EFFECTS OF PLANTER TYPE, PLANTING SPEED, AND TILLAGE SYSTEM ON EMERGENCE AND SPACING UNIFORMITY OF MAIZE.

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(M.ENG/EA/07/0405)

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A PROJECT REPORT SUBMITTED TO THE DEPARTMENT OF AGRICULTURAL AND ENVIRONMENTAL ENGINEERING, MODIBBO ADAMA UNVERSITY OF TECHNOLOGY, YOLA IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF DEGREE OF MASTERS OF ENGINEERING IN AGRICULTURAL AND ENVIRONMENTAL ENGINEERING (FARM POWER AND MACHINERY).

DEPARTMENT OF AGRICULTURAL AND ENVIRONMENTAL ENGINEERING, SCHOOL OF ENGINEERING AND ENGINEERING TECHNOLOGY

MARCH, 2013

Declaration

I Abdulkadir Salihu Ahmed do solemnly declare that, this work was undertaken by myself, and no part of it either in full or otherwise has been submitted for the award of Masters Degree of Engineering (M. Eng.) or any other certificate in any other field of the university or elsewhere.

Signature_________________

Date__________________

Abdulkadir S. Ahmed

Approval Page

This project report entitled, “Effects of Planter Type, Planting Speed, and Tillage Systems on Emergence and Spacing Uniformity of Maize”, meets the regulations governing the award of Master of Engineering of the Modibbo Adama University of Technology, Yola and is approved for its contribution to knowledge and literary presentation.

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Dedication

This project is dedicated to Almighty Allah, and the entire generation of Late Mall. Abdulkadir Ahmed.

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Abstract

Planter type, maintenance, and operation play an important role in uniform stand establishment in Maize (Zea mays L.). Research was conducted to determine if planter types (Monosem pneumatic planter and Parmiter mechanical planter) affects Maize, mean emergence and uniformity of spacing and in relation to yield by applying different tillage system (Conventional tillage, Reduced tillage, Minimum tillage, and No-tillage) with 10cm with in row plant spacing and forward speeds of 7.20 and 11.30km/h. This experiment was performed at Mbilla farms limited in Mayo-belwa local government area of Adamawa state, Nigeria. Result of mean treatments interaction were statistically analyzed using ANOVA and means were separated using Duncan multiple range test showed that tillage systems, planter types, planting speed and the interaction between planter type and speed of planting and tillage systems, planter type and speed measured were significant at 5%, while interaction in tillage system and planter speed was not significant difference at 5% level of probability respectively. Maize plant height, within plants spacing, Mean emergence date, Emergence rate index showed Monosem Pneumatic planter at forward speed of 11.30km/h gave the highest mean yield of 6.25t/h. A simple linear correlation at 5% probability showed that for parmiter mechanical planter was significant except plant height with correlation coefficient(r) 0.02, while Monosem pneumatic planter was significant except in spacing with correlation coefficient of (r) 0.30. A multiple linear correlation of relation between yield and height, mean emergence date and emergence rate index, Spacing which gave coefficients of (r) 0.54. Planter type, tillage and planting forward speed have positive effect on the spacing, mean emergence rate and emergence rate index with respect to growth and yield (output) of Maize. The ideal speed based on this research to be used for forward speed of planting maize in mayo belwa, Adamawa state was found to be 11.30km/h. Recommended tillage practice with respect to suitable maize plant emergence is Conventional tillage, which was found to be suitable for maize Plant emergence at a spacing of 10cm in terms of maize yield (output).

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CHAPTER ONE

INTRODUCTION

Spacing uniformity, timing and rate of emergence, maize stand is the most common characteristics used by producers in assessing or evaluating planter performance. Seed metering mechanism and maintenance along with planting speed of a planter may all influence seed singulation and placement and can further affect plant spacing and emergence variability, which may ultimately affect plant growth and grain yield, (Liu *et al*., 2004a). The effect of planter speed on final plant density makes evaluating the impact of variations in plant spacing a difficult task. Vanderlip *et al*., (1988) reported that plant spacing variability gave a considerable yield while maintaining a constant plant density through hand thinning. Nielsen (1995a) reported that the effects of planter speed might have been confounded by plant density and did not account for the influence of multiples or misses on corn yields, whereas Nafziger (1996) reported that multiple plants can increase yields by approximately 6% whereas misses can decrease yields by as much as 7%.

Soil tillage, in general, is one of the fundamental agro-technical operations in agriculture because of its influence on soil properties, environment, and crop production. For normal plant growth, the soil must be prepared in such a manner that roots can have enough air, water, and nutrients. Structure of the Ap horizon is largely influenced by soil tillage system and the implements used for tillage (Husnjak *et al*., 2002). Tillage plays an important role in controlling weeds and managing crop residues, but the primary purpose of tillage is to change the soil structure (Raney and Zingg, 1957). The first tillage after the last harvest and usually the most aggressive one is called primary tillage. Primary tillage of soil is mainly used to cut and loosen soil to a depth of 15 to 90 cm (McKyes, 1985). Soil physical properties are extremely vital to plant growth. The influence of tillage implements on soil physical properties is significant. Buschiazzo *et al*., (1998) reported that the soil physical properties changes as a result of soil tillage treatments and could influence the yield level of grown crops. Aggregate size, moisture content, penetration resistance, and bulk density are important soil physical properties. Defossez and Richard.(2002), reported that Corn yields are undoubtedly affected by field characteristics and operations such as soil strength, compaction, soil water, tillage and residue practices, time of field operations and soil fertility, which altogether influence seedling emergence, root development and nutrient availability.

The size and stability of aggregates can be indicators of the effects of tillage system and crop on soil structure. Well aggregated soils provide better moisture retention, adequate aeration, easy penetration for the roots, and good permeability. The size of aggregates and aggregation state are affected by soil tillage implements and agricultural activities that alter the organic matter content and the biological activity of the soil. Hughes and Baker (1977) reported that the rotary cultivation treatment resulted in the greatest proportion of soil in the smaller aggregate size fraction at all sampling dates. Carter (1996) observed that the aggregates formed by chisel plough were larger than those formed by mouldboard plough.

Soil moisture is the single most important limiting factor to crop yields in many areas. Tillage techniques that conserve moisture are important for increasing crop yields and limiting the devastating consequences of drought. Bauder *et al.*, (1981a) found that the chisel plough treatment created a driest surface, while the wettest one was from a no tillage treatment, while the disk and mouldboard plough treatments were intermediate. Lyles and Woodruff (1962), stated that soil moisture content at tillage affected the size distribution of the aggregates produced, and aggregates formed at low moisture content were 3 to 4 times more resistant to crushing than those formed at higher moisture content.

Penetration resistance is a measure of soil strength and an indicator of how easily roots can penetrate into soil, and thus a measure of plant growth and crop yield (Singh *et al.,*1992). Soil strength is affected by soil type, clay content, voids, water content, bulk density, soil depth, and soil tillage systems. Many experiments have shown that crop yields decreased as the strength of soil layers increased. For example, Carter *et al*., (1965) found that seed cotton yield decreased linearly from 3.6 to 1.45 Mgha^{-1} as soil strength increased from 0.3 to 4 MPa. Bauder *et al*., (1981b) reported that penetration resistance ranked as follows: mouldboard plough less than chisel plough less than spring disk equal to no till in a clay loam soil and they also reported that penetration resistance decreased with increase in soil moisture content and vice versa

Bulk density is nearly always altered by tillage operations. An ideal soil contains about 50% solid particles and 50% pore space by volume (Hillel, 1982).The magnitude of bulk density for agricultural soils commonly varies from 0.9 to 1.8 Mg m^{-3}(Erbach *et al.*, 1982). The bulk density of a typical mineral soil is about 1.3 Mgm^{-3}. Bulk density is inversely related to the total porosity, which provides a measure of the porous space left in the soil for air and water movement. Osunbitan *et al*., (2005) examined the effects of tillage on bulk density, hydraulic conductivity and strength of a loam sand soil. They found that the bulk density and penetration resistance of surface soil decreased with increase in the intensity of soil loosening by tillage operation. Lindwall and Erback (1983a) reported that tillage and planting systems often had significant effects on soil bulk density, soil moisture, soil particle size distribution and residue cover. Husnjak *et al*., (2002) reported that among the soil physical properties strong reciprocal dependence was found between crop yield and soil bulk density, and strong direct dependence between crop yield and total porosity. Carman (1997) observed that different methods of tillage produced different yields, which appeared to relate to the soil conditions produced by tillage. Soil physical properties change not only because of constructional properties of soil tillage implements, but also because of their operational variables, such as operating speed.

Many factors can contribute to delayed emergence in Maize. Some of the most important and most researched factors are soil temperature, soil moisture, tillage crop residue, planting depth, and bulk density. Some of these factors are relatively uncontrollable and unpredictable, while others can be modified by management practices as reported by Christopher (1999) Rapid and complete germination and emergence of wheat seeds improve the odds for obtaining good yields (Nasr and Selles, 1995). Tillage practices affect mechanical characteristics of seedbed considerably and thus crop emergence (Mohanty and Painuli, 2004). Gan *et al.,* (1992) reported that plants that emerge early contribute more to crop yield than those that emerge later. Thus, desirable crop yields are achieved by providing seeds with an environment that encourages early germination and emergence.

Excessive planting speed can alter seeding rates, increase stand establishment variability, and consequently decrease grain yield. Increasing planting speed increased the standard deviation of plant spacing. Nielsen, (1995b) reported a decrease in plant population at 1 of 22 sites and an increase at 9 of 22 sites, and that faster planting speeds can decrease uniformity of seeding depth and affect seed-to-soil contact, causing uneven emergence, and concluded that future planter speed studies should go beyond measuring uniformity of seed placement (depth and spacing) and include a measure of emergence uniformity.

1.1 Statement of Problem

The effect of planter type, planting speed, and tillage on seedling emergence and spacing uniformity is vital because previous researches have examined the mean response of commonly used Planters to planting speed and generally have ignored the possible differences of individual planters with different mechanisms. In addition, there is insufficient data to determine if planter performance is the same in reduced tillage systems compared with conventional tillage systems and other tillage systems or whether there are interactions between planters and planting speed in Adamawa state. A comparison of planter performance under different tillage system and planting speeds may assist in improving planter performance, thereby increasing yield and returns. More practically, it may assist farmers in assessing maize-Planter requirements before improving the efficiency of the planter in terms of indigenous design of new planters or replacing existing planters.

Most developing countries depend on imported planters without putting into consideration effects of such planters, soil type and other yield components. Also, there are insufficient data or information as regards the appropriate planter type, planter speed and tillage system for maize producers suitable for output maximisation. This has drastically affected yields as source of income to farmers and industries requiring maize as a source of raw material and also as a source of revenue to the country at large.

1.2 Objective of Study

The General objective is to determine the effects of different available planter types used locally by farmers around Adamawa and its environs, at different planting speeds with different tillage systems on seedling emergence and plant row spacing uniformity of maize. The specific objective of this study includes;

i. To assess the relationship among yield, Planter types, Planting speeds and tillage in terms of emergence rate index, mean emergence rate, and plant spacing.

ii. To assess the effects of planter types while varying planting speed and tillage management system on emergence date and emergence index.

iii. To develop a simple linear and multiple linear regression equations to predict yield based on plant height, mean emergence date (MED), emergence rate Index (ERI), and plant spacing for monosem pneumatic planter and parmeter planter and their combination of both the planters

1.3 Justification of the Study.

This study is very important in the sense that most of the machinery that are imported into the country are not tested and certified for our environments especially as to our soil conditions and the appropriate tillage systems that are suitable for the Planters, Thus the study will enable farmers and government alike to know the kind of planters that will be suitable for our environment and has required performance efficiency.

1.4 Scope of the study

The research was focused on planter types, speed of operation (km/h), tillage and its effects on seedling emergence and plant stand uniformity of maize. This research was limited to time of emergence after planting and stand variability of maize growth with one month after planting. The crop depended on the type of soil available, types of planters that were available, soil moisture content on the field during research, method of planting, and the tillage management systems commonly practiced in Yola and its environs.

CHAPTER TWO

LITERATURE REVIEW

2.1 Effects of Planter Type and Planter Speed on Plant Stands Uniformity.

One factor affecting the quality of crop in mechanized crop production system is the planting operation. The more precise the planting operation, the better the quality of crop harvested. Precision planting reduces seed scattering, which facilitates drill calibration on the basis of the number of seeds to be placed along a unit length of the furrow. Uniform germination and growth of plants makes the subsequent operations, such as weeding and harvesting, easy with least cost (Domier 1991).

Jasa and Dickey (1982) reported that relative surface roughness, amount of residue present, level of pre-plant tillage, and tillage system are important factors affecting corn seed spacing uniformity in 100 Nebraska fields using nine brands and 35 models of planters. They also concluded that no-till planting could provide at least a uniform seed spacing as other tillage systems and found that seed spacing uniformity was not affected by planter forward speed, which ranged from 4.8 to 11.2 km/h.

The effect of within-row plant spacing variability on grain yield is somewhat unclear. Various studies have demonstrated that a corn yield reduction is associated with spacing variability (Krall *et al*., 1977 and Nielsen, 2001), whereas other studies indicate that spacing variability commonly observed in many commercial fields did not reduce grain yield if plant population is adequate (Erbach *et al*., 1972; Edmeades and Daynard, 1979; Muldoon and Daynard, 1981; Daynard and Muldoon, 1983; Liu *et al*., 2004a, 2004b). In contrast, uneven emergence almost always reduces grain yield with early emerged plants unable to compensate for lower yield of late-emerging plants (Carter and Nafziger, 1989; Ford and Hicks, 1992; Liu *et al*., 2004b).

Krall *et al*. (1977) reported that a significant decrease in yield as within row plant spacing variability increased at two of three sites. Regression results showed a potential decrease of 85 kg/ha per cm of standard deviation in plant spacing. The impact of planter speed on final plant density makes evaluating the impact of variations in plant spacing's a difficult task. Vanderlip *et al*. (1988) produced plant spacing variability while maintaining a constant plant density through hand thinning. Nielsen (1991) reported that effects of planter speed might have been confounded by plant density. Staggenborg et al., (1999) reported a 2.0−kg/ha increase in corn yields for 2470−plants/ha increase in plant density for northeast Kansas. Nafziger (1996) reported that multiple plants can increase yields approximately by 6% whereas misses can decrease yields by as much as 7%. These results are further complicated by the use of both finger pickup and vacuum planter units (Nielsen, 1995b) with no clear indication of either metering device used at a particular location. Planter manufacturers clearly indicate that when operated at speeds above recommended thresholds, the two metering systems respond differently (Anonymous, 1987). Operating instructions for the Max Emerge II (Model 7200, Deere and Co., Moline, Ill.) indicated that when a vacuum metering system is over−speeded, lower than desirable seeding rates will be achieved and if a finger pickup meter is over−speeded, greater than desirable seeding rates will be achieved.

