THE EFFECTS OF CONVENTIONAL TILLAGE TECHNIQUES ON SOME SOIL AND CROP PARAMETERS

BY

RICHARD OMOYELE AKINBAMOWO.
(AGE / 95/6929)

A Thesis in the Department of Agricultural Engineering submitted to the School of Postgraduate Studies towards the degree of Master of Engineering (Farm Power and Machinery).

FEDERAL UNIVERSITY OF TECHNOLOGY.
AKURE.

JULY, 2000.

CERTIFICATION

This is to certify that this work was carried out by Mr. ***Richard Omoyele Akinbamowo*** in partial fulfilment for the requirements for the award of Master of Engineering (Farm Power and Machinery) at the Department of Agricultural Engineering, Federal University of Technology, Akure.

Engr. (Dr.) A. S. OGUNLOWO.
Supervisor

24-7-2000
Date

DEDICATION

This project is dedicated firstly to the all knowing and ever living God. Also to my wife and children

ACKNOWLEDGEMENT

I wish to acknowledge the support of my Supervisor, Dr A. S. Ogunlowo for directing the content, scope and style of the research work and also for reading through the project manuscript for correction.

The contributions of Mr Adams and staff of the Federal Polytechnic Ado Ekiti soil mechanics laboratory are also acknowledge. Similarly the contributions of Mr Adeola of the Federal college of Agriculture, Akure in the measurement of the soil parameters are worthy of mention.

I also wish to express my appreciation for the assistance of my lecturers, colleagues and friends at the ministry of Agriculture, Akure.

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ABSTRACT.

This work was carried out at Akure, latitude 7°. 5' N and longitude 5°. 10' E in the rain forest zone of Nigeria on soil type classified as alfisol to determine the effects of conventional tillage techniques on soil and crop parameters. Maize was used as the indicator crop.

Soil parameters measured include bulk density, moisture retention, soil temperature, porosity aggregate stability and soil shear strength while crop parameters measured include root length and number of main roots, stem diameter, time taken before emergence and total emergence. The tillage treatments used included zero tillage (ZT), one ploughing (PL), one ploughing followed by harrowing (PH) and ploughing, harrowing and ridging in sequence (PHR). All operations are single pass.

The result provided enough evidence that the soil structural condition as modified during tillage, affects the soil physical properties and some crop properties using maize as an indicator crop. The effects of cultivation on the soil temperature, moisture retention, total porosity appear insignificant at the 95% confidence interval. But the soil density was significantly altered by the tillage treatments used.

The total cost and gross margin of each tillage system used was also determined with an assumed constant yield of 2 tons per hectare at N17,000. 00 per ton for all tillage treatments. Experimental results of all measured data established the superiority of one disc ploughing over the other treatments. ANOVA results indicated that P.0.05 for most of the physical properties are statistically significant at 95 % confidence level except soil density and the mean weight diameter (MWD) by dry and wet sieving. Analysis of results revealed that shear strength of the soil decreased with tillage treatments.

It was found that emergence was earliest in treatment three and lowest in treatment four, decreasing directly with increasing soil strength although results from statistical analysis

showed that the total emergence was not significant. This trend of insignificant result was also observed for the measured stem diameter.

The least root system both in number and length was observed on the zero tillage plots. The emergence force exerted by seedlings was significantly affected by tillage. Measured values of seedling emergence force, decreased from a maximum of 10.63 kN at the zero tillage plots to 8.96 kN for plots ploughed, harrowed and ridged. Values recorded for other treatments are 939.34 grams for single pass disc ploughing and 913.76 grams for one disc ploughing followed by disc harrowing.

CHAPTER ONE

INTRODUCTION

In the middle ages very little was known about the effects of cultural operations on growth of crops until 1731 when Jethro Tull Published his *New horse houghing husbandry* in England (Martin et al; 1976). He thought that plants survived on the minute soil particles and that the more finely the soil was divided the more of such soil particles will be absorbed by plant roots. Later developments have proved that plants actually depend on the release of adequate amounts of plant nutrients in the soil and the availability of these nutrients is regulated by some factors which include soil composition and management practices. Land preparation in the less developed countries is largely carried out using hand tools or hoes and cutlasses and more recently by mechanical means. In developed countries cultivation by tractorisation has become a standard practice. Progress in these areas has been very rapid. We now have highly sophisticated and efficient machines carrying out same operations that were done manually many years ago.

These land preparation methods have proved to be largely successful in that they have resulted in continuous high yields and weed control. Specific tillage techniques using various implements or a combination of tillage techniques have hitherto served this purpose. When soil was worked manually, there was no time and energy to over-till the soil. This is also true for animal traction. But due to the ease of mechanical cultivation, many farmers erroneously believe that since tillage is good it cannot be overdone. Overworking the soil results in excessive pulverisation of soil particles thus making the soil easily erodible. It can lead to tillage pan as a result of frequent wheel traffic and also results in waste of time and fuel. All these consequences directly or indirectly lead to increase cost of production.

The effects of continuous tillage are more noticeable in urban farms and developed countries where the land tenure system prevents shifting cultivation and bush fallowing which are the traditional methods of preserving soil fertility and structural characteristics. Economic pressure due to high operational cost and capital outlay on Tractors and implements is now forcing a review of these conventional systems of cultivation which are now considered over elaborate. The question now arises: What is the minimum tillage treatment that can be applied to produce a particular crop in a particular farm without a reduction in growth and yield characteristics ?. The use of improper and heavy machinery will result in soil compaction which in the extreme case can adversely affect soil water, pore space and density. In addition, soil shear strength will be increased and root growth can be impeded when soils are not suitably compacted. Although compacting operations can be beneficial through promotion of good contact between soil and seed during planting.

