	512	5.4	1690

NS = Not Significant

Similarly, analysis of variance showed statistically significant difference in dry matter yield between the different tillage treatments at harvest in both seasons. *Akposoe* maize plants in the disc ploughing followed by disc harrowing tillage treatment plots produced significantly higher dry matter yield in 2010 minor (4208 kg ha^{-1}) and 2011 major (5750 kg ha^{-1}) cropping seasons compared with those in the no tillage treatment plots.

4.2.11 Effect of Fertiliser Application on root length and dry matter yield

Table 4.2 presents the results obtained on the effect of fertiliser application rate on *Akposoe* maize root length and dry matter yield at harvest in the 2010 minor and 2011 major cropping seasons. Analysis of variance showed no statistically significant difference in root length between the different fertiliser application rates. In the 2010 minor season, the longest root (32.5 cm) was produced by the 250 kg ha^{-1} fertiliser treatment plots, followed by 31.1 cm in the 350 kg ha^{-1} treatment plots. The shortest root (27.8 cm) was produced by the 0 kg ha^{-1} fertiliser treatment plots. In 2011, the longest root (45.6 cm) was recorded by the 350 kg ha^{-1}fertiliser treatment plots followed by 43.6

cm in the 150 kg ha^{-1}plots and 42.7 cm in the 250 kg ha^{-1} fertiliser treatment plots. The shortest root (40.5 cm) was recorded by the 0 kg ha^{-1} fertiliser application treatment plots.

Table 4.2: Effect of NPK 15-15-15 Fertiliser Application on Root Length and Dry Matter Yield

	Minor Season 2010		Major Season 2011	
Fertiliser Application	Root Length (cm)	Dry Matter Yield (kg ha^{-1})	Root Length (cm)	Dry Matter Yield (kg ha^{-1})
0 kg ha^{-1}	27.8	2159	40.5	2013
150 kg ha^{-1}	29.1	3626	43.6	4934
250 kg ha^{-1}	32.5	4053	42.7	5426
350 kg ha^{-1}	31.1	4283	45.6	4538
Average	30.1	3530	43.1	4228
LSD ($p<0.05$)	NS	362	NS	1195

NS = Not Significant

Dry matter accumulation is as a result of nutrient uptake. It is one of the measures of plant growth (Noggle and Fritz, 1983) and it reflects the relative growth rate with regards to net assimilation rate (Ibeawuchi, 2004). At harvest in both the 2010 minor and 2011 major cropping seasons, analysis of variance showed statistically significant difference in dry matter yields between the different fertiliser application rates. Dry matter yields in the 150 kg ha^{-1}, 250 kg ha^{-1} and 350 kg ha^{-1} fertiliser application plots were significantly higher than those in the no fertiliser application plots for both the 2010 minor and 2011 major cropping seasons. In the 2010 minor cropping season, the highest dry matter yield (4,283 kg ha^{-1}) was produced in the 350 kg ha^{-1} fertiliser application treatment plots while the lowest dry matter yield (2159 kg ha^{-1}) was produced in the 0 kg ha^{-1} fertiliser treatment plots. Dry matter yields in both the 350 kg ha^{-1} and 250 kg ha^{-1} fertiliser treatment were significantly higher than that in the 150 kg ha^{-1} treatments. There was no statistically significant difference in dry matter yield between the 350 kg ha^{-1} and 250 kg ha^{-1} fertiliser application rates.

In the 2011 major cropping season, fertiliser application rate had significant effect on *Akposoe* maize dry matter yield at harvest. The highest maize dry matter yield in 2011 (5426 kg ha^{-1}) was produced by the 250 kg ha^{-1} fertiliser application plots and was followed by the 150 kg ha^{-1} and 350 kg ha^{-1} rates with 4934 kg ha^{-1} and 4538 kg ha^{-1} respectively. There was no significant difference in dry matter yield between the 150 kg ha^{-1}, 250 kg ha^{-1} and 350 kg ha^{-1} fertiliser application treatments. The plants in the 0 kg ha^{-1} treatment plots produced the lowest dry matter yield in 2011 (2013 kg ha^{-1}). The results suggest that fertiliser application rates influenced the maize dry matter accumulation, consistent with an earlier research by Jones, (1976) on legumes.

4.2.12 Effect of Tillage Treatment on Dry Cob Weight and Grain Yield

The results on the effect of tillage treatment on *Akposoe* maize dry cob weight and grain yield at harvest in the 2010 minor and 2011 major cropping seasons are presented in Table 4.3. Analysis of variance revealed that tillage did not significantly affect dry cob weight in the 2010 minor season although the disc ploughing followed by disc harrowing treatment presented higher dry cob weight (7943 kg ha^{-1}) over the No tillage treatment (7791 kg ha^{-1}). However, there was statistically significant effect of tillage treatment on dry cob weight in 2011. The disc ploughing followed by disc harrowing treatment plots produced plants with higher dry cob weight (9092 kg ha^{-1}) compared with that in the No tillage treatment plots (5822 kg ha^{-1}).

Table 4.3: Effect of Tillage Treatment on Dry Cob Weight and Grain Yield

Tillage Treatment	Minor Season, 2010		Major Season, 2011	
	Dry Cob Weight (kg ha^{-1})	Grain Yield (kg ha^{-1})	Dry Cob Weight (kg ha^{-1})	Grain Yield (kg ha^{-1})
No Tillage	7791	4502	5822	3761
Plough + Harrow	7943	4287	9092	6223
Average	7867	4395	7457	4992
LSD (p<0.05)	NS	NS	1429	1281

NS = Not Significant

In the 2010 minor cropping season, the No tillage treatment produced a higher grain yield (4502kg ha^{-1}) but the analysis of variance showed that the difference was not statistically significant compared with that in the disc ploughing followed by disc harrowing treatment plots (4287kg ha^{-1}). In the 2011 major season, tillage significantly affected *Akposoe* maize grain yield. At harvest, the disc ploughing followed by disc harrowing treatment produced a higher grain yield (6223 kg ha^{-1}) compared with the No tillage treatment plots (3761kg ha^{-1}). This is similar to that of Memon *et al*. (2012) who recorded a significantly lower grain yield and dry matter yields on no-till treatment plots as compared with conventionally tilled plots on loamy soils in Islamabad, Pakistan.

4.2.13 Effect of NPK 15-15-15 Fertiliser Application on Dry Cob Weight and Grain Yield

The pattern of dry matter accumulation affected the dry cob weight and grain yield of *Akposoe* maize. It means that nutrients provided by the fertiliser were taken up by the maize plants, effectively used and converted to stem, leaf tissues, cobs and grains respectively. Table 4.4illustrates the effect of fertiliser application on dry cob weight and grain yield of *Akposoe* maize at harvest in both the 2010 minor and 2011 major cropping seasons.

Table 4.4: Effect of NPK 15-15-15 Fertiliser Application on Dry Cob Weight and Grain Yield

	Minor Season, 2010		Major Season, 2011	
Fertiliser Application	Dry Cob Weight (kg ha^{-1})	Grain Yield (kg ha^{-1})	Dry Cob Weight (kg ha^{-1})	Grain Yield (kg ha^{-1})
0 kg ha^{-1}	4516	4219	4837	3396
150 kg ha^{-1}	8181	4644	7138	4728
250 kg ha^{-1}	9840	4418	9172	6287
350 kg ha^{-1}	8931	4297	8681	5556
Average	7867	4,395	7457	4,992
LSD (p<0.05)	1244	NS	1018	906

NS = Not Significant

Analysis of variance showed statistically significant difference in dry cob weight between the different fertiliser application rates in both cropping seasons. In the 2010 minor season, the highest dry cob weight (9890 kg ha^{-1}) which was recorded in the 250 kg ha^{-1} fertiliser application rate plots did not significantly differ from that produced in the 350 kg ha^{-1}fertiliser application rate (703 kg ha^{-1}). However, both the 250 kg ha^{-1} and 350 kg ha^{-1} fertiliser application rates produced significantly higher dry cob weight compared with the 0 kg ha^{-1} (4516 kg ha^{-1}). In the 2011 major season, plants in the 250 kg ha^{-1} fertiliser application rate plots produced the highest dry maize cob weight (9172 kg ha^{-1}) while maize plants in the 0 kg ha^{-1} fertiliser rate plots produced the lowest dry cob weight

(4837 kg ha^{-1}). There was no significant difference in dry cob weight between the 250 kg ha^{-1} and 350 kg ha^{-1} fertiliser application at harvest in the 2011 major cropping season. However, dry cob weight in both the 250 kg ha^{-1} and 350 kg ha^{-1} were significantly higher than those in the 150 kg ha^{-1}.

In the 2010 minor cropping season, there was no significant difference in grain yield between the fertiliser application treatments at harvest. The highest and lowest grain yield values of 4644 kg ha^{-1} and 4219 kg ha^{-1} were given by maize plants in the 150 kg ha^{-1} and the 0 kg ha^{-1} fertiliser rate plots respectively. At harvest in the 2011 major cropping season, analysis of variance showed statistically significant difference in grain yield between the different fertiliser application rates. The highest grain yield (6287 kg ha^{-1}) which was recorded in the 250 kg ha^{-1} fertiliser application plots was not significantly different from that produced in the 350 kg ha^{-1} (5556 kg ha^{-1}). However, both were significantly higher than those in the 150 kg ha^{-1} and 0 kg ha^{-1} fertiliser application plots. Grain yields among plants in the 150 kg ha^{-1}, 250 kg ha^{-1} and 350 kg ha^{-1} fertiliser application plots were significantly higher than those in the no fertiliser application plots, an observation consistent with that of Memon *et al*. (2012) who observed that grain yields were affected by different fertilizer treatments and they had a positive linear relationship with fertilizer application.

4.2.14: Interaction Effects of Tillage Treatments and NPK 15-15-15 Fertiliser Application on Seedling Emergence

Table 4.5 displays the interaction effects of tillage and fertiliser application rates on *Akposoe* maize seedling emergence at 20 days after planting in the 2010 minor and 2011 major growing seasons. The analysis of variance showed no statistical significance on interaction effect.