Plant spacing variability is often defined by the standard deviation and as noted above has had mixed results when used to explain yield and plant spacing variability. Though it is easy to calculate and understand, Kachman and Smith (1995) reported that plant spacing is poor descriptor of plant spacing variability. Jasa and Dickey (1982) developed a planter index to evaluate plant spacing for various tillage systems. The planter index was an indicator of the average percent difference from the ideal plant spacing and was independent of seeding rate. They reported that even the best planters in their study had 20% to 30% error in seed placement and that tillage system had little impact on planter index.

Within row plant spacing variability is potentially caused by two items, metering irregularities and seed bounce in the trench. Panning *et al.*, (2000) evaluated performance of two sugar beet planters and compared laboratory and field performance. In all situations, they reported that the coefficient of precision decreased with increasing speed. They concluded that laboratory test results could not be used to predict field test results. Their findings would indicate that seed spacing variability could be more related to seed bounce in the trench than metering system irregularities.

Non−uniform plant emergence over time is also a concern of corn growers. Nafziger *et al*.,(1991) reported that uneven corn emergence could reduce yields. However, they suggested that if plants emerged over a period of time less than two weeks, the yield loss was small (<3%) and did not justify replanting. To assess corn and soybean stand establishment Erbach *et al.*, (1982) developed the emergence rate index (ERI). The ERI is an indication of how fast and uniform in time the crop emerges from the soil. He reported ERIs ranging from 4.9% to 11.0% for corn and 4.9% to 12.7% for soybeans.

Precision seeders theoretically place seeds at a required spacing and provide a good growing area per seed. Bracy *et al.*, (1998) reported that variability in seed spacing with a precision vacuum seeders decreased with increased nominal seed spacing but with a belt seeders, seed spacing uniformity was not affected by nominal seed spacing. Wanjura and Hudspeth (1969) reported that an 8 mm seed drop height consistently produced a better seed pattern than a 15 mm drop height with precision vacuum seeders. They recommended that the metering device on seeder should be located as low as feasible and that seed should fall freely to the bottom of the soil trench. Karayel and Özmerzi (2001) stated that the variability in seed spacing with precision vacuum seeders increased with increasing forward speed. They found that a forward speed of 1 m/s consistently produced a better seed pattern than 1.5 and 2.0 m/s for precision sowing of melon and cucumber seeds.

When planters are not operated or functioning properly, gaps may occur. Some researchers have suggested using standard deviation (SD) as a measure of in-row corn stand uniformity (Nielson, 1991) similarly, stated that corn grain yield declines at about 2.5 cm/acre for each 1 cm increase in standard deviation above a value of 2 cm. According to Butzen, (1998) standard deviation (SD) alone is not a good means of predicting yield responses to stand variability because of the differing and interactive effects of row skips, doubles, and plant density. When a crop is planted, the aim is to establish a plant population whose spacing contributes to the maximum return per surface area (Kepner *et al*., 1982). Optimizing the density of plants is of prime importance, and this requires precision in terms of seed metering and distribution by the seeding machine. The objective of seed metering is accurate and uniform seeding according to Jorgenson, (1988), but causes no damage to the seed as reported by (Barañao, 1955).

Seed distribution refers to the planting of seeds according to a predetermined pattern as reported by (Colombino *et al.,* 1989).and should taken into account the requirement for equidistant spacing between seeds. The depth at which they are planted should be adjusted to provide them with the best moisture conditions (Kumar, 1989). It is therefore important to take into account the components of the drill and the possibilities of their adjustment.

Three different planting methods can be distinguished by the horizontal pattern of seed placement, i.e. broadcasting, drilling, and row crop seeding. In precision row crop seeding the mechanical or pneumatic seeders precisely separate the seeds. Seeds that are drilled by precision planting are theoretically sown with optimum row and within-row spacing which depend on the seeding requirements for each specific crop. Plant spacing can affect growth and yield, and plant spacing uniformity begins with seed spacing uniformity (Bracy and Parish, 1998).

Liu *et al*., (2004c) indicated that non-uniform plant spacing within the row has little or no effect on plant growth and grain yield of corn if the plant population is adequate for high yield and that the yield of an individual plant is influenced not only by the directly adjacent plant but also by a second adjacent plant. Wilkins *et al*., (1991) developed an equation to provide a spacing uniformity index (SUI). They reported that SUI provided an excellent means for evaluating plant spacing and it was used to evaluate the performance of planting equipment. Gil and Carnasa (1996) found out that pneumatic seeders provided better results than mechanical seeders in terms of within row uniformity.

Parish *et al*., (1991) compared vacuum and belt seeders for vegetable planting and found that a vacuum seeders used 90% less seed as compared with the standard bulk metering planter. Bracy and Parish (1998) evaluated the seeding accuracy of three precision seeders for five vegetable crops using the measures of accuracy as described by Kachman and Smith (1995). They reported that the seeding uniformity of all seeders with elongated (carrot and cucumber) or angular (spinach) seeds were inadequate for precision seeding.

Planters sow seeds individually in furrows according to a predetermined pattern, while drills meter plant seeds in a steady flow. With respect to soybean, individual seed metering is possible for up to 30 seeds per linear meter of furrow. For higher densities, however, a flow of seeds is required (Maroni and Medera, 1990). Soza *et al*., (1996) compared individual and flow metering systems and found a coefficient of variation for seed spacing uniformity within rows of 74.33-76.19% for the first and 94.86-97.77% for the second values regarded as high according to the classification of Pimentel (1981). Nave and Paulsen (1979), analyzed five seed metering devices involving either individual metering or flow systems, then obtained values in seed spacing uniformity of between 84% and 97%, with no significant differences between specific treatments. In other testes, the damage inflicted on seeds by internal double-run metering was treated satisfactorily. Earlier, Ewen *et al*., (1981) indicated the indifference of crop with respect to uniform seed distribution and reported that seeding machines with either individual metering devices or flow systems could be used. However, Cavalheiro Touriño and Daniel (1996) stated that an irregular distribution of seeds leads to increased losses at harvest and the sub-optimum use of soil resources.

The increasing world demand for food needs to be met, but technologies should be employed that guarantees the sustainability of agricultural systems. Direct seeding is an alternative that should be considered since it helps establish a better soil structure, increases soil organic matter content, and improves rainwater infiltration and retention capacities (Méndez and Satorre, 1998). However, it has the drawback that the drill has to operate on plots with abundant surface stubble, with all the difficulties this entails-such as the attention required by the distribution train and the particular care necessary in the use of the furrower if planting is to be efficient (Brown and Baker, 1986).

Many distribution trains for direct seeding have a rolling coulter and a double disc furrower that can be used on many types of soil (Tice and Hendrick, 1991;Morrison *et al.*, 1996). Richey (1981) reported that a V shaped furrow with smooth sides, reduce the dispersion of seeds, and contribute to the flow of moisture towards them. In his review, Baker (1994) stated that a planter assembly can operate without choking, although furrow walls can be left compacted, little loose soil is produced with which to cover the seeds, stubble can be introduced into the furrow, and seeds can be inadequately placed. These problems impair germination and emergence. Maroni (1994) report that furrow wall compaction is worse when the Furrowers are required to break the soil without prior preparation with a coulter.

An alternative distribution train for drills is the double disc opener, composed of a double disc furrower equipped with a displaced assemblage or discs of different diameter, the idea being that the forward disc mimics the action of a rolling coulter. This helps to reduce the number of machine parts and increases penetration (Baumer *et al.*, 1994) and the drawback is premature wearing of the forward disc and the rubbing of components. The lateral walls of the furrows produced may also be excessively compacted (Maroni, 1994).

The above distribution trains thus have a common disadvantage, which is the compaction of the lateral wall of the sowing furrow. If soil is tightly packed around the seed, its chances of obtaining sufficient air for germination are reduced. Even if it manages to germinate its roots may not be able to explore water and nutrients with sufficient speed (Bragachini *et al*., 2001). The number of plants obtained is therefore less than the number of viable seeds sown.

2.2 Effects of Different Soil Tillage Systems on Seedling Emergence and Stand Uniformity of Maize

Soil tillage is among the important factors affecting soil physical properties and crop yield. Among the crop production factors, tillage contributes up to 20% (Khurshid *et al.,* 2006). Tillage method affects the sustainable use of soil resources through its influence on soil properties (Hammel, 1989). The proper use of tillage can improve soil related constrains, while improper tillage may cause a range of undesirable processes, example. Destruction of soil structure, accelerated erosion, depletion of organic matter and fertility, and disruption in cycles of water, organic carbon and plant nutrient (Lal, 1993). Use of excessive and unnecessary tillage operations is often harmful to soil. Therefore, currently there is a significance interest and emphasis on the shift to the conservation and no-tillage methods for the purpose of controlling erosion process (Iqbal *et al.,* 2005).

Conventional tillage practices modify soil structure by changing its physical properties such as soil bulk density, soil penetration resistance and soil moisture content. Seasonal soil disturbance and pulverizing caused by conventional tillage produce a finer and loose soil structure as compared to conservation and no-tillage method which leaves the soil intact (Rashidi and Keshavarzpour, 2007). This difference results in a change of a number of properties, shape, continuity and size distribution of the pores network, which controls the ability of soil to store and transmit air, water and agricultural chemicals. This in turn controls erosion, runoff and crop performance (Khan *et al.,* 2001).

Tillage systems	**Abbreviation**	**Description**
Conventional tillage	CT	Disc plough + two (2) passes of disc harrow.
Reduced tillage	RT	Two (2) passes of disc harrow.
Minimum tillage	MT	One (1) pass of disc harrow.
No-tillage	NT	Direct planting but no tillage

Majid and Fereydoun (2008)

As reported by Hill, (1990), Bauder *et al.,(*1981b) and Horne *et al., (*1992), conservation tillage methods often results in decreased pore space and increased soil strength and stable aggregates The pore network in conservational tilled soil is usually more continues because of earthworms, root channels and vertical cracks (Cannel, 1985). Therefore, conservation tillage may reduce disruption of continues pores. Whereas, conventional tillage decreases soil penetration resistance and soil bulk density (Khan *et al.,* 1999). This also improves porosity and water holding capacity of the soil. Continuity of pore network is also interrupted by conventional tillage, which increases the tortuousity of soil. This all leads to a favourable environment for crop growth and nutrient use (Khan *et al.,* 2001). However, the results of no-tillage are contradictory (Iqbal *et al.,* 2005). No-tillage methods in arid regions of Iran had an adverse effect on crop yields (Hemmat and Taki, 2001); while Ghuman and Lal (1984) comparing conventional tillage method to no-tillage method concluded that higher moisture preservation and 13% more income was obtained in case of no-tillage.

Maize (*Zea mays* L.) is a major food and cash crop for small-scale farmers in Nigeria. A rapid increase in population in the country and subsequently higher food demands make mechanized agriculture viable. However, with the recent increase in the mechanization of agriculture and intensive tillage operations are the main causes of soil compaction in northern Nigeria. The weights of wheeled tractors used vary from 2 to 5 t coupled with various implements for land cultivation.

Previous researchers (Lipiec *et al.*, 1991; Oussible *et al.*, 1992 and Håkansson and Reeder, 1994) reported that the response of soil physical properties to soil compaction is manifested in an increase in bulk density, a decrease in total porosity, air permeability, plant-available water and crop yield. Soil compaction adversely affects soil structure, reduces crop production, increases runoff and erosion, and accelerates potential pollution of surface water by organic wastes and agro-chemicals applied. Therefore, knowledge of soil compaction is increasingly important in agriculture and for environmental protection (Assouline, 2002). Studies have also shown that changes in pore size distribution due to soil compaction resulted in a lower water infiltration rate (Yusuf and Yiljep, 2000; Yusuf, 2001) and slow down the downward growth of roots with restricted root systems to the upper part of the soil profile (Black and Hartge, 1986). Field experiments were conducted by Laboski *et al*., (1998) to determine if soil strength and/or available water could be the factors limiting maize rooting depth on an irrigated fine sandy soil. They reported that a compacted soil layer confined roots almost entirely to the top 0.06m of soil because it had high soil strength and bulk density; the compacted layer, in turn, retained more water for maize use. Despite the considerable amount of research done elsewhere which shows the negative effects of wheel-induced soil compaction on crop yield (Negi *et al*., 1981; Heberle and Vach, 1992), very limited work has been done to investigate the effect of soil compaction on maize production in Nigeria. Greater knowledge of the effects of various tillage systems on crop establishment and yield is needed to assess the contribution of these tillage systems to sustainable land use and management, soil water and air retention characteristics, water and nutrient use efficiencies and crop production.

Changes in soil properties due to tillage may not be of the high magnitude to affect crop production. Tessier *et al*., (1990) reported, in general, conservation tillage significantly improved water available to crops. However, despite enhanced soil water reserve, zero tillage practices did not consistently yield more than conventionally grown wheat. Lindwall and Erback (1983b) indicated tillage and planting systems often had significant effects on soil bulk density, soil moisture, soil particle size distribution and residue cover. Again, these effects were usually not of the magnitude to significantly affect emergence and early plant growth. A ten year study by Chang and Lindwall (1990a) reported that saturated hydraulic conductivity and plant available water holding capacity was significantly lower and bulk density was higher at the 30 to 60 mm depth in no till treatments than in the conventional tillage regime. However, none of the soil properties approached values that would limit yield of Winter Wheat crops. In addition, Chang and Lindwall (1990b) reported that soil physical properties at a depth of 0 to 30 mm and 90 to 120 mm (below the tillage zone) were not significantly different among tillage and crop rotation treatments. Englehorn (1946) indicated the storage of soil moisture, either under summer fallow or continuous cropping, was not greatly affected by type of tillage.

Most tillage experiment inconsistencies are due to the complexity of the changes in soil properties caused by tillage (Douglas and Mckyes, 1983). Chang and Lindwall (1990c) stated that, soil properties changes due to tillage are related to several things. Those things include soil type, type of tillage equipment, tillage depth, soil conditions such as moisture content at the time of tillage and climatic conditions. Bauer and Kucera (1978) reported inconsistencies in relative grain yield differences among tillage treatments over a period of years were, in part, associated with inconsistent differences in soil properties produced by given tillage treatments from one year to another. Inconsistencies were concluded to be likely associated with the presence of soil water at the time of tillage and climatic conditions - primary water supply, water distribution and temperature. Van Doren *et al.,* (1976) stated that conservation tillage practices resulted in lower yields on poorly drained soils and produced higher yields on well drained soils. Rydberg (1990) reported that zero tillage reduced the rate of evaporation, mainly by reducing slaking of the surface. Slaking was as a result of higher content of under graded crop residues and better stability of soil particles. He also observed that zero tillage could reduce evaporation more on a silty clay loam than on heavy clay, indicating soil type influenced results. Burwell *et al.,* (1966) stated that the amount of moisture in the soil when it is tilled affects the resulting pore space. When soil moisture content level was different than the moisture content normally favourable for working a seedbed the pore space increased, indicating soil changes in pore space were greater than when tillage was performed at the favourable moisture content level. Ideal soil moisture content was not outlined.