The other question is: What is the minimum tillage treatment that can be applied for optimum yield that will at the same time protect the soil from the undesirable characteristics of continuous tillage ?. That is, when does soil manipulation and, or pulverisation seize to be beneficial to crops ?. Agricultural Engineers should be involved in this problem of defining this optimum soil environment for economic production through improved operational treatment. It now seems obvious that the greatest chance of increasing the benefit to cost ratio in the field lies not so much in the expectation of obtaining a greater yield from new or a more elaborate tillage method but more in the possibility of maintaining the same high yields while simplifying and economising tillage operations (Hillel, 1980a).

1.1 OBJECTIVES

The main objectives of this study are to determine the amount of soil manipulation that will produce specific soil physical characteristics using given soil type and to determine the level at which tillage will be considered enough or over elaborate.

Specific objectives include:

(i) Determination of the effects of tillage treatment on soil i.e. soil temperature, bulk density, porosity, soil wetness.

(ii) Determination of the effects of soil strength characteristics (cohesion and angle of internal friction) on specific soil and find if they affect crop parameters like emergence and root growth as a result of tillage operations.

(iii) Prediction of the emergence force exerted by the growing seedling under different tillage systems.

(iv) Making recommendations for improvement of the conventional tillage system used locally.

1.2 PROJECT JUSTIFICATION

Farming is a business and it is also time bound. Time and cost resources can be saved even if only an elementary knowledge of the optimum soil conditions required for crop growth is available to farmers.

Although most experimental results from this type of study might not have a universal application because they are usually highly localised depending on the prevailing soil type and condition, the efforts will go a long way in the determination of the proper soil environment for crop production.

This study is also very essential because the yield of crops is dependent on adequate root and shoot growth which in turn are dependent on creation of favourable soil environment by tillage operations.

Over tilling the soil results in the breakdown of soil structure and particle size, erosion, soil compaction and tillage pans, hence this study will provide useful information for a reduction of these defects in tillage activities .

A good choice of tillage will help in reducing the inherent increases in production cost on land reclamation in areas where the soil structure has been damaged and will also reduce wastage of fuel and operation time.

CHAPTER TWO

REVIEW OF LITERATURE

2.1 General Nature of Tillage Investigations

Soil cultivation has reached its present stage of development due to the experience by trial and error of local farmers than the work of researchers. Hillel (1980a) recognises two major aims of soil tillage investigations as :

a). Defining the optimum soil physical environment required to satisfy a given purpose or combination of uses, plant needs, mechanisation needs and soil and water needs. A way to this is to take detailed measurements of soil physical properties such as texture, structure and relief. The problem is that these physical characteristics only provide little information since they bear no direct significant relationship with crop growth. In line with this thoughts, Reece (1970) recommended the evaluation of tillage in terms of changes that they may bring about in the physical properties of soil that are directly involved in plant growth. These properties include : Soil temperature, aeration, impedance to roots and soil moisture (infiltration, drainage, evaporation and conductivity). Spoor (1975) noted that deciding the soil physical environment involves taking these detailed measurements on the soil as soon as possible after tillage before other factors have time to compensate.

Spoor (1975) also found that soil physical environment may be decided by plant assessment which involves identification of plant factors which respond to changes in cultivation; root development, time for shoot emergence and internal stress. However as with measurement of the soil physical characters, plants must be assessed within a short period after treatment especially if it is desired to evaluate effects of cultivation which are short lived due to natural changes that take place there (Spoor 1975; Kowal and Kassam, 1978).

b) Improving operational efficiency. This involves finding the most efficient way of transforming soil from that initial status to the required by selection of correct implement shape and weight and considering the soil moisture and consistency status (Spoor 1975).

Most tillage investigations tend to compare the effect of specific implement or depth of work on the final yield of crops over a period (Kuipers, 1988). These experiment have largely recorded results that are inconclusive or insignificant for some reasons. Spoor (1975) enumerated these reasons as :

(a) Treatments to which plant respond vary from year to year, therefore the same implements produces different soil environment for crop growth thus, yield results becomes faulty.

light availability, water management seed genotype, insect and disease control and other factors (Table 1).

The schematic diagram of crop production systems adapted from Hearns (1976) in figure 1, shows that farming operations affect and are affected by the environment and the variety of a particular crop chosen. Lieftink et al; (1969) noted that cultivation accounts for only 21% of considered yield improving factors.

Fig. 1: Effect of the Environment and other Plant Factors on Farming Operations.

Also plants are affected by both their aerial and root environment plus the activities of other animals and plants which inhabit the environment in a dynamic constantly changing environment Trouse, (1979) in Wingate-Hill in book Emerson et al. (1979). This further shows that final yield alone is not a good measure of tillage effects.

Therefore obtaining conclusive result from the cultivation effect on crop yield will entail an in-depth knowledge of soil environment required for crops and producing the same treatments every year with different implement or a combination of implements.

Hillel (1980a) attributed these confusing results to faulty selection of measurable criteria, inexact measurement and soil variability.

Spoor (1975). Recommended that plant assessment backed up with physical measurements will provide a better idea of what is happening. As an alternative, he recommended that for each soil, widely differing treatments with a fair margin for safety on each side should be selected for the determination of the required soil environment.

Table 1: Contribution to Yield from Selected Yield – Improving Factors from 1965 – 2000 in the Indus Plain of Pakistan.

	Factors Contribution In Isolation	Cumulative yield	Apparent contribution in combination
Present Yield	-	100	-
Additional water Supplies above	10	110	10
Removal of H20 Logging & Salinity	10	121	11
Application of Fertiliser	40	169	48
Disease and pest Control	15	195	26
Improved seedbed Preparation and Cultivation	20	234	39
Improved varieties	20	281	47

SOURCE: Lieftink et al (1969).

