Tillage Implements Performance and their Effects on Two Types of Soil in Khartoum Area

By

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Dedication
To my wonderful family&friends
With love
Especially my mother
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Abstract

An experiment was carried out during September 2006 at two different locations, the Demonstration farm of the Faculty of Agriculture, University of Khartoum at Shamba t (fallow ridged sandy clay soil), and clay soil of Abu–halema project (15 Km north of Khartoum). The experiment was conducted to investigate and compare the effect of three types of tillage implements (Chisel plough, offset disc harrow, and ridger) on soil bulk density, porosity, soil aggregation stability, and soil resistance to penetration in the two different locations. At the same time to identify some field performance parameters: wheel slippage, fuel consumption rate and field efficiency of the three implements. All soil and field performance parameters were analyzed by using complete randomized block design.

The results indicated no significant differences between the effect of tillage treatments on the soil bulk density in the sandy clay soil location, while they have significantly (p<0.01) affected the soil porosity, the soil aggregation stability and soil resistance to penetration. The ridger recorded the highest mean bulk density (1.33 gm/cm³), and the lowest mean porosity (48.23%) and resistance to penetration (4.2 Kg/cm²). The disc harrow gave the highest mean aggregation stability (35.63%) while the lowest value (30.64%) measured by the no-tillage treatment. In contrast to the disc harrow and the ridger, the chisel plough gave the overall higher mean penetration resistance (9.0Kg/cm²). At the clay soil location, the tillage treatments did not record any significant differences on their effects on bulk density. Generally bulk density increased with depth while porosity was decreased. All the tillage implements significantly (p<0.01) decreased the aggregation stability of soil, the disc
harrow recorded the lowest mean aggregation stability of (25.73%) compared to (56.34%) for no-tillage treatment.

The implements performance parameters showed higher slippage, fuel consumption rates, and field efficiencies especially for chisel and ridger implements at sandy clay soil location. The disc harrow gave the highest field efficiency of (79.9%) at the clay soil location. The chisel plough demonstrated the highest wheel slippage (19.2%) and fuel consumption rate (15.7L/ha). The lowest slippage (10.4%) and fuel consumption rates (5.97 L/ha -1.06 L/hr) were recorded by the disc harrow.
 démarchة الأطراف

أجريت هذه الدراسة في سبتمبر 2006 بموقعين، المزرعة التجريبية بكلية الزراعة جامعة الخرطوم، ومنطقة شعبات والذي تميز بتربة رملية طينية ووجود سرابات، ومشروع ابوجيما الزراعي (15 كم شمال الخرطوم بحري) والذي تميز بتربة طينية. استدفنت التجربة دراسة ومقارنة أثر ثلاثة أنواع من الآلات الحراج (المحارات الحفار، المشط القرصي المنحرف، والطراد) على الكثافة الظاهرة ومسامية التربة، نسبة ثبات تكتل التربة، مقاومة التربة للاختراق في المواقع المختلفين. وكذلك دراسة أثر اندلاع الخفيف للدلافات مماثلة في الانزلاق، و معدل استهلاك الوقود، وكفاءة الخفيفة. جميع عوامل التربة وألاداء تم تحليها باستخدام تصميم القطاعات العشوائية الكامل.

جميع معامولات الحراج لم تسجل أي فروقات معنوية على كثافة التربة الظاهرة في الموقع ذو التربة الرملية الطينية، بينما أثرت معنوية (p<0.01) على المسامية، نسبة ثبات تكتل التربة ومقاومة التربة للاختراق. الطراد سجل أعلى متوسط كثافة ظاهرية (3.31/سم²) وأدنى متوسط مسامية (48.23%) ومقاومة اختراق للترية (4.2 كجم/سم²). سجل المشط القرصي أعلى متوسط لثبات تكتل التربة حوالي (35.63%) مقاير والدندوني (30.64) تم قياسة في ألاحواج غير المفرطة، خلافاً للمسحة الفصي والطراد، المحرات الحفار سجل أعلى متوسط مقاومة اختراق (9 كجم/سم²). في الموقع حيث التربة طينية لم تسجل معاملات الحراج فروقات معنوية في تأثيرها على كثافة التربة الظاهرة. بصفة عامة الكثافة الظاهرة تزداد مع عمق التربة، بينما تناقصت المسامية. كل معامولات الحراج أدت إلى انخفاض عالي المعنوية (p<0.01) في نسبة تكتل التربة، المشط القرصي أدى إلى أقل متوسط نسبة ثبات تكتل (25.73%) مقاير ب (56.34%) للترية غير المفرطة.

معاير أداء الآلات أوضحت أن أعلى نسب انزلاق، ومعدلات استهلاك وقود، وكفاءات خلقية خاصة للطراد ومحرات الحارس ت تسجيلها في الموقع حيث التربة الرملية الطينية. المشط القرصي أعطى أعلى نسبة كفاءة حقيقية في الموقع ذو التربة الطينية (79.9%). المحارات الحارس أعطى أعلى نسبة انزلاق (19.2%) ومعدلات استهلاك وقود (15.7 لتر/هكتار). أقل نسبة انزلاق (10.4%) ومعدلات استهلاك وقود (1.06 لتر/ساعة - 5.97 لتر/هكتار) سجلت نتيجة للمشط القرصي.
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CHAPTER ONE
INTRODUCTION

Agricultural machinery has an important role in development of agriculture and crop production. Efficient use of farm machinery reduces time required of any operation (timeliness). Agricultural mechanization has been receiving considerable interest in recent times due to mainly increasing in population and in turn increasing food demands (Doorenbos and Pruitt, 1977) and (Yusuf and Asota, 1998). It does not necessarily mean tractorization, however it is a field in which physical and biological sciences are perfectly blended and utilized for producing, handling, processing and storing food, fiber and fodder, and should be introduced with respect to prevailing environmental, human and social constraints. Modern agriculture has resulted in an increase in farm power units. Large equipments have been used. These heavy machines apply higher loads, higher pressure and greater soil-working forces to the soil (Al-Hashem, 2004). The machinery traffic led to serious problems in the physical conditions of soil, which attributed to compact soil layers, greater bulk density (lower porosity), lower penetrability, and governed water and air flow to plant roots.

Tillage is the first agricultural operation upon which depends the success or failure of the agricultural season, since it is the preparatory stage of seedbed which is the critical stage in plant life. At the same time soil tillage is one of the main energy inputs for agricultural production (Belel and Dahab, 1997). It consumes about half of the entire seasonal energy budget before the seed is planted (Coates and Thacker, 2001).

There are many tillage implements, differing from primary or secondary implements, which follow each other in the tillage operation to achieve the tillage objectives. They are essentially aimed to improve the
soil physical properties, in which their performance can be affected by soil types and the surrounding conditions. Therefore the selection of suitable tillage implements to match certain soil types and conditions is an essential factor in reducing the cost of operation and energy loss, and as a consequence, optimizing the field performance of tractor, and conserving the soil fertility as well as reducing the adverse effects on soil structure such as compaction.

The objectives of this study are:-

1\ To identify and compare the effect of three types of tillage implements (Chisel plough, offset disc harrow, and ridger) on some soil physical properties in two different locations.

2\ To investigate and compare the effect of the two soil types and conditions in the two locations on some performance parameters of the three implements.
2.1 Importance of tillage operation:-

Tillage term is usually restricted to the change of the soil condition for the purpose of crop production (ASAE, 1979). Lal (1995) stated that tillage includes all operations leading to seedbed preparation that optimizes both soil and environmental conditions for good seed germination, seedling establishment, and crop growth. Tillage operation changes the soil surface in a number of ways, the obvious change is roughing or smoothing of the surface (Abdalla and Mohamed, 1998), it was confirmed that, undisturbed soil seems to be harder and more resistant to root penetration than tilled soil (Campbell and Henshall, 1991). In fact, high soil strength has been proved to reduce and even to stop root growth. One of the goals of tillage is to reduce soil bulk density (increase soil porosity), and the large pores in the soil generally favor high infiltration rates, good tilth, and adequate aeration for plant growth. In contrast to temperate regions, tillage practices in arid and semi-arid climates should aim to increase water intake and conservation capacities of soils, reduce evaporation and decomposition rate of organic matter as well as decreasing erosion and control weeds (Lal, 1995).

2.2 Tillage systems:-

According to tillage intensity and mode, systems are categorized into conventional and conservation tillage systems. A tillage system may comprise a single pass or more with one machine, or machines in sequence depending on crop state of previous residue or weeds, soil characteristics, water quality and socio-economic factors (Lal, 1995).

Conventional tillage term is used for the type of tillage that begging with primary deep tillage followed by some secondary tillage
operation (Baeumer and Bakermans, 1973). In conventional tillage the topsoil is usually loosened, but at some depth just below the ploughed layer. Consequently, a compacted layer commonly called plough sole develops and is characterized by abnormally high bulk density (Maurya, 1993).

Conservation systems comprise varying degrees of soil disturbance described as minimum, reduced, low, and finally zero-till (Lal, 1995). These systems reduce preplant tillage operations, thus reducing soil erosion while saving labor and fuel. Conservation tillage may represent a broad spectrum of systems, but is best described as tillage that leaves a minimum crop residue cover of 20 to 30 percent on the soil surface after planting (Melvin, 2005). Reduced tillage systems, tested over several years and it has been proved that, it offers energy savings and reduced dust emissions because they are less intensive than conventional systems. Those types of tillage systems are associated with reduced soil compaction, especially when they restrict wheel traffic to set paths in the field, a system known as controlled traffic farming. It also reduces field work time requirements because they require fewer passes over the field (Coates and Thacker, 2001), but at the same time restoring or maintaining a good soil structure under minimal, or no-till. On the other hand, it can take place only if the organic matter in the soil increases considerably, and macrospores continuity is guaranteed, mostly due to sustained mulch (Lal, 1995).

Melvin (2005) confirmed that no single tillage system is best for all situations at all times. Rotating tillage systems to coincide with crop rotations often provides a better alternative than a single system. For example, a no-till system could follow soybeans while a chisel or disk system might follow corn. This rotation may provide adequate cover following soybeans while providing an opportunity for some tillage in the
less fragile and more abundant corn residue. These opportunities may exist for fields where erosion rates are low to moderate or where other erosion control practices reduce the need for high residue cover to meet erosion control requirements. However, because tillage influences yields only indirectly, it is difficult to improve yields by tilling the soil in different ways as it alters both soil conditions and affect farm management requirements (Stevens, 1994).

2.3 Tillage operation implements:-

Ploughing is mostly carried out through two tillage operations: primary and secondary with implements as consequence divided into categories (Lal, 1995).