Other soil and cropping factors may affect crop yields more than soil moisture content changes due to tillage. Ojeniyi and Dexter (1979a) stated that cropping history showed continuous cereal crops produced larger soil particles and voids when periods of pasture or fallow are included in the rotation. Ojeniyi and Dexter (1979b) attributed the results to smaller organic matter content under continuous cropping and greater frequency of tillage after fallow was also a contributing factor. Several studies have been conducted to assess effects of tillage systems on hydraulic properties of soils (Adeoye, 1982, Blevins *et al.,* 1983), Hamblin and Tennant, 1981, Wittmuss and Yazar, 1980). Allmaras *et al*., (1977) reported an increase in hydraulic conductivity with chisel plowing. Ehlers *et al*., (1980) reported that tillage may change soil bulk density, shoot and root growth and the water uptake pattern of a crop. McFarland *et al*., (1990) reported on the long term effects of tillage practices on soil physical properties which may depend on the associated cropping sequence. Spomer and Hjelmfelt (1984) observed that the watersheds soil moisture was affected more by cropping (grass vs. corn) than tillage (conventional versus till plant). However, neither treatment caused significant differences.

In addition to soil moisture changes, tillage may also affect other soil physical and chemical properties. Changes in soil chemical properties can affect crop yield and crop responses to tillage. Bauer and Kucera (1978) stated that in addition to physical properties, certain chemical properties of soil can be affected by tillage, especially when tillage affects soil temperature.

Cooke and Scott (1993), reported that the intensity of freight movement in the field, up to nine passes might be necessary just for seedbed preparation, application of fertilizer, herbicides and planting. Compaction decreases soil porosity, water capacity and adversely affects crop establishment, plant growth and final yield. Soil tillage system affects mechanical behaviours of soil layers, Horn (2004) reported that Soils under a long term conservation tillage induced change in the physical properties compared with conservation tilled soil, being more resistant and thus less susceptible to deformation which have affected crop emergence and yield.

Dennis *et al* (2003) reported that the basic soil tillage method can involve a wide range of tillage method easily from intensive to reduced cultivation system. The state or quality of soil to which these tillage methods are been applied for maize crop management was not easily determined and excessive cultivation was used and it was based on soil physical properties and on several factors which included; differences in properties, weather condition, history of management, intensity and type of tillage.

CHAPTER THREE

MATERIALS AND METHOD

3.1 Research Site and Location

The research was carried out at Mbilla Farms Limited, Adamawa State, in the Northern Guinea Savannah agro-ecological zone of Niger

The Farm is located within Latitude 93^{o} 00^{1} north and Longitude 123^{o} 00^{1} East at an Altitude of 255m, relative humidity of 59% within the Northern guinea Savannah zone of Nigeria. Rainfall commences in April and last till October, while harmattan starts from November to February, the average minimum rainfall ranges from 770mm to 1600mm (Adebayo and Tukur, 1999).

3.2 Experimental Design

The experimental design used was the split-split plot arrangement of a randomized complete block with three replicates of each treatment. The split split plot design is used because of the following:

1. Three plot sizes corresponding to the three factors; namely, the largest plot for the main factor, the intermediate size plot for the subplot factor, and the smallest plot for the sub-subplot factor.

2. There are three levels of precision with the main plot factor receiving the lowest precision, and the sub-subplot factor receiving the highest precision. Gomez (1984b)

Four tillage systems were taken as the main plots (Conventional tillage, reduced tillage, Minimum tillage, No-tillage), two types of planters (Parmiter Mechanical planter and Monosem Pneumatic Planter) were usePd as subplots, and two levels of planting speed {7.20km/h (2m/s) and 11.30km/h (3.2m/s)} were used as the sub-subplots treatments. Each sub-subplot consisted of four rows having 0.76-m row spacing with 25m length. Each main plot had 0.76-m row spacing and 25m length. The treatment combinations used were the tillage system, planter type, and planter speed resulting in a total of sixteen (16) treatment levels. The tillage systems were; Conventional Tillage (CT), Reduced Tillage (RT), Minimum Tillage (MT) and No Tillage (NT),as reported by Majid and Fereydoun (2008) which also resulted to the total number of 16 main plots as shown in Table 3.1 and Fig 3.1, tillage, planter type, Monosem pneumatic planter (MPP) and Parmeter mechanical planter (PMP) and planter speed (S_1=7.2km/h and S_2=11.30km/h) abbreviation showing the randomised split-split plot design for the research.

The two planter types are used in the experiment because they are the only available planters that are available and been used presently in the research environment. The speed 7.20km/h and 11.30km/h as the minimum and the maximum speed of corn planting according to Jasa and Dickey (1982). The randomization of the treatment is to minimized error and minimizing error will give precision to the research work.

Table3.1. Treatments and their abbreviations as used in the Experimental design and Data analysis.

Treatment(tillage systems)	Abbreviation	Description
Conventional tillage	CT	Disc plough + two (2) passes of disc harrow.
Reduced tillage	RT	Two (2) passes of disc harrow.
Minimum tillage	MT	One (1) pass of disc harrow.
No-tillage	NT	Direct planting but no tillage

Majid and Fereydoun (2008)

Table 3.2: Available planter types used in the research

Planter type	abbreviation	Planting method
Monosem pneumatic planter	MPP	Pneumatic planting method
Parmiter Mechanical planter.	PMP	Mechanical method of planting

Table 3.3: Speed levels used in field work

Speed levels	abbreviations	Planting speed
Speed level 1	S_1	Planting forward speed of 7.20km/h
Speed level 2	S_2	Planting forward speed of 11.30km/h

Jasa and Dickey (1982)

3.3 Treatment Variation as Used in Randomization of Split-Split Plot Design

The treatment combination were two (2) planter types available (Monosem Pneumatic planter and parmiter planter), operated at two (2) speed planting speed level (11.30km/h and 7.20km) as reported by Jasa and Dickey (1982) with the four (4) tillage systems (Conventional Tillage (CT), Reduced Tillage (RT), Minimum Tillage (MT) and No Tillage (NT)) as reported by

Majid and Fereydoun (2008) which gave a total treatment variation of (2×2×4) and a total of sixteen 16 treatment combinations as shown in table 3.4

Table 3.4 Treatment variation as used in randomization of split-split plot design

S/N	Variation in treatments abbreviations	Treatment variations
1	**$CT\times PMP\times S_1$**	Conventional tillage× Parmiter Mechanical planter× Planting forward speed of 7.20km/h
2	**$RT\times PMP\times S_1$**	Reduced tillage× Parmiter Mechanical planter× Planting forward speed of 7.20km/h
3	**$MT\times PMP\times S_1$**	Minimum tillage× Parmiter Mechanical planter × Planting forward speed of 7.20km/h
4	**$NT\times PMP\times S_1$**	No-tillage× Parmiter Mechanical planter× Planting forward speed of 7.20km/h
5	**$CT\times MPP\times S_1$**	Conventional tillage× Monosem pneumatic × planter Planting forward speed of 7.20km/h
6	**$RT\times MPP\times S_1$**	Reduced tillage× Monosem pneumatic planter× Planting forward speed of 7.20km/h
7	**$MT\times MPP\times S_1$**	Minimum tillage× Monosem pneumatic planter × Planting forward speed of 7.20km/h
8	**$NT\times MPP\times S_1$**	No-tillage× Monosem pneumatic planter× Planting forward speed of 7.20km/h
9	**$CT\times PMP\times S_2$**	Conventional tillage× Parmiter Mechanical planter× Planting forward speed of 11.30km/h

10	**RT×PMP×S_2**	Reduced tillage× Parmiter Mechanical planter× Planting forward speed of 11.30km/h
11	**MT×PMP×S_2**	Minimum tillage× Parmiter Mechanical planter× Planting forward speed of 11.30km/h
12	**NT×PMP×S_2**	No-tillage× Parmiter Mechanical planter× Planting forward speed of 11.30km/h
13	**CT×MPP×S_2**	Conventional tillage× Monosem pneumatic planter× Planting forward speed of 11.30km/h
14	**RT×MPP×S_2**	Reduced tillage× Monosem pneumatic planter× Planting forward speed of 11.30km/h
15	**MT×MPP×S_2**	Minimum tillage× Monosem pneumatic planter× Planting forward speed of 11.30km/h
16	**NT×MPP×S_2**	No-tillage× Monosem pneumatic planter× Planting forward speed of 11.30km/h

Replication I		Replication II		Replication III	
$T_2 P_1S_1$	$T_2 P_1S_2$	$T_1 P_2S_1$	$T_1 P_2S_2$	$T_4 P_1S_2$	$T_4 P_1S_1$
$T_2 P_2S_1$	$T_2 P_2S_2$	$T_1 P_1S_1$	$T_1 P_1S_2$	$T_4 P_2S_2$	$T_4 P_2S_1$
$T_3 P_1S_1$	$T_3 P_1S_2$	$T_4 P_2S_2$	$T_4 P_2S_1$	$T_1 P_1S_1$	$T_1 P_1S_2$
$T_3 P_2S_1$	$T_3 P_2S_2$	$T_4 P_1S_2$	$T_4 P_1S_1$	$T_1 P_2S_1$	$T_1 P_2S_2$
$T_4 P_1S_1$	$T_4 P_1S_2$	$T_2 P_2S_2$	$T_2 P_2S_1$	$T_3 P_1S_2$	$T_3 P_1S_1$
$T_4 P_2S_1$	$T_4 P_2S_2$	$T_2 P_1S_2$	$T_2 P_1S_1$	$T_3 P_2S_2$	$T_3 P_2S_1$
$T_1 P_2S_2$	$T_1 P_1S_1$	$T_3 P_2S_2$	$T_3 P_2S_1$	$T_2 P_1S_2$	$T_2 P_1S_1$
$T_1 P_2S_2$	$T_1 P_2S_1$	$T_3 P_1S_2$	$T_3 P_1S_1$	$T_2 P_2S_2$	$T_2 P_2S_1$

Figure 3.1 Randomisation of treatment for 4×2×2 research

Randomisation of treatment for 4×2×2 research. P_1 is Parmiter mechanical planter, P_2 Monosem pneumatic planter,T_1 is the conventional tillage, T_2 is reduced tillage, T_3 is the minimum tillage, T_4 is No-tillage and S_1 speed at 7.20km/h, S_2 speed at 11.30km/h

3.4 Marking out of the Experimental Site.

Two (2) planters were chosen to represent the range within which planter technologies were currently available for maize in Adamawa and environs. For the purpose of description, the two planters are referred to as (i) Parmiter Mechanical Planter, (ii) Monosem Pneumatic Planter, and all planters were adjusted to a depth of 5 cm, a row width of 76 cm and plant spacing of 10cm in between rows for both planters. The two Planting treatments of 7.20km/h and 11.30 km/h are chosen to represent low and high speed as reported by Weidong *et al*., (2004).

3.5 Tractor Wheel Slip

Wheel slippage was determined by operating the tractor across the field with the implement raised (no load) and secondly with the implement in the soil under load. The number of revolutions in the drive where counted for each runs as described by Gary (2001).

$$Slippage = \frac{(DWR_L - DWR_{NL})}{DWR_L} \times 100 \qquad 3.1$$

$where: Slippage = wheel\ slippage\ in$ %

$DWR_L = Drive\ wheel\ revolutions\ under\ land$

$DWR_{NL} = Drive\ wheel\ revolutions, no\ load$

3.6 Determination of Power Requirement

In order to calculate the power exerted by the tractor, the following observations have been taken:

a. Average draught from the dynamometer reading (N)

b. Distance moved by the implement (m).

c. Time taken by the implement to cover the above distance (second).

Power (P) developed by the power unit (tractor) was calculated as:

$$Draw - bar\ power\ = \frac{P \times V}{3.6}\ \ kW \qquad 3.2$$

(Onwualu et al 2006)

$Where;$
$P\ =\ drawbar\ pull\ (KN)$
$V\ =\ forward\ speed\ (Km/h)$

$$P\ =\ k\ x\ a\ x\ b$$

$Where;$
$k\ =\ specific\ soil\ resistance\ (KN/m^2)$
$a\ =\ depth\ (cm)$
$b\ =\ width\ of\ cut\ (m)$

3.7 Soil Physical Properties.

The soil properties which were considered before and after treatment application included: Soil particle size analysis, Soil moisture content, Bulk Density, Penetration resistance (Cone Index).

3.7.1 Soil Particle Size Analysis.

Soil Particle size analysis was carried out using the hydrometer method following the procedure of Lambe (1951). The sample were collected on each plot before and after tillage application and then oven dried for 24 hours (one day) at 104℃. The sample was grounded to pass through set of sieves to determine soil Particle size distribution results are shown in Table 3.5.

3.7.2 Soil Penetration (Cone Index).

Soil penetration resistance was measured using an analogue penetrometer. The penetrometer tip having a 60° cone, Penetrometer measurements were taken in various depth, in increments of 0 to 5 cm, 5 to 10 cm, 10 to 15 cm, 15 to 20 cm, 20 to 25 cm, and 25 to 30 cm at random with Three (3) replications in each plot before and after tillage application, the results of which are shown in Tables.3.5.

3.7.3 Bulk Density

Bulk density was determined by carrying an intact core sample as described by Blake and Hartage (1986) at a depth of 0 – 20cm to be taken from each Plot before and after tillage application. Core samples were oven dried in Laboratory at $105^{o}C$ for 48 hours. Then bulk densities of the soil samples were determined using the following relationship shown in equation 3.3 and result are in Table 3.5

From $$\rho_b = \frac{M_d}{\pi r^2 h} \quad 3.3$$

$where$:

$\rho_b = \ Bulk\ Density\ (kg/cm^3.$

$M_d\ = mass\ of\ oven\ dried\ sample.$

$\pi = 3.142.$

$r = radius\ of\ the\ Auger\ (cm).$

$h = height\ of\ Auger\ (cm).$

3.7.4 Soil Moisture Content

The soil moisture content was determined before and after treatment application at 0 – 20cm depth of sample for each plot. Moisture content was calculated using gravimetric method. Using the equation 3.4 and result presented in Table 3.5

$$mc(\%) = \frac{M_{wt} - D_{wt}}{D_{wt}} \qquad 3.4$$

$mc = moisture\ content\ (\%).$

$M_{wt} = weight\ of\ moist\ soil\ (kg).$

$D_{wt} = weight\ of\ dry\ soil\ (kg).$

The moisture content was measured on the experimental site when the soil moisture content was on wet basis.

3.8 Tillage Depth

The tillage implement was adjusted to a depth 15 cm which is a moderate deep tillage within the range of 15-20 cm is required for maize as reported by Hunsjak *et al*.,

Table 3.5: Soil physical characteristics of the Experimental Site before and after tillage treatment were applied.