However, he remarked that this type of experiment would only produce positive results if the present traditional practice is extremely conservative, or it may show that current practice is correct.

2.2 Definition and Aims of Tillage

Tillage is the breaking up of the soil to create a favourable soil condition for crop growth. Early tillage with crude sticks started when agriculture started. The history of tillage tool development has been traced as far back as the biblical era 6000 BC as evidenced by paintings in Egyptian tombs depicting oxen yoked together by the horns pulling a plough made from a forked tree, Buckingham (1976).

There are three principal functions of tillage. These are:

(a) Eradication of weeds

(b) Incorporation of organic matter into the soil, and

(c) Improving the soil structural status.

There are two main classes of tillage: Primary and Secondary. Bagger and Kepner (1987) noted that distinction among the two is not always clear cut. Generally, primary tillage is the initial aggressive soil cutting and shattering operation by an implement up to a depth of 30cm which leaves the soil in a rough finish. While secondary tillage is the stirring of the soil at comparatively shallow depths usually following the deeper primary tillage operations.

An auxiliary function of tillage, still insufficiently understood is the conservation of soil moisture where the process of rain infiltration, runoff and evaporation are involved Hillel et al, (1969). Other such auxiliary functions include:

(a) Creating a favourable condition for other mechanisation operations.

(b) Breaking soil hard pans and bringing clay particles to the soil surface in the soils deficient in it.

(c) Increasing soil sanitation by exposing soil pests.

(d) Improve soil aeration and microbial activities.

2.3 Traditional and Modern Tillage Practices

Various methods, operations and principles are involved in combining tillage implements used. They are broadly divided into ploughing and non-ploughing.

Buckingham (1976) reported that although several of the terms used in describing tillage practises are only loosely defined and often mean different things in different culture. Conventional tillage is the tillage operation traditionally performed for preparing a seed bed for a given crop grown in a given geographical area (ASAE EP 291. 1). Conventional tillage practices for maize planting in the rain forest belt of Nigeria (site of study) includes one or *two passes of disc ploughing, harrowing with tine or disc harrows (Table 2). Ridges are* normally made if the crop is to be inter cropped with cassava or to be irrigated. The mouldboard is not used for any operation in this area because of root outgrowths and stumps.

Lal (1977) described conventional tillage as the system of cultivation which involves the uses of implements like plough, harrows and hoe in which the frequency of operation depends on the soil characteristics, soil moisture content and nature of crops grown. Bakermans and De wit (1973) considered conventional tillage as the traditional tillage system consisting of deep primary tillage and secondary tillage operations.

Tillage practices variously referred to as "Minimum", "Reduced", "Optimum", "Economy" tillage have the aims of reducing energy input and labour requirement for crop production, conserving soil moisture, reducing erosion and providing optimum seedbed growth areas rather than homogenising the entire soil surface and reducing wheel traffic associated with traditional tillage systems (Buckingham, 1976). Many researchers have suggested that reduced cultivation by using tine implements is disadvantageous where a serious weed problem was ignored, especially rhizomatous weeds or where there was a serious soil structure or drainage defects on the site where work was carried out. Zero tillage or no-till planting is the practice of introducing seed into previously undisturbed soil (ASAE EP 291.2). This eliminates all pre-planting seedbed operations that are commonly used in conventional tillage Lal, (1977).

Advantages of No-till planting is in its suitability for hilly, rocky and rough land where animals or tractor traction is difficult or impossible (Martin, et al; 1976). It uses smaller and less expensive equipment (Phillips and Phillips, 1984) and also reduces both water and wind erosion of soil. Mannering (1979), Lal (1985), Gingrich et al. (1981) and Buchingham (1976) noted that zero tillage leaves surface residue that may help prevent crusting. No-till has been severally criticised especially in the developed countries for its propensity for ground water contamination with herbicides/insecticides Woods, (1989)and also for its high risk of chronic diseases resulting from it. Intensive hoeing, weeding which is also labour intensive are some of the adverse

Table 2: Tillage Options for Farm Operations.

Tillage Operation	Tillage Action	Conventional Implements used
Ploughing	- Complete soil inversion and burial of trash - loosening	- Mouldboard plough - Disc plough - Subsoilers
Harrowing	- Puddling - Rearrangement - Mixing	- Spike tine, Spring tine harrows - Disc harrows
Ridging	- Rearrangement - Clod formation	- Mouldboard Ridger - Disc Ridger

Hillel (1980a) presented a more modern approach to soil structure management suitable for a perennial cropping program. This approach classified the field as three distinct zones: A planting zone where conditions are to be optimal for sowing and conducive to rapid germination and seedling establishment, a management zone between the rows where soil structure is to be coarse and open allowing maximal intake of water and air and minimal erosion and weed growth and finally a third zone considered as the traffic zone where passage by tractors and implements over the field are confined to reduce soil compaction effects.

2.4 Contribution of Engineering Theory to Soil Tillage Research

Reece (1970), Kuipers (1985) listed three main areas in which engineering theory is beneficial to cultivation research. These are: Design of soil engaging parts of farm implements which is the most visible input of engineering to tillage research. The challenges here is to design for minimum energy, minimum labour requirements and directing applied stresses of tillage implements towards positive cultivation.

ii) Engineering is concerned with the soil strength and its reaction under load, what stresses can be safety applied at various moisture content and what are the corresponding soil strengths and permeability. Soil structure as an aggregate of different organic and inorganic particles is subjected to stresses by water, its weight, action of crop roots, machinery traffic. Such stresses might collapse this structure leading to a reduction of its porosity and increased impedance to crop roots.

iii) The third area is concerned with the mechanic of root penetration aimed at finding the maximum soil strength and minimum permeability that will permit proper root development.