Table 4.5: Interaction Effects of Tillage Treatments and NPK 15-15-15 Fertiliser Application on Seedling Emergence at 20 Days after Planting

Tillage Treatment x Fertiliser Application	2010 Seedling Emergence, %	2011 Seedling Emergence, %
No Tillage x 0 kg ha^{-1}	97.9	97.1
No Tillage x 150 kg ha^{-1}	97.5	97.9
No Tillage x 250 kg ha^{-1}	100.0	98.3
No Tillage x 350 kg ha^{-1}	100.0	99.2
Plough + Harrow x 0 kg ha^{-1}	100.0	99.2
Plough + Harrow x 150 kg ha^{-1}	99.2	100.0
Plough + Harrow x 250 kg ha^{-1}	97.1	100.0
Plough + Harrow x 350 kg ha^{-1}	100.0	100.0
Average	99.0	99.0
LSD ($p \geq 0.05$)	NS	NS

NS = Not Significant

4.2.15: Interaction Effects of Tillage Treatments and NPK 15-15-15 Fertiliser Application on Plant Height and Stem Girth

The interaction effects of tillage treatment and fertiliser application rates on *Akposoe* maize plant height and stem girth in the 2010 minor and 2011 major growing seasons is presented in Table 4.6.

Table 4.6: Interaction Effects of Tillage Treatments and NPK 15-15-15 Fertiliser Application on Plant Height and Stem Girth at 10 Weeks after Planting

	2010		2011	
Tillage Treatment x Fertiliser Application	Plant Height, cm	Stem Girth, mm	Plant Height, cm	Stem Girth, mm
No Tillage x 0 kg ha^{-1}	154	57	95	55
No Tillage x 150 kg ha^{-1}	188	67	120	65
No Tillage x 250 kg ha^{-1}	190	72	118	70
No Tillage x 350 kg ha^{-1}	193	77	117	66
Plough + Harrow x 0 kg ha^{-1}	175	66	130	76
Plough + Harrow x 150 kg ha^{-1}	202	81	158	84
Plough + Harrow x 250 kg ha^{-1}	199	85	152	78
Plough + Harrow x 350 kg ha^{-1}	195	82	152	84
Average	187	74	130	72
LSD ($p \geq 0.05$)	NS	NS	NS	NS

NS = Not Significant

At 10 weeks after planting, analysis of variance showed no statistically significant effect in plant height and stem girth as regards interaction between tillage treatment and fertiliser application rate. The Disc ploughing followed by disc harrowing x 150 kg ha^{-1}

interaction yielded the tallest plants in both 2010 minor (202.0 cm) and 2011 major (158.1 cm) cropping seasons. Analysis of variance also showed that the Disc ploughing followed by disc harrowing x 250 kg ha^{-1} interaction yielded plants with the biggest stems in the 2010 minor season (85.0 mm) while the Disc ploughing followed by disc harrowing x 350 kg ha^{-1} interaction yielded plants with the biggest stems in the 2011 major cropping season (84.4 mm). At 10 weeks after planting, the No Tillage x 0 kg ha^{-1}interaction yielded the shortest plant height and the smallest stem girth in both the 2010 minor and 2011 major cropping seasons.

4.2.16: Interaction Effects of Tillage Treatments and NPK 15-15-15 Fertiliser Application on Number of Leaves per Plant and Leaf Area

Table 4.7 summarises the interaction effects of tillage treatments and NPK 15-15-15 fertiliser application rates on number of leaves per plant and leaf area at 10 weeks after planting in the 2010 minor and 2011 major cropping seasons. In terms of leaf area, analysis of variance showed no statistically significant difference in interaction effect in both the 2010 minor and 2011 major cropping seasons. At 10 weeks after planting, the Disc ploughing followed by disc harrowing x 250 kg ha^{-1} interaction produced maize plants with the biggest leaf area in the 2010 minor cropping season (594.9 cm^2) while the Disc ploughing followed by disc harrowing x 150 kg ha^{-1} interaction gave the biggest leaf area in 2011 major cropping season (936.0 cm^2). The smallest leaf area in 2010 (324.0 cm^2) and 2011 (433.9 cm^2) were recorded by the No Tillage x 0 kg ha^{-1} interaction.

Table 4.7: Interaction Effects of Tillage Treatments and NPK 15-15-15 Fertiliser Application on Number of Leaves per Plant and Leaf Area

Tillage Treatment x Fertiliser Application	2010		2011	
	No. of Leaves/Plant	Leaf Area, cm^2	No. of Leaves/Plant	Leaf Area, cm^2
No Tillage x 0 kg ha^{-1}	12.3	324.0	14.2	433.9
No Tillage x 150 kg ha^{-1}	12.7	459.7	15.3	578.4
No Tillage x 250 kg ha^{-1}	12.9	493.4	15.1	564.8
No Tillage x 350 kg ha^{-1}	13.2	576.4	15.1	578.4
Plough + Harrow x 0 kg ha^{-1}	12.8	410.6	15.8	709.4
Plough + Harrow x 150 kg ha^{-1}	13.2	572.8	15.9	936.0
Plough + Harrow x 250 kg ha^{-1}	13.5	594.9	16.0	880.1
Plough + Harrow x 350 kg ha^{-1}	13.1	545.2	15.9	893.5
Average	13.0	497.1	15.4	696.8
LSD ($p \geq 0.05$)	NS	NS	0.26	NS

NS = Not Significant

At 10 weeks after planting in the 2010 minor cropping season, analysis of variance showed no statistically significant interaction effect between tillage treatment and fertiliser application on the number of leaves per plant. A greater number of leaves per plant was recorded in the Disc ploughing followed by disc harrowing x 250 kg ha^{-1} interaction plots in the 2010 minor cropping season. At 10 weeks after planting in the 2011 major cropping season, analysis of variance showed statistically significant interaction effect in the number of leaves per plant. The Disc ploughing followed by disc harrowing x 250 kg ha^{-1} interactions produced the highest number of leaves per plant. At

10 weeks after planting, the number of leaves per plant in the Disc ploughing followed by disc harrowing x 0 kg ha^{-1}, Disc ploughing followed by disc harrowing x 150 kg ha^{-1}, Disc ploughing followed by disc harrowing x 250 kg ha^{-1}, and Disc ploughing followed by disc harrowing x 350 kg ha^{-1} interaction plots were significantly higher than those in the No Tillage x 0 kg ha^{-1}, No Tillage x 150 kg ha^{-1}, No Tillage x 250 kg ha^{-1} and No Tillage x 350 kg ha^{-1} interaction plots in the 2011 major cropping season. There was no significant difference in the number of leaves per plant between the Disc ploughing followed by disc harrowing x 0 kg ha^{-1}, Disc ploughing followed by disc harrowing x 150 kg ha^{-1}, Disc ploughing followed by disc harrowing x 250 kg ha^{-1}, and Disc ploughing followed by disc harrowing x 350 kg ha^{-1} interactions in 2011. Plants in the No Tillage x 0 kg ha^{-1} interaction plots produced the lowest number of leaves per plant at 10 weeks after planting in both the 2010 minor and 2011 major cropping seasons.

4.2.17a: Interaction Effects of Tillage Treatments and NPK 15-15-15 Fertiliser Application on Root Length and Dry Matter Yield

Table 4.8 displays the interaction effects of tillage treatments and NPK 15-15-15 fertiliser application on root length and dry matter yield of *Akposoe* maize at harvest in the 2010 minor and 2011 major cropping seasons.

Table 4.8: Interaction Effects of Tillage Treatments and NPK 15-15-15 Fertiliser Application on Root Length and Dry Matter Yield

Tillage Treatment x Fertiliser Application	2010		2011	
	Root Length, cm	Dry Matter Yield, kg ha^{-1}	Root Length, cm	Dry Matter Yield, kg ha^{-1}
No Tillage x 0 kg ha^{-1}	23.7	1775	27.8	1206
No Tillage x 150 kg ha^{-1}	25.7	2608	28.8	1877
No Tillage x 250 kg ha^{-1}	29.0	2828	28.7	4053
No Tillage x 350 kg ha^{-1}	31.0	4200	34.4	3685
Plough + Harrow x 0 kg ha^{-1}	31.8	2543	53.2	2820
Plough + Harrow x 150 kg ha^{-1}	32.5	4644	58.4	7991
Plough + Harrow x 250 kg ha^{-1}	35.9	5278	56.7	6799
Plough + Harrow x 350 kg ha^{-1}	31.1	4365	56.7	5391
Average	30.1	3530	43.1	4227
LSD ($p \leq 0.05$)	NS	723	NS	2390

NS = Not Significant

At harvest, analysis of variance showed no statistically significant interaction effect on root length for both the 2010 minor and 2011 major cropping seasons. In the 2010 minor cropping season, the Disc ploughing followed by disc harrowing x 250 kg ha^{-1} interaction plots produced plants with the longest roots (35.9 cm) while the No Tillage x 0 kg ha^{-1} interaction plots produced plants with the shortest roots (23.7 cm).At harvest in the 2011 major cropping season, the Disc ploughing followed by disc harrowing x 150 kg ha^{-1} interaction plots produced plants with the longest roots (58.4 cm) while the No Tillage x 0 kg ha^{-1} interaction plots produced plants with the shortest roots (27.8 cm). At harvest, analysis of variance showed statistically significant interaction effects in dry matter yields for both the 2010 minor and 2011 major cropping seasons. In the 2010 minor cropping season, the highest dry matter yield (5278 kg ha^{-1}) which was produced by plants in the Disc ploughing followed by disc harrowing x 250 kg ha^{-1} interaction plots was significantly higher than all the other interaction effects except for the Disc ploughing followed by disc harrowing x 150 kg ha^{-1} interaction plots. Similarly, in the 2011 major cropping season, the highest dry matter yield (7991 kg ha^{-1}) which was produced by plants in the Disc ploughing followed by disc harrowing x 150 kg ha^{-1} interaction plots was significantly higher than all the other interaction effects except for the Disc ploughing followed by disc harrowing x 250 kg ha^{-1} interaction plots. Plants in the No Tillage x 0 kg ha^{-1} interaction plots produced the lowest dry matter yields at harvest for both the 2010 minor and 2011 major cropping seasons.