Soil physical properties	Before tillage	After tillage
Sand (%)	32.60	32.60
Silt (%)	30.00	30.00
Clay (%)	37.40	37.40
Texture	Clay-loam	Clay-loam
Mean Bulk density (g/cm^3) for CT.	1.35	1.02
Mean Bulk density (g/cm^3) for RT.	1.31	1.11
Mean Bulk density (g/cm^3) for MT.	1.37	1.20
Mean Bulk density (g/cm^3) for NT.	1.24	1.24
Mean Soil moisture content before tillage CT(%).	17.10	16.10
Mean Soil moisture content RT(%).	17.30	16.90
Mean Soil moisture content MT (%).	17.70	17.50
Mean Soil moisture content NT(%).	17.80	17.80
Mean Cone Index for CT (MPa)	1.31	1.02
Mean Cone Index for RT(MPa)	1.21	1.11
Mean Cone Index for MT(MPa)	1.50	1.43
Mean Cone Index for NT(MPa)	1.62	1.63

Source: (field test)

3.9 Seedling Emergence.

Plant emergence was recorded by daily counting the number of emerged plant in randomly selected rows of each sub-subplot which commenced seven (7) days after Planting and the counting continued for the next thirty (30) days. Maize emergence rate was counted for several days at each plot during at emergence date (MED) in four (4) rows.

The emergence rate index (ERI) was calculated directly from emergence counts as follows (Nasr and Selles, 1995; Carman, 1997; Mohanty and Painuli, 2004): as shown in equation 3.5

$$MED = \frac{N_1.D_1 + N_2.D_2 + \cdots + N_n D_n}{N_1 + N_2 + \cdots + N_n} \quad 3.5$$

$$ERI = \frac{Total\ Number\ of\ emerged\ plant}{MED} \quad 3.6$$

Where $N_1, N_{2\ldots\ldots}N_n =$ The increase in the number of newly emerged plant stems compared with the previous count. As in equation 3.6

$D_{1\,,}D_{2\ldots\ldots\ldots}D_n\ =$ Number of days after planting.

3.10 Yield.

The crop was harvested from each plot of 3.0m × 4m when the grains were matured and dry and then sun dried to reduce the moisture content. The grains were separated from the stalk by threshing manually and the weight measured and converted to tonne per hectare. The yield per plot was subjected to analysis of variance as shown in Table 4.7

3.11 Plant Heights

Heights of 20 randomly selected plants from each plot were measured at 10, 20, and 30 days after seedling emergence using a meter rule from point of emergence to emergence after 30 days and mean plant height was obtained for each plot. The Plant height was subjected to analysis of variance as shown in Table 4.1

3.12 Statistical Analysis

Analyses of variance for a split-split plot design were performed All treatment factors in the experiments were considered as fixed effects with the locations, and blocks were treated as random effects. To determine the mean effect between treatments, mean comparison was performed using Duncan Multiple Range Test (DMRT) comparisons. Linear Correlation was performed to determine the relationship between plant height, spacing, emergence rate indices (ERI), and Mean Emergence date (MED), and grain yield. Multiple linear correlations were also performed for yield and plant height, spacing, emergence rate index (ERI), Mean Emergence date (MED).

CHAPTER FOUR
RESULT AND DISCUSSION

4.1 Effect of Planter Type, Planting speed, and Tillage on Plant Height

The results of plant height as affected by planter type, planting speed and tillage obtained was subjected to analysis of variance (ANOVA) in Table 4.1 below. The analysis shows, the effect of the whole treatment on plant height in the main plot, sub plot and the sub-sub plot factors and their interactions at both at 5% level significance.

Considering the main plot factors in the table, tillage (T), was highly significant this is because Soil tillage is among the important factors affecting soil physical properties and crop yield. Among the crop production factors, tillage contributes up to 20% (Khurshid *et al.*, 2006). The sub plot analysis also shows that the planter type (P) is also significant at 5% level and the interactions effects between Tillage system and Planter type (T×P) was not significant at 5% levels. Considering the sub-sub plot factors, planter speed (PS) was highly significant. The effects of interactions between Tillage and planter speed (T×PS), planter type and planting speed (P×PS) was also significant at 5% levels mean while the three (3) factor interaction between tillage system, planter type, speed of planting (T×P×PS) was significant at P< 0.05 as shown in the analysis table 4.1.

Table 4.1: Analysis of variance (ANOVA) for Plant Height (cm) in Maize

Source of Variation	Df	SS	MS	Com. F	Tab-F 5%
Main plot analysis					
Replication	2	10.91	5.45		
Tillage(T)	3	22.22	7.41	6.91**	4.76
Error(t)	6	6.44	1.073		
Sub-plot analysis					
Planter(P)	1	113.47	113.47	42.00**	5.32
T*P	3	6.17	2.06	<1	-
Error(p)	8	21.61	2.70		
Sub-sub plot analysis					
Planter speed(PS)	1	11.41	11.41	9.08**	4.49
T*PS	3	13.70	4.57	3.63*	3.24
P*PS	1	18.75	18.75	14.92**	4.49
T*P*PS	3	2.09	0.70	<1	-
Error (ps)	16	20.11	1.26		
Total	47	246.87			

***highly significant, *significant, ns not significant, T tillage, planter, PS planting speed.*

The mean data for plant height were subjected to mean separation using the Duncan Multiple range test (DMRT) at 5% level of probability. Table 4.2 presented below shows the Duncan's Multiple Range Test for plant Height, Mean emergence date, Emergence rate Index, with in row spacing, and yield in columns. The letters a, b, c… and z indicates the level of significance of each treatment at 5% level of significance ($P<0.05$). From the table, plant height decreases from the highest mean to the lowest mean in descending order indicated with alphabets . Treatment means with the same letter are not significantly different at $P< 0.05$. And the effects of planter type, planter speed, and Tillage system were significant at $P<0.05$

However, comparing the mean plant height of treatments with Duncan's Multiple Range Tests (DMRT), Table 4.2 shows that, the treatments mean with the same letter are not significantly different. The treatment combination of conventional tillage (CT), Monosem Pneumatic planter (MPP), and planter forward speed of 11.30km/h (S_2) recorded the highest Plant height, with mean height of 56.80cm and the treatment was indicated with letter "**a**" but it did not show significant difference with mean height of 55.80cm with treatment combination of reduced tillage (RT), Monosem Pneumatic Planter (MPP), and planter forward speed of 7.20km/h (S_1) also indicated by "**a**". The next mean plant height based on ranking is 55.47cm labeled with "**ab**" with treatment combination of reduced tillage (RT), Monosem pneumatic planter, and planter forward speed of 11.30km/h (S_2), followed by 54.23cm indicated by "**bc**", followed by treatment combination of No tillage, Monosem pneumatic planter and forward speed of 7.20km/h (S_1) indicated by "**bcd**" and is 54.13cm.

53.63cm is the next mean height and is a treatment combination of reduced tillage, Parmiter planter and 7.20km/h planter forward speed (S_1) but did not show significant difference at $p<0.05$ with treatment combination of minimum tillage (MT), Monosem planter (MPP), and forward speed of 7.20km/h (S_1) and they are indicated with "**cd**", followed by treatment combination of No tillage, Monosem planter and 11.30km/h forward speed with mean height of 53.47cm labeled with "**cde**". The next is 52.63cm mean height indicate with "**def**" with a treatment combination of conventional tillage system (CT), 7.20km/h planter forward speed (S_1) and Parmiter planter (PMP). The treatment combination of minimum tillage (MT), Parmiter planter (PMP) and a planting forward speed of 7.20km/h (S_1) with mean height of 52.06cm indicated by "**ef**". The mean heights of 51.80cm, 51.73cm and 51.53cm with treatment of No tillage (NT), Parmiter planter (PMP), 7.20km/h (S_1) planter speed, Parmiter planter (PMP), conventional tillage (CT), 7.20km/h forward speed (S_1) and conventional tillage, Parmiter planter (PMP), 11.30km/h forward speed (S_2) were not significantly different at 5% level of significance and all indicated by "f**g**". The next treatment in ranking is the combination of reduced tillage (RT), Parmiter planter (PMP) and forward planting speed of 11.30km/h (S_2) with mean height of 50.43cm indicated with "**gh**". The second lowest mean height is 49.60cm indicated with "**hi**"and treatment of No tillage, 7.20km/h planting speed and Parmiter mechanical Planter.

The treatment combination of No tillage (NT), Parmiter mechanical planter and the 11.30km/h planter forward speed of (S_2) recorded the lowest mean height of 48.90cm indicated by latter "**i**".

Table 4.2. Mean Values for Effect of Planter Types, Planting Speed and Tillage on Plant Height, Mean Emergence Date, Emergence Rate Index, and Plant Spacing and Yield Using Duncan Multiple Range Test (DMRT)

S/N	Treatment	Plant Height (cm)	MED(days)	ERI(days)	Spacing(Cm)	Yield (t/h)
1	**CT×PMP×S_1**	52.fg	13.24ef	11.40fg	10.57ab	4.83cd
2	**RT×PMP×S_1**	54cd	13de	13.48c	10.64a	5.06bcd
3	**MT×PMP×S_1**	52ef	13de	10.70h	10.41ab	4.82cd
4	**NT×PMP×S_1**	52fg	14.cd	13.40c	10.64a	5.74ab
5	**CT×MPP×S_1**	52.63def	14cd	11.gh	10.64a	5.28bcd
6	**RT×MPP×S_1**	56a	13ef	12ef	10.17ab	5.30bcd
7	**MT×MPP×S_1**	54cd	14bc	11g	10.59ab	4.96bcd
8	**NT×MPP×S_1**	54bcd	13ef	12d	10.25ab	5.39bc
9	**CT×PMP×S_2**	51fg	14ab	13d	10.59ab	4.60d
10	**RT×PMP×S_2**	50.gh	13g	15ab	10.49ab	5.07bcd
11	**MT×PMP×S_2**	49i	14.a	12ef	10.41ab	4.52d
12	**NT×PMP×S_2**	50hi	13g	15a	10.64a	5.23bcd
13	**CT×MPP×S_2**	57a	13cd	11fg	10.09b	6.25a
14	**RT×MPP×S_2**	55ab	13f	14b	10.09b	5.73ab
15	**MT×MPP×S_2**	54bc	14cd	11fg	10.18ab	5.51bc
16	**NT×MPP×S_2**	53cde	13f	15ab	10.09b	5.18bcd

Source: Field test

Means with the same letter are not significantly different using Duncan multiple range test (DMRT) at $p \geq 0.01$, CT convetional tillage, RT reduced tillage, MT minimum tillage, NT no tillage MED mean emergence date, ERI emergence rate index, MPP Monosem pneumatic planter, PMP parmiter mechanical planter, S_1 planter speed at 7.20km/h, S_2 planter speed at 11.30km/h. a,b,c,d....... shows the separation of mean based on 5% level of significance. Means with same letters are not significantly different.

A linear correlation between plant height and yield, shows the linear correlation models equation 4.1 below within a range of 48.90cm - 53.60cm and correlation model equation 4.2 within a range of 52.60cm - 56.10cm for both Monosem pneumatic planter (MPP) and Parmiter mechanical planter (PMP), at all combinations from table 4.10.

$$\boldsymbol{y = 2.26 + 0.050h_1} \quad 4.1$$

$$\boldsymbol{y = -1.17 + 0.121h_2} \quad 4.2$$

$where,$

$y = yieild$ (t/h).

$h_1 = height\ for\ parmiter\ mechanical\ planter\ (cm)$

$h_2 = height\ for\ Monosem\ Pnuematic\ planter (cm).$

Similarly, the correlation coefficient $\mathbf{r = 0.02, 0.34}$ for both the two (2) planter and the treatment combination were both not significant in relation to mean plant height because the value of the calculated coefficient 0.02, 0.34(**r-calculated)** is less than the tabular correlation coefficient(**r- tabular)** which shows that the correlation coefficient under plant height for all treatment combinations were not significant as shown in Table 4.3.

Table 4.3 Linear correlations for effect of planter type, planting speed and tillage on plant height, spacing, emergence rate index, and mean emergence date.

Planter	Independent Variable	Y Intercept	Slope	R	r^2
(PMP) Parmiter Mechanical planter	HT(48.9-53.6CM)	2.26	0.05	0.02	0.04
	SP(10.3-10.6CM)	16.23	2.01	0.58**	0.34
	ERI(10.7-11.7d)	7.98	0.26	0.86**	0.74
	MED(13.2-1313.9d)	1.54	0.25	0.89**	0.79
(MPP) Monosem Pneumatic Planter	HT(52.6-56.10CM)	1.17	0.12	0.34**	0.12
	SP(10.0-10.6CM)	15.38	0.97	0.06	0.30
	ERI(11.9-14.8d)	2.44	0.22	0.98**	0.96
	MED(12.9-13.5d)	25.79	1.54	0.96**	0.92

Source: Field test

HT plant height,SP spacing, ERI emergence rate Index, MED mean emergence date** significant.

Linear Correlation graph as shown in Fig 4.1(a) and Fig 4.1(b) shows a linear correlation relation between maize plant height and yield for both Monosem pneumatic planter (MPP) and Parmiter mechanical planter (PMP) with the treatment combinations of tillage systems and planter speed levels. The graph shows that there is a direct correlation relationship between plant height and yield, as the plant height increases the yield also increases with regards to relationship between variables observed.

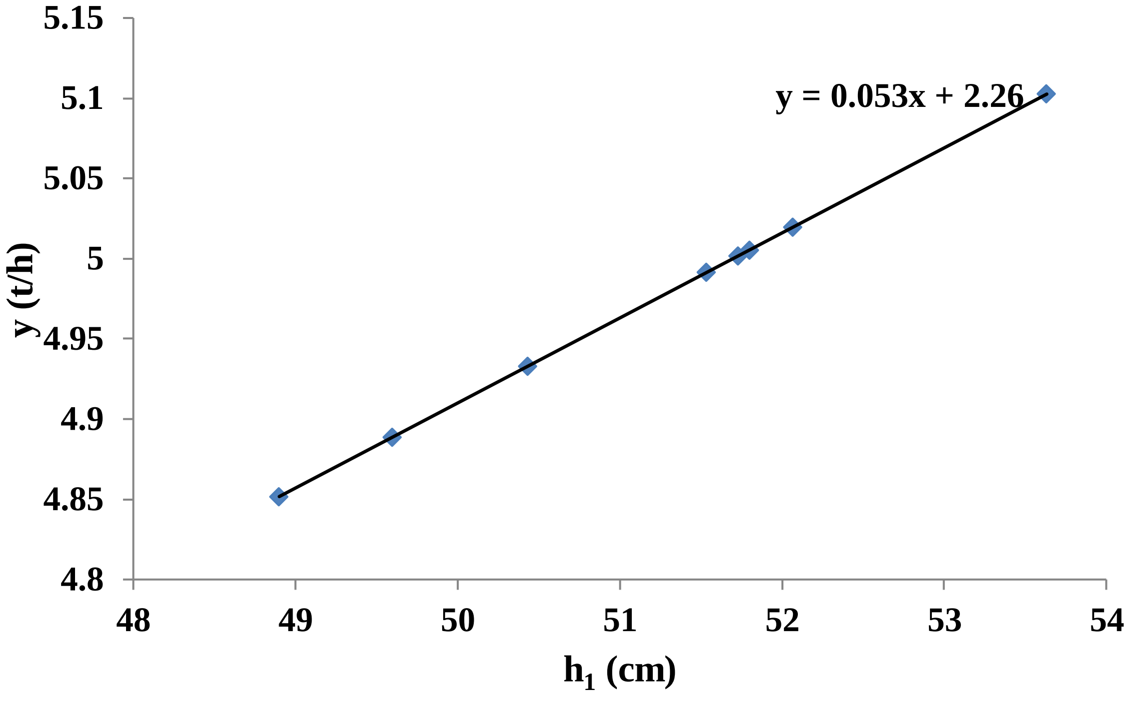

Fig 4.1: Linear Relationship between Yield and plant height for Parmiter planter.