Hittieratchi (1987) grouped the focus areas into classical soil mechanics and critical state soil mechanics. The former is concerned with handling analysis of soil forces in machine elements and identifying soil disturbance zones induced by soil failure while the later studies the strains on the soil and models soil volume changes taking place during the loading process.

Hittieratchi (1987) and Reece (1990) remarked that most engineers appear to be concentrating efforts solely on "Hardware" and even there, to be mainly interested in development and testing rather than research. They contended that although this problem appears to lie across the boundary of many disciplines e.g. Soil Chemistry, Soil Physics, Agronomy and Engineering, A group based research outfit was recommended and that social pressures tending to separate each components should be resisted.

2.5 Environmental Factors against Tillage

Generally, removal of natural vegetation for arable cropping in the tropics leads to a host of soil and environmental problems. Brady (1990) listed some of these as follow:

i) Runoff and erosion.

ii) Pollution of domestic water supply.

iii) Loss of biological diversity through the extinction of several species of plants and animal life especially in rain forest areas.

iv) Destruction of tropical forest releases vast amounts of CO_2 into the atmosphere compounding the greenhouse effect, which negatively affects world climate.

On the short term tillage is generally favourable due to the provision of a favourable seedbed. However on the long term continuous cultivation or if performed during inappropriate times can be injurious to soil productivity. For fine textured soils, tillage during excessive dryness encourages production of big hard clods and tilling plastic soils leads to soil puddling a condition of breakdown of soil structure. Long term effects of tillage include reduced aggregation, tillage pans formation, and reduced aeration and water circulation.

2.6 Evaluation of Soil Structural Changes resulting from tillage operations.

Soil structure indicates how different soil particles adhere together to form secondary aggregates. An aggregate consists of many soil particles held in a single mass or cluster (Schmidt, 1967). Stability of a soil structure due to cultivation resides in the aggregates. The soil structure is the soil physical property that is most significantly affected by tillage. A well structured soil is one with a suitable size distribution and stable voids Such soils recommended for agricultural purpose is called a crumb structure Biswas and Mukherjee, (1987). Peds are maximum 5mm in diameter, soft, low bulk density, rich in organic manure and porous for adequate root penetration, aeration and water retention. Soil structure influences water transport, soil temperature, air transport and mechanical impedance of soil to seedling emergence and root penetration Koorevaar, et al; (1983).

Evaluation of structural changes due to tillage involves investigating changes between the initial soil condition and final soil condition. Kepner et al. (1987) named three aspects of final soil condition that may be of interest:

(i) The degree of soil breakdown

(ii) Segregation of clod sizes in relation to depth

(iii) Uniformity of mixing throughout the tilled depth

The most frequently studied is the degrees of soil break-up. Although Koorevaar et al. (1983) opined that it is nearly impossible to measure soil structure directly.

Biswas and Mukherjee (1987) grouped various methods of evaluating soil structure into direct and indirect methods. They said direct method include the following:

(a) Microscopic method in which thin soil sections are examined in situ under a petrographic microscope to determine clearly the nature, shape, size of secondary particles and voids.

(b) Macroscopic method where portion of soil is excavated and allowed to fall into small pieces of peds of different sizes and shapes such that the type of structure (shape and arrangement of peds), class of structure (sizes of aggregates) and the grade of soil structure (degree of aggregation) can be determined. The indirect method involves the evaluation of:

(c) Size distribution of aggregation through dry or wet sieving.

(d) Stability of aggregates.

(e) Some soil properties which are due to soil structure.

Biswas and Mukherjee (1987) outlined the procedure for the wet sieving method as follow: Sample of soil is then placed on the uppermost sieve in a nest of sieves and subjected to the slaking action of water. The nest of sieves of sizes 5.0, 2.0, 1.0, 0.5, and 0.25 and 0.1mm are then vibrated vertically with a mechanical shaker and the dry weight of aggregates of each fraction is then collected to give the distribution of aggregates. This result should be corrected for the coarse primary particles retained in each sieve to avoid designating them falsely as aggregates Hillel (1980b). As pointed out by Singh (1989) the wet sieving method is the standard procedure for testing water stability of soil aggregates . It is well adapted to separation of large aggregates. It has also been reported that wetting the sample before analysis reduces the size of large aggregates Baver et al. (1972).

The dry sieving method also uses the rotary nest of sieves that are vibrated to simulate the vibratory action of the wind. For such measurement dry samples are obtained to minimise disturbances during the process of drying. Soil factors which are evaluated for soil structural changes are bulk density, rate of the infiltration, hydraulic conductivity, rate of aeration, pore space, available soil water, degree of compaction, capillary intake of water Biswas and Mukherjee, (1987) Baver et al. (1972) noted that dry sieving method is advantageous since the sample requires no special preparation. The major disadvantage is the breaking up of weak aggregates due to mechanical action during sieving.

Quantitative assessment of such performance into a single characteristic parameter so that it might be correlated with other factors such as moisture retention has been with the Mean weight diameter (MWD) or pulverisation modulus Kepner et al. (1987), Biswas and Mukherjee (1987), Singh (1989), Hillel (1980b) and the Geometric mean diameter Biswas and Mukhejee (1987), Singh (1989). Other indexes proposed are coefficient of aggregation, Log standard deviation and weighted mean diameter (Hillel 1980b). De boodt, et al. (1961) in Singh (1989) has shown that changes in the MWD are correlated with crop yield when other conditions are uniform.

The soil tilth index (TI) is a quantitative value used to describe soil conditions that relate to plant growth and water movement. It ranges from 0.0 for the worst to 1.0 for the best soil condition as related to crop production Singh and colvin, (1990). The set of factors used in the computation of the TI includes the bulk density, plasticity index, cone index soil particles uniformity, organic matter content. These factors thought to be important in determining soil tilth were evaluated and determined with a Tilth Coefficient Factor for different tillage systems and their effects were combined to calculate the TI.