2.3.1 Primary tillage operation implements:-

Primary tillage is operated to initially break up or shatter compacted soil, and then loosening the soil downwards to create pore volume for absorbing water and air to improve plant root and water penetration. At the same time it causes inversion of soil to bring up leached fine soil materials and nutrients to the surface and decomposition of organic matter into deeper layers, plus the primary control of weeds. Four main types of implements are used as primary tillage implements; moldboards, disc plough, chisel plough, and subsoilers plough. Each of them has its specific features (Adam, 2005).

1-Moldboard:-

Moldboard is the common implement of the temperate regions (Hussein and Munir, 1986). It is adapted to the breaking of many types of soil and is well suited for burying and covering crop residues (Smith and Wilkes, 1986). Since soil types and ploughing conditions vary widely, many different shapes of mold boards have been developed. From functional stand point, common types include general purpose bottoms, black land bottoms and slat mold board (Kepner et al., 1982).
2-Disc plough:-

It partially or completely inverts and mixes soil horizons, as well as buries weed at a range of depths of 30-46 cm (Hussein and Munir, 1986). It is more suitable for conditions under which moldboard ploughs do not operate satisfactorily, such as hard dry soils, in sticky soils where moldboard ploughs are not able to scour and in loose soils (Kepner et al., 1982).

Shirin et al., (1993) reported that disc plough consumes much energy, and has greater draft requirements which increase with increased speed and clay content. Degree of soil inversion tends to be reduced with increased tilt angle, and that disc penetration was best at a low tilt angle. Reduced penetration has the advantage of reduced draft requirements.

3- Chisel plough:-

Chisel plough is one of the primary tillage implements, which has a maximum loosening effect on soil, but with minimum pulverizing, mixing, and inverting effects. It has a workable depth range of 46-76 cm (Doorenbos and Pruitt, 1977), so that it used to break and shatter compacted soil to improve water penetration; it is operated more effectively at the dry soil (Kepner et al., 1982). Chiseling at depths more than 16 inches is termed sub-soiling (ASAE, 1979).

4- Subsoilers:-

They are implements having a very specific and specialized function such as the deep ploughing for breaking hard pans of up to 100 cm soil depth even in a very compacted hard clay soil, and loosens soils below the normal depth of tillage for maximum retention of water and root development (Hussein and Munir, 1986).

2.3.2 Secondary tillage operation implements:-

Secondary tillage operations are optional complementary measures that mostly follow a primary tillage operation. Sometimes secondary
operations may be considerably reduced or even completely omitted for economical or conservational justifications, depending on prevailing farming conditions. They include implements that crush, or pulverize clods resulting from primary tillage, land smoothing and leveling, and establishing furrows or beds for crop planting (Adam, 2005). Lal (1995) added that in this case lighter equipments are used to control weeds, and smooth and firm the soil for good seed bed. The secondary tillage implements are:

1-Disc harrows:

The disc harrows are used as secondary implements to crush the clods, cutting up and mixing stubble, level the ground and controlling weeds (Smith and Wilkes, 1986). They can be used also as primary implements for orchards (Adam, 2005). Smith and Wilkes (1986) enumerated factors within the harrow itself that influence the depth to which it penetrates the soil such as: the angle of the disc gang, the weight of the harrow, the sharpness of the discs, the size of the discs, the concavity of the discs, and the angle of hitch. Other factors include soil type and conditions also affect the penetration of the disc harrow.

Disc harrows divided into three types; single acting, which has two opposite gangs of disc blades, both throwing soil outward from center of tilled strip. The second type is the tandem disc harrow, in which two traditional gangas, which throw the soil back toward the center as second operation. Thus tilling the soil twice and leaving the field more nearly leveled. The last one is the offset disc harrow, in which one right hand gang, operating in tandem (Kepner et al., 1982).

2-Ridger:

Ridging is the operation by which soil is mounted to specific configuration to facilitate irrigation (ASAE, 1979); it results in better soil and water management in surface irrigation than just establishing a
seedbed. It determines the slope along which water can run off and may further decrease that slope to safer ranges when non-erosive speeds of water flow are required (Stevens, 1994). Ridger works when the share or shovel of the ridging body penetrates the soil, with keeping the attacked angle, and the depth control setting. The soil is lifted and transported evenly along the breast and wings onto the shoulders or top of ridge (Lorenz et al., 1984).

A ridger consists of ridging bodies (3-5), with adjustable spacing. Ridges that of 70-80 cm spaced are commonly used. They are becoming reliable primary tillage tools in irrigated farming, particularly in furrow irrigation (Yusuf and Asota, 1998).

3- Scraper:-

A large number of different models of land planes (scrapers) are available. The basic frame is constructed from steel that carries a rigid plane blade, or bucket with a replaceable edge, mounted perpendicularly to the direction of travel. Scraper's depth can be adjusted manually or hydraulically (Lorenz et al., 1984).

Finally, (Pietola, 2005) reported that reducing number of passes by substituting the combined machine instead of single operation has been a major concern of many studies. Minimum pass in the field particularly for tillage operation was goal to achieve sustainable farming, especially of that, increasing number of pass in tillage operation created plow pan and would lead to hard pan after five years (Brikas et al., 2005).

2.4 Effects of tillage operations on some soil physical properties:-

The structure of the soil is related to many important soil physical properties, especially those pertaining to the retention and transport of solutions, gases, and heat (Danielson and Sutherland, 1986). The soil physical properties were commonly assessed and evaluated to detect the
influence of different tillage practices on soils (Michael, 1978). Lal (1995) also concluded that tillage requirements are generally soil and crop specific, and hence climate is a tightly relevant variable. It is however difficult to predict the effects of tillage on soils as its physical, biological and chemical characteristics will be affected by the manipulation process. The mode and intensity of tillage depends on the type of soil and related constraints to crop production, to avoid topsoil degradation and subsequent erosion, as well as to fulfill soil conditions favorable for water infiltration, and seedling and root development which ultimately results in economic yield (Michael, 1978).

2.4.1 Effect of tillage on soil bulk density:

Soil structure can be measured in various ways, but perhaps it is most meaningfully evaluated through some knowledge of the amount, size, configuration, or distribution of soil pores. It is often the information concerning these pore spaces, rather than the soil particles, that is most useful in characterizing the soil as a medium for plant growth or other uses (Danielson and Sutherland, 1986).

The soil bulk density, is the ratio of the mass of dry solids to the bulk volume of the soil (Danielson and Sutherland, 1986), the bulk volume includes the volume of the solids and of the pore space. Bulk density is a widely used value for calculating porosity, which gives us an idea of the porous space left in soil for air and water movement (Cassel, 1982). It varies with structural condition of the soil, particularly that related to packing. Therefore it is often used as a measure of soil structure. Al-Hashem (2004) supported this statement, as soil bulk density is the most widely used property to assess the changes in soil compactness resulting from the device load and other equipment. The soil characteristics that affect the bulk density are texture, organic matter (Chen et al., 1998), structure (Cassel, 1982) and gravel content (Franzen
et al., 1994). It varies over years due to the action of several processes: freezing and thawing (Unger, 1991), settling by desiccation and kinetic energy of rainfall, loosing by root action and animal activity and finally crop operations especially tillage process may also alter bulk density (Cassel, 1982).

Porosity and pore size distribution change whenever soil bulk density is changed. Decreasing the bulk density increases the amount of water held at high soil water potentials and decreases the amount of water held at lower potentials. The optimal bulk density for plant growth is different for each soil, in general less than optimal bulk density (high porosity) lead to poor water relations, and high bulk density (low porosity) reduces aeration and increases soil penetration resistance, limiting root growth (Cassel, 1982).

In general, root tips are unable to penetrate pores narrower than their diameter. Bulk density values that limit root growth that depend on water content ranged between 1.46-1.90 mg/m³ (Campbell and Henshall, 1991).

Numerous experiments were performed to compare the effect of no-tillage with other conservation and the more conventional tillage systems on soil bulk density. They are different results but in most of them bulk density was greater in no-tillage in the first 5 to 10 cm of soil (Unger and Jones, 1998 and Wander and Bollero, 1999). In others no differences in bulk density were found between tillage systems (Cassel, 1982; Logsdon and Cambardella, 2000). In a third group bulk density even decreased under no-tillage especially when an increase in organic matter was observed in the first layer of soil (Edwards, 1996; Crovetto, 1998). Maurya (1993) reported, increased bulk density values with disturbed soil depth up to 10 cm. According to Kinsella (1995) the first five years after the change from conventional tillage to no-tillage, the
soil was in transition or repair period, in which it builds humus and, retains its structural stability and restores the pore space. During this period there is first an increase in bulk density until a maximum, and then a decrease due to destructing process, until an equilibrium level is reached when the structure is fully restored.

Bulk density was significantly influenced by tillage outcome, particularly compaction. Al-Hashem (2004) reported that, when a compaction force is applied by wheel traffic, the bulk density and consequent soil compaction will increase to values based on factors such as soil moisture and wheel load. Meek et al., (1992) found that, a wheel mass of 2.7 tons working on a tilled sandy soil resulted in a bulk density of 1.92 g/cm³ compared to 1.67 g/cm³ for un-trafficked soil.

Results of the interactions between plough types and ploughing depths indicated that chisel plough at (10-15cm) depth gave significantly less bulk density among the other treatments such as ridging and no-till (Abdalla and Mohamed, 1998).

Cavalieri et al., (2006) studied the effects of different tillage systems on some physical properties used in sandy and sandy loam soils; these were no-tillage (NT), minimum tillage using chiseling (MT) and conventional tillage with moldboard plow and disking (CT). They evaluated soil bulk density (BD), soil water retention curve, and the least limiting water range (LLWR) in the (0–0.15m) and (0.15–0.30m) soil layers. The higher values of BD verified in the NT and MT treatments, while the soil water retention curve was only influenced by BD, which incorporated the effects of the soil tillage systems independent of sampled layers. The increase in the BD led to a reduction in the LLWR due to the effects of soil resistance to penetration and air-filled porosity, which in turn determined the range of soil available water. The critical bulk density value (BDc), the BD value at which LLWR = 0, was lower
in NT and MT tillage systems compared to CT, therefore resulted in a smaller frequency of higher BD values than BDc in soil under CT.

Franzluebbers et al., (1995) showed that the effect of tillage on the soil bulk density is temporary, and after tillage the soil rapidly settles, and recovers to its former bulk density. Kinsella (1995) supported that as in some soils porosity under no-tillage decreases in the first few years until the soil recovers its natural structure, so that owing to progressive increase in bulk density after tillage and differences between tillage and no-tillage become smaller as time between tillage practices increases.