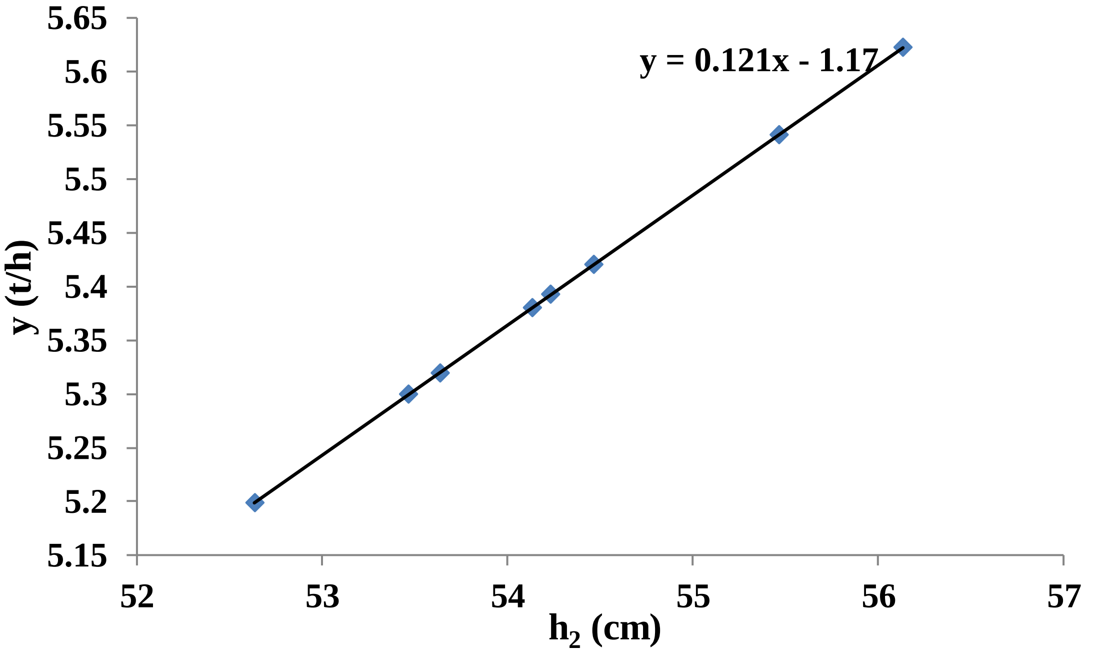

Fig 4.1b: Linear Relationship between Yield and plant height for Monosem planter.

4.2 Effect of Planter Type, Planting speed, and Tillage on mean emergence date (MED)

Table 4.4 shows the analysis of variance (ANOVA) table for the effects of planter type, planter forward planting speed and tillage system on mean emergence date (MED). Considering tillage system (T) the main plot factors in the table, which shows the tillage was significant at $P<0.05$ level of significance. This is because Soil tillage is among the important factors affecting soil physical properties and crop yield. Among the crop production factors, tillage contributes up to 20% (Khurshid *et al.*, 2006). The sub plot analysis also shows that the planter type (P) is also significant at 5% level and the interactions effects between Tillage system and Planter type (T×P) was not significant at 5% level. Considering the sub-sub plot factors, planter speed (PS) was highly significant. The effects of interactions between Tillage and planter speed (T×PS) was not significant at 5% level of significance. While the interaction between planter type and planting speed (P×PS) was significant at 5% levels. Similarly the three way (3) factor interaction between tillage systems (T), planter type (P), and forward speed of planting (T×P×PS) was significant at $P< 0.05$ as shown in the analysis table below.

Table 4.4: Analysis of Variance (ANOVA) for Mean Emergence Date (MED) in Maize

Source of Variation	df	SS	MS	Com. F	Tab-F 5%
Main plot analysis					
Replication	2	0.43	0.21		
Tillage(T)	3	4.60	1.53	178.64**	4.76
Error(t)	6	0.052	0.0086		
Sub-plot analysis					
Planter(P)	1	63.58	63.58	1824.76**	5.32
T*P	3	1.72	0.57	16.44**	4.07
Error(p)	8	0.28	0.035		
Sub-sub plot analysis					
Planter speed(PS)	1	18.21	18.21	200.69**	4.49
T*PS	3	0.101	0.034	<1	-
P *PS	1	4.466	4.47	49.21**	4.49
T*P*PS	3	2.17	0.72	7.96**	3.24
Error (ps)	16	1.45	0.091		
Total	47	97.06			

Source: Field test.

***highly significant, *significant, ns not significant, T tillage, P planter, PS planting speed.*

The mean data for Mean emergence date were subjected to mean separation using the Duncan Multiple range test (DMRT) at 5% level of significance. Table 4.2 presented shows the Duncan's Multiple Range Test, Mean emergence date. The letters a, b, c… and z indicates the level of significance of each treatment at 5% level of significance ($P<0.05$). From the table, mean emergence date decreases from the highest mean to the lowest in descending order. Treatment means with the same letter are not significantly different at $P< 0.05$. And the effects of planter type, planter speed, and Tillage system were significant at $P<0.05$

However, comparing the mean emergence date of treatments with Duncan's Multiple Range Tests (DMRT), Table 4.2 shows that, the treatments mean with the same letter are not significantly different. The treatment combination of minimum tillage (MT), Parmiter planter (MPP), and planter forward speed of 11.30km/h (S_2) recorded the highest MED, with mean emergence date (MED) of 14days and the treatment was indicated with letter "**a**" with a significant difference with all subsequent MED. The next mean emergence date (MED) based on ranking is 14days labeled with "**ab**" with treatment combination of conventional tillage (CT), Parmiter mechanical planter (PMP), and planter forward speed of 11.30km/h (S_2), followed by 14days indicated by "**bc**" and significantly different from all other treatment combination at 5% level of significance, followed by treatment combination of conventional tillage, Monosem pneumatic planter and forward speed of 7.20km/h (S_1) indicated by "**cd**" and is 14days and there was no any significant difference with14days, then 14days, and 13days, with treatments combinations of No tillage (NT), Parmiter planter (PMP), 7.20km/h planter forward speed (S_1), then minimum tillage (MT), Monosem planter (MPP), and forward speed of 11.30km/h (S_1) then conventional tillage (CT), Monosem planter(MPP) and 11.30km/h forward speed. The next is 13days mean emergence date (MED) indicate with "**de**" with a treatment combination of reduced tillage system (RT), 7.20km/h planter forward speed (S_1) and Parmiter planter (PMP) and did not show any significant difference with 13days a combination of minimum tillage (MT), Parmiter planter (PMP) and a planting forward speed of 7.20km/h (S_1) at $p<0.05$. Mean emergence date (MED) of 13days is next in ranking indicated by "**ef**" without any significant difference with 13days with a treatment of No tillage (NT),Monosem Pneumatic planter (MPP), 7.20km/h (S_1) planter speed and 13days which has Parmiter planter (PMP), conventional tillage (CT), 7.20km/h forward speed (S_1) also indicated "**ef**". Treatment combination of reduced tillage (RT), Monosem Pneumatic Planter (MPP), forward speed of 11.30km/h (S_2) with mean emergence date of 13days has no significant difference at 5% level of significance with treatment of No tillage, Monosem planter (MPP), 11.30km/h forward speed (S_2) and MED of 13days both indicated with"**f**".   The mean emergence date (MED) of 13days is the next in mean ranking with Parmiter planter (PMP), reduced tillage system, (S_2).1130km/h forward speed and has not show any significant difference with last mean emergence date in ranking at $P<0.05$ and the last MED is 13days with combination of No tillage system, Parmiter mechanical planter (PMP) and 11.30km/h speed of planter which is indicated with "**g**".

A linear correlation between yield and mean emergence date (MED), shows the linear correlation models, equation 4.3 below within a range of 13.20days – 13.90days and correlation model, equation 4.4 within a range of 12.90days – 13.50days for both Monosem pneumatic planter (MPP) and Parmiter mechanical planter (PMP), at all combinations from table 4.10.

$$\boldsymbol{y = 1.54 + 0.25M_1} \qquad 4.3$$

$$\boldsymbol{y = 25.79 - 1.54M_2} \qquad 4.4$$

$where,$

$M_1 = Mean\ emergence\ date\ for\ parmiter\ mechanical\ planter\ (cm)$

$M_2 = Mean\ Emergence\ Datae\ for\ Monosem\ Pnuematic\ planter(cm).$

Similarly, the correlation coefficient $\mathbf{r = 0.89, 0.96}$ for both the two (2) planter and the treatments combination were both significant at 5% level of significance with relation to average mean emergence date because the value of the calculated coefficient 0.89, 0.96(**r-calculated)** is greater than the tabular correlation coefficient(**r- tabular)** which impliedly shows that the correlation coefficient under mean emergence date (MED) for all treatment combinations were significant at $P < 0.05$ as shown in Table 4.3 above.

Linear Correlation graph as shown in Fig 4.2(a) and Fig 4.2(b) shows a linear correlation relation between average Mean emergence date and yield for both Monosem pneumatic planter (MPP) and Parmiter mechanical planter

(PMP) with the treatment combinations of tillage systems and planter speed levels. The graph shows that there is a direct correlation relationship between plant height and yield, as the plant height increases the yield also increases with regards to relationship between variables observed.

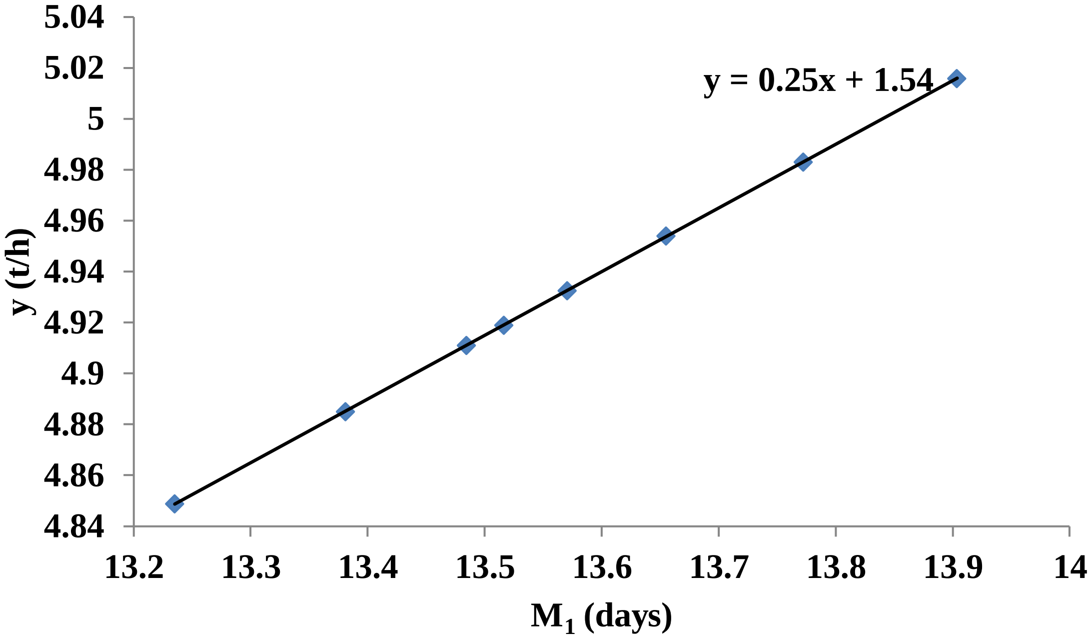

Fig4.2a: Linear correlation relationship between yield and MED for Parmiter Planter

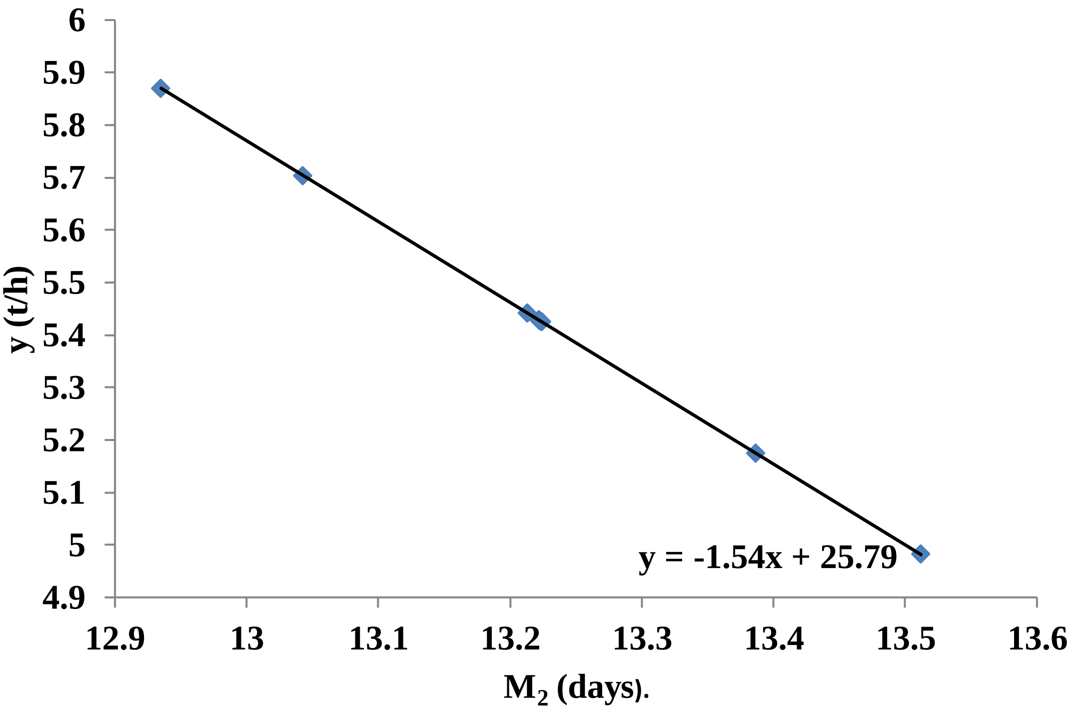

Fig4.2b: Linear correlation relationship between yield and MED for Monosem Planter.