$TI = CF_1 \times CF_2 \times \ldots\ldots\ldots\ldots\times\ CF_n$ .... (1)

Where:

TI = Tilth Index ($0.0 < TI < 1.0$)

CF_1 = Tilth Coefficient Factor One ($0.0 < CF < 1.0$)

CF_2 = Tilth Coefficient Factor Two ($0.0 < CF < 1.0$)

n = No of soil properties used for the calculation.

The modified tilt index (MTL) which is an improvement on the TI was described by Tapela and Colvin (1998). They used different limiting levels of soil factors to determine the Tilth Coefficient Factors

Other factors that may be used to evaluate the degree of soil pulverisation by tillage include:

a) Soil disturbance: Soil disturbance is a function of field capacity and depth of operation. Soil volume disturbed in cubic meters per hour can be calculated by multiplying the field capacity with depth of cut and 10000 Bukhari et al.(1992).

$V = 10000CD$ ....(2)

Where,

V = Soil volume disturbed (m^3/h)

C = Field capacity (ha/h)

D = Depth of cut (m)

b) Soil inversion: Soil inversion is expressed as the ratio of weeds and stubble after tillage to the total quantity of such surface cover before operation Bulhari et al. (1988). It is computed from the relationship:

$$F = (w_p - w_e) / w_p \times 100 \quad \text{...} (3)$$

Where,

F = Soil inversion in percentage

W_p = weight of weeds and stubble before tillage (g)

W_e = weight of weeds and stubble after tillage (g)

c) Uniform soil mixing: Uniform soil mixing is determined by applying tracer materials to the soil. Their distribution after tillage is then evaluated to see how uniformly they mix with the soil Kepner et al, (1987). Such tracer materials include easily identifiable granules or pellets, radioactive materials, fluorescence materials, dyes whose concentration can be found through spectrophotometry.

2.7 Effect on Tillage on Soil Physical Properties.

Tillage modifies soil physical properties to make soil more productive. Different tillage practises affect soils in a variety of ways depending on their stability and moisture level. The most critical of these properties often changed by cultivation is the soil structure. The soil structure is the most vaguely defined of all soil properties and is one that is most significantly affected by tillage. Tillage activities moderates soil structure by improving porosity of fine textured soil. The soil structure also influences water movement, heat transfer, aeration, bulk density and porosity Biswas and Murherjee, (1987). Spoor (1975) listed five ways that soil structure is affected by tillage, viz.:

(a) Formation of soil aggregates
(b) Disintegration of soil aggregates
(c) Changes in clod size distribution
(d) Rearranging soil particles by inversions or loosing
(e) Transformation of the soils surface

Sing and Colvin (1990) noted that the basic ingredients for seed germination are water, warmth and a good soil tilth. He made efforts to obtain a quantitative value for measuring soil structure by proposing that if the soil conditions associated with a good tilt can be optimised tilth will be adequate for crop growth. The soil factors used in his study are bulk density, plasticity index, cone index, organic matter content aggregate uniformity.

Bulk density values for various tillage operation except for intensive tillage fall within the optimum bulk density values for crops recommended by Larson (1964) in Douglas and

Zoufa (1983). Tillage processes lower bulk density and penetration resistance. Brady (1990) reported bulk densities of between 1.25 – 1.5 mg/m^3 for ploughed land, between 1.35 – 1.6mg/m^3 for no-tilled soils and about 2.0mg/m^3 or greater in the sub soils.He noted that root growth becomes impaired at densities of 1.6mg/m^3 or greater. But an intensive tillage practice that compacts the soil increases this resistance Douglas and Zuofa (1983).

Kowal and Kassam (1978) found that lowered bulk densities obtained in ploughed lands increase steadily as the growing season advances. Low (1972) attributed such bulk density increases in tilled land to compaction by tractor and implement tyres. Experiments by Brady, (1990) showed that tillage effects appear to be favourable for plant on the short-term basis only. Under tillage soil is loosened and total pore space is higher than untilled. However on the long term, the breakdown of soil organic matter in tillage results in unpleasant consequences of runoff and compaction due to traffic, growth of plough pans and reduction in aggregate stability. He further found that conventional tillage increases soil bulk density through compaction to more than 1.8mg/m3 which is the limit of penetration for cotton roots. Similar effect of soil tillage on compaction was reported by Ohu and Folorunso (1989). Low (1972) gave bulk density values of 1.3 – 1.4 times higher for the old cultivated soil than for the unploughed or newly ploughed old grassland.

2.7.1 Sole formation effects

A Sole is the compressed layer at the bottom of zone of ploughing, Almost every agricultural implement creates a sole under moist soil conditions such as Plough, Harrow, Subsoiler and traffic soles, due to the action of the same forces that enhances their penetration. Baver et al; (1972) noted that such zones of compaction apparently move closer to the surface as the number of tillage operations increase (Fig 2). His observation on a number of seedbed profiles indicated that from 50-70% of the soil loosened by disc ploughing operation was recompacted by subsequent disc harrowing.

Kohnke (1982) recommended that minimum tillage is required for medium – coarse textured soils with a good humus content which can enhance the retention of a favourable structure for a long time. For soil rich in clay and silt, more frequent and elaborate tillage is recommended because of its tendency to “run together” and inhibit the passage of water and air.