### 2.4.2 Effect of tillage on hydraulic conductivity of soil:

The soil properties that determine the behavior of soil water flow systems are the hydraulic conductivity and water–retention characteristics. The hydraulic conductivity of a soil is a measure of its ability to transmit water; water–retention characteristics are an expression of its ability to store water. These properties determine the response of water system to the imposed boundary conditions. In some cases, the hydraulic or soil water diffusivity, which is the ratio of the hydraulic conductivity to the differential water capacity, may be used to analyze the behavior of soil water system (Klute and Dirksen, 1986). They also mentioned that, the conductivity of soil depends on the geometry of the pores and the properties of the fluid in them (viscosity and density). The texture and structure of the soil are the principal determinants of the geometry of the water in the soil pores.

It is a difficult task to consider the effect of tillage on long–term hydrological components (water infiltration, storage, and runoff) (Mahmoud et al., 1990). Some findings were observed when infiltration increased in undisturbed, non-trafficed clay loam, but decreased when the same non-trafficed soil was tilled. It was concluded that, when infiltration
is to be improved by altering bulk density values, tillage should be restricted only to compacted soils (Adam, 2005).

Huxley (1979) reported that in semi arid tropical conditions, crops grown under untilled land are stunted and show symptoms of water and nutrients deficiencies because of high surface soil bulk density, low porosity, impeded infiltration and low water holding capacity of the soil.

Water intake rates before initial run-off was modified by tillage practices, tillage provides water stable aggregates at the surface and soil pores open to the surface were effective for achieving favorable infiltration, even when the surface was bare or when amounts of surface residue were low. However, for soils with unstable aggregates, soil dispersion and surface sealing may occur rapidly, thus causing a rapid decline in infiltration rate (Abdalla and Mohamed, 1998).

Chisel ploughing leaves a rough surface and creates channels when the soil is still dry. Thus, it improves retention of water by percolation into the subsoil, and it was shown to be very effective in increasing rain water storage (Lindstorm et al., 1974). A significant difference in moisture content of the soil was found when using chisel plough compared to other ploughs. So that, tillage influenced nutrient relationship and fertilizer placement through its effect on water content in soil surface layers and root zone (Bushan et al., 1973).

Duke (1992) reported that, infiltration process is affected by spatially variable physical conditions of the soil near the surface and the vertical soil matric-potential gradient at the onset of those processes which resulted mainly from tillage and irrigation. Meek et al., (1992) reported similar observations that infiltration rate of a tilled sandy loam soil tend to increase due to decreased bulk density. However, for an untilled-cropped soil, it can be improved with time, as channels will be developed, as the soil sample with many roots should have lower bulk
densities and higher infiltration, otherwise root might have filled macropores (Mark et al., 1990). Generally, deep ploughing is often accompanied by better infiltration rates, at least during early events mainly due to improved bulk density (Sabir et al., 1996). 33% higher infiltration rates observed under the disc harrow, rather than no-till treatments, and two fold higher for both disc plough and chisel (Ray and Gupta, 2001). Abdalla and Mohamed (1998) found that, chisel ploughing gave significantly higher values of infiltration rate and cumulative infiltration than the ridging and no-till treatments.

2.4.3 Effect of tillage on soil aggregation stability:-

Soil structure is often described in terms of size, shape and strength of aggregates (FAO, 1990). The size of aggregates is a valuable criterion of soil structure, and the quality of soil structure may be expressed in terms of porosity, aggregation, cohesiveness and permeability for water or air (Michael, 1978).

An aggregate is a group of primary particles that cohere to each more strongly than to other surrounding soil particles. Most adjacent particles adhere to some degree (Kemper and Rosenau, 1986). Stability of aggregates is a function of whether the cohesive forces between particles withstand the applied disruptive force (force in the field). These forces are generally related to cultivation, erosion (wind and water), and wetting of soils. Aggregate stability is generally strongly correlated with soil organic matter content. With cultivation the organic matter content of soils decreases with a corresponding decrease in aggregate stability (Chenu et al., 2000). The most important factors determining whether water will soak in or run off is the ability of soil surface to resist slaking or reconsolidation or crusting of soil surface.

Slaking is when soil aggregate (clusters or clumps) break apart in water into separate soil particles. When the individual sand, silt and clay
particles are free to move, they settle into a very compact layer immediately after cultivation. Most soils contain an abundance of the large pores; their continued existence in the soil depends on the stability of the aggregates. Erodibility of soils decreases as aggregate stability increases (Kemper and Rosenau, 1986). Therefore, soil aggregation is a very important property of most soils, as it controls water infiltration to a greater extent than amounts of sand, silt and clay (Wuest et al., 2006).

Most investigators have decided to use stability of the aggregates rather than aggregate-size distribution as an index of soil structure in the field, the bases of these decisions have generally been that (i) a simpler procedure involving only one size fraction may be used for stability analysis, (ii) results of stability analysis are highly correlated with aggregate-size distribution and field phenomena, and (iii) the ability of the aggregates to resist breakdown by continuing or increasing disruptive forces is often an important factor in the phenomena being studied (Kemper and Rosenau, 1986).

The size of aggregates and aggregation state can be influenced by different cropping processes and agricultural activities that alter the content of organic matter and the biological activity of the soil, probably being more related to changes in the organic constituents than to the actual total organic matter content (Haynes et al., 1991). However, over long periods of time, the stability of the aggregates diminishes as the organic matter content declines as well as a result of being used as an energy source for the microorganisms of the soil (Taboada et al., 2004). The impact of crop rotation and soil management systems (conventional tillage systems and no-tillage) on its structural stability, measured from the distribution of the size of water stable aggregates by (Taboada et al., 2004). Better aggregate stability of the soil was observed in conventional tillage, as seen by the high percentage of aggregates of diameter >4 mm
(aggregate size class) at a depth of 0 to 5 cm (range from a minimum of 56.8% to a maximum of 67.9%) compared to that calculated in no-tillage (48.2% to 53.4%). They explained that the better structure in conventional tillage could be attributed due to a higher organic matter content as a consequence of the incorporation to the soil residues coming from winter cropping (beans). On the other hand, during tillage operations, the effect of soil turning, compacted horizons would be taken to the surface, forming stable aggregates that would arise from the compression, but not from the biological action of roots or microorganisms. The lower proportion of macro aggregates in no-tilling would be a consequence of the decrease in the organic matter content of the soil at the time of sampling because the residues of the cover plants had not been managed. Furthermore, for aggregates >4 mm the results show a considerable reduction in the percentage of water stable aggregates in no-tilling at a depth of 5-15 cm, with values that do not surpass 40% (Taboada et al., 2004).

Crops are basically affected, in terms of emergence percent and speed, by bulk density and aggregate size of seedbed, and their interaction. Increased bulk density or aggregate size tends to delay or reduce emergence by reducing volume of voids. However, effect of bulk density was small in seedbeds with large aggregates, and the effect of aggregate size was negligible in compacted seedbeds (Nasr and Selles, 1995).

Abdalla and Mohamed (1998) observed in a soil profile consisting of two distinct layers, a sandy clay layer to a depth of about 30 cm from the soil surface over a clay layer, that the deeper ploughing provided by chiseling had disrupted the restricting surface layer and underlying soil layers. Rough surface with large clods created by chiseling, increased the area available for water infiltration. On the other hand, when the clods
erode, the dispersed soil material is washed into the bottoms of depressions leaving the sloping eroded surfaces free of fine materials and able to absorb water rapidly. In contrast they also observed that, ridging and no-till showed significantly low values of infiltration rates due to surface seal formation on the top compacted layer. This layer was less permeable than the sub-layer and, therefore, it controlled the infiltration rate into the soil and consequently the cumulative infiltration. In case of chiseling, the well aggregated top layer, which was more porous than the sub-layer, did not impede flow. In this case, the infiltration rate was apparently regulated by the properties of sub-layer alone. The soil of the top layer (porous) reached saturation, while the soil of the sub-layer (less porous) remained unsaturated throughout the entire infiltration event. In addition, when soil cohesion is to be reduced, disc plough was proved to be the best (Sabir et al., 1996). On the other hand, the smallest size fractions of aggregates are usually subjected to erosion more than other aggregates (Hughes and Baker, 1977).

Generally, large or macro-pores that exist between aggregates and clods can not retain water against gravity, at field capacity they are filled with air. On the other hand micro or capillary pores within aggregates or beds have ability to retain water against gravity. Also remarkable decrease in water infiltration may be caused by excessive tillage of soil with low structural stability due to the reduction in aggregate size and porosity (Hullugalle et al., 1990).

2.4.4 Effect of tillage on soil resistance to penetration:-

Soil penetrability is a measure of the ease with which an object can be pushed or driven into the soil (Bradford, 1986). It is one method of measuring soil strength (Al-Hashem, 2004). Campbell and Henshall (1991) stated similar statement and added that, the most common variables used to assess the soil strength in tillage studies are bulk density
and penetrometer resistance. They are interrelated and the use of only one of these variables may lead to misleading results. Cone indices, computed from static penetrometer data, have been used to characterize available soil compaction, resistance to root growth, and tillage effects, wheel traffic effects and hard pan resistance into the soil (Herrick and Jones, 2002). So that the soil scientist’s concern, however, is to relate penetrometer resistance to root growth, crop yield, and soil physical properties descriptive of tilth (Bradford, 1986).

The cone indices values depend on cone properties (i.e., diameter, height, and included angle), as well as soil properties (e.g., bulk density, shear strength, soil water content, texture, organic matter, particles surface roughness (Cassel, 1982). Mechanical impedance of soil increases as bulk density increases and water content decreases (Ehlers et al., 1983). Strength in some horizons of soil can restrict root growth even when water content is at field capacity, and strength increases as the soil dries (Bradford, 1986). As a consequence the roots exert a vertical pressure ranging from 0.7 to 2.5 Mpa, depending on the crop species (Gregory, 1994). Bradford, (1986) also found different penetration resistance produced in different soils or in different layers in the same soil. Generally penetration resistance increases with depth due to the increase in shaft friction (Franzen et al., 1994).

The applied force required to press the cone penetrometer into a soil is an index of the shear resistance of the soil and was called the “cone index”, usually reported in kilopascals (Bradford, 1986). Herrick and Jones (2002) explained the soil penetration resistance as the force applied to the dynamic penetrometer by the soil causing the penetrometer to decelerate from its initial velocity, resulting from the hammer blow, to zero velocity. They showed that, resistance can be calculated as the work done by the soil to stop the movement of the penetrometer divided by the
distance the penetrometer travels. They explained that, when the penetrometer is driven into the soil by the hammer, the kinetic energy of the hammer is transferred to the penetrometer cone. Its kinetic energy is zero. Therefore, the work done by the soil equals the kinetic energy transferred to the cone from the penetrometer when the hammer contacts the strike plate (its drop points), if there are large number of blows needed to cause the cone to penetrate a short distance, the soil/material is well compacted, and if the cone penetrates easily with few blows the soil/material is poorly compacted or "unsuitable" (Summers, 2000). The penetration distance depends on the kinetic energy applied to the penetrometer, the geometry of the penetrometer tip, and the soil penetration resistance (Herrick and Jones, 2002).