4.3 Effect of Planter Type, Planting speed, and Tillage on mean Emergence rate Index (ERI)

The results of Emergence rate index (ERI) as affected by planter type, planting speed and tillage obtained were subjected to analysis of variance (ANOVA) in Table 4.5 below. The analysis shows, the effect of the whole treatment effects in the main plot, sub plot and the sub-sub plot factors and their interactions at both at 5% level significance.

Considering the main plot factors in the table, tillage (T), was highly significant these is because Soil tillage is among the important factors affecting soil physical properties and crop yield. Among the crop production factors, tillage contributes up to 20% (Khurshid *et al.*, 2006). The sub plot analysis also shows that the planter type (P) is also significant at 5% level and the interaction effects between Tillage system and Planter type (T×P) was significant at 5% level. Considering the sub-sub plot factors, planter speed (PS) was also highly significant. The effect of interactions between Tillage and planter speed (T×PS), was not significant while that of planter type and planting speed (P×PS) was significant at both 1% and 5% levels, mean while the three (3) factor interaction between tillage system, planter type, speed of planting (T×P×PS) was significant at $P < 0.05$ as shown in the analysis table below.

Table 4.5: Analysis of variance (ANOVA) for Emergence Rate Index (ERI) in Maize

SV	df	SS	MS	Com. F	5%
Main plot analysis					
Replication	2	0.67	0.34		
Tillage(T)	3	5.53	1.85	101.21**	4.76
Error(t)	6	0.11	0.018		
Sub-plot analysis					
Planter(P)	1	65.67	65.67	1225.64**	5.32
T *P	3	1.46	0.49	9.04**	4.07
Error(p)	8	0.43	0.05		
Sub-sub plot analysis					
Planter speed(PS)	1	19.63	19.63	189.21**	4.49
T* PS	3	0.26	0.09	<1	-
P*PS	1	3.83	3.83	36.8935**	4.49
T *P*PS	3	1.79	0.60	5.73899**	3.24
Error (ps)	16	1.67	0.11		
Total	47	101.03			

Source: Field test

***highly significant, *significant, ns not significant T tillage, planter, PS planting speed.*

The mean data for emergence rate Index (ERI) were subjected to mean separation using the Duncan Multiple range test (DMRT) at 5% level of significance. Table 4.2 presented above shows the Duncan's Multiple Range Test, Emergence Rate Index (ERI). The letters a, b, c… and z indicates the level of significance of each treatment at 5% level of significance ($P<0.05$). From the table above, emergence rate Index decreases from the highest mean to the lowest in descending order. Treatment means with the same letter are not significantly different at $P < 0.05$. And the effects of planter type, planter speed, and Tillage system were significant at $P<0.05$

However, comparing the mean emergence date of treatments with Duncan's Multiple Range Tests (DMRT), Table 4.2 above shows that, the treatments mean with the same letter are not significantly different. The treatment combination of zero or No tillage (MT), Parmiter planter (MPM), and planter forward speed of 11.30km/h (S_2) recorded the highest ERI, with an emergence rate Index (ERI) of 15days and the treatment was indicated with letter "**a**" with a significant difference with all subsequent ERI. The next emergence rate Index (ERI) based on ranking is 15days indicated with "**ab**" with treatment combination of reduced tillage (RT), Monosem pneumatic planter (MPP), and planter forward speed of 11.30km/h (S_2), followed by 15days indicated by "**ab**" and did not show any significantly different from the previous treatment combination at 5% level of significance with a combination of No tillage (NT), Parmiter mechanical Planter (PMP), and planting speed 11.30km/h followed by treatment combination of Reduced tillage, Monosem pneumatic planter and forward speed of 11.30km/h (S_2) indicated by "**b**" and with ERI of 14days and there was a significant difference from all the mean values ERI , then 13days, and 13days, with treatments combinations of Reduced tillage (RT), Parmiter planter (PMP), 7.20km/h planter forward speed (S_1), and No or zero tillage (NT), Parmiter planter (PMP), with forward speed of 7.20km/h (S_1) both indicated with "**c**" with no significant difference at 5% level followed by conventional tillage (CT), Parmiter planter (PMP) and 11.30km/h forward speed and No tillage (NT), pneumatic planter(MPP),7.20km/h forward speed and mean values of 13days and 12days labeled "**d**" with no significant different between them at5% level of significance. The next is 12days emergence rate index (ERI) both indicate with "**ef**" with no significant difference at 5% level with a treatment combination of reduced tillage system (RT), 11.30km/h planter forward speed (S_2), Pneumatic planter (MPP) and Minimum tillage (MT), 7,20km/h planting speed, Parmiter planter (PMP). Subsequently, the treatments conventional tillage (CT),Parmiter Mechanical Planter (PMP), forward speed of 7.20km/h, followed by minimum tillage (MT), Monosem pneumatic planter (MPP), planter speed of 11.30km/h, followed by conventional tillage (CT), monosem pneumatic planter (MPP), forward speed 11.30km/h gave ERI means of 11days, with no significant difference between them and indicated with "**fg**" at 5% level of significance,11days is the next mean value of emergence rate index labelled "**g**" with a significant difference with all other means having treatment of minimum tillage (MT), pneumatic planter (MPP), and 7.20km/h planter forward speed. The next mean is 11.days indicated with "**gh**" with combination of conventional tillage (CT), puematic planter (MPP) and planter speed of

7.20km/h with a clear significant difference with all the means at 5% level. Last ERI in ranking is the treatment of minimum tillage (MT), 7.20km/h speed and mechanical planter (PMP) with a mean ERI of 10days indicated with "**h**" with a clear significant difference with all other means.

A linear correlation between yield and emergence rate index (ERI) calculated and gave the linear correlation models in, equation 4.16 below within a range of 10.70days – 11.70days and correlation model, equation 4.17 within a range of 11.90days – 14850days for both Monosem pneumatic planter (MPP) and Parmiter mechanical planter (PMP), at all combinations from table 4.10 above.

$$\boldsymbol{y = 7.98 - 0.26E_1} \qquad 4.5$$

$$\boldsymbol{y = 2.44 + 0.22E_2} \qquad 4.6$$

$Where,$

$E_1 = Emergence\ rate\ Index\ for\ parmiter\ mechanical\ planter\ (cm)$

$E_2 = Emergence\ rate\ Index\ for\ Monosem\ Pnuematic\ planter (cm).$

Similarly, the correlation coefficient $\mathbf{r = 0.34\ , 0.68}$ for both the two (2) planter and the treatment combination were both significant at 5% level of significance in relation to average mean emergence rate index because the value of the calculated coefficient 0.34, 0.68(**r-calculated)** is greater than the tabular correlation coefficient(**r- tabular)** which impliedly shows that the correlation coefficient under emergence rate index (ERI) for all treatment combinations were significant at $P < 0.05$ as shown in Table 4.3 above.

Linear Correlation graph as shown in Fig 4.7(a) and Fig 4.7(b) shows a linear correlation relation between average emergence rate index and yield for both Monosem pneumatic planter (MPP) and Parmiter mechanical planter (PMP) with the treatment combinations of tillage systems and planter speed levels. The graph shows that there is an inverse correlation relationship between ERI and yield in the parmiter mechanical planter, as the ERI increases the yield also decreases with regards to relationship between variables observed.

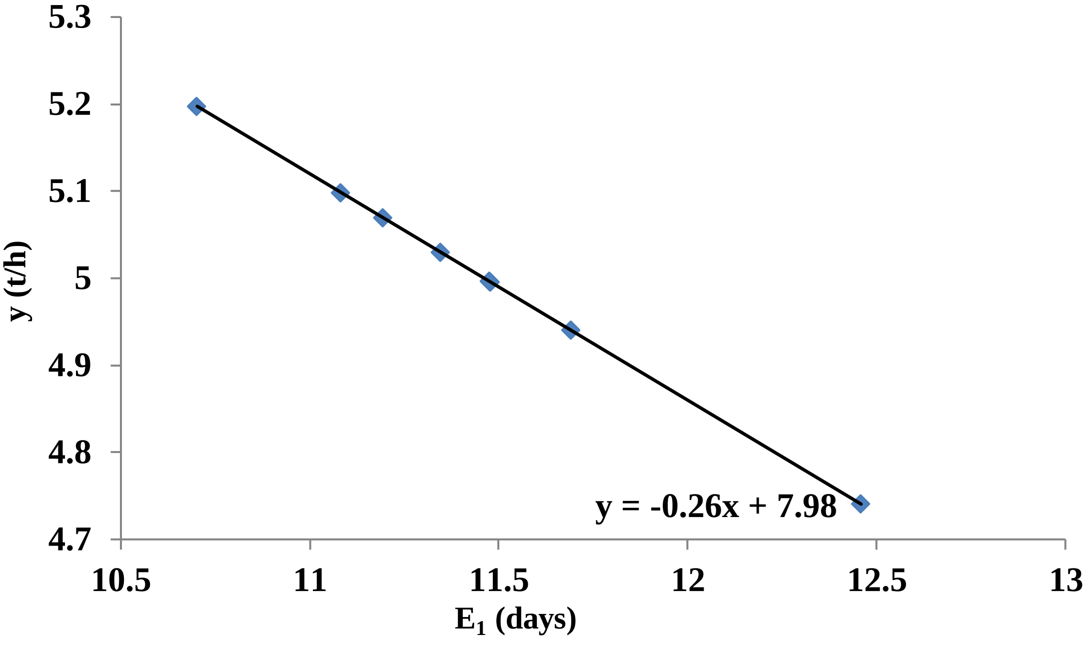

Fig 4.7a: Linear correlation relationship between yield and ERI for Parmiter Planter.

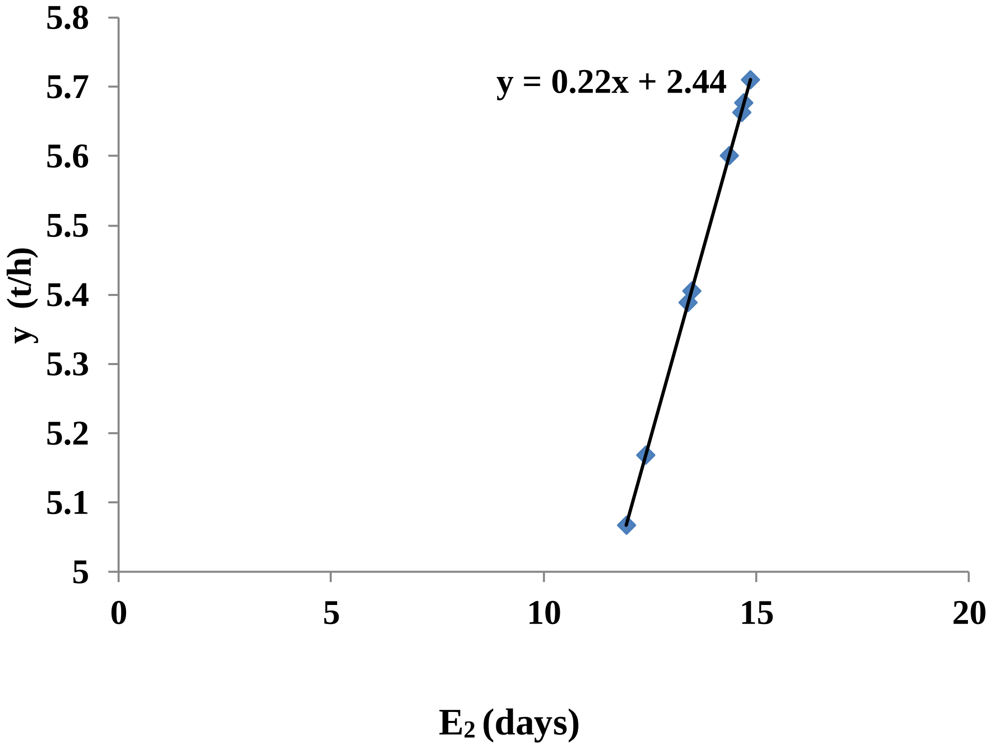

Fig4.7b: Linear correlation relationship between yield and ERI for Monosem Planter.

4.4 Effect of Planter Type, Planting speed, and Tillage on mean plant spacing.

The results of plant spacing as affected by planter type, planting speed and tillage obtained were subjected to analysis of variance (ANOVA) in Table 4.6 below. The analysis shows, the effect of the treatment and interaction effects in the main plot, sub plot and the sub-sub plot factors and their interactions at 5% level significance.

Considering the main plot factors in the table, tillage (T), was significant, these is because Soil tillage is among the important factors affecting soil physical properties and crop yield. Among the crop production factors, tillage contributes up to 20% (Khurshid *et al.,* 2006). The sub plot analysis also shows that the planter type (P) was also significant at 5% level and the interaction effects between Tillage system and Planter type (T×P) was significant not significant at both 5% level. Considering the sub-sub plot factors, planter speed (PS) was also significant. The effect of interactions between Tillage and planter speed (T×PS), was not significant while that of planter type and planting speed (P×PS) was not significant at both 5% level of significance. Similarly, the three (3) factor interaction between tillage system, planter type, and speed of planting (T×P×PS) was not significant at P<0.05 as shown in the analysis table below.

Table 4.6: Analysis of variance (ANOVA) for Plant Spacing (cm) in Maize

SV	D*f*	SS	MS	Com. F	5%
Main plot analysis					
Replication	2	0.47	0.233		
Tillage(T)	3	0.099	0.333	6.66*	4.76
Error(t)	6	0.30	0.0500		
Sub-plot analysis					
Planter(P)	1	0.94	0.935	12.10**	5.32
T*P	3	0.45	0.549	7.13*	4.07
Error(p)	8	0.62	0.077		
Sub-sub plot analysis					
Planter speed(PS)	1	0.30	0.397	5.43*	4.49
T*PS	3	0.054	0.018	<1	3.24
P*PS	1	0.25	0.346	4.74*	4.49
T*P*PS	3	0.20	0.265	3.63*	3.24
Error (ps)	16	1.17	0.073		
Total	47	4.84			

Source: Field test

***highly significant, *significant, ns not significant T tillage, planter, PS planting speed.*

The mean data for plant spacing were subjected to mean separation using the Duncan Multiple range test (DMRT) at 5% level of probability. Table 4.2 presented above shows the Duncan's Multiple Range Test for plant Height, Mean emergence date, Emergence rate Index, with in row spacing, and yield in columns. The letters a, b, c… and z indicates the level of significance of each treatment at 5% level of significance ($P<0.05$). From the table, plant spacing decreases from the highest mean to the lowest mean in descending order indicated with alphabets. Treatment means with the same letter are not significantly different at $P< 0.05$. And the effects of planter type, planter speed, and Tillage system were significant at $P<0.05$

However, comparing the mean plant spacing of treatments with Duncan's Multiple Range Tests (DMRT), Table 4.2 above showed that, the treatments mean with the same letter are not significantly different. The first four highest Plant spacing, with mean spacing of 10.64cm and treatment indicated with letter "**a**" with The treatment combination of no tillage (NT), Parmiter mechanical planter (PMP), planter forward speed of 7.20km/h (S_1) followed by Reduced Tillage (RT), mechanical planter (PMP),speed of 7.20km/h followed by no tillage (NT), mechanical planter (PMP), planting speed of 11.30km/h, and then conventional tillage (CT), Pneumatic planter (MPP), 7.20km/h forward speed and there no any significant difference among the highest mean spacing treatments at 5% level of significance. The next spacing's are 10.59cm, 10.59cm, 10.57cm,10.49cm, 10.41cm, 10.40cm, 10.25cm, 10.18cm, and 10.16cm all indicated with "**ab**" with no significant difference at 5% level of significance with treatment combination of conventional tillage (CT), mechanical planter (PMP), forward speed 11.30km/h followed by minimum tillage (MT), pneumatic planter (MPP),7.20km/h planter speed then conventional tillage (CT),mechanical planter (PMP),7.20km/h planter forward speed followed by reduced tillage (RT), mechanical planter (PMP),forward speed of 11.30km/h then minimum tillage (MT), mechanical planter (PMP),11.30km/h forward speed followed by minimum tillage (MT), Pneumatic planter (MPP),planter speed of 7.20km/h then no tillage (NT),monosem pneumatic planter (MPP),planting speed of 7.20km/h followed by MT, MPP,11.30km/h and then reduced tillage (RT), pneumatic planter (MPP), 7.20km/h planting speed and lowest mean plant spacing where treatment combination of reduced tillage (RT),pneumatic planter (MPP), planting speed of 11.30km, followed by conventional tillage (CT),pneumatic planter (MPP), 11.30km/h planter forward speed and no tillage (NT), pneumatic planter (MPP),planter speed of 11.30km/h indicated with "**b**".