4.2.17b: Interaction Effects of Tillage Treatments and NPK 15-15-15 Fertiliser Application on Dry Cob Weight and Grain Yield

Table 4.8a shows the interaction effects of tillage treatments and NPK 15-15-15 fertiliser application on dry cob weight and grain yield after harvest of *Akposoe* maize in the 2010 minor and 2011 major cropping season. In the 2010 minor season, the No tillage x 350 kg ha^{-1} NPK 15-15-15 fertiliser application interaction recorded the highest maize grain yield (5258 kg ha^{-1}) while the No tillage x 0 kg ha^{-1} NPK 15-15-15 fertiliser application interaction recorded the lowest maize grain yield (3203 kg ha^{-1}). In the 2011 major cropping season, the disc ploughing followed by disc harrowing x 250 kg ha^{-1} NPK 15-15-15 fertiliser application interaction recorded the highest maize grain yield (7582 kg ha^{-1}) while the No tillage x 0 kg ha^{-1} NPK 15-15-15 fertiliser application interaction recorded the lowest maize grain yield (2157 kg ha^{-1}). There was no significant interaction effect of tillage and NPK 15-15-15 fertiliser application on *Akposoe* maize grain yield.

Table 4.8a: Interaction Effects of Tillage Treatments and NPK 15-15-15 Fertiliser Application on Root Length and Dry Matter Yield

Tillage Treatment x Fertiliser Application	2010		2011	
	Dry Cob Weight kg ha^{-1}	Grain Yield, kg ha^{-1}	Dry Cob Weight kg ha^{-1}	Grain Yield, kg ha^{-1}
No Tillage x 0 kg ha^{-1}	4179	3203	3255	2157
No Tillage x 150 kg ha^{-1}	7926	4538	4948	3278
No Tillage x 250 kg ha^{-1}	9263	5009	7530	4991
No Tillage x 350 kg ha^{-1}	9795	5258	7553	4617
Plough + Harrow x 0 kg ha^{-1}	4853	5236	6418	4635
Plough + Harrow x 150 kg ha^{-1}	8436	4750	9328	6178
Plough + Harrow x 250 kg ha^{-1}	10416	3827	10813	7582
Plough + Harrow x 350 kg ha^{-1}	8066	3337	9810	6495
Average	7867	4395	7457	4992
LSD ($p \leq 0.05$)	NS	NS	NS	NS

NS = Not Significant

In the 2010 minor season, the disc ploughing followed by disc harrowing x 250 kg ha^{-1} NPK 15-15-15 fertiliser application interaction recorded the highest maize dry cob weight (10416 kg ha^{-1}) while the No tillage x 0 kg ha^{-1} NPK 15-15-15 fertiliser application interaction recorded the lowest maize dry cob weight (4179 kg ha^{-1}). Similarly, in the 2011 major cropping season, the disc ploughing followed by disc harrowing x 250 kg ha^{-1} NPK 15-15-15 fertiliser application interaction recorded the highest maize dry cob weight (10813 kg ha^{-1}) while the No tillage x 0 kg ha^{-1} NPK 15-15-15 fertiliser application interaction recorded the lowest maize dry cob weight (3225 kg ha^{-1}). There was no significant interaction effect of tillage and NPK 15-15-15 fertiliser application on *Akposoe* maize dry cob weight in over the course of the study.

4.3 Effect of Tillage and Fertiliser Application on Soil Properties

4.3.1 Effect of Tillage Treatment on Soil Penetration Resistance

Table 4.9 shows the effect of tillage treatment on soil penetration resistance before ploughing, at tasselling and after harvest in the 2010 minor and 2011 major cropping seasons. Before ploughing in the 2010 minor cropping season, analysis of variance showed no statistically significant difference in penetration resistance. At the time, soils on the No Tillage plots had lower penetration resistance (300.6 kPa) compared with that in the disc ploughing followed by disc harrowing plots (318.3 kPa).At tasselling in the 2010 minor cropping season, analysis of variance showed statistically significant difference in penetration resistance in which the No tillage treatment plots recorded higher penetration resistance values (352.9 kPa) compared with that in the disc ploughing followed by disc harrowing plots (158.1 kPa). Similarly, results recorded after harvest of *Akposoe* maize in the 2010 minor season showed significantly higher penetration resistance values in the No tillage treatment plots (393.8 kPa)compared with the disc ploughing followed by disc harrowing plots (256 kPa).

Table 4.9: Effect of tillage on soil penetration resistance (kPa)

Tillage Treatment	2010 Before Ploughing 26 August	2010 At Tasselling 20 October	2010 After Harvest 22December	2011 Before Ploughing 7 April	2011 At Tasselling 24 May	2011 After Harvest 12 July
No Tillage	300.6	352.9	393.8	231.8	249.1	303.1
Plough + Harrow	318.3	158.1	256.0	242.6	210.7	210.9
Mean	309.5	255.5	324.9	237.2	229.9	257.0
LSD ($p \leq 0.05$)	NS	39.78	36.65	NS	NS	27.7

NS = Not Significant

In the 2011 major cropping season, analysis of variance showed no statistically significant difference in soil penetration resistance before ploughing and at tasselling. In both cropping seasons, soils in the disc ploughing followed by disc harrowing plots yielded soils with lower penetration resistance compared with that of the No tillage treatment plots. After harvest of *Akposoe* maize in the 2011 major cropping season, the disc ploughing followed by disc harrowing plots gave penetration resistance values (210.9kPa) significantly lower than that in No tillage plots (303.1kPa). This is in agreement with studies conducted by Ishaq *et al*. (2002) in which deep tillage reduced soil penetration resistance compared with No Tillage systems on a fine-loamy, mixed, hyperthermic Typic Haplargids soils in Faisalabad in Pakistan.

4.3.2 Effect of fertiliser application on Soil penetration resistance

Table 4.10 presents the effect of fertiliser application rate on soil penetration resistance before ploughing, at tasselling and after harvest in the 2010 minor and 2011 major cropping seasons.

Table 4.10: Effect of NPK 15-15-15 Fertiliser Application on soil penetration resistance (kPa)

	2010			2011		
Fertiliser Application	Before Ploughing 26 August	At Tasselling 20October	After Harvest 22December	Before Ploughing 7 April	At Tasselling 24 May	After Harvest 12 July
0 kg ha^{-1}	311.1	263.0	333.8	230.9	205.4	281.2
150 kg ha^{-1}	294.0	245.2	329.1	236.3	221.6	248.2
250 kg ha^{-1}	326.1	265.5	324.9	239.3	219.4	247.6
350 kg ha^{-1}	306.6	248.4	311.7	242.5	273.1	251.2
Mean	309.5	255.5	324.9	237.3	229.9	257.1
LSD ($p>0.05$)	NS	NS	NS	NS	NS	NS

NS = Not Significant

Analysis of variance showed that there was no statistically significant effect of NPK 15-15-15 fertiliser application treatments on soil penetration resistance before ploughing, at tasselling and after harvest over the course of the study for both 2010 minor and 2011 major cropping seasons.

4.3.3 Interaction Effects of Tillage Treatments and NPK 15-15-15 Fertiliser Application on Soil Penetration Resistance after Harvest

Table 4.11 shows results on interaction effect of tillage treatment and fertiliser application on soil penetration resistance after harvest of *Akposoe* maize in the 2010 minor and 2011 major cropping seasons. In both cropping seasons, analysis of variance revealed no significant interaction effect on soil penetration resistance.

Table 4.11: Interaction Effects of Tillage Treatments and NPK 15-15-15 Fertiliser Application on Soil Penetration Resistance

Tillage Treatment x Fertiliser Application	2010	2011
	Penetration Resistance, kPa	Penetration Resistance, kPa
No Tillage x 0 kg ha^{-1}	402	337
No Tillage x 150 kg ha^{-1}	407	295
No Tillage x 250 kg ha^{-1}	401	285
No Tillage x 350 kg ha^{-1}	366	296
Plough + Harrow x 0 kg ha^{-1}	266	226
Plough + Harrow x 150 kg ha^{-1}	252	202
Plough + Harrow x 250 kg ha^{-1}	249	210
Plough + Harrow x 350 kg ha^{-1}	258	207
Average	325	257
LSD ($p<0.05$)	NS	NS

NS = Not Significant

In the 2010 minor season, the No Tillage x 150 kg ha^{-1} interaction plots recorded the highest penetration resistance (407 kPa) while the Plough + Harrow x 250 kg ha^{-1} interaction plots recorded the lowest penetration resistance (249 kPa). The highest penetration resistance in the 2011 major cropping season (337 kPa) was produced by soils in the No Tillage x 0 kg ha^{-1} interaction plots while the lowest (202 kPa) was produced by soils in the Plough + Harrow x 150 kg ha^{-1} interaction plots.

4.3.4 Effect of Tillage on Soil Dry Bulk Density

Table 4.12 presents the effect of tillage treatment on soil dry bulk density in the 0-15 cm and 15-30 cm soil depth layers for the 2010 minor cropping season.

Table 4.12: Effect of Tillage on Soil Dry Bulk Density (2010)

		Soil Dry Bulk Density (Mgm^{-3})					
		Before Ploughing		At Tasselling		After Harvest	
Tillage Treatment	Soil Depth	0–15 cm	15–30 cm	0–15 cm	15–30 cm	0–15 cm	15–30 cm
No Tillage		1.38	1.45	1.42	1.30	1.23	1.23
Plough + Harrow		1.41	1.44	1.37	1.08	1.18	1.18
Average		1.39	1.45	1.40	1.19	1.21	1.21
LSD (p<0.05)		NS	NS	NS	0.11	NS	NS

NS = Not Significant

Before ploughing, there was no statistically significant difference in dry bulk density between soils in both 0-15cm and 15-30cm soil depth layers. Soils in the No tillage treatment plots had lower dry bulk density in the 0-15cm soil depth layer (1.38 Mgm^{-3}) compared with the disc ploughing followed by disc harrowing treatment (1.41 Mgm^{-3}). At tasselling in the 2010 minor season, tillage recorded no significant effect in the 0-15cm soil depth soil layer. However, in the 15-30cm soil depth layer, analysis of variance showed that the dry bulk density of soils in the No tillage treatment plot (1.30 Mgm^{-3}) was significantly higher than that on the disc ploughing followed by disc harrowing treatment plot (1.08 Mgm^{-3}). After harvest in the 2010 minor cropping season, dry bulk densities recorded in both layers were higher in the No tillage treatment plots (1.23 Mgm^{-3}) than those on the disc ploughing followed by disc harrowing treatment plots (1.18 Mgm^{-3}). Analysis of variance however, showed no significant difference between them.