Bradford (1986) stated that, any device designed to measure resistance to penetration may be called a penetrometer. There are two principal types of penetrometers and ways of measuring penetration: (1) the static (penetrometers are designed to measure the force required to push a probe (usually a cone or blunt tip) through the soil at a constant velocity. (2) the dynamic penetrometers form a second general class. These probes rely on one or more discrete applications of kinetic energy to advance the probe. They are measuring different parameters: Static penetrometers generate a cone index, which is force per unit area; while the dynamic penetrometers measure actual resistance in terms of energy per unit depth (Herrick and Jones, 2002). The soil penetrometers range from the inexpensive and simple (the pocket penetrometer, static penetrometer) to the sophisticated motorized friction-sleeve cone penetrometer and dynamic penetromter (Bradford, 1986). Manually operated static penetrometers suffer from several limitations (i) They are relatively expensive, (ii) must be moved through the soil at a constant velocity, (iii) must be recalibrated on a regular basis in order to generate
consistent, repeatable measurements, and (iv) are designed for a relatively limited range of soil resistance, and the dynamic penetrometer design concerns all those points. On the other hand, the hammer type penetrometer design is limited by the fact that resistance increases with increasing depth due to the increased contact area with the corer (Herrick and Jones, 2002).

Soil penetrometers are designed to measure either (i) the cone or point resistance (resistance to penetration developed by the cone) such as the cone penetrometer; (ii) both cone resistance and friction–sleeve resistance (the resistance to penetration developed by the moveable sleeve–friction sleeve-located above the cone and surrounding a central rod), separately as the friction–sleeve cone penetrometer; or (iii) total resistance (the sum of cone and friction–sleeve resistance) such as the pocket penetrometer. Cone resistance is calculated as the vertical force applied to the sleeve divided by its surface area.

Bradford (1986) stated that, the cone penetrometer is a hand–operated device, and has been used extensively in agricultural soils research to locate hardpans or traffic compaction areas, to correlate soil strength parameters with root growth and crop yield, and to quantify the physical state of soil.

Since plant roots are flexible and grow through zones of least resistance, minimum cone resistance values possibly have more meaning than maximum or average horizon resistance values (Bradford, 1986). Penetration resistance measured with penetrometer is usually 2 to 8 times greater than that actually undergone by the root tip (Gregory, 1994). Penetrometer values greater than 2Mpa are generally reported to produce a significant root growth reduction (Atwell, 1993).

To select the test location for cultivated areas, the location must be defined in relation to tillage relief, wheel tracks, plant rows, and other
horizontal nonuniformities. The specific position selected depends upon the study objectives (Bradford, 1986). If the soil is extremely nonuniform, additional replications should be made based on pre-sampling survey of the area (Cassel, 1982).

Maurya (1993) reported that, soil strength tends to increase with depth of soil. Saber and Mrabet (2002) stated that, maximum bulk density and soil strength was found in the upper 30 cm in no-tilled plots than deep tilled ones.

Busscher et al., (2000) studied the timing effects of deep tillage (in Fall and in Spring) compared with surface tillage (disked and not disked) on penetration resistance and wheat and soybean yield. They observed that, disking compacted the soil more than it loosened it, it developed 60-kPa higher mean profile soil cone indices than non-disked treatments, generally it never reduced mean profile cone index. It loosened the top 5 to 15 cm of the profile, and compacted soil below the disked zone to produce mean profile cone indices that were equivalent to or higher than none disked treatments for the deep tillage treatments. They found that the cone indices were generally lowest in deep-tilled plots averaged over all dates of measurement, spring deep tillage maintained lower mean cone indices than the fall deep tillage. The probable reason for this was the lower evapotranspiration in the winter. Sadler and Camp (1986) confirmed that in areas where rainfall is on the average fairly uniform throughout the year at about 10 cm per month, more water will percolate through the soil reconsolidating the tilled subsoil more during the winter than during the summer.

The soil resistance to root penetration was found to be higher due to no-tillage treatment rather than minimum tillage treatment using chiseling and conventional tillage with moldboard plow and disking, while the latest one reported the minimum penetration resistance, and
that was accentuated at the (0.15–0.30 m) depth compared (0– 0.15 m) soil layer in sandy and sandy loam soils (Cavalieri et al., 2006).

Franzen et al., (1994) observed significantly smaller cone index under no-tillage down to 10 cm soil depth due to mulching. As for bulk density, differences between no-till and more conventional soil-distributing tillage methods are great soon after tillage operations, but fall quickly during the growing season and may disappear at the end.

The tillage system affects not only soil resistance to penetration but also its related variables such as water content and bulk density. For this reason it is important to separate the direct effect of tillage on cone index from its direct effect on water content and bulk density in different ways in order to allow better comparisons (Busscher et al., 1997). However in well-structured soils or those in which biochannels are preserved (as in non-tilled soil), roots continue to extent at greater penetrometer readings because they can grow in the interaggregate spaces (Campbell and Henshall, 1991).

2.4.5 Adverse effect of tillage practices on soil:

Several studies have indicated that machinery traffic and adoption of different tillage systems greatly affected several soil properties under different plant growth systems (Al-Hashem, 2004). From a physical side of view, tillage is exerting a pressure on soil profile, which differs in magnitude and direction. The soil tends to react differently to that pressure through compaction, deformation, cutting, crumbling, pulverization, or transportation (Lorenz et al., 1984). The degree of compaction relates to the soil compressibility, its moisture content, axle load and how often equipment is driven on the soil (Plaster, 1992). Heavy equipment, especially when operated under moderately wet soils, also tends to reduce soil air content and to increase the physical resistance to penetration of the soil by roots. The effects of soil
compaction include restriction of root development, nutrient and water movement, and oxygen availability which often results in reduced yields of both agronomic and horticultural crops (Nafziger and Young, 2001).

Lal (1995) confirmed that collapsed soil structure results in loss of inter and intra aggregate voids which significantly contribute the declination of soil productivity. Crusted and sealed soil surfaces reduce infiltration through blocked upper most pores; the final result is root aeration impedance and water logging.

Tillage, especially when including moldboard ploughing, can be one of the dominant causes of soil organic carbon reductions (Reicosky et al., 1995). With the adoption of sustainable management practices, such as conservation tillage, agricultural soils can increase the amount of SOC (soil organic carbon) and contribute to mitigate carbon dioxide (CO₂) emissions (Paustian et al., 2000). However, the magnitude of conservation tillage response can considerably vary depending on soil and climate conditions. In addition Coates and Thacker (2001) reported that, tillage operations can contribute significantly to soil compaction and dust emissions, resulting in reduced yield and degradation of the environment. Melvin (2005) stated that the wind and water erosion hazard is one of "clean-tilled" system outputs.

Meek et al., (1992) confirmed that the improvement of hydraulic characteristics of soils as due to increased porosity and decreased bulk density resulting from tillage, were temporary and will last soon after the first irrigation when the recently tilled soil particles settle back to its former conditions of bulk density, and thus block water pores.

For all that, when energy, time and impact of tillage on soil are to be reduced, the working depth, intensity and action of tillage should be kept at the minimum level (Lonita et al., 1999).
2.5 performance parameters of agricultural implement:

Measures of agricultural machine performance are the rate and quality at which the operations are accomplished (Hunt, 1979). There are many different parameters reflecting the machine performance such as field capacities and efficiencies, fuel consumption, slippage, draft, and drawbar power.

2.5.1 Implements field capacities and efficiencies:

Field efficiency is the ratio of effective field capacity to theoretical field capacity, expressed as percent. It includes the effects of time lost in the field and failure to utilize the full width of the machine (Kepner et al., 1982). It varies with the size and shape of the field, pattern of field operation, crop yield, moisture, and crop conditions (ASAE, 1983). Theoretical field capacity of an implement is the rating of field coverage that would be obtained if the machine is performing its 100 percent of time at the rated forward speed and always covering 100 percent of the rated width (Kepner et al., 1982). Effective field capacity is the actual rate of performance of land or crop processed in a given time based upon total field time (ASAE, 1983). Calculations of machine capacity involve measuring areas or masses and times as following equation (Hunt, 1979):

\[ C = \frac{SWE}{C} \]  

\[ \text{Where:} \]
\[ C = \text{effective capacity, ha/hr [acre/hr]} \]
\[ S = \text{speed, Km/hr [mi/hr]} \]
\[ W = \text{rated width of implement, m [ft]} \]
\[ E = \text{field efficiency as a decimal} \]
\[ C = \text{constant, 10[8.25]} \]
2.5.2 Fuel consumption:-

Fuel consumption is usually expressed as specific consumption (L/KWh), or per hour or hectare consumption (L/h) or (L/ha) (Pensson et al., 1986). Smith (1993) reported that 45-60% of consumed fuel required for the tractor to propel itself.

Many factors affect fuel consumption of a machine. Lonnemark (1977) concluded these factors: machine use, size and kind of implement attached (load), operating speed, and soil conditions.

2.5.3 Slippage (Travel reduction):-

Excessive travel reduction of tractor as well as fuel waste is a common problem in developing countries. Slip is the relative movement in the direction of travel at the mutual contact surface of the traction or transport device and the surface which supports it. It is also known as power loss during operation. ASAE (1983) explains that, excessive wheel slip causes vital losses of tractor work output, for example loss of length of ploughing per wheel revolution, per gallon of fuel used, per hour of payment for tractor operation, per return against capital outlay.

Slippage hastens tire wear and compaction, particularly in light and wet soils (Laurel, 1988). Pensson et al., (1986) indicated a top limit to travel reduction about 25% under maximum loading and depth when working on a heavy clay soil.

Slip can never be eliminated entirely but can some times be minimized by reducing the load, and working in higher gear, and it may be remedied by adding weight to force plough into the soil and create more draft, fitting streaks, or fitting alternative types of wheel or track equipment (Culpin, 1986).

2.5.4 Draft:-

Traction is defined by (Shebi et al., 1988) as the force applied to the tool which causes the elements to move through the soil. The net draft
of an inclined tine is given by the horizontal components of the tangential and normal soil surfaces acting on the surface of the tine.

Draft requirement of tillage implements has great concern for designing tillage implements, and deciding suitable tractor size (Igbal et al., 1994). Draft requirements of machines varied according to machine and tire types, soils, field conditions, tractor characteristics, depth and speed of work, and the interaction between these factors (Bashford et al., 1991).