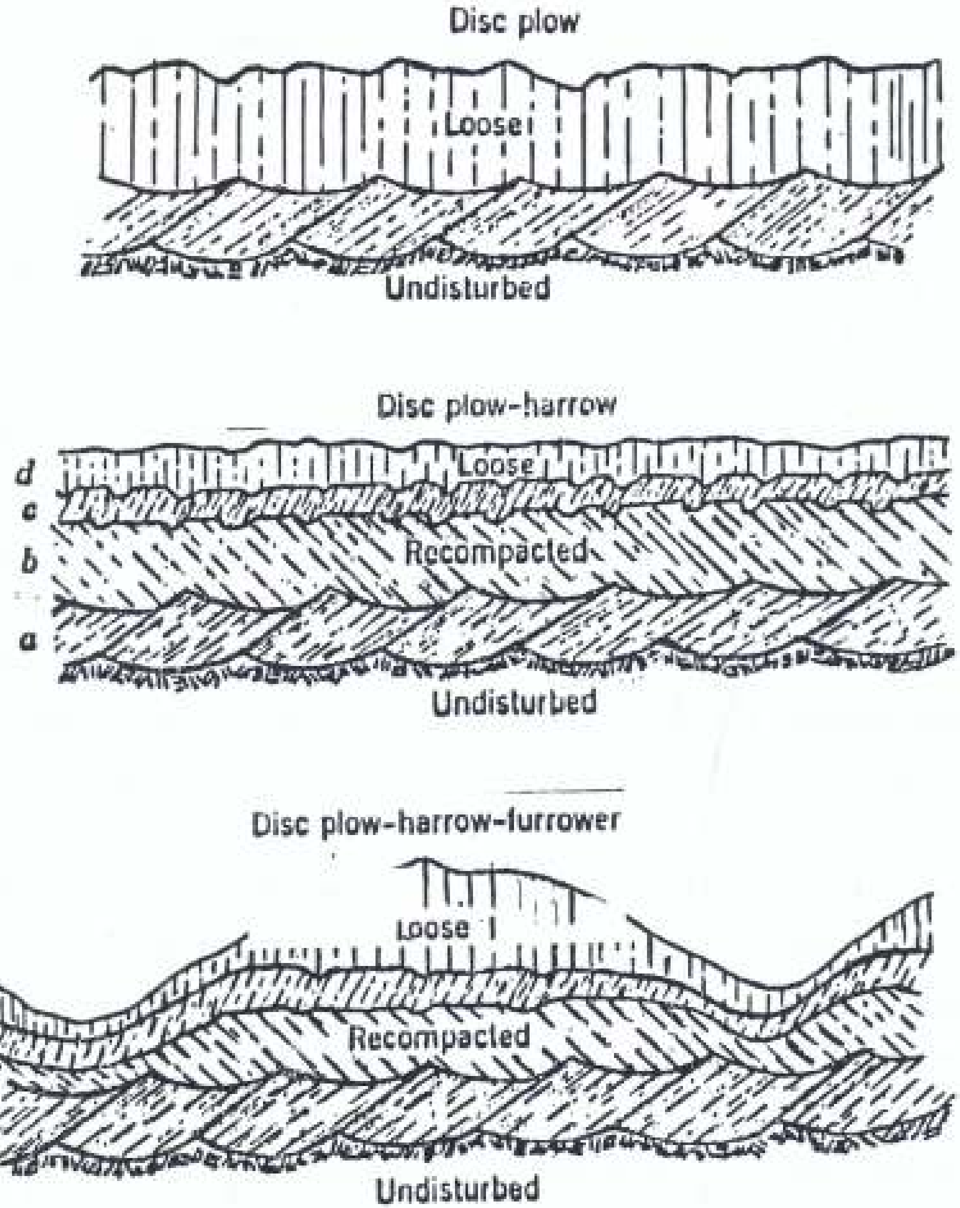

Fig. 2: Diagramatic illustration of seed bed profile in a tillage sequence.
Source: Baver et al (1972)

2.7.2 Soil Water Retention

The major influence of tillage on soil water may be in two forms:

(a) Reduction of transpiration losses through effective weed control.

(b) Water movement in, out and within the soil i.e. infiltration, evaporation, drainage and conductivity Wingate- Hill (1978) in Emerson et al 1978). .

Soil water content differences due to tillage may be small and therefore difficult to measure but they may be large enough to be agronomically significant Allmaras, (1967) in Douglas and Zoufa, (1983).

Douglas and Zoufa (1983) in his study at Ibadan Onne and PortHarcourt reported that the effect of different tillage implements and practices on the soil water content vary according to soil type. In the test at Ibadan Alfisols the tilled plots had the highest water content, though differences were far from being significant. This trend was repeated on the Portharcourt soils (Ultisols – sandy loams). At Onne the rotovator and mouldboard plough contained significantly higher amounts of soil water than the disk plough. However, the study concluded that in general intensive tillage practices which compacts the soil leave little or no soil volume for accumulating soil water.

No tillage techniques usually implies the presence of a mulch on the topsoil. Such mulch materials include, plant residue, gravel, pealite or any other material. Phillips and Phillips (1984), Lal (1985), Brady (1990) agreed that the loss of water through mulches in No-till soil is generally very low in comparison to the rate of water loss from a moist soil surface, for three reasons:

(a) Reduced evaporation due to mulching and crop residues slows air flow over the soil surface.

(b) Reduced direct solar radiation reaching the soil.

(c) Insulating qualities of mulch materials that are lighter in colour than bare soil to downward conduction of heat into the soil. Kowal and Kassam (1978) observed that the effect of tillage methods on crop growth and yield are to a large extend due to differences in soil water status brought about by improved infiltration, reduction of evaporation, better soil conservation and changes in water retention characteristics of the soil. They also noted that ploughing and leaving a rough surface increase rainfall infiltration by 20%.