Table 4.13shows the effect of tillage treatment on soil dry bulk density in the 0-15 cm and 15-30 cm soil depth layers for the 2011 major cropping season. There was no significant difference in dry bulk density between tillage treatments in both soil layers before ploughing and at tasselling in the 2011 major cropping season.

Table 4.13: Effect of Tillage on Soil Dry Bulk Density (2011)

		Soil Dry Bulk Density (Mgm^{-3})					
		Before Ploughing		At Tasselling		After Harvest	
Tillage Treatment	Soil Depth	0–15 cm	15–30 cm	0–15 cm	15–30 cm	0–15 cm	15–30 cm
No Tillage		1.49	1.53	1.42	1.46	1.37	1.42
Plough +Harrow		1.48	1.51	1.37	1.43	1.25	1.33
Average		1.48	1.52	1.40	1.44	1.31	1.38
LSD ($p<0.05$)		NS	NS	NS	NS	0.04	0.05

NS = Not Significant

After harvest of *Akposoe* maize in the 2011 major cropping season, analysis of variance revealed statistically significant effect of tillage on dry bulk density in the 0-15cm and 15-30cm soil depth layers. Soils in the No tillage treatment plots had significantly higher dry bulk density in the 0-15cm soil depth layer (1.37 Mgm^{-3}) compared with that in the disc ploughing followed by disc harrowing tillage treatment plots (1.25 Mgm^{-3}). Similarly, in the 15-30cm soil depth layer, soils in the No tillage plots had significantly higher dry bulk density (1.42 Mgm^{-3}) compared with that in the disc ploughing followed by disc harrowing tillage treatment plots (1.33 Mgm^{-3}). After harvest in the 2011 major cropping season, tillage had significantly reduced soil bulk density, an assertion similar to that of Hamblin (1985) and Howeler *et al*. (1993)(cited by Ishaq *et al.*, 2002).

4.3.5 Effect of Fertiliser Application on Soil Dry Bulk Density

Table 4.14 summarises the effect of fertiliser application rate on soil dry bulk density in the 0-15 cm and 15-30 cm soil depth layers for the 2010 minor cropping season. In the 2010 minor cropping season, there was no significant effect of NPK 15-15-15 fertiliser application rate on soil dry bulk density before ploughing and at tasselling in both the 0-15cm and 15-30cm soil layers.

Table 4.14: Effect of NPK 15-15-15 Fertiliser Application on Soil Dry Bulk Density (2010)

		Dry Bulk Density (Mgm^{-3})					
		Before Ploughing		At Tasselling		After Harvest	
Fertiliser Application	Soil Depth	0–15 cm	15–30 cm	0–15 cm	15–30 cm	0–15 cm	15–30 cm
0 kg ha^{-1}		1.40	1.45	1.41	1.17	1.15	1.13
150 kg ha^{-1}		1.36	1.45	1.37	1.21	1.26	1.25
250 kg ha^{-1}		1.45	1.45	1.39	1.20	1.12	1.13
350 kg ha^{-1}		1.35	1.43	1.41	1.17	1.32	1.31
Average		1.39	1.45	1.40	1.19	1.21	1.20
LSD ($p \leq 0.05$)		NS	NS	NS	NS	0.062	0.085

NS = Not Significant

After harvest of *Akposoe* maize in the 2010 minor cropping season, analysis of variance showed statistically significant effect of fertiliser application rate on dry bulk density in the 0-15cm and 15-30 cm soil depth layers. In the 0-15cm soil depth layer, the 350 kg ha^{-1} fertiliser application rate gave the highest bulk density (1.32 Mgm^{-3}) and was followed by the 150kg ha^{-1} (1.26 Mgm^{-3}) although the difference between them was not significant. The dry bulk densities of both the 350kg ha^{-1} and 150kg ha^{-1} fertiliser application rates were significantly higher than those produced by the 250 kg ha^{-1} (1.12 Mgm^{-3}) and the 0kg ha^{-1} (1.15 Mgm^{-3}). Dry bulk density in the 15-30cm soil depth layer was similar to that produced by the 0-15kg ha^{-1} cm soil depth layer in the 2010 minor cropping season. In the 15-30cm soil depth layer, the 350 kg ha^{-1} fertiliser application rate gave the highest bulk density (1.31 Mgm^{-3}) and was followed by the 150 kg ha^{-1} (1.25 Mgm^{-3}) although the difference between them was not significant. The dry bulk densities of both the 350 kg ha^{-1} and 150 kg ha^{-1} fertiliser application rates were significantly higher than those produced by the 250 kg ha^{-1} (1.13 Mgm^{-3}) and the 0 kg ha^{-1} (1.13 Mgm^{-3}).

Table 4.15shows the effect of fertiliser application rate on soil dry bulk density in the 0-15 cm and 15-30 cm soil depth layers for the 2011 major cropping season.

Table 4.15: Effect of NPK 15-15-15 Fertiliser Application on Soil Dry Bulk Density (2011)

		Dry Bulk Density (Mgm^{-3})					
		Before Ploughing		At Tasselling		After Harvest	
Fertiliser Application	Soil Depth	0–15 cm	15–30 cm	0–15 cm	15–30 cm	0–15 cm	15–30 cm
0 kg ha^{-1}		1.47	1.51	1.41	1.45	1.31	1.36
150 kg ha^{-1}		1.49	1.53	1.37	1.44	1.30	1.38
250 kg ha^{-1}		1.49	1.53	1.39	1.44	1.32	1.39
350 kg ha^{-1}		1.47	1.51	1.41	1.46	1.30	1.38
Average		1.48	1.52	1.40	1.44	1.31	1.38
LSD ($p \leq 0.05$)		NS	NS	NS	NS	NS	NS

NS = Not Significant

There was no significant difference in soil dry bulk density between NPK 15-15-15 fertiliser application treatments in the 0-15 cm and 15-30 cm soil depth layers before ploughing, at tasselling and after harvest of *Akposoe* maize in the 2011 major cropping season.

4.3.6 Interaction Effect of Tillage Treatment and NPK 15-15-15 Fertiliser Application on Soil Dry Bulk Density

Table 4.16 presents the interaction effect of tillage treatment and NPK 15-15-15 fertiliser application rates on soil dry bulk density of *Akposoe* maize in the 0-15 cm and 15-30 cm soil depth layers for the 2010 minor and 2011 major cropping seasons.

Table 4.16: Interaction Effects of Tillage Treatments and NPK 15-15-15 Fertiliser Application on Dry Bulk Density

Tillage Treatment x Fertiliser Application	2010		2011	
	0 – 15 cm Soil Depth	15 – 30 cm Soil Depth	0 – 15 cm Soil Depth	15 – 30 cm Soil Depth
	Dry Bulk Density, Mg m^{-3}		Dry Bulk Density, Mg m^{-3}	
No Tillage x 0 kg ha^{-1}	1.06	1.06	1.37	1.42
No Tillage x 150 kg ha^{-1}	1.35	1.33	1.35	1.41
No Tillage x 250 kg ha^{-1}	1.16	1.17	1.39	1.44
No Tillage x 350 kg ha^{-1}	1.37	1.36	1.37	1.42
Plough + Harrow x 0 kg ha^{-1}	1.23	1.19	1.26	1.30
Plough + Harrow x 150 kg ha^{-1}	1.16	1.17	1.26	1.35
Plough + Harrow x 250 kg ha^{-1}	1.08	1.10	1.26	1.34
Plough + Harrow x 350 kg ha^{-1}	1.27	1.26	1.24	1.34
Average	1.21	1.20	1.31	1.38
LSD ($p<0.05$)	0.12	NS	NS	NS

NS = Not Significant

After harvest in the 2010 minor cropping season, analysis of variance showed statistically significant interaction effect of tillage treatment and fertiliser application rates on soil dry bulk density in the 0-15cm soil depth layer. In the 0-15cm soil depth layer, the No Tillage x 350 kg ha^{-1} interaction gave the highest bulk density (1.37 Mgm^{-3}) and was followed by the No Tillage x 150 kg ha^{-1} (1.35 Mgm^{-3}) although the difference between them was not significant. The dry bulk density of the No Tillage x 350 kg ha^{-1} interaction was significantly higher than all the other interaction effects in that layer except for the No Tillage x 150 kg ha^{-1} interaction. Also in the 0-15cm soil depth layer, dry bulk density of soils in the No Tillage x 150 kg ha^{-1} interaction plots were significantly higher compared with that in the No Tillage x 0 kg ha^{-1}, No Tillage x 250 kg ha^{-1}, Disc ploughing followed by disc harrowing x 0 kg ha^{-1}, Disc ploughing followed by disc harrowing x 150 kg ha^{-1} and Disc ploughing followed by disc harrowing x 250 kg ha^{-1} interaction plots. In the 0-15cm soil depth layer, the No Tillage x 0 kg ha^{-1}interaction plots gave the lowest soil bulk density in the 2010 minor cropping season (1.06 Mgm^{-3}). In the 2010 minor cropping season, there was no statistically significant interaction effect of tillage treatment and fertiliser application rate on soil dry bulk density in the 15-30cm soil depth layer. After harvest of *Akposoe* maize in the 2011 major cropping season, there was no statistically significant interaction effect of tillage treatment and fertiliser application rate on dry bulk density in the 0-15cm and 15-30cm soil depth layers.

4.3.7 Effect of Tillage on Soil Moisture Content

Table 4.17 shows the effect of tillage treatment on soil moisture content in the 0-15cm and 15-30 cm soil depth layers before ploughing, at tasselling and after harvest of *Akposoe* maize in the 2010 minor cropping season.