Draft can be calculated due to drawbar power (it is the power, in relation to pull-type or mounted implements, actually required to pull or move the implement at uniform speed) by the following equation (Hunt, 1979):

\[
D = \frac{C \times DBP}{S} \quad (2.2)
\]

Where:
D = draft kn [lb],
C = constant 3.6[375],
DBP = draw bar power kW [hp],
S = travel speed km/hr [mi/hr].

2.6 Effect of soil types and conditions on the tillage implement performance:

Measures of agricultural machine performance are the rate and quality at which the operations are accomplished (Hunt, 1979). Tillage operations are soil-related procedure; soil type and condition are cardinal factors affecting the field performance of the tractor through their effect on the powered implement and tractor traction (Belel and Dahab, 1997). Smith (1993) stated that the performance of plough varies considerably according to the type of soil, its moisture content, weed growth, crop residues and shape of the field. The soil physical characteristics which
affecting crop production and tillage requirements, are hard to be studied or assessed directly; these involve size, shape, and arrangement of solids and continuous voids, and forces relevant to physical soil characteristics. Structural stability is usually assessed in terms of different properties including total porosity, pore size distribution, available water content, and bulk density (Lal, 1995).

Generally, when the soil compaction increased, the bulk density increased and consequently the soil penetration resistance became high, accordingly, the implements in the firm soils require a greater draft force to overcome a considerable amount of soil resistance, thus the draft force required to pull the implement in firm soil condition was greater than that of loose condition (John et al., 1987). High bulk density, higher slippage and increased fuel consumption, and decreased operating speed should be achieved in the firm soil. Simple correlation analysis showed that, the draft accounted for 77.3% of the availability of the slippage and 63% of the availability of fuel consumption (Belel and Dahab, 1997). They observed that, the implement in firm soil conditions gave better efficiency than in loose ones.

Osman (1964) mentioned that there are many factors that affect the draft of an implement. The draft of blades in the wet sand was about 45% higher than that in the dry sand, showing the effect of cohesion in increasing the draft, while the draft in the clay soil was greater than sandy soil by 17%, showing the effect of soil type on draught. Salokhe and Shirn (1992) stated that increase in soil moisture content and disc angle, decreased the specific draft requirement. Similar results were recorded by Dahab and Mohamed (2002) that there are significant differences in traction performance between tested implements due to soil moisture content, and tire inflation pressure. Belel and Dahab (1997) observed that implement type also affects draft, and they attributed the lower draft
force of disc plough to the effect of rotating disc elements. Riethmuller (1989) stated that all the tested implements for draft requirements showed linear increase in draft with depth and speed. Bukhari et al., (1988) confirmed that wheel slip is increased in clay loamy soil, when the speed of ploughing increased.

Energy consumption depends on many factors including soil type and strength, tilling depth, forward speed and quality of tillage. Shebi et al., (1988) and Kepner et al., (1982) explained the effects of soil type as they reported that clay soil has a higher break up energy requirement than sandy loamy soils. For a given soil, energy requirements increased with bulk density. Ahmed and Haffar (1993) confirmed that differences in fuel consumption were attributed mainly to draft characteristics and depth of work. Bukhari et al., (1992) reported that disc harrow required more fuel per hour due to accelerated engine speed. Also, it is evident that as the plough width increased, the energy efficiency to pulverize the soil increased. Belel and Dahab (1997) showed that the waste of energy in tractors was reduced when wheel slippage was adjusted between 15% and 18 percent.

Field efficiency of chisel plough tends to increase with increased soil texture coarseness, but decreases in loose soil state. In contrast, for disc harrow, field efficiency increased in both states of soil (firm and loose) with the increase in soil texture coarseness. Disc plough has an increasing field efficiency but at an increasing rate when soil texture becomes coarser (Abdul Razzag and Sabir, 1992).

2.7 Importance of Tillage implements selection:

Tillage is the most costly operation in the budget of the farmer (Igbal et al., 1994). Thirty percent of total power used through agricultural production is expended in the mechanical manipulation of the soil. Therefore, efforts must be exercised in the selection and use of
tillage implements (Igbal et al., 1994). Selecting a tillage system is one of a crop producer's most important management decisions (Melvin, 2005), especially from an economic side of view. Improper and justified use of tillage implements destroy the root zone in the soil and ultimately stagnates crop yield, and the unwise use of tillage implements wasted fuel and human energy with minimum benefits in terms of yield (Hussein and Munir, 1986). Pudjiono and MacMillan (1995) reported that reduction in energy waste in tillage operations depends upon the matching of tractor–implement and their operating characteristics and this can be adjusted only by experimentation and understanding of requirements.

Selecting the best tillage system for a particular soil and cropping situation requires matching the operation to the crop sequence, topography, and soil type, and know the immediate effect of the operation on the soil properties, and how this operation modifies short term change in soil organic matter and productivity. To assist in matching tillage systems to different soil types, the type of limitation of various tillage systems based on wetness and soil temperature, water erosion, wind erosion, flooding frequency, topsoil thickness and soil tilth. This data can assist you in selecting appropriate tillage systems for a certain soil (Melvin, 2005). He explained that, matching tillage systems to a farming enterprise requires the consideration of soil characteristics, weed pressure, accessibility to equipment, and management ability. Because of the variety of conditions encountered, there is no one best tillage system usually suited for each soil type and condition. For example, ridge or till planting is better suited to a soil that tends to be poorly drained or wet in the spring because the ridges dry out and warm up sooner. For the same soil, fall tillage, such as chiseling, also can be a good choice and would help reduce soil compaction commonly associated with working or driving on wet soils. However, no-till is generally not well suited to wet
soils because the residue may slow drying. In well drained soils, no-till is an appropriate alternative.

Management of crop residue is the most efficient technique for controlling soil erosion in terms of investment and convenience, especially when compared to tillage practices. 20 to 30 percent residue cover will reduce erosion by 50 percent of that occurring from a cleanly till field. Crop residue reduces surface crusting, sealing, and rainfall-induced soil compaction, all of which increase runoff by reducing infiltration (Melvin, 2005). Also it has a great effect on the crop growth through changes in soil temperature, soil moisture, gas exchange, and compaction (The Missouri Certified Crop Adviser Programme .2004). Residue management with various tillage systems is one of the primary factors to be considered when selecting a conservation tillage system. Limiting the number of field operations is also important. This is especially true following crops with low volumes of residue or fragile residue such as soybeans (Melvin, 2005).

Deer and company (1993) concluded the important factors that determine the choice of the tillage system as soil aeration, management of crop residues, weed control, incorporation of fertilizers, moisture management, erosion control, preparation surface for other operations, timeliness for cultivation, cost and energy conservation. Careful selection and management of tillage implements and systems means saving of environment and maximizing of returns.
CHAPTER THREE
MATERIALS AND METHODS

3.1 Materials :

3.1.1 Experimental Location :

The experiment was conducted during Sept 2006 at two different locations; first site at the Demonstration Farm of the Faculty of Agriculture, University of Khartoum at Shambat, where second one at Abu–Halema project (15 Km north of Khartoum North). Both locations at latitude 15.40 N and longitude 32.32E. The soil in the first location is sandy clay (fallow ridged) soil, and in the other is clay soil. Some physical and chemical characteristics of the two soil locations are shown in the table (3.1a) and (3.1b).

3.1.2 Tractor and Tillage Implements used :

Massey Ferguson 165 tractor, and three tillage implements were used and their specifications are shown in Appendix A (Tables 1 and 2) respectively.

3.1.3 Other equipments:

1\ Measuring tape: - 30 cm long was used for measuring the dimensions and distances.

2\ Steel pegs: - were used for marking the distances during the experiment.

3\ Stop watch: - It was used for determining the time periods during the experiment ((productive time, and times for turns).

4\ Pieces of chalk: - Used for marking the rear wheel of the tested tractor for measuring the slippage.

5\ Graduate cylinder (one-liter):- It was used to refill the tractor fuel tanks, to determine fuel consumption in each operation.
3.2 Methods:-

3.2.1 Experimental treatments and design:

The treatments included three types of tillage implements replicated three times in each location, which were: chisel plough, offset disc harrow, and ridger. Complete randomized block design was used in which the treatments were randomly distributed in each block of (7×64 m²) size.

3.2.2 Land preparation:-

The experimental area (1600 m²) was divided into nine plots at each location, as three plots for the replication of each treatment. The plot size was 7×20 meters. Plots were separated from each other by a distance of 2 meters, this inter distance to avoid the interaction between the plot borders, a space will be left at the ends of the block to be used as head lands during the commencement of the tillage operations, and that shown through figure (3.1).

3.2.3 Machinery Measured Parameters:-

A\ Field Efficiency Measurement: -

1-Ploughing started and continued at constant speed after finishing the preparation of the experimental area, and the start time was recorded by using the stopwatch in (sec).

2-Time needed to finish one tractor travel (20m distance), which is the plot length, was recorded.

3-Time to finish the plot ploughing was also recorded, and then the field efficiency (FE %) was calculated as follows:

\[
FC\% = \frac{\sum \text{Times of all executed travels inside the plot}}{\text{Total time to finish the plot}} \times 100........................... (3.1)
\]
**B\ Wheel Slippage Measurement:-**
The rear wheel slippage was determined as follows: -
1-First the rear wheel was marked tangent to the ground surface by a piece of chalk.
2-The number of revolutions of the wheel when the tractor was unloaded with implement (WL) were marked and counted until the tractor finished travel.
3-The number of revolutions is counted and marked again for the same travel, when the tractor was loaded with the implement (L).
4-The wheel slippage was calculated as follows: -

\[
\text{Wheel slippage } \% = \frac{L - WL \times 100}{WL} \]

**C\ Fuel Consumption Measurement: -**
1-The tractor started working the plot with its full tank capacity.
2-After finishing the plot, the tank was refilled with the graduate cylinder.
3-The amount of fuel that was used to refill the fuel tank was recorded.
4-The fuel consumption rates were calculated in liter/ha and liter/hr as follows:-
   a-The rate (L/ha) = \( \frac{\text{Reading of cylinder (ml)} / 1000}{\text{Area of the plot m}^2 / 10.000} \) \( \text{................ (3.3)} \)
   b-The rate (L/hr) = \( \frac{\text{Reading of cylinder (ml)} / 1000}{\text{Time required covering the plot (hr)}} \) \( \text{............ (3.4)} \)

**3.2.4 Soil Physical Properties Measurements: -**
1\ Initial Soil Samples Analysis: -
Soil samples were taken from the three blocks in each location before application of the treatments, one at the field center and the others from the different sides of the field. The samples were taken by a soil auger from four depths (0-15, 15-30, 30-45, 45-60 cm). Samples were
placed immediately in a polythene bags to avoid the moisture losses between the field and the laboratory. Soil (MC %) was determined in each sample. The remaining samples were air dried ground, and some general physical and chemical properties were determined according to Richard (1954).