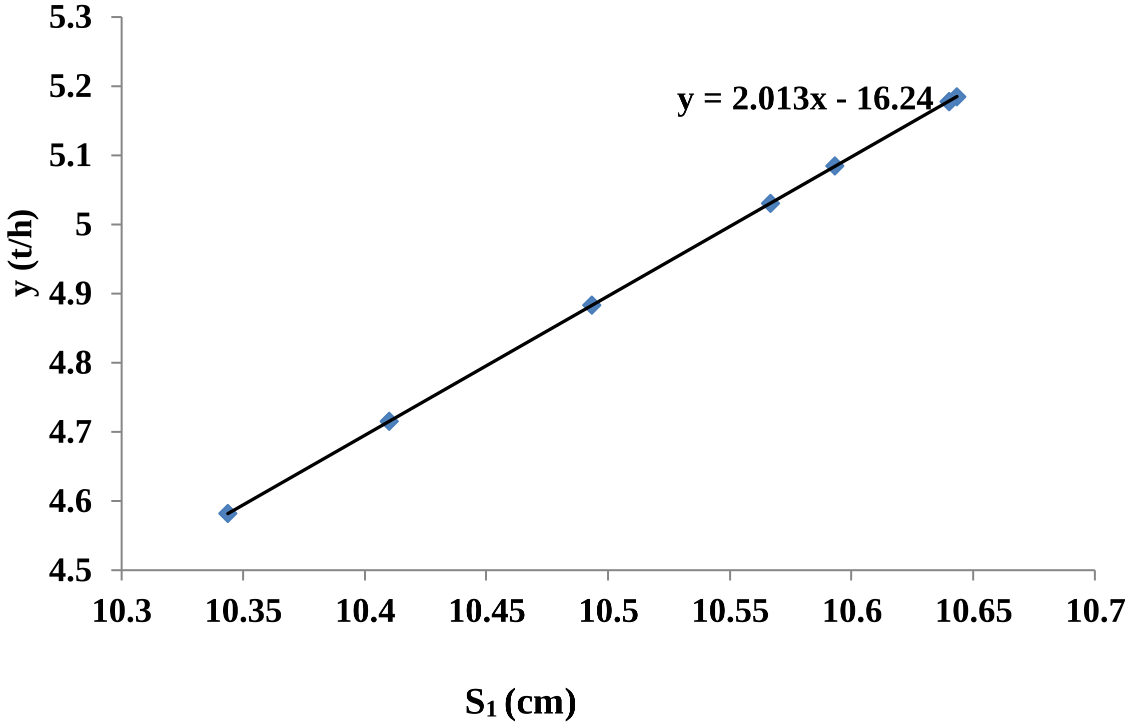

Fig 4.4b: Linear correlation relationship between yield and spacing for Parmiter Planter.

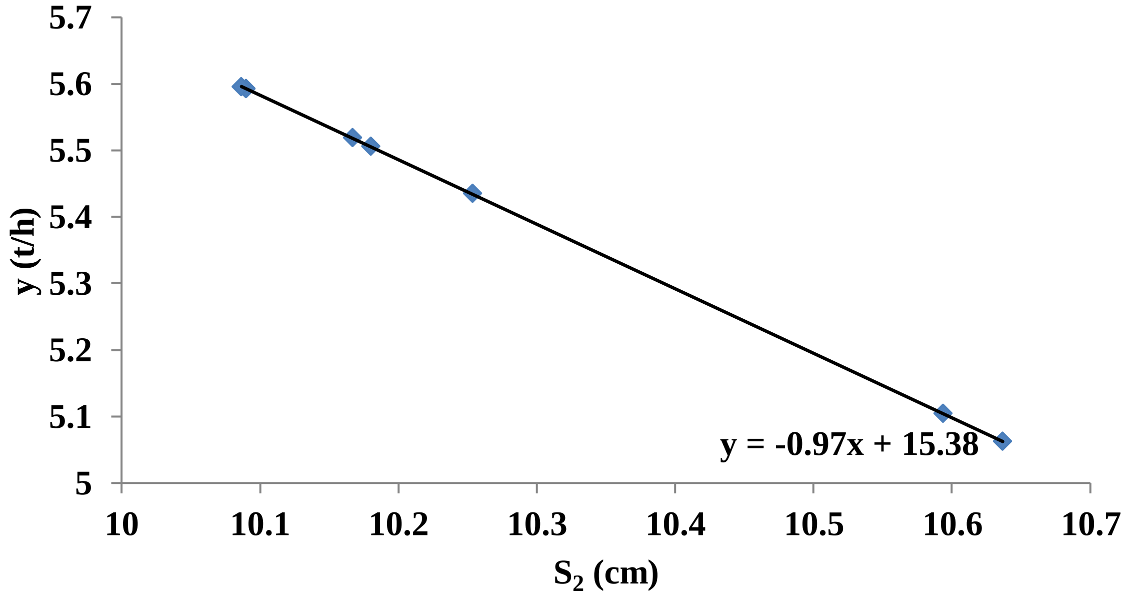

Fig. 4.4b: Linear correlation relationship between yield and spacing for Monosem Planter.

A linear correlation between yield and plant spacing calculated and it gave the linear correlation models in, equation 4.7 below within a range of 10.00cm – 10.60cm and correlation model, equation 4.8 within a range of 10.00cm – 10.60cm for both Monosem pneumatic planter (MPP) and Parmiter mechanical planter (PMP), at all combinations from table 4.10 above.

$$\boldsymbol{y = -16.24 + 2.013S_1} \quad 4.7$$

$$\boldsymbol{y = 15.38 - 0.970S_2} \quad 4.8$$

$Where,$

$S_1 = plant\ spacing\ for\ parmiter\ mechanical\ planter\ (cm)$

$S_2 = plant\ spacing\ for\ Monosem\ Pnuematic\ planter(cm)$

Similarly, the correlation coefficient **r** $= \mathbf{0.59}$, for parmiter mechanical planter was significant at 5% level while correlation coefficient **r** $= \mathbf{0.06}$, for Monosem pneumatic plant was not significant at 5% level of in relation to average mean spacing because the value of the calculated coefficient , 0.59(**r-calculated)** is greater than the tabular correlation coefficient(**r-tabular)** which impliedly shows that the correlation coefficient under Parmiter mechanical planter treatment combinations were significant at $P < 0.05$ as shown in Table 4.3 above.

Linear Correlation graph as shown in Fig 4.4(a) and Fig 4.4(b) shows a linear correlation relation between average spacing and yield for both Monosem pneumatic planter (MPP) and Parmiter mechanical planter (PMP) with the treatment combinations of tillage systems and planter speed levels. The graph showed that there is an inverse correlation relationship between spacing and yield in the parmiter mechanical planter, as the spacing increases the yield also decreases with regards to relationship between variables observed and a direct correlation relationship between spacing and yield in the monosem pneumatic planter, as the spacing increases the yield also increases with regards to relationship between variables observed.

The within plant spacing for the treatment combination on direct measurement on the field are shown in appendix 1, it showed that, the most suitable spacing in all the treatment combinations where 10.09cm, 10.06cm, 10.03cm, 10.05cm and all the combination are related with monosem pneumatic planter which shows that the MPP has a more precision spacing than the PMP but generally the spacing did not show much significant difference on the raw data as shown in appendix 1.but even with the DMRT after mean separation did not show much significant difference.

4.5 Effect of Planter Type, Planting speed, and Tillage on mean yield.

The results of average estimated plant yield as affected by planter type; planting speed and tillage obtained were subjected to analysis of variance (ANOVA) as shown in Table 4.7. The analysis shows, the effect of the treatment effects in the main plot, sub plot and the sub-sub plot factors and their interactions at 5% level of significance.

Considering the main plot factors in the table, tillage (T) was significant, these is because Soil tillage is among the important factors affecting soil physical properties and crop yield. Among the crop production factors, tillage contributes up to 20% (Khurshid *et al.*, 2006). The sub plot analysis also shows that the planter type (P) was significant at 5% level and the interaction effects between Tillage system and Planter type (T×P) was significant. Considering the sub-sub plot factors, planter speed (PS) was not significant which did not agree with the result of Nafziger (1996). This is because at high speed the seeds tend to flick out of the furrow line. The effect of interactions between Tillage and planter speed (T×PS), was not significant while that of planter type and planting speed (P×PS) was highly significant. Similarly, the three (3) factor interaction between tillage system, planter type, and speed of planting (T×P×PS) was significant at $P<0.05$ as shown in the analysis table below.

Table 4.7: Analysis of variance (ANOVA) for Yield for Maize (t/h)

SV	dF	SS	MS	Com. F	5%
Main plot analysis					
Replication	2	0.17	0.084		
Tillage(T)	3	1.31	0.72	4.80*	4.76
Error(t)	6	0.75	0.15		
Sub-plot analysis					
Planter(P)	1	2.57	2.57	8.96*	5.32
T * P	3	2.50	1.43	4.93*	4.07
Error(p)	8	2.29	0.29		
Sub-sub plot analysis					
Planter speed(PS)	1	0.096	0.096	<1	-
T*PS	3	0.96	0.32	2.93^{ns}	3.24
P*PS	1	1.31	1.31	11.95**	4.49
T*P*PS	3	0.40	0.51	4.64*	3.24
Error (ps)	16	1.75	0.11		
Total	47	14.11			

Source: Field test

***highly significant, *significant, ns not significant T tillage, planter, PS planting speed.*

The mean data for average plant yield were subjected to mean separation using the Duncan Multiple range test (DMRT) at 5% level of probability. Table 4.2 presented above shows the Duncan's Multiple Range Test for plant Height, Mean emergence date, Emergence rate Index, with in row spacing, and yield in columns. The letters a, b, c… and z indicates the level of significance of each treatment at 5% level of significance ($P<0.05$). From the table, mean yield decreased from the highest mean to the lowest mean in descending order indicated with alphabets. Treatment means with the same letter are not significantly different at $P< 0.05$. The effects of planter type, planter speed, and Tillage system were significant at $P<0.05$

However, comparing the mean plant spacing of treatments with Duncan's Multiple Range Tests (DMRT), Table 4.2 above showed that, the treatments mean with the same letter are not significantly different. The highest mean yield was6.25t/h and indicated with letter "**a**" the proceeding treatment are 5.74t/h and 5.73t/h with The treatment combinations of no tillage (NT), par miter mechanical planter (PMP), planter forward speed of 7.20km/h (S_1) and Reduced Tillage (RT), pneumatic planter (PPM),speed of 11.30km/h both indicated with "**ab**" with no significant difference followed by treatments combination of minimum tillage (MT), Pneumatic planter (MPP), 11.30km/h forward speed and no tillage (NT), Pneumatic planter (MPP), planting speed of 7.20km/h, indicated both with "**cb**" with mean yield of 5.51t/h and 5.39t/h without any significant difference then 5.30t/h, 5.28t/h, 5.23t/h, 5.10t/h, 5.07t/h, 5.06t/h, 4.96t/h all indicated with "**bcd**" Reduced Tillage (RT), Pneumatic planter (MPP), planter forward speed of 7.20km/h (S_1), then conventional tillage (CT), Pneumatic planter (MPP), 7.20km/h forward speed(S_1), followed by no tillage (NT), par miter mechanical planter (PMP), planter forward speed of 11.30km/h (S_2), then no tillage (NT), Pneumatic planter (MPP), planter forward speed of 11.30km/h (S_2) followed by Reduced Tillage (RT), par miter mechanical planter (PMP), planter forward speed of 11.30km/h (S_2), Reduced Tillage (RT), par miter mechanical planter (PMP), planter forward speed of 7.20km/h (S_1), then minimum tillage (MT), Pneumatic planter (MPP), planter forward speed of 7.20km/h (S_1) the next treatments are conventional tillage (CT), parmiter mechanical planter (PMP), planter forward speed of 7.20km/h (S_1) and minimum tillage (MT), parmiter mechanical planter (PMP), planter forward speed of 7.20km/h (S_1) with mean yield of 4.83t/h and 4.82t/h indicated with **"cd"** showing no significant difference between them. The treatment that recorded the lowest yield are combination of conventional tillage (CT), parmiter mechanical planter (PMP), planter forward speed of 11.30km/h (S_2) and minimum tillage (MT), parmiter mechanical planter (PMP), planter forward speed of 11.30km/h (S_2) with yield value of 4.60t/h and 4.52t/h indicated with alphabet **"d"** with no significant difference between them

The multiple linear correlation subjected to the data to obtain a model relating the yield and all other parameters considered gave a linear model and is given as;

$$yield = -3.87 + 0.134\boldsymbol{h} - 0.0053\boldsymbol{M} + 0.076\boldsymbol{E} + 0.106\boldsymbol{S} \qquad 4.9$$

$where,$

$h = plant\ heigh\ in\ cm$

$M = mean\ emergence\ date\ in\ days$

$E = emergence\ rate\ index\ in\ days$ and $S = plant\ spacing\ in\ cm$

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary

Maize is an important crop grown under semi – arid tropical condition. It is known worldwide for its contribution to human as a source of products for domestic consumptions, agro – industrial use, export, manufacturing Industries and economic activities which all depend on its as raw material for production. However, its production (yield) has been reducing due to low mechanised production, which needs to be increased through encouraged suitable tillage and planter/planting methods basically mechanised by local design and adoption of local and imported tillage and planting implements through using the combination of a suitable tillage, planter type, and forward speed of planting maize to attain maximum yield.