Table 4.17: Effect of Tillage on Soil Moisture Content (2010)

		Soil Moisture Content (%)					
		Before Ploughing		At Tasselling		After Harvest	
Tillage Treatment	Soil Depth	0–15 cm	15–30 cm	0–15 cm	15–30 cm	0–15 cm	15–30 cm
No Tillage		11.0	11.7	5.3	5.5	5.2	5.4
Plough + Harrow		11.4	13.4	12.4	12.4	6.8	6.9
Average		11.3	12.6	8.8	8.9	6.0	6.2
LSD (p<0.05)		NS	NS	2.1	1.9	NS	NS

NS = Not Significant

Before ploughing in the 2010 minor cropping season, there was no significant difference in soil moisture content in the 0-15cm and 15-30cm soil depth layers between tillage treatments. At tasselling in the 2010 minor cropping season, both soil layers showed significant difference in soil moisture content between the different tillage treatments. In the 0-15cm soil depth layer, the No tillage treatment plots recorded significantly lower soil moisture content (5.3%) compared with soils in the disc ploughing followed by disc harrowing treatment plots (12.4%). Similarly, at tasselling in the 15-30cm soil depth layer, the No tillage treatment plots recorded significantly lower soil moisture content (5.5%) compared with soils in the disc ploughing followed by disc harrowing treatment plots (12.4%). After harvest of *Akposoe* maize in the 2010 minor cropping season, the No tillage treatment plots recorded lower soil moisture content in both the 0-15cm and 15-30cm soil depth layers, although the differences were not statistically significant.

Table 4.18shows the effect of tillage treatment on soil moisture content in the 0-15cm and 15-30cm soil depth layers before ploughing, at tasselling and after harvest of *Akposoe* maize in the 2011 major cropping season.

Table 4.18: Effect of Tillage on Soil Moisture Content (2011)

		Soil Moisture Content (%)					
		Before Ploughing		At Tasselling		After Harvest	
Tillage Treatment	Soil Depth	0–15 cm	15–30 cm	0–15 cm	15–30 cm	0–15 cm	15–30 cm
No Tillage		1.5	1.5	7.9	10.3	16.3	14.7
Plough + Harrow		1.5	1.5	9.4	11.2	26.6	21.2
Average		1.5	1.5	8.7	10.7	21.4	17.9
LSD (p<0.05)		NS	NS	NS	NS	7.3	6.2

NS = Not Significant

There was no significant difference in soil moisture content in the 0-15cm and 15-30cm soil depth layers before ploughing in the 2011 major cropping season. At tasselling, the No tillage treatment plots gave lower soil moisture content compared with the disc ploughing followed by disc harrowing tillage treatment plots in both the 0-15 cm and 15-30 cm soil layers. The difference was, however, not statistically significant. After harvest of *Akposoe* maize in the 2011 major cropping season, both soil layers showed significant difference in soil moisture content between the different tillage treatments. In the 0-15cm soil depth layer, the No tillage treatment plots recorded significantly lower soil moisture content (16.3%) compared with soils in the disc ploughing followed by disc harrowing treatment plots (26.6%). Similarly, after harvest in the 2011 major cropping season in the 15-30cm soil depth layer, the No tillage treatment plots recorded significantly lower soil moisture content (14.7%) compared with soils in the disc ploughing followed by disc harrowing treatment plots (21.2%).

4.3.8 Effect of Fertiliser Application on Soil Moisture Content

Table 4.19shows the effect of fertiliser application on soil moisture content in the 0-15cm and 15-30cm soil depth layers before ploughing, at tasselling and after harvest of *Akposoe* maize in the 2010 minor cropping season.

Table 4.19: Effect of NPK 15-15-15 Fertiliser Application on Soil Moisture Content (2010)

		Soil Moisture Content (%)					
		Before Ploughing		At Tasselling		After Harvest	
Fertiliser Application	Soil Depth	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
0 kg ha^{-1}		9.6	12.7	8.7	8.6	8.3	8.5
150 kg ha^{-1}		11.9	12.0	8.9	9.2	5.3	5.3
250 kg ha^{-1}		12.1	13.6	8.6	9.3	7.7	7.5
350 kg ha^{-1}		11.4	12.0	9.0	8.6	2.8	3.4
Average		11.2	12.6	8.8	8.9	6.0	6.1
LSD ($p<0.05$)		NS	NS	NS	NS	2.4	NS

NS = Not Significant

Before ploughing in the 2010 minor cropping season, there was no statistically significant difference in soil moisture content in the 0-15cm and 15-30cm soil depth layers with regards to fertiliser application. Similarly at tasselling, analysis of variance showed no significant difference in soil moisture content in the 0-15cm and 15-30cm soil depth layers between the different fertiliser application rates. After harvest of *Akposoe* maize in the 2010 minor cropping season, fertiliser application showed significant effect on soil moisture content in the 0-15cm soil depth layer. In the 0-15cm soil depth layer, the 0 kg ha^{-1} fertiliser application produced soils with the highest moisture content (8.3%). This soil moisture content was significantly higher than those in the 150 kg ha^{-1}(5.3%) and 350 kg ha^{-1} (2.8%) fertiliser application rate plots. The 250 kg ha^{-1} fertiliser application plots produced the second highest moisture content in the 0-15cm soil depth layer (7.7%) after harvest in the 2010 minor cropping season. This moisture content was not significant compared with that in the 0 kg ha^{-1} and 250 kg ha^{-1} fertiliser application plots. After harvest of *Akposoe* maize in the 2010 minor cropping season, fertiliser application showed no significant effect on soil moisture content in the 15-30cm soil depth layer.

Table 4.20 shows the effect of fertiliser application on soil moisture content in the 0-15cm and 15-30cm soil depth layers before ploughing, at tasselling and after harvest of *Akposoe* maize in the 2011 major cropping season.

Table 4.20: Effect of NPK 15-15-15 Fertiliser Application on Soil Moisture Content (2011)

Fertiliser Application		Soil Moisture Content (%)					
		Before Ploughing		At Tasselling		After Harvest	
	Soil Depth	0–15 cm	15–30 cm	0–15 cm	15–30 cm	0–15 cm	15–30 cm
0 kg ha^{-1}		1.5	1.5	7.2	11.2	16.4	16.3
150 kg ha^{-1}		1.5	1.5	8.3	13.3	23.9	17.6
250 kg ha^{-1}		1.5	1.5	9.5	9.7	24.3	19.5
350 kg ha^{-1}		1.5	1.5	9.6	8.8	21.2	18.4
Average		1.5	1.5	8.7	10.7	21.4	17.9
LSD ($p<0.05$)		NS	NS	NS	1.9	NS	NS

NS = Not Significant

Before ploughing in the 2011 major cropping season, there was no statistically significant difference in soil moisture content in the 0-15cm and 15-30cm soil depth layers between the fertiliser application rates. At tasselling, analysis of variance showed no significant difference in soil moisture content in the 0-15cm between the different fertiliser application rates. However, at tasselling in the 15-30cm soil depth layer, fertiliser application gave significant effect on soil moisture content. In the 15-30cm soil depth layer, soil moisture content in the 0 kg ha^{-1} fertiliser application plots were significantly higher than those in the 350 kg ha^{-1}, 250 kg ha^{-1} and 0 kg ha^{-1} fertiliser application plots. At tasselling, the 350 kg ha^{-1} fertiliser application plots produced the soils with the lowest soil moisture content in the 15-30cm layer in the 2011 major cropping season. After harvest of *Akposoe* maize in the 2011 major cropping season, fertiliser application showed no significant effect on soil moisture content in both the 0-15cm and 15-30cm soil depth layer.

4.3.9 Interaction Effects of Tillage Treatments and Fertiliser Application on Soil Moisture Content after Harvest

Table 4.21 shows the interaction effects of tillage treatments and NPK 15-15-15 fertiliser application on soil moisture content after harvest of *Akposoe* maize for both 2010 minor and 2011 major cropping seasons.

Table 4.21: Interaction Effects of Tillage Treatments and NPK 15-15-15 Fertiliser Application on Moisture Content

Tillage Treatment x Fertiliser Application	2010		2011	
	0–15 cm Soil Depth	15–30 cm Soil Depth	0–15 cm Soil Depth	15–30 cm Soil Depth
	Moisture Content, %		Moisture Content, %	
No Tillage x 0 kg ha^{-1}	9.9	9.8	14.4	13.8
No Tillage x 150 kg ha^{-1}	3.6	3.8	18.9	13.5
No Tillage x 250 kg ha^{-1}	4.4	5.2	16.9	16.2
No Tillage x 350 kg ha^{-1}	2.7	2.7	14.8	15.4
Plough + Harrow x 0 kg ha^{-1}	6.6	7.1	18.4	18.8
Plough + Harrow x 150 kg ha^{-1}	6.9	6.8	28.9	21.7
Plough + Harrow x 250 kg ha^{-1}	11.0	9.7	31.7	22.8
Plough + Harrow x 350 kg ha^{-1}	2.8	4.0	27.6	21.4
Average	6.0	6.1	21.4	17.9
LSD ($p \leq 0.05$)	4.8	NS	NS	NS

NS = Not Significant

There was significant interaction effect of tillage and fertiliser application on soil moisture content in the 0-15cm soil depth layer after harvest of *Akposoe* maize in the 2010 minor cropping season. During that period, soils in the Disc ploughing followed by disc harrowing x 250 kg ha^{-1}interaction plots gave the highest soil moisture content (11.0%) which was significantly higher than all the other interaction effects except for soils in the No Tillage x 0 kg ha^{-1} interaction plots. Soil moisture content in the No Tillage x 0 kg ha^{-1} interaction plots was also significantly higher compared with that in the No Tillage x 150 kg ha^{-1}, No Tillage x 250 kg ha^{-1}, No Tillage x 350 kg ha^{-1}, and Disc ploughing followed by disc harrowing x 350 kg ha^{-1}interaction plots. There was no significant interaction effect of tillage and fertiliser application on soil moisture content within the 15-30cm soil depth layer after harvest of *Akposoe* maize in the 2010 minor cropping season. In the 2011 major cropping season, there was no significant interaction effect of tillage and fertiliser application on soil moisture content within the 0-15cm and15-30cm soil depth layers after harvest of *Akposoe* maize.

4.3.10 Effect of Tillage on Soil Porosity

Table 4.22shows the effect of tillage treatment on soil porosity in the 0-15cm and 15-30cm soil depth layers before ploughing, at tasselling and after harvest of *Akposoe* maize in the 2010 minor cropping season.