2) **Soil Moisture Content Determination:**

The moisture content was determined directly using gravimetric sampling technique, in which the weights of wet samples were measured, and then soil samples were dried in an oven at temperature of 105-110 c° for 24 hours. Soil moisture content percentage on weight basis is calculated as follows (Gardner, 1986):

\[
MC\% \text{ on wet basis} = \frac{\text{wet sample weight} - \text{dried sample weight}}{\text{dried sample weight}} \times 100 \ldots (3.5)
\]

MC% on volume basis = MC% on weight basis × bulk density × 100 \ldots (3.6)

4) **Soil Bulk Density Determination:**

The determination of the soil bulk density and porosity is interrelated. The bulk density was determined using the (clod method), that is described by Blake and Hartge, (1986), making use of Archimedes’ principle, according to the following formula:

\[
\text{Bulk density (gm/cm}^3\) = \frac{\text{PwWods/ [Wsa-Wspw+Wpa-(WpaPw/Pp)]}}{\ldots \ldots (3.7)}
\]

Where:

- \(\text{Pw}\) = density of water at temperature of determination (gm/ cm³),
- \(\text{Wods}\) = oven – dry weight of soil sample (clod) (gm),
- \(\text{Wsa}\) = net weight of clod in air (gm),
- \(\text{Wspw}\) = net weight of soil sample with coating in water (gm),
Wpa=weight of the coat in air (gm),
Pp=density of coat water –repellent substance.

5\ Soil Porosity Determination: -

Particle density was calculated based on Archimedes’ principle, the soil sample mass determined by weighing; the volume, by calculation from the mass and density of water displaced by the soil sample, by using (Pycnomotor) method according to the following formula (ASTM, 1958) : -

Particle density (gm/cm³) = Pw (Ws-Wa)/ [(Ws-Wa)-(Wsw-Ww)]…… (3.8)

Where:
Pw=density of water at temperature of determination (gm/ cm³),
Ws=weight of pycnometer plus soil sample corrected to oven-dry water content,
Wa=weight of pycnometer filled with air,
Wsw=weight of pycnometer filled with soil and water,
Ww=weight of pycnometer filled with water at determination temperature.

A volumetric flask (100 ml) was used in place of a pycnometer, because the sample was large enough to compensate the decrease in precision of measuring fluid volume.

Total porosity, was therefore calculated as described by Danielson and Sutherland, (1986): -

Soil porosity = \( \frac{1}{\text{Particle density}} \times \text{bulk density} \times 100 \)………………………… (3.9)

Which means Soil porosity = Soil voids volume \( \times 100 \)……… (3.10)

Total volume of soil
5\ Soil Aggregation Stability Determination: -

Soil aggregation stability was identified by using (Aggregation particles less than 50 microns) method that is described by Richard (1954), and by applying the following formula: -

Soil aggregation stability % = \( \frac{W_2 - 0.06 \times 100}{(W_2 - S) + W_1} \) .......................... (3.11)

Where: -

W1 = Weight of soil sample in water,
W2 = Weight of soil sample in (Calgon),
S = Weight of calgon (0.06).

6\ Resistance to Penetration Measurement: -

These measurements were carried out before and after tillage operations, by using hand operated soil test penetrometer [Dynamic cone penetrometer (DCP)]. Specifications are shown in figure (3.2).

--Operation:-

Three points were taken at each block spaced 6 cm apart (just three blocks before the proceeding of treatments were taken).

The penetrometer is operated by placing the cone on the soil surface with the shaft oriented vertically (soil surface is set level with the base of the cone) and the operator should periodically ensure keeping the penetrometer at that position (before and after dropping the mass); this minimizes variability in starting depth. The cone is then pressed into the soil until it just becomes buried; this initial penetration is recorded as “Blow 0.” The operator then raised and released the slide hammer one or more times depending on the strength of the soil. Depth of penetration after each blow and total blows to reach a desired depth can be recorded. This process continues until the desired depth of testing is reached (600 mm for this experiment) (Herrick and Jones, 2002).
--Measurements:-

Penetration resistance of soil was measured as \( \text{Kg/cm}^2 \) by calculating the pressure exerted by an 8 kg falling hammer on a base of 50 mm diameter through a number of blows, depending on the strength of soil. The falling hammer exerts \( 0.408 \text{ Kg/cm}^2 \) through one blow and the soil resistance to penetration for certain depth was calculated by gathering all blows needed to reach that depth, multiplied by the pressure of one blow \( 0.408 \text{ Kg/cm}^2 \).
Chapter Four

Results and discussions

4.1 Effect of tillage on some physical properties of soil:

4.1.1. Effect on soil bulk density (g/cm³) and porosity (%):

Average bulk density values as affected by different tillage methods on four soil depths in the two locations are presented in Figures (4.1a and 4.1b) (Appendix B (Tables1a and b)). All the recorded bulk density values were between 0.90 to 1.80 gm/cm³, which is the range described by Chi et al., (1993) for usual agricultural soils. Higher bulk density with lower porosity (as shown in Figures (4.2a and b) –Appendix B (Table2 a and b)) are recorded for the location of clay soil than sandy clay soil location, and that is probably referred to the variation in the structural conditions of the soil as described by (Chen et al, 1998). In both locations, the bulk density decreased (p<0.01) (increased porosity) from sub soil depths upward to soil surfaces (Maurya, 1993) that the soil strength tends to increase with depth of soil.

Statically there were no significant differences in bulk density, due to different tillage systems in both locations, and this is in line with the findings of Cassel, (1982) and Logsdon and Cambardella, (2000). In the location of sandy clay soil, the tillage treated plots gave greater bulk density (smaller porosity) than those obtained from no-till treatment. The ridger gave the highest average bulk density (1.33 gm/cm³) and the lowest porosity (48.23%). This finding may be attributed according to Mahboubi et al., (1993) to the contradicting effect of tillage when the attained improvements in soil bulk density and porosity might be offset by wheel induced compaction resulting from static and dynamic weights of machinery. In the clay soil location, insignificant improvements in bulk density and porosity resulted from the disc harrow (1.33 gm/cm³) bulk density and (48.16%)
Figure (4.1) Effect of tillage treatments on bulk density (g/cm³)

(a) Sandy Clay Soil

(b) Clay Soil
Figure (4.2) Effect of tillage treatments on soil porosity (%)

(a) Sandy Clay Soil

(b) Clay Soil
porosity. This result agreed with Cavalieri et al., (2006). The chisel plough reported high average bulk density of (1.34 gm/m³) and the lowest porosity of (46.48%), but has resulted in reduced bulk densities at deeper depths (15-45cm), which could be attributed to its characteristic design features in distributing deeper layers. This is in line with Bukhari et al., (1992) and Abdul Razzag and Sabir, (1992).

Generally porosity and bulk density are interrelated and porosity tends to increase with decreased bulk density and that is clearly shown from the previous results, but on the contrary of bulk density there are high significant differences on average percentages of porosity between tillage treatments in both types of soil (p<0.01).

4.1.2 Effect on soil aggregation stability (%):-

The results represented on Figure (4.3a and b) (Appendix B (Tables 3a and b)) show highly significant differences (p<0.01) in the average percentages of aggregation stability between the tillage treatments at the two locations and within soil depths. The percentages of aggregation stability in the clay soil location through the different depths are higher than in the location of sandy clay soil, (range from 30.92% to 74.54%) and (19.03% to 52.17%) for the two soils respectively. That could be due to a high content of decomposed organic matter in the clay soil compared to sandy clay soil.

In the location of sandy clay soil, the disc harrow gave higher average aggregate stability of about (35.63%) comparing to (30.64%) measured in the no-tillage treatment, and that may be due to its unique capability in cutting up and mixing stubble as mentioned by Smith and Wilkes(1986). The chisel plough recorded the lowest average of (32.38%), probably as it is characterized by a maximum loosening effect on soil, but with minimum pulverizing, mixing, and inverting effects as
Figure (4.3) Effect of tillage treatments on soil aggregation stability (%)

(a) Sandy Clay Soil

(b) Clay soil
described by Doorenbos and Pruitt, (1977). At the same time the average percentages of aggregate stability in all tillage treatments decreased in the depth (15-30 cm).

In clay soil location, it seems that the mechanical process of tillage implements lead to a higher decrease in aggregate stability within all soil depths. That may be probably due to the distributing effect of the different tillage implements. The disc harrow gave the lowest mean aggregate stability of (25.73 %) compared to (56.34%) for no-tillage treatment due to its capability in crushing and pulverizing the clods, according to Smith and Wilkes, (1986).

4.1.3 **Effect on soil resistance to penetration (Kg/cm²):**

Figure (4.4) (Appendix B (Table 4)) show the averages soil resistance to penetration as measured by the dynamic penetrometer for the different tillage treatments through the four depths in the sandy clay soil location. Statistically there are highly significant differences (p<0.01) between the tillage treatments, and the depth's effect on the penetration resistance. The result indicated that the soil has its highest strength within the depth (15-30 cm), as shown from the mean values of the penetration resistance of the soil. The higher strength within that layer could be justified due to the finding of Saber and Mrabet (2002) that the highest soil strength is recorded in the upper 30 cm of No-tilled plots compared to deep tilled ones.

The disc harrow and the ridger treatments improved the over–all mean penetration resistance, from (8.1 Kg/cm²) in no-tilling treatment to (6.9 Kg/cm²) and (4.2 Kg/cm²) for the two implements respectively. The interpretation of those results could lead to that implements have disrupted the soil in a rough surface with a very large stable aggregate. Consequently, the effect of increased bulk density has been small in the seed bed with those large aggregates (Nasr and Selles, 1995).At the same
Figure (4.4) Effect of tillage treatments on soil resistance to penetration (Kg/cm²) at sandy clay soil location
time disc harrow increased the mean value of penetration resistance within the lower soil profile (45-60 cm) from (8.3 Kg/cm²) to (9.2 Kg/cm²). In contrast the chisel plough increased the overall mean of penetration resistance from (8.1 Kg/cm²) to (9.0 Kg/cm²), and it seems that, the chisel treatment has loosened the soil much more than the other tillage treatments and left smaller size fractions of aggregates (it has recorded the lower mean of (aggregate stability %) compared to the other tillage treatments). This result is in agreement with Doorenbos and Pruitt (1977), then the effect of the increased bulk density been higher due to (Nasr and Selles, 1995), which lead to that increased means of soil resistance to penetration due to Ehlers et al., (1983) that mechanical impedance of soil increases as bulk density increases and water content decreases. At the same time the chisel loosened the lower depth (45-60 cm) and penetration resistance decreased from (8.30 Kg/cm²) to (7.60 Kg/cm²), which could also be attributed to its characteristic design features (Bukhari et al., 1992 and Abdul Razzag and Sabir, 1992).
4.2 Implements performance in the two locations:-

The statistical analysis revealed that, there were no significant differences (p<0.05) due to the implements type on the mean measured parameters.