In view of this Research was conducted to determine if planter types (Monosem pneumatic planter and Parmiter mechanical planter) affects Maize, mean emergence and uniformity of spacing and in relation to yield by applying different tillage system (Conventional tillage, Reduced tillage, Minimum tillage, and No-tillage) with 10cm with in row plant spacing and forward speeds of 7.20 and 11.30km/h. This experiment was performed at Mbilla farms limited in Mayo-belwa local government area of Adamawa state, Nigeria in year 2010.

Result of mean treatments interaction were statistically analyzed using ANOVA and means were separated using Duncan multiple range test showed that tillage systems, planter types, planting speed and the interaction between planter type and speed of planting and tillage systems, planter type and speed measured were highly significant at 1%, significant at 5%, while interaction in tillage system and planter speed was not significant difference at both 1% and 5% level of probability respectively. Maize plant height, within plants spacing, Mean emergence date, Emergence rate index showed Monosem Pneumatic planter at forward speed of 11.30km/h gave the highest mean yield of 6.25t/h. A simple linear correlation at 5% probability showed that for parmiter mechanical planter was significant except plant height with correlation coefficient, while Monosem pneumatic planter was significant except in spacing. A multiple linear correlation of relation between yield and all measurements was determined and it shows a linear relationship between them. Planter type, tillage and planting forward speed have positive effect on the spacing, mean emergence rate and emergence rate index with respect to growth and yield (output) of Maize. The ideal speed to adopt for forward speed of planting to be adopted for maize planting in Adamawa state is 11.30km/h. The Tillage practice to be adopted with respect to suitable maize plant emergence is Conventional tillage suitable Plant spacing 10cm in terms of maize yield (output)

5.2 Conclusions

All measurement as a result of the treatments combination as yield determinants of Maize growth (maize plant height, within plants spacing, Mean emergence date, Emergence rate index showed that both the two planters at forward speed of 11.30km/h gave the highest values of the yield and its determinants but the Monosem planter gave the highest and suitable values for consideration. The values are; plant height of 56.80cm MPP at 11.30km/h with conventional tillage system, MPP plant spacing of 10.08cm at 11.30km/h with both conventional, reduced and zero tillage systems, Mean Emergence Date of 13days Parmiter Mechanical Planter at speed of 11.30km/h with Reduced Tillage and No Tillage systems, Emergence Rate Index of 11.days forward speed of 7.20km/h with Minimum Tillage combination. The suitable total mean yield value for treatment combination was also 6.25t/h Monosem pneumatic planter at 11.30km/h and a Conventional Tillage system.

A simple linear correlation showed that for parmiter mechanical planter, all the parameters where significant except plant height with correlation coefficient of $r = 0.58, 0.86, 0.89$ for spacing, Emergence Rate Index, mean emergence date and $r = 0.05$ for plant height. While that of Monosem pneumatic planter with correlation coefficient of $r = 0.34,\ 0.98,\ 0.96$ for plant height, emergence rate index, mean emergence date and are all significant while for spacing $r = 0.06$ and was not significant. A multiple linear correlation of relation between yield and all other parameters gave a coefficient of $0.134,\ 0.0053,\ 0.076\ and\ 0.106$ for height, mean emergence date, emergence rate index, and Spacing respectively.

The mean emergence and emergence rate index (MED and ERI) varied at thirty (30) days after emergence but after these, the growth was directly proportional after each day after 30 days of emergence. All parameter did not show much different in daily growth.

From results obtained, it can be concluded that;

1. Planter type, tillage and planting forward speed have positive effect on the spacing, mean emergence rate and emergence rate index with respect to growth and yield (output) of Maize.
2. The ideal speed to adopt for forward speed for maize planting in Adamawa state is 11.30km/h, because spacing, emergence rate index, mean emergence date and height gave highest values with both parmiter and monosem planters and tillage combinations.
3. The Tillage practice to be adopted with respect to suitable maize plant emergence was Conventional tillage suitable Plant spacing 10cm in terms of maize yield (output).

5.3 Recommendations

The under listed recommendations for future work are put forward;

1. The use of indigenous planters should be studied to find their effects on maize mean emergence and emergence rate index.

2. The data obtained from this research should be used as the basis for specifications on designed indigenous planters, such that the maize stand and spacing uniformity should be evaluated in order to increase yield.

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APPENDICES

Appendix 1

PLANT SPACING (cm)

S1		S2			
10.2	10.4	10.9	10.1	10.15	10.2
10.1	10.2	10.6	10.05	10.05	10.08
10.7	10.3	10.22	10.1	10.4	10.4
10.11	10.2	10.9	10.06	10.09	10.1
11.6	10.8	11.3	10.08	10.7	10.12
10.9	10.51	10.9	10.4	10.03	10.1
11.9	10.8	11.2	10.8	11.1	10.6
10.5	10.3	10.6	10.9	11	10.8

Appendix 2

MEAN EMERGENCE DATE (MED)

S1				S2	
13.312	13.267	13.126	13.935	13.667	13.714
13.375	13.413	13.387	12.923	12.786	12.935
13.262	13.546	13.334	13.743	13.978	13.991
13.502	13.654	13.512	12.831	12.671	13.043
13.463	13.578	13.671	13.556	13.454	13.442
13.295	13.341	13.213	13.223	13.121	13.224
13.601	13.711	13.654	13.526	13.461	13.562
13.345	13.275	13.222	13.121	13.121	13.223

Appendix 3

EMERGENCE RATE INDEX(ERI)

S1			S2		
11.452	11.478	11.507	12.137	12.32	12.921
13.162	13.512	13.761	14.87	14.912	14.349
10.631	10.512	10.963	11.861	11.783	11.434
13.108	13.234	13.871	14.807	14.888	14.904
11.067	11.21	10.971	11.215	11.113	11.712
11.958	12.101	11.766	14.217	14.112	14.77
11.113	11.014	11.453	11.329	11.612	11.487
12.218	12.321	12.661	14.403	14.882	14.671

Appendix 4

The GLM Procedure

Class Level Information

Class	Levels	Values
TRMT	16	T1P1S1 T1P1S2 T1P2S1 T1P2S2 T2P1S1 T2P1S2 T2P2S1 T2P2S2 T3P1S1 T3P1S2 T3P2S1 T3P2S2 T4P1S1 T4P1S2 T4P2S1 T4P2S2

Number of observations 48

The GLM Procedure

Dependent Variable: HEIGHT_1 HEIGHT 1

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	15	162.1391667	10.8092778	13.69	<.0001
Error	32	25.2733333	0.7897917		
Corrected Total	47	187.4125000			

R-Square	Coeff Var	Root MSE	HEIGHT_1 Mean
0.865146	2.084321	0.888702	42.63750

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TRMT	15	162.1391667	10.8092778	13.69	<.0001

3

The GLM Procedure

Dependent Variable: MED MED

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	15	3.77850392	0.25190026	25.86	<.0001
Error	32	0.31172600	0.00974144		
Corrected Total	47	4.09022992			

R-Square	Coeff Var	Root MSE	MED Mean
0.923788	0.737578	0.098699	13.38146

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TRMT	15	3.77850392	0.25190026	25.86	<.0001

4

The GLM Procedure

Dependent Variable: ERI ERI

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	15	94.86582198	6.32438813	92.91	<.0001
Error	32	2.17826133	0.06807067		
Corrected Total	47	97.04408331			

R-Square	Coeff Var	Root MSE	ERI Mean
0.977554	2.074254	0.260904	12.57819

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TRMT	15	94.86582198	6.32438813	92.91	<.0001

5

The GLM Procedure

Dependent Variable: SPACING SPACING

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	15	6.75933125	0.45062208	5.69	<.0001
Error	32	2.53226667	0.07913333		
Corrected Total	47	9.29159792			

R-Square	Coeff Var	Root MSE	SPACING Mean

0.727467	2.676189	0.281306	10.51146

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TRMT	15	6.75933125	0.45062208	5.69	<.0001

The GLM Procedure

Dependent Variable: _HEIGHT_2 HEIGHT 2

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	15	42.60479167	2.84031944	8.60	<.0001
Error	32	10.57333333	0.33041667		
Corrected Total	47	53.17812500			

R-Square	Coeff Var	Root MSE	_HEIGHT_2 Mean
0.801171	1.389920	0.574819	41.35625

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TRMT	15	42.60479167	2.84031944	8.60	<.0001

The GLM Procedure

Duncan's Multiple Range Test for HEIGHT_1

NOTE: This test controls the Type I comparison wise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	32
Error Mean Square	0.789792

Number of Means	2	3	4	5	6	7	8	9
Critical Range	1.478	1.553	1.603	1.638	1.664	1.685	1.702	1.716

Number of Means	10	11	12	13	14	15	16
Critical Range	1.727	1.737	1.745	1.752	1.758	1.763	1.768

Means with the same letter are not significantly different.

Duncan Grouping			Mean	N	TRMT
	A		45.8000	3	T2P2S1
	A				
B	A		44.4667	3	T1P2S2
B					
B	C		44.2333	3	T3P2S2
B	C				
B	C		44.1333	3	T4P2S1
B	C				
B	C		43.9667	3	T2P1S1
B	C				
B	C		43.8000	3	T2P2S2
B	C				
B	C	D	43.6333	3	T3P2S1
B	C	D			
B	C	D	43.4667	3	T4P2S2
	C	D			
E	C	D	42.6333	3	T1P2S1
E		D			
E	F	D	42.0667	3	T3P1S1
E	F				
E	F		41.8000	3	T4P1S1
E	F				
E	F		41.7333	3	T1P1S1
E	F				
E	F		41.5333	3	T1P1S2
	F				
G	F		40.4333	3	T2P1S2
G					
G			39.6000	3	T4P1S2
G					
G			38.9000	3	T3P1S2

8

The GLM Procedure

Duncan's Multiple Range Test for MED

NOTE: This test controls the Type I comparison wise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	32
Error Mean Square	0.009741

Number of Means	2	3	4	5	6	7	8	9
Critical Range	.1642	.1725	.1780	.1819	.1848	.1871	.1890	.1905

Number of Means	10	11	12	13	14	15	16
Critical Range	.1918	.1929	.1938	.1946	.1952	.1958	.1963

Means with the same letter are not significantly different.

Duncan Grouping	Mean	N	TRMT
A	13.90400	3	T3P1S2
A			
B A	13.77200	3	T1P1S2
B			
B C	13.65533	3	T3P2S1
C			
D C	13.57067	3	T1P2S1
D C			
D C E	13.55600	3	T4P1S1
D C E			
D C E	13.51633	3	T3P2S2
D C E			
D C E	13.48400	3	T1P2S2
D E			
D F E	13.39167	3	T2P1S1
F E			
F E	13.38067	3	T3P1S1
F			
G F	13.28300	3	T2P2S1
G F			
G F	13.28067	3	T4P2S1
G F			
G F	13.23500	3	T1P1S1
G			
G	13.18933	3	T2P2S2
G			
G	13.15500	3	T4P2S2
H	12.88133	3	T2P1S2
H			
H	12.84833	3	T4P1S2

9

The GLM Procedure

Duncan's Multiple Range Test for ERI

NOTE: This test controls the Type I comparison wise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	32
Error Mean Square	0.068071

Number of Means	2	3	4	5	6	7	8	9
Critical Range	.4339	.4561	.4705	.4808	.4886	.4947	.4996	.5037

Number of Means	10	11	12	13	14	15	16
Critical Range	.5070	.5099	.5123	.5144	.5161	.5176	.5190

Means with the same letter are not significantly different.

Duncan Grouping	Mean	N	TRMT
A	14.8663	3	T4P1S2
A			
B A	14.7103	3	T2P1S2
B A			
B A	14.6520	3	T4P2S2
B			
B	14.3663	3	T2P2S2
C	13.4783	3	T2P1S1
C			
C	13.4043	3	T4P1S1
D	12.4593	3	T1P1S2
D			
D	12.4000	3	T4P2S1
E	11.9417	3	T2P2S1
E			
F E	11.6927	3	T3P1S2
F E			
F E G	11.4790	3	T1P1S1
F E G			
F E G	11.4760	3	T3P2S2
F G			
F G	11.3467	3	T1P2S2
G			
G	11.1933	3	T3P2S1
G			
H G	11.0827	3	T1P2S1
H			
H	10.7020	3	T3P1S1

The GLM Procedure

Duncan's Multiple Range Test for SPACING

NOTE: This test controls the Type I comparison wise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	32
Error Mean Square	0.079133

Number of Means	2	3	4	5	6	7	8	9
Critical Range	.4679	.4917	.5072	.5184	.5268	.5334	.5387	.5430

Number of Means	10	11	12	13	14	15	16
Critical Range	.5467	.5498	.5524	.5546	.5565	.5581	.5595

Means with the same letter are not significantly different.

Duncan Grouping	Mean	N	TRMT
A	11.3000	3	T3P2S1
A			
B A	11.2333	3	T1P2S1
B A			
B A C	10.9000	3	T4P2S2
B A C			
B D A C	10.8333	3	T3P2S2
B D C			
B D C	10.7700	3	T2P2S1
D C			
D E C	10.5000	3	T1P1S1
D E C			
D E C	10.4667	3	T4P2S1
D E C			
D E C	10.4067	3	T3P1S1
D E C			
D E C	10.4033	3	T4P1S1
D E			
D E	10.3000	3	T3P1S2
D E			
D E	10.3000	3	T1P2S2
D E			
D E	10.3000	3	T2P1S1

E			
E	10.1767	3	T2P2S2
E			
E	10.1500	3	T1P1S2
E			
E	10.0833	3	T4P1S2
E			
E	10.0600	3	T2P1S2

Duncan's Multiple Range Test for _HEIGHT_2

NOTE: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	32
Error Mean Square	0.330417

Number of Means	2	3	4	5	6	7	8	9
Critical Range	0.956	1.005	1.037	1.059	1.076	1.090	1.101	1.110

Number of Means	10	11	12	13	14	15	16
Critical Range	1.117	1.123	1.129	1.133	1.137	1.140	1.143

Means with the same letter are not significantly different.

Duncan Grouping			Mean	N	TRMT
	A		42.4667	3	T4P2S2
	A				
B	A		42.2333	3	T2P2S2
B	A				
B	A	C	42.1667	3	T2P1S2
B	A	C			
B	A	C	42.1333	3	T4P1S2
B	A	C			
B	A	C	41.9667	3	T2P2S1
B	A	C			
B	A	C	41.9000	3	T1P2S1
B	A	C			
B	A	C	41.7000	3	T4P2S1
B	A	C			
B	A	C	41.6000	3	T3P2S1

B		A	C			
B		A	C	41.5333	3	T1P1S2
B		A	C			
B	D	A	C	41.4000	3	T1P1S1
B	D		C			
B	D		C	41.3000	3	T2P1S1
B	D		C			
B	D		C	41.3000	3	T3P1S1
	D		C			
	D		C	41.0667	3	T4P1S1
	D					
	D	E		40.4333	3	T3P1S2
		E				
F		E		39.6000	3	T3P2S2
F						
F				38.9000	3	T1P2S2