Table 4.22: Effect of Tillage on Soil Porosity (2010)

		Soil Porosity (%)					
		Before Ploughing		At Tasselling		After Harvest	
Tillage Treatment	Soil depth	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
No Tillage		48.0	45.2	50.9	51.1	52.1	53.6
Plough + Harrow		47.0	45.7	59.2	59.3	53.0	55.5
Average		47.5	45.4	55.0	55.2	52.5	54.6
LSD (p<0.05)		NS	NS	3.3	2.8	NS	NS

NS = Not Significant

Before ploughing in the 2010 minor cropping season, there was no significant difference in soil porosity in the 0-15cm and 15-30cm soil depth layers between tillage treatments. At tasselling in the 2010 minor cropping season, both soil layers showed significant difference in soil porosity between the different tillage treatments. In the 0-15cm soil depth layer, the No tillage treatment plots recorded significantly lower soil porosity (50.9%) compared with soils in the disc ploughing followed by disc harrowing treatment plots (59.2%). Similarly, at tasselling in the 15-30cm soil depth layer, the No tillage treatment plots recorded significantly lower soil porosity (51.1%) compared with soils in the disc ploughing followed by disc harrowing treatment plots (59.3%). After harvest of *Akposoe* maize in the 2010 minor cropping season, the No tillage treatment plots recorded lower soil porosity in both the 0-15cm and 15-30cm soil depth layers, although the differences were not statistically significant.

Table 4.23 shows the effect of tillage treatment on soil porosity in the 0-15cm and 15-30cm soil depth layers before ploughing, at tasselling and after harvest of *Akposoe* maize in the 2011 major cropping season.

Table 4.23: Effect of Tillage on Soil Porosity (2011)

		Soil Porosity (%)					
		Before Ploughing		At Tasselling		After Harvest	
Tillage Treatment	Soil Depth	0–15 cm	15–30 cm	0–15 cm	15–30 cm	0–15 cm	15–30 cm
No Tillage		44.3	43.0	46.6	44.9	48.4	46.4
Plough + Harrow		44.2	43.1	48.2	46.1	52.7	49.7
Average		44.2	43.1	47.4	45.5	50.6	48.0
LSD (p<0.05)		NS	NS	NS	NS	1.6	1.9

NS = Not Significant

There was no significant difference in soil porosity in the 0-15cm and 15-30cm soil depth layers before ploughing in the 2011 major cropping season. At tasselling, the No tillage treatment plots gave lower soil porosity compared with the disc ploughing followed by disc harrowing tillage treatment plots in both the 0-15 cm and 15-30 cm soil layers. The difference was, however, not statistically significant. After harvest of *Akposoe* maize in the 2011 major cropping season, both soil depth layers showed significant difference in soil porosity between the different tillage treatments. In the 0-15cm soil depth layer, the No tillage treatment plots recorded significantly lower soil porosity (48.4%) compared with soils in the disc ploughing followed by disc harrowing treatment plots (52.7%). Similarly, after harvest in the 2011 major season in the 15-30cm soil depth layer, the No tillage treatment plots recorded significantly lower soil porosity (46.8%) compared with soils in the disc ploughing followed by disc harrowing treatment plots (49.7%).These results are similar with an earlier assertion made by Hamblin (1985) who reported that tillage increased total porosity by increasing the pores and pore size distribution.

4.3.11 Effect of NPK 15-15-15 Fertiliser Application on Soil Porosity

Table 4.24 shows the effect of fertiliser application on soil porosity in the 0-15cm and 15-30cm soil depth layers before ploughing, at tasselling and after harvest of *Akposoe* maize in the 2010 minor cropping season.

Table 4.24: Effect of NPK 15-15-15 Fertiliser Application on Soil Porosity (2010)

Fertiliser Application	Soil Depth	Soil Porosity (%) Before Ploughing 0–15 cm	15–30 cm	At Tasselling 0–15 cm	15–30 cm	After Harvest 0–15 cm	15–30 cm
0 kg ha^{-1}		47.4	45.2	55.8	55.9	53.8	57.5
150 kg ha^{-1}		48.5	45.3	54.1	54.4	51.4	52.8
250 kg ha^{-1}		45.2	45.2	54.7	54.6	55.3	57.3
350 kg ha^{-1}		48.9	46.0	55.4	55.8	49.6	50.6
Average		47.5	45.4	55.0	55.2	52.5	54.6
LSD ($p<0.05$)		NS	NS	NS	NS	NS	3.0

NS = Not Significant

Before ploughing in the 2010 minor cropping season, there was no statistically significant difference in soil porosity in the 0-15cm and 15-30cm soil depth layers with regard to fertiliser application. Similarly at tasselling, analysis of variance showed no significant difference in soil porosity in the 0-15cm and 15-30cm soil depth layers between the different fertiliser application rates. After harvest of *Akposoe* maize in the 2010 minor cropping season, fertiliser application showed no significant effect on soil porosity in the 0-15cm soil depth layer. After harvest of *Akposoe* maize in the 2010 minor cropping season, fertiliser application showed significant effect on soil porosity in the 15-30cm soil depth layer. In the 15-30cm soil depth layer, the 0 kg ha^{-1} fertiliser application produced soils with the highest porosity (57.5%) followed by that on the 250 kg ha^{-1} fertiliser application (57.3%) with no statistically significant differences between them. However, the porosity of soils within these two fertiliser application rates was significantly higher than those in the 150 kg ha^{-1} (52.8%) and 350 kg ha^{-1} (50.6%) fertiliser application rate plots.

Table 4.25 shows the effect of fertiliser application on soil porosity in the 0-15cm and 15-30cm soil depth layers before ploughing, at tasselling and after harvest of *Akposoe* maize in the 2011 major cropping season.

Table 4.25: Effect of NPK 15-15-15 Fertiliser Application on Soil Porosity (2011)

		Soil Porosity (%)					
		Before Ploughing		At Tasselling		After Harvest	
Fertiliser Application	Soil Depth	0–15 cm	15–30 cm	0–15 cm	15–30 cm	0–15 cm	15–30 cm
0 kg ha^{-1}		44.4	43.1	46.9	45.4	50.5	48.7
150 kg ha^{-1}		44.4	43.6	48.3	45.8	50.8	48.0
250 kg ha^{-1}		43.7	42.3	47.5	45.8	50.1	47.5
350 kg ha^{-1}		44.4	43.1	46.8	45.0	50.9	48.0
Average		44.2	43.0	47.4	45.5	50.6	48.0
LSD ($p<0.05$)		NS	NS	NS	NS	NS	NS

NS = Not Significant

Before ploughing in the 2011 major cropping season, there was no statistically significant difference in soil porosity in the 0-15cm and 15-30cm soil depth layers with regard to fertiliser application. Similarly, at tasselling, analysis of variance showed no significant difference in soil porosity in the 0-15cm and 15-30cm soil depth layers between the different fertiliser application rates. Also, after harvest of *Akposoe* maize in the 2011 major cropping season, fertiliser application showed no significant effect on soil porosity in the 0-15cm and 15-30cm depth layers.

4.3.12 Interaction Effects of Tillage Treatments and Fertiliser Application on Soil Porosity after Harvest

Table 4.26 shows the interaction effects of tillage treatments and NPK 15-15-15 fertiliser application on soil porosity after harvest of Akposoe maize for both 2010 minor and 2011 major cropping seasons.

Table 4.26: Interaction Effects of Tillage Treatments and NPK 15-15-15 Fertiliser Application on Soil Porosity

	2010		2011	
Tillage Treatment x Fertiliser Application	0–15 cm Soil Depth Porosity, %	15–30 cm Soil Depth	0–15 cm Soil Depth Porosity, %	15–30 cm Soil Depth
No Tillage x 0 kg ha^{-1}	56.4	59.9	48.5	46.5
No Tillage x 150 kg ha^{-1}	49.0	49.7	49.0	46.7
No Tillage x 250 kg ha^{-1}	54.4	56.0	47.6	45.7
No Tillage x 350 kg ha^{-1}	48.5	48.7	48.5	46.6
Plough + Harrow x 0 kg ha^{-1}	51.3	55.0	52.6	50.9
Plough + Harrow x 150 kg ha^{-1}	53.8	55.8	52.6	49.2
Plough + Harrow x 250 kg ha^{-1}	56.1	58.6	52.5	49.3
Plough + Harrow x 350 kg ha^{-1}	50.7	50.7	53.3	49.4
Average	52.5	54.3	50.6	48.0
LSD ($p \leq 0.05$)	NS	NS	NS	NS

NS = Not Significant

There was no significant interaction effect of tillage and fertiliser application on soil porosity within the 0-15 cm and 15-30 cm soil depth layers after harvest of *Akposoe* maize in both the 2010 minor and 2011 major cropping seasons.

5. CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The objectives of the study were to determine the effect of tillage treatments and NPK 15-15-15 fertiliser application rates on *Akposoe* maize variety seedling emergence, plant height, stem girth, number of leaves per plant, root length, dry cob weight, dry matter yield and grain yield; and to determine the effect of tillage treatments and NPK 15-15-15 fertiliser application rates on soil penetration resistance, dry bulk density, moisture content and total porosity. Based on these objectives the following conclusions were drawn:

5.1.1 Effect of Tillage Treatment on Seedling Emergence

Tillage did not have a significant effect on seedling emergence in both the 2010 minor and the 2011 major cropping seasons although the overall percentage seedling emergence of *Akposoe* maize plants in the disc ploughing followed by disc harrowing tillage treatment plots was higher than those in the No tillage treatment plots.

5.1.2 Effect of Tillage Treatment and Fertiliser Application rates on Plant height and Stem Girth

Tillage treatment did not show a significant effect on *Akposoe* maize plant height during the 2010 minor season at 10 weeks after planting. The disc ploughing followed by disc harrowing tillage treatment plots produced taller plants relative to that of the No tillage treatment plots. At 10 weeks after planting in the 2011 major cropping season, plant height was significantly higher in the disc ploughing followed by disc harrowing tillage treatment plots compared with that in the No tillage treatment plots.

At 10 weeks after planting, analysis of variance showed statistically significant difference in plant height between the different fertiliser application rates. Plants in the 150 kg ha^{-1}, 250 kg ha^{-1} and 350 kg ha^{-1} fertiliser application plots were significantly taller than those in the no fertiliser application plots for both the 2010 minor and 2011 major cropping seasons. There was no significant difference in plant height between the 150kg ha^{-1}, 250kg ha^{-1} and 350kg ha^{-1} fertiliser application rates.

The analysis of variance showed that at 10 weeks after planting, the disc ploughing followed by disc harrowing tillage treatment plots produced significantly bigger stems in *Akposoe* maize plants compared with those in the No tillage treatment plots.

At 10 weeks after planting, maize plant stem girth in the 150 kg ha^{-1}, 250 kg ha^{-1} and 350 kg ha^{-1} fertiliser application plots were significantly bigger than those in the no fertiliser application plots (0 kg ha^{-1}) for both the 2010 minor and 2011 major cropping seasons. The 350 kg ha^{-1} fertilizer application rate produced the biggest stem in both the 2010 minor and 2011 major cropping seasons.

5.1.3 Effect of Tillage Treatment and Fertiliser Application Rates on Number of Leaves per Plant and Leaf Area

At 10 weeks after planting, *Akposoe* maize plants in the disc ploughing followed by disc harrowing tillage treatment plots produced significantly more number of leaves per plant compared with the no tillage treatment plots in both the 2010 minor and 2011 major cropping seasons. Similarly, fertiliser application gave significantly higher number of leaves per plant over no fertiliser application (0 kg ha^{-1}) in both the 2010 minor and 2011 major cropping seasons. *Akposoe* maize plants in the 250 kg ha^{-1} and 150 kg ha^{-1} NPK 15-15-15 fertiliser application plots registered the highest number of leaves per plant in the 2010 major (13.17) and 2011 minor (15.58) crop growing seasons respectively.

At 10 weeks after planting in both cropping seasons, the disc ploughing followed by disc harrowing treatment plots produced plants with bigger leaf area compared with the No tillage treatment plots. Also, fertiliser application yielded significantly bigger *Akposoe* maize leaves compared with the no fertiliser application in both the 2010 minor and 2011 major crop growing seasons. The biggest *Akposoe* maize leaves in the 2010 minor (560.8 cm^2) and 2011 major (757.2 cm^2) cropping seasons were produced by the 350 kg ha^{-1} and 150 kg ha^{-1} fertiliser application rates respectively while the lowest leaf areas were produced by the 0 kg ha^{-1} fertiliser application plots in 2010 (367.3 cm^2) and 2011 (571.6 cm^2).

5.1.4 Effect of Tillage Treatment and Fertiliser Application Rates on Root Length and Dry Matter Yield

At harvest, *Akposoe* maize plant roots in the disc ploughing followed by disc harrowing tillage plots were significantly longer than those in the No Tillage plots in both the 2010 minor and 2011 major cropping seasons. The longer roots developed by plants in the disc ploughing followed by disc harrowing tillage treatment plots may be ascribed to the loosening effect of the operation on the impeding soil layer at the site. Fertiliser application did not significantly affect root length in the course of the study. *Akposoe* maize plants in the 250 kg ha^{-1} and 350 kg ha^{-1} fertiliser application rate plots recorded the longest roots in the 2010 minor (32.5 cm) and 2011 major (45.6 cm) cropping seasons respectively. The 0 kg ha^{-1} fertiliser application rate recorded the shortest roots in both the 2010 minor (27.8 cm) and 2011 major (40.5 cm) cropping seasons.

Tillage treatment significantly affected *Akposoe* maize dry matter accumulation over the study period. At harvest, the analysis of variance showed that *Akposoe* maize dry matter yield was significantly higher in the disc ploughing followed by disc harrowing tillage treatment in both the 2010 minor (4208 kg ha^{-1}) and 2011 major (5750 kg ha^{-1}) crop growing seasons.

Similarly, fertiliser application significantly affected dry matter yield over no fertiliser application at harvest of *Akposoe* maize in both the 2010 minor and 2011 major cropping seasons. The 350 kg ha^{-1} and 0 kg ha^{-1} fertiliser rates gave the highest (4283 kg ha^{-1}) and lowest (2159 kg ha^{-1}) *Akposoe* maize dry matter yields in the 2010 minor crop growing season while the 250 kg ha^{-1} and 0 kg ha^{-1} fertiliser rates gave the highest (5426 kg ha^{-1}) and lowest (2013 kg ha^{-1}) *Akposoe* maize dry matter yields in the 2011 major crop growing seasons respectively.

5.1.5 Effect of Tillage Treatment and Fertiliser Application Rates on Dry Cob Weight and Grain Yield

Tillage did not significantly affect dry cob weight at harvest in the 2010 minor season although the disc ploughing followed by disc harrowing tillage treatment presented plants with greater dry cob weight. However, at harvest in the 2011 major cropping season, the disc ploughing followed by disc harrowing tillage treatment plots produced plants with significantly greater dry cob weight (9092 kg ha^{-1}) compared with those in the No tillage treatment plots (5822 kg ha^{-1}).

In the 2010 minor cropping season, although *Akposoe* maize grain yield was higher with plants in the no tillage treatment plots, it was not statistically different compared with that in the disc ploughing followed by disc harrowing treatment plots. In the 2011 major cropping season, however, a significantly higher grain yield (6223 kg ha^{-1}) was recorded in the disc ploughing followed by disc harrowing tillage treatment plots over the No tillage treatment plots (3761 kg ha^{-1}).

NPK 15-15-15 fertiliser application significantly affected dry cob weight over the no fertiliser application in both cropping seasons. In the 2010 minor season, the 250 kg ha^{-1} fertiliser application plots gave the highest dry cob weight (9890 kg ha^{-1}) while the 0 kg ha^{-1} gave the lowest dry cob weight (4516 kg ha^{-1}). Also in the 2011 major season, *Akposoe* maize plants in the 250 kg ha^{-1} fertiliser application rate plots produced plants with the highest dry cob weight (9172 kg ha^{-1}) while plants in the 0 kg ha^{-1} fertiliser application rate plots produced maize plants with the lowest maize dry cob weight (4837 kg ha^{-1}). Fertiliser application did not produce a significant effect on *Akposoe* maize grain yield in the 2010 minor cropping season. Grain yield was highest (4644 kg ha^{-1}) in the 150 kg ha^{-1} fertiliser application plots while it was lowest (4219 kg ha^{-1}) in the 0 kg ha^{-1} fertiliser application plots. Fertiliser application, however, produced significant effect in *Akposoe* maize grain yields at harvest in the 2011 major cropping season in which the 250 kg ha^{-1} fertiliser application rate recorded the highest grain yield (6287 kg ha^{-1}) while the 0 kg ha^{-1} fertiliser application rate recorded the lowest maize grain yield (3396 kg ha^{-1}).

5.1.6 Effect of Tillage Treatment and Fertiliser Application Rates on Soil penetration resistance

Before ploughing in the 2010 minor cropping season, soil penetration resistance was lower in the No tillage treatment plots over the disc ploughing followed by disc harrowing treatment plots although the difference was not statistically significant. At tasselling and after harvest of *Akposoe* maize in the 2010 minor cropping season, soil penetration resistance in the disc ploughing followed by disc harrowing plots were significantly lower compared with that in the No tillage plots.

Also, in the 2011 major cropping season, although the disc ploughing followed by disc harrowing tillage treatment plots recorded lower soil penetration resistance values over the No tillage treatment, the difference was not significant. After harvest of *Akposoe* maize in the 2011 major cropping season, the disc ploughing followed by disc harrowing tillage treatment plots recorded significantly lower soil penetration resistance (210.9 kPa) in comparison with that in the No tillage treatment plots (303.1 kPa).

Soil penetration resistance values were not significantly affected by NPK 15-15-15 fertiliser rate application before ploughing, at tasselling and after harvest of *Akposoe* maize. After harvest, soils in the 0 kg ha^{-1} fertiliser application rate plots recorded the highest penetration resistance in both the 2010 minor (333.8kPa) and 2011 major (281.2 kPa) cropping seasons.

5.1.7 Effect of Tillage Treatment and Fertiliser Application Rates on Soil Dry Bulk Density

In the 2010 minor cropping season, although the disc ploughing followed by disc harrowing tillage treatment recorded lower soil dry bulk density values, the difference over the No tillage was not statistically significant except for the 15-30 cm soil depth at tasselling. Similarly, the disc ploughing followed by disc harrowing tillage treatment recorded lower soil dry bulk density in the 2011 major crop growing seasons. However, difference were not significant before ploughing and at tasselling except after harvest when the disc ploughing followed by disc harrowing tillage treatment recorded significantly lower soil dry bulk density values over the No tillage in both the 0-15 cm (1.25 Mgm^{-3}) and 15-30 cm (1.33 Mgm^{-3}) soil depth layers. In general, over the course of the experiment, NPK 15-15-15 fertiliser application rate did not significantly influence soil dry bulk density except for the case after harvest in the 2010 minor cropping season when the 250 kg ha^{-1} NPK 15-15-15 fertiliser application gave the lowest dry bulk density in both the 0-15 cm (1.12 Mgm^{-3}) and 15-30 cm (1.13 Mgm^{-3}) soil depth layers.

5.1.8 Effect of Tillage Treatment and Fertiliser Application Rates on Soil Moisture Content

Generally, higher soil moisture content was recorded before ploughing, at tasselling and after harvest of *Akposoe* maize in the disc ploughing followed by disc harrowing tillage treatment in both the 2010 minor and 2011 major cropping seasons. In the 2010 minor cropping season, soil moisture content was only significant at tasselling of *Akposoe* maize in both the 0-15cm (12.4%) and 15-30cm (12.4%) soil depth layers. In the 2011 major cropping season, significantly higher soil moisture content was recorded only after harvest of *Akposoe* maize in both the 0-15 cm (26.6%) and 15-30 cm (21.2%) soil depth layers in favour of the disc ploughing followed by the disc harrowing tillage treatment.

Overall, NPK 15-15-15 fertiliser application did not significantly influence soil moisture content in both soil depth layers except for the case after harvest in 2010 when the 250 kg ha^{-1} NPK 15-15-15 fertiliser application gave the highest soil moisture content (7.7%) in the 0-15 cm soil depth layer. Similarly, in the 2011 major cropping season, NPK 15-15-15 fertiliser application did not significantly affect soil moisture content before ploughing and after harvest except at tasselling when 150 kg ha^{-1} NPK 15-15-15 fertiliser application gave the highest soil moisture content (13.3%) in the 15-30 cm soil depth layer.

5.1.9 Effect of Tillage Treatment and Fertiliser Application Rates on Total Porosity

Tillage treatment did not significantly influence soil total porosity before ploughing and after harvest in the 2010 minor cropping season although higher total porosity values were recorded in favour of the disc ploughing followed by disc harrowing treatment. At tasselling in the 2010 minor cropping season, significantly higher total porosity was produced in favour of the disc ploughing followed by disc harrowing treatment in both 0-

15 cm (59.2%) and 15-30 cm (59.3%) soil depth layers. In the 2011 major cropping season, total porosity was generally higher in the disc ploughing followed by disc harrowing treatment although the difference over the No tillage was not significant before ploughing and at tasselling. However, after harvest of *Akposoe* maize, the disc ploughing followed by disc harrowing treatment recorded significantly higher total porosity in both the 0-15 cm (52.7%) and 15-30 cm (49.7%) soil depth layers. Overall, NPK 15-15-15 fertiliser application did not significantly affect soil total porosity except for the case after harvest in 2010 minor cropping season when the 0 kg ha^{-1} NPK 15-15-15 fertiliser application recorded the highest total porosity (57.5%) in the 15-30 soil depth layer.

5.1.10 Interaction Effects of Tillage Treatments and NPK 15-15-15 Fertiliser Application on Maize Plant Parameters

In general, there was no significant ($p>0.05$) interaction effects of tillage and NPK 15-15-15 fertiliser application on *Akposoe* maize seedling emergence at 20 days after planting and on plant height, stem girth and leaf area at 10 weeks after planting in both the 2010 minor and 2011 major cropping seasons. There was no significant ($p>0.05$) interaction effects of tillage and NPK 15-15-15 fertiliser application on the number of leaves per plant in the 2010 minor cropping season. However, there was significant interaction effect of tillage and NPK 15-15-15 fertiliser application on the number of leaves per plant in the 2011 major cropping season where the disc ploughing followed by disc harrowing x 250 kg ha^{-1} NPK 15-15-15 fertiliser application interaction recorded, significantly, the highest number of leaves per plant (16.0) while the No tillage x 0 kg ha^{-1} NPK 15-15-15 fertiliser application interaction recorded the lowest number of leaves per plant (14.2).

In general, there was no significant ($p>0.05$) interaction effects of tillage and NPK 15-15-15 fertiliser application on maize root length at harvest in both the 2010 minor and 2011 major cropping seasons. However, there was significant ($p>0.05$) interaction effects of tillage and NPK 15-15-15 fertiliser application on maize dry matter yield at harvest in both the 2010 minor and 2011 major cropping seasons. In the 2010 minor growing season, the disc ploughing followed by disc harrowing x 250 kg ha^{-1} NPK 15-15-15 fertiliser application interaction recorded the highest maize dry matter yield (5278 kg ha^{-1}) while the No tillage x 0 kg ha^{-1} NPK 15-15-15 fertiliser application interaction recorded the lowest dry matter yield (1775 kg ha^{-1}). In the 2011 major growing season, the disc ploughing followed by disc harrowing x 150 kg ha^{-1} NPK 15-15-15 fertiliser application interaction recorded the highest maize dry matter yield (7991 kg ha^{-1}) while the No tillage x 0 kg ha^{-1} NPK 15-15-15 fertiliser application interaction recorded the lowest dry matter yield (1206 kg ha^{-1}). There was no significant ($p>0.05$) interaction effects of tillage and NPK 15-15-15 fertiliser application on *Akposoe* maize grain yield in both the 2010 minor and 2011 major cropping seasons. The No tillage x 350 kg ha^{-1} NPK 15-15-15 fertiliser application interaction recorded the highest maize grain yield (5258 kg ha^{-1}) in the 2010 minor cropping season while the disc ploughing followed by disc harrowing x 250 kg ha^{-1} NPK 15-15-15 fertiliser application interaction recorded the highest maize grain yield (7582 kg ha^{-1}) 2011 major cropping season. The No tillage x 0 kg ha^{-1} NPK 15-15-15 fertiliser application interaction recorded the lowest maize grain yields in both the 2010 minor (2157 kg ha^{-1}) and 2011 major crop growing seasons (3203 kg ha^{-1}). There was no significant ($p>0.05$) interaction effects of tillage and NPK 15-15-15 fertiliser application on *Akposoe* maize dry cob weight in both the 2010 minor and 2011 major cropping seasons. In both cropping seasons, the disc ploughing followed by disc harrowing x 250 kg ha^{-1} NPK 15-15-15 fertiliser application interaction recorded the highest maize dry cob weight in both the 2010 minor (10416 kg ha^{-1}) and 2011 major (10813 kg ha^{-1}) cropping seasons. Also, the No tillage x 0 kg ha^{-1} NPK 15-15-15 fertiliser application interaction recorded the lowest maize dry cob weights in both the 2010 minor (4179 kg ha^{-1}) and 2011 major crop growing seasons (3225 kg ha^{-1}).

5.1.11 Interaction Effects of Tillage Treatments and NPK 15-15-15 Fertiliser Application on Soil Properties after Harvest

In general, after harvest of *Akposoe* maize in both cropping seasons, there was no significant ($p>0.05$) interaction effects of tillage and NPK 15-15-15 fertiliser application on soil penetration resistance, dry bulk density, moisture content and total porosity except for the following exceptions;

- Significantly, the No tillage x 0 kg ha^{-1} NPK fertiliser application interaction gave the lowest dry bulk density in the 0-15 cm soil layer (1.06 Mg m^{-3}) compared to all other interaction effects in the 2010 minor cropping season.
- The disc ploughing followed by disc harrowing x 250 kg ha^{-1} NPK fertiliser application interaction significantly recorded the highest soil moisture content in the 0-15 cm soil depth layer (11.0%) with the lowest moisture content recorded in the No Tillage x 0 kg ha^{-1} NPK interaction in the 2010 minor season.

5.2 RECOMMENDATIONS

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

1. There is the need to determine the long-term effect of tillage and fertiliser application rates on maize growth yield and on soil properties.
2. The experiment should be replicated in other agro-ecological zones in Ghana to determine NPK 15-15-15 fertiliser requirements under the different tillage treatments.
3. Field experiments should be conducted to determine the suitable tillage treatment and fertiliser application rates for different maize varieties and other crops.
4. Economic analysis should also be undertaken to determine costs and benefits of the effects of tillage and NPK 15-15-15 fertiliser application on maize performance and soil properties.

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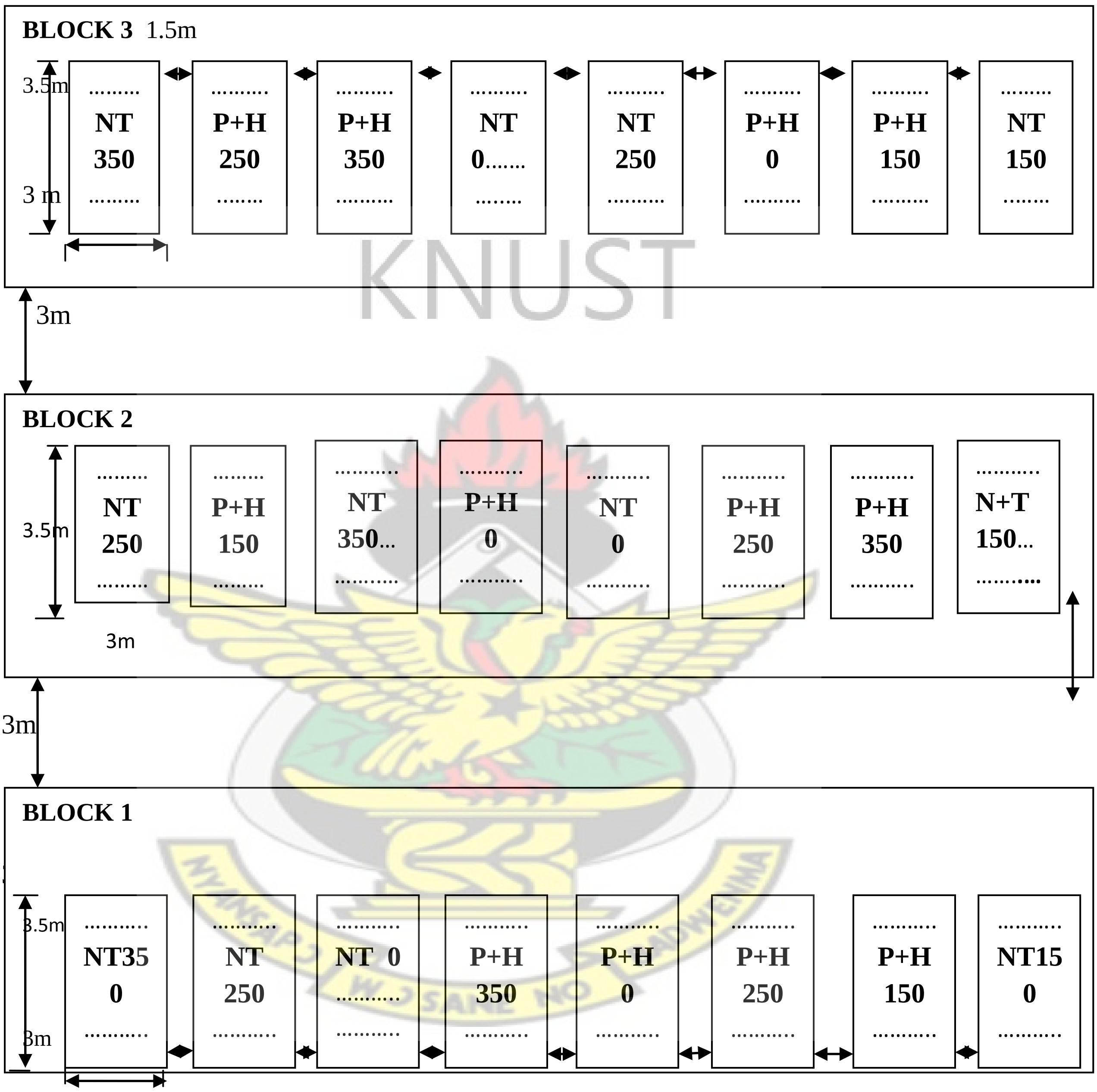
APPENDICES

APPENDIX 1: FIELD LAYOUT



Tillage Treatments: NT = No Tillage **P+H** = Ploughing followed by Harrowing

NPK 15-15-15 Fertiliser Application Rates:

0= 0 kg ha^{-1} **150** = 150 kg ha^{-1} **250** = 250 kg ha^{-1} **350** = 350 kg ha^{-1}

APPENDIX 2: PLOT LAYOUT