4.2.1 Effect on rear wheel slippage (%):-

The results presented in Figure (4.5) (Appendix B (Table (5)) revealed that the average percentage of wheel slippage for all implements used is below the top limit of wheel slippage (20%) (Pensson et al., (1986)). All implements recorded higher wheel slippage in the sandy clay soil than the clay soil, and that may be due to the presence of ridges in the first location which probably created a harsh working condition and made the soil in that location more firm causing a noticeable motion resistance. This is agreed with the findings of Belel and Dahab (1997). Higher slippage values in the two locations are recorded by the chisel plough and ridger. The chisel plough gave the highest slippage value of (19.2%), and this may be due to increased load transfer to the rear drive wheel of tractor. This is in agreement with Riethmuller, (1989) who stated that, all the tested implements for draft requirements showed linear increase in draft with depth and speed. The lowest slippage values at the two locations (sandy clay soil, clay soil) were recorded by the disc harrow (15.57%) and (10.4%) respectively. This is most likely due to its shallower ploughing depth. Generally, fluctuations in ploughing depth and speed depend on the field condition and operator skill, and the latter is the key factor that might alter values of slippage by determining the depth and speed of ploughing. The same statement was given by Baloch et al., (1993) and Igbal et al., (1994).

4.2.2 Effect on fuel consumption (L/ha & L/hr):-

As shown in Figures (4.6a and b) (Appendix B (Table (5)), fuel consumption rates in (L/ha) and (L/hr) are numerically higher in the
location of sandy clay soil than the clay soil location for all implements, and that probably referred to the higher draft requirements for the implements in the first location. That is in line with Belel and Dahab, (1997) who reported that, as draft increased, wheel slippage and fuel consumption by the tractor increased. Chisel plough recorded the highest rate of fuel consumption (15.7L/ha) in both locations. While the ridger gave the highest fuel consumption rates in the clay soil location (10.83L/ha and 3.27 L/hr). Also the disc harrow recorded the lowest rates of fuel consumption at both location (5.97 L/ha and 1.06 L/hr).

4.2.3 Effect on field efficiency (%):-

The results of field efficiency are shown in table (4.5) and Fig (4.7). In the first location of sandy clay soil the chisel plough and the ridger numerically achieved higher field efficiencies 74.33 % and 74.37% respectively. This result could be explained by Belel and Dahab (1997), as operating the implement in the firm soil condition increased the draft and fuel consumption, but gave better efficiency than in loose soil. On the contrary, disc harrow gave the higher field efficiency in the clay soil location (79.9%) compared to (71.97%) in the location of sandy clay soil. That probably might be attributed to reduced time losses, and as confirmed by Igbeka, (1986) field efficiencies, which are assessed on time –basis, are generally influenced by operator skill in adjusting his operating pattern.
Fig (4.5) Effect of different locations and implements types on wheel slippage (%)
Fig (4.6a) Effect of different locations and implements types on fuel consumption rate (L/ha)
Fig (4.6b) Effect of different locations and implements types on fuel consumption rate (L/hr)
Fig (4.7) Effect of different locations and implements types on field efficiency (%)
Chapter Five
Conclusions and Recommendations

5.1 Conclusions:

The following conclusions may be drawn from the present study:-

- Bulk density tends to increase with soil depth in the two locations, while porosity tends to decrease.

- In the location of sandy clay soil the disc harrow gave the maximum average aggregate stability (35.63%) while the lowest value (30.64%) measured by the no-tillage treatment.

- In the clay soil location all the tillage implements decreased the aggregation stability and the disc harrow recorded the lowest mean (25.73 %).

- In the sandy clay soil location the disc harrow and the ridger have decreased the mean soil penetration resistance (6.9 and 4.2Kg/cm²) respectively; while the chisel plough has increased the mean of soil resistance to penetration up to (9.02Kg/cm²).

- Wheel slippage, fuel consumption for all the implements are higher in the sandy clay location than in clay soil location.

- The chisel plough gave the highest wheel slippage (19.2%) and fuel consumption rate (15.7L/ha), while the lowest slippage value (10.4%) and fuel consumption rate (5.97 L/ha and 1.06 L/hr) were recorded by the disc harrow.

- Field efficiency for the chisel and ridger were higher in the sandy clay location (74.33 % and 74.37%) than in clay soil location (71.94% and 72.9%). While the disc harrow recorded the highest field efficiency compared to other implements in two soils in the clay soil location (79.9%).
5.2 Recommendations:-

– The tested implements were affected differently by soil type and condition, which needs more investigation.

– Further research should focus on controlling the secondary compaction resulting from the mechanical land preparation as it alters the positive outcomes of the tillage operation.
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e-mail: kiml@mo-ag.com


APPENDIXS

Appendix (A)

Table (1): Some specifications of the tractor:

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<thead>
<tr>
<th>Mark</th>
<th>Massey Ferguson 165</th>
</tr>
</thead>
<tbody>
<tr>
<td>Make</td>
<td>England</td>
</tr>
<tr>
<td>Engine type</td>
<td>Diesel</td>
</tr>
<tr>
<td>No. of cylinders</td>
<td>4</td>
</tr>
<tr>
<td>Stroke cycle</td>
<td>4</td>
</tr>
<tr>
<td>Cooling system</td>
<td>Water</td>
</tr>
<tr>
<td>Engine power</td>
<td>70 Hp(52.2Kw)</td>
</tr>
<tr>
<td>Size of rear tires</td>
<td>14.9×28</td>
</tr>
<tr>
<td>Size of front tires</td>
<td>750×16</td>
</tr>
</tbody>
</table>
Appendix (A)

Table (2): Some specifications of the implements:

<table>
<thead>
<tr>
<th>Specifications</th>
<th>Chisel Plough</th>
<th>Offset disc harrow</th>
<th>Ridger</th>
</tr>
</thead>
<tbody>
<tr>
<td>Make</td>
<td>England</td>
<td>England</td>
<td>Turkish</td>
</tr>
<tr>
<td>Width of cut</td>
<td>180 cm</td>
<td>225 cm</td>
<td>210 cm</td>
</tr>
<tr>
<td>Number of units</td>
<td>5</td>
<td>9 × 2</td>
<td>3</td>
</tr>
<tr>
<td>Hitching</td>
<td>3- Point linkage</td>
<td>3-Point linkage</td>
<td>3- Point linkage</td>
</tr>
<tr>
<td>Tractor power requirement</td>
<td>50/60 kw</td>
<td>50/60 kw</td>
<td>50/60 kw</td>
</tr>
<tr>
<td></td>
<td>70/80Hp</td>
<td>70/80Hp</td>
<td>70/80Hp</td>
</tr>
</tbody>
</table>

Source: GIAD Tractors and Agricultural Equipment Catalog
Appendix (B)

Table (1) Effect of some tillage treatments with soil depths on bulk density (gm/cm³)

(a) Sandy Clay Soil

<table>
<thead>
<tr>
<th>Soil depths</th>
<th>No-tillage</th>
<th>Chisel plough</th>
<th>Disc Harrow</th>
<th>Ridger</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-15</td>
<td>1.26</td>
<td>1.28</td>
<td>1.26</td>
<td>1.31</td>
<td>1.28c</td>
</tr>
<tr>
<td>15-30</td>
<td>1.28</td>
<td>1.30</td>
<td>1.31</td>
<td>1.32</td>
<td>1.30bc</td>
</tr>
<tr>
<td>30-45</td>
<td>1.30</td>
<td>1.32</td>
<td>1.34</td>
<td>1.36</td>
<td>1.33bc</td>
</tr>
<tr>
<td>45-60</td>
<td>1.34</td>
<td>1.34</td>
<td>1.36</td>
<td>1.35</td>
<td>1.35ab</td>
</tr>
<tr>
<td>Mean</td>
<td>1.29a</td>
<td>1.31a</td>
<td>1.32a</td>
<td>1.33a</td>
<td></td>
</tr>
</tbody>
</table>

Means with the same letters are not significantly different.

LSD₀.₀₅ for (Treatments) = 0.041
LSD₀.₀₅ for (Depths) = 0.041
LSD₀.₀₅ for (T×D) = 0.082

(b) Clay Soil

<table>
<thead>
<tr>
<th>Soil depths</th>
<th>No-tillage</th>
<th>Chisel plough</th>
<th>Disc Harrow</th>
<th>Ridger</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-15</td>
<td>1.31</td>
<td>1.31</td>
<td>1.31</td>
<td>1.31</td>
<td>1.31c</td>
</tr>
<tr>
<td>15-30</td>
<td>1.33</td>
<td>1.32</td>
<td>1.32</td>
<td>1.33</td>
<td>1.32bc</td>
</tr>
<tr>
<td>30-45</td>
<td>1.35</td>
<td>1.34</td>
<td>1.34</td>
<td>1.36</td>
<td>1.35ab</td>
</tr>
<tr>
<td>45-60</td>
<td>1.39</td>
<td>1.39</td>
<td>1.36</td>
<td>1.38</td>
<td>1.38ab</td>
</tr>
<tr>
<td>Mean</td>
<td>1.34a</td>
<td>1.34a</td>
<td>1.33a</td>
<td>1.34a</td>
<td></td>
</tr>
</tbody>
</table>

Means with the same letters are not significantly different.