Kowal and Kassam (1978), Lal (1977a) also reported that as part of tillage system to improve water retention in the soil surface, a system of tied ridges was developed. Although this did not prove to be very economical not effective in the sandy soils of Northern Nigeria.

Sheikh et al; (1978) found out that there was a significant difference between the levels of soil moisture at a specific depth of 15cm for different tillage operations tried. His analysis however could not pin point a particular treatment which contributed most towards the optimum level of soil moisture and thereby affecting the yield. Ojeniyi (1991) also reported that the significant influence of tillage treatments on soil water is related to the bulk density. He said that soil water and bulk density decreased in the order untilled flat, ridge and heap with the highest bulk density of 1.48g/cm^3 at the highest percentage moisture of 13.5%. Ojeniyi (1982) reported that finer structured tillage treatments conserves more water and that voids greater than 8mm diameter are mainly responsible for water loss in untilled soils. His work further revealed that tillage directly affects the amount of water retained in the soil. Blackwell and Proffitee (1996), contended that soil moisture conservation is improved by less tillage, particularly in loams and clayey soils because tilled soils dries more quickly than untilled soils. The exception is when adequate moisture exists in the deeper uncultivated layers and the loose, dry layers effectively mulches the deeper soil. The experiment also found that reduced cultivation of heavier textured soil, improves rainfall infiltration and it increases the amount of soil water available for plants. Most structurally weak soil form crusts when exposed to rainfall which reduces infiltration.

2.7.3 Soil Temperature.

Soil temperature has a great influence on seed germination, nutrient uptake and crop growth. Crop seedlings do not germinate above a certain range of temperature. The optimum germination temperature for maize is between 7 – 10°C and optimum root growth is at 25°C (Brady 1990). Soil temperature exceeding 40°C at 5cm depth for 3-6hours a day during the seedling stage can be injurious to crop growth Lal, (1974a) in Lal (1985). Biswas and Mukherjee (1987) reported that the sensitivity is such that even a minor difference in soil temperature can have a significant effect on plant growth.

Fluctuations in the soil temperature are influenced by both the heat capacity and thermal conductivity of the soil. These are in turn affected by the proportions of the void filled with solids, liquid or gaseous constituents. Thorne and Thorne (1979), Singh (1989) linked soil temperature fluctuation to water availability since the thermal conductivity of water is greater than those of soil particles and air. They noted that the rate of heat flow increases with increasing moisture content, also that, the amount of heat necessary to change the temperature of a volume of soil increases as moisture content increases since water has a greater specific heat capacity than the solid and gaseous components. Phillips and

Phillips (1984), Olaitan and Lombin (1984), Brady (1990) reported that reduced soil temperature in no-till soils might delay or reduce seed emergence in colder climates. Lal (1974b) however, added that this could be an advantage in the tropics. He also noted that normal insulation provided by surface mulch in no-till conditions will minimise the range in day time temperature fluctuation such that may limit biological activity and harm soil microganisms.

Lal (1977b) found out that with greater exposure of soil, greater temperature extremes are reached and also that tillage practices used for better water retention like tied ridging often interact negatively in terms of effect on soil temperature. This suggests that an intermediate tillage method might prevent the onset of such extreme conditions. Brady (1990) reported that in the low temperature soil region, ridging permits water to drain out of the ridge and enhances the germination of crops planted on the ridges. Richard et al. (1952), Blane (1958) in Singh (1989) recommended the measuring of soil temperature at 5cm, 10cm uniform depth among other, and that direct radiation which might influence readings be avoided to obtain correct results. Ojeniyi (1991) reported that for most tillage treatments, untilled flat, ridge and heap soil temperature decreased in the reverse order while Ojeniyi (1986) reported no significant difference in soil temperature due to tillage treatments tried.

2.7.4 Soil Aeration.

The aeration of soil is influenced by those factors that affect soil macro-pores i.e. soil texture, bulk density and aggregate stability. Virgin soils are higher in total pore spaces and macro-pores due to its many interlinked channels for water infiltration Ojeniyi (1990). Brady (1990), Ojeniyi (1982) noted that cultivation of soil also helps to loosen the soil particles and encourages circulation of air while continuos cultivation results in reduction of large pores and an increase in the micropores. Biswas and Mukherjee (1987) observed that root elongation is sensitive to aeration. Glinski (1985) reported that plant roots need more energy while penetrating compact soils thus making them to require more oxygen. Past work have also revealed that poor soil aeration may result from compaction by tractor tyres or the exposure of the denser subsoil due to runoff. This will create a variety of problems that include anaerobic conditions, reduced nutrient availability, accumulation of toxic chemicals in the root environment and increased susceptibility of the root system to invasion by parasitic micro-organism Olaitan and Lombin (1984).

Low (1972) in his study in England found out that total pore space was greater by 13 – 14% for an old grassland and the newly ploughed grassland soils than for the old regularly cultivated soils. Brady (1990) found that cultivation is indispensable for maintaining optimum aeration in poorly drained and heavy textured soils. In studying soil aeration conditions, Kohnke (1982) recommended the determination of individual soil properties that represent aeration or are related to aeration. Such include:

a) Gaseous diffusion rates in soil.
b) Amount of $C0_2$ given off at the soil surface.
c) Composition of soil air.
d) Resistance to mass flow of air under pressure.
e) Aeration porosity (total volume of pores with diameter larger than 0.06mm).
f) Air capacity.
g) Oxidation –reduction potential and amount of reduced materials in the soil.

2.8 Effect on Soil Strength

The shear strength of soil is its maximum internal resistance to movements of its particles. Shear value is therefore generally accepted as a major dynamic property. Koolen and Kuipers (1983) remarked that the strength properties of soil is determined by:

(i) Number of particles.
(ii) Spatial distribution of particles relative to pore size distribution.
(iii) Moisture content as a percentage of total volume.
(iv) Moisture distribution.
(v) Bond between particles.
(vi) Distribution of bonds.

Most of these are influenced by tillage activities. According to coulomb's law in Baver et al. (1972) the shear strength of soil is expressed as:

$$\tau = C + \sigma \tan \theta \quad \text{...} (4)$$

Where,

τ = Shear strength
C = Cohesion
σ = Effective pressure normal to the shear plane
$\tan \theta$ = Coefficient of friction
θ = Angle of friction

Crossley and Kilgour (1983) noted that the values of C and θ vary with the type of soil and its condition depending on whether it is loose or compacted, friable or plastic.

The components of shear resistance are cohesion and friction. Baver et al, (1972) noted that water availability plays an important role in determining the magnitude of the cohesion component as it effects the distance between particles and the attractive forces associated with air water menisci. Of the two main methods of evaluating shear strength (direct and triaxial shear tests, Fig 3) the triaxial shear test is more complicated but more reliable though results from the direct shear test method are also reported to be equally reliable by Bowles (1986). Maurya and Lal (1979) in Lal and Greenland (1979) emphasised that the resistance to root development is a function of the shear strength exerted by the soil while the shear strength itself is affected by soil moisture potential and bulk density.

2.9 Tillage System and Root Growth

A good soil structure produces root systems that are large, deep and expansive. Root respiration in such soils is adequate due to better access to oxygen. This frequently provides optimum condition for improved crop yield. For individual roots to elongate at daily rates of 6-8cm, the soil must be warm, fertile, moist, well aerated and the shoot system must have ample temperature and light for food production. The untilled soils has most of these properties. Root growth is a function of the soil bulk density measurement which has been reported to be negatively correlated by Sanchez (1976). Trouse (1979) reported that in loose soils with a density of 1.10g/m^3 , root grows rapidly. Soils compressed by 0.35g/cm^3 can reduce elongation rates to about tenth of their capacity. Similar results of root sensitivity to density were obtained by Russell (1978) in Emerson et al. (1978), Derichaud and Hainnauix (1979), Nicou and Chorpart (1979) and Osborne et al. (1978) for grain yield.

In such cases where the soil is compressed, the root system slowly penetrates the dense zone or bypass obstacles to reach out for nutrients. An examination of such roots at harvest might not reveal the stress undergone by such root to a casual observer. However, when an ample supply of water and nutrients is maintained in the restricted rooting zone Russell (1978), Osborne et al. (1978) in Emeson et al. (1978) reported that the total weight of the root system and its ability to absorb nutrients may not be affected the restriction on root elongation as it compensates for the restriction of root axes by development of laterals.

Rooting also depends on tillage type. Trouse (1974) reported a mean rooting depth of 50.8cm for subsoiled tillage treatment against 21.3cm for conventional tillage with a dense plough pan at 22.5cm.

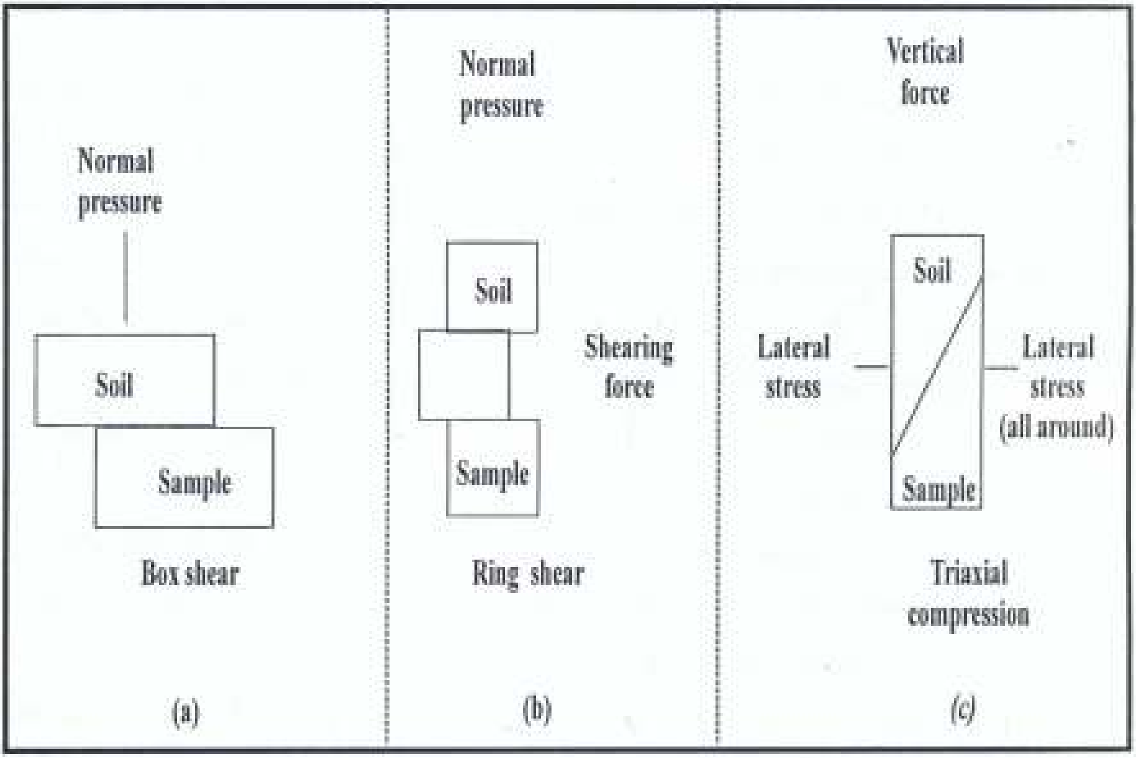

Fig. 3 