LSD₀.₀₅ for (Treatments) = 0.034
LSD₀.₀₅ for (Depths) = 0.034
LSD₀.₀₅ for (T×D) = 0.068
Appendix (B)

Table (2) Effect of some tillage treatments with soil depths on soil porosity (%)

(a) Sandy Clay Soil

<table>
<thead>
<tr>
<th>Soil depths</th>
<th>No-tillage</th>
<th>Chisel plough</th>
<th>Disc Harrow</th>
<th>Ridger</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-15</td>
<td>55.05</td>
<td>52.95</td>
<td>53.17</td>
<td>50.85</td>
<td>52.99a</td>
</tr>
<tr>
<td>15-30</td>
<td>53.25</td>
<td>51.0</td>
<td>50.45</td>
<td>49.65</td>
<td>51.09b</td>
</tr>
<tr>
<td>30-45</td>
<td>51.05</td>
<td>49.75</td>
<td>47.05</td>
<td>47.30</td>
<td>48.79c</td>
</tr>
<tr>
<td>45-60</td>
<td>48.30</td>
<td>48.55</td>
<td>45.85</td>
<td>45.10</td>
<td>46.95d</td>
</tr>
<tr>
<td>Mean</td>
<td>51.91a</td>
<td>50.56b</td>
<td>49.17c</td>
<td>48.23d</td>
<td></td>
</tr>
</tbody>
</table>

Means with the same letters are not significantly different.
LSD0.05 for (Treatments) =0.467
L.S.D0.05 for (Depths) =0.467
L.S.D0.05 for (T×D) =0.934

(b) Clay Soil

<table>
<thead>
<tr>
<th>Soil depths</th>
<th>No-tillage</th>
<th>Chisel plough</th>
<th>Disc Harrow</th>
<th>Ridger</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-15</td>
<td>50.80</td>
<td>49.55</td>
<td>50.45</td>
<td>49.60</td>
<td>50.10a</td>
</tr>
<tr>
<td>15-30</td>
<td>49.55</td>
<td>47.6</td>
<td>49.45</td>
<td>47.70</td>
<td>48.58b</td>
</tr>
<tr>
<td>30-45</td>
<td>47.55</td>
<td>45.10</td>
<td>47.20</td>
<td>45.55</td>
<td>46.35c</td>
</tr>
<tr>
<td>45-60</td>
<td>43.85</td>
<td>43.65</td>
<td>45.55</td>
<td>43.70</td>
<td>44.19d</td>
</tr>
<tr>
<td>Mean</td>
<td>47.94a</td>
<td>46.48b</td>
<td>48.16a</td>
<td>46.64b</td>
<td></td>
</tr>
</tbody>
</table>

Means with the same letters are not significantly different.
LSD0.05 for (Treatments) =0.234
L.S.D0.05 for (Depths) =0.234
L.S.D0.05 for (T×D) =0.469
Appendix (B)

Table (3) Effect of some tillage treatments with soil depths on aggregation stability (%).

(a) Sandy Clay Soil

<table>
<thead>
<tr>
<th>Soil depths</th>
<th>Tillage implements (Treatments)</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No-tillage</td>
<td>Chisel plough</td>
</tr>
<tr>
<td>0-15</td>
<td>19.03</td>
<td>30.86</td>
</tr>
<tr>
<td>15-30</td>
<td>52.17</td>
<td>29.75</td>
</tr>
<tr>
<td>30-45</td>
<td>28.72</td>
<td>37.81</td>
</tr>
<tr>
<td>45-60</td>
<td>22.65</td>
<td>31.10</td>
</tr>
<tr>
<td>Mean</td>
<td>30.64d</td>
<td>32.38c</td>
</tr>
</tbody>
</table>

Means with the same letters are not significantly different.

LSD$_{0.05}$ for (Treatments) = 0.004

L.S.D$_{0.05}$ for (Depths) = 0.004

L.S.D$_{0.05}$ for (T×D) = 0.009

(b) Clay Soil

<table>
<thead>
<tr>
<th>Soil depths</th>
<th>Tillage implements (Treatments)</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No-tillage</td>
<td>Chisel plough</td>
</tr>
<tr>
<td>0-15</td>
<td>74.54</td>
<td>23.47</td>
</tr>
<tr>
<td>15-30</td>
<td>56.20</td>
<td>24.59</td>
</tr>
<tr>
<td>30-45</td>
<td>63.67</td>
<td>30.57</td>
</tr>
<tr>
<td>45-60</td>
<td>30.92</td>
<td>27.04</td>
</tr>
<tr>
<td>Mean</td>
<td>56.34a</td>
<td>26.42c</td>
</tr>
</tbody>
</table>

Means with the same letters are not significantly different.

LSD$_{0.05}$ for (Treatments) = 0.0048

L.S.D$_{0.05}$ for (Depths) = 0.0048

L.S.D$_{0.05}$ for (T×D) = 0.0096
Appendix (B)

Table (4) Effect of some tillage treatments with soil depths on soil resistance to penetration (Kg/cm²) at sandy clay soil location

<table>
<thead>
<tr>
<th>Soil depths</th>
<th>No-tillage</th>
<th>Chisel plough</th>
<th>Disc Harrow</th>
<th>Ridger</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-15</td>
<td>2.9</td>
<td>5.4</td>
<td>2.0</td>
<td>1.5</td>
<td>2.9d</td>
</tr>
<tr>
<td>15-30</td>
<td>10.7</td>
<td>12.4</td>
<td>7.8</td>
<td>3.5</td>
<td>8.6b</td>
</tr>
<tr>
<td>30-45</td>
<td>10.3</td>
<td>10.7</td>
<td>8.5</td>
<td>5.7</td>
<td>8.8a</td>
</tr>
<tr>
<td>45-60</td>
<td>8.3</td>
<td>7.6</td>
<td>9.2</td>
<td>6.3</td>
<td>7.9c</td>
</tr>
<tr>
<td>Mean</td>
<td>8.1b</td>
<td>9.0a</td>
<td>6.9c</td>
<td>4.2d</td>
<td></td>
</tr>
</tbody>
</table>

Means with the same letters are not significantly different.

LSD_{0.05} for (Treatments) = 0.0048
L.S.D_{0.05} for (Depths) = 0.0048
L.S.D_{0.05} for (L\times D) = 0.0096
Appendix (B)

Table (5) Effect of two different soil types and conditions with implement type on some performance parameters of the tractor

<table>
<thead>
<tr>
<th>Tillage Implement</th>
<th>Sandy Clay Soil Location</th>
<th>Clay Soil Location</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>WS%</td>
<td>FC L/ha</td>
</tr>
<tr>
<td>Chisel Plough</td>
<td>19.20</td>
<td>15.70</td>
</tr>
<tr>
<td>Disc Harrow</td>
<td>15.57</td>
<td>12.63</td>
</tr>
<tr>
<td>Ridger</td>
<td>15.77</td>
<td>12.63</td>
</tr>
<tr>
<td>Mean</td>
<td>16.84</td>
<td>13.66</td>
</tr>
<tr>
<td>LSD0.05</td>
<td>14.79</td>
<td>23.88</td>
</tr>
</tbody>
</table>

WS% = Wheel slippage  
FC = Fuel consumption  
FE = Field efficiency
Appendix (C)

Table (1) Mean squares for the effect of the tillage implement type with soil depth on the soil bulk density for the two locations.

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>D.F</th>
<th>Sandy clay soil</th>
<th>Clay soil</th>
</tr>
</thead>
<tbody>
<tr>
<td>Block</td>
<td>2</td>
<td>0.006ns</td>
<td>0.05**</td>
</tr>
<tr>
<td>Implement Type(I)</td>
<td>3</td>
<td>0.003ns</td>
<td>0.0005ns</td>
</tr>
<tr>
<td>Soil Depth(D)</td>
<td>3</td>
<td>0.012**</td>
<td>0.01**</td>
</tr>
<tr>
<td>(I×D)</td>
<td>9</td>
<td>0.0004ns</td>
<td>0.0003ns</td>
</tr>
<tr>
<td>Pooled Error</td>
<td>30</td>
<td>0.002</td>
<td>0.0017</td>
</tr>
</tbody>
</table>

* ns means not significant.
* * means significant at 0.05 level of probability.
* ** means significant at 0.01 level of probability.
Appendix (C)

Table (2) Mean squares for the effect of the tillage implement type with soil depth on the soil porosity for the two locations.

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>D.F</th>
<th>Sandy clay soil</th>
<th>Clay soil</th>
</tr>
</thead>
<tbody>
<tr>
<td>Block</td>
<td>2</td>
<td>2.33**</td>
<td>1.53**</td>
</tr>
<tr>
<td>Implement Type(I)</td>
<td>3</td>
<td>31.59**</td>
<td>9.08**</td>
</tr>
<tr>
<td>Soil Depth(D)</td>
<td>3</td>
<td>83.59**</td>
<td>80.22**</td>
</tr>
<tr>
<td>(I×D)</td>
<td>9</td>
<td>1.57**</td>
<td>0.79**</td>
</tr>
<tr>
<td>Pooled Error</td>
<td>30</td>
<td>0.31</td>
<td>0.079</td>
</tr>
</tbody>
</table>

ns means not significant.
* means significant at 0.05 level of probability.
** means significant at 0.01 level of probability.
Appendix (C)

Table (3) Mean squares for the effect of the tillage implement type with soil depth on the soil aggregation stability for the two locations.

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>D.F</th>
<th>sandy clay soil</th>
<th>clay soil</th>
</tr>
</thead>
<tbody>
<tr>
<td>Block</td>
<td>2</td>
<td>0.00219ns</td>
<td>0.828ns</td>
</tr>
<tr>
<td>Implement Type(I)</td>
<td>3</td>
<td>51.97**</td>
<td>2703.56**</td>
</tr>
<tr>
<td>Soil Depth(D)</td>
<td>3</td>
<td>688.80**</td>
<td>265.21**</td>
</tr>
<tr>
<td>(I×D)</td>
<td>9</td>
<td>203.61**</td>
<td>272.10**</td>
</tr>
<tr>
<td>Pooled Error</td>
<td>30</td>
<td>.0059</td>
<td>.418</td>
</tr>
</tbody>
</table>

*ns means not significant.
* * means significant at 0.05 level of probability.
** means significant at 0.01 level of probability.
Appendix (C)

Table (4) Mean squares for the effect of the tillage implement type with soil depth on the soil resistance to penetration for sandy clay soil.

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>D.F</th>
<th>sandy clay soil</th>
</tr>
</thead>
<tbody>
<tr>
<td>Block</td>
<td>2</td>
<td>16.32**</td>
</tr>
<tr>
<td>Implement Type(I)</td>
<td>3</td>
<td>51.84**</td>
</tr>
<tr>
<td>Soil Depth(D)</td>
<td>3</td>
<td>92.12**</td>
</tr>
<tr>
<td>(I×D)</td>
<td>9</td>
<td>7.95**</td>
</tr>
<tr>
<td>Pooled Error</td>
<td>30</td>
<td>.00003</td>
</tr>
</tbody>
</table>

ns means not significant.
* means significant at 0.05 level of probability.
** means significant at 0.01 level of probability.
Appendix (C)

Table (5) Mean squares for the effect of different soil types and conditions with implement type on some performance parameters of the tractor

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>D.F</th>
<th>Sandy Clay Soil Location</th>
<th>Clay Soil Location</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>WS%</td>
<td>FC L/ha</td>
</tr>
<tr>
<td>Block</td>
<td>2</td>
<td>10.81</td>
<td>59.59</td>
</tr>
<tr>
<td>Implement type</td>
<td>2</td>
<td>12.51</td>
<td>9.40</td>
</tr>
<tr>
<td>Pooled Error</td>
<td>4</td>
<td>42.57</td>
<td>110.97</td>
</tr>
</tbody>
</table>

**ns** means not significant.
* means significant at 0.05 level of probability.
** means significant at 0.01 level of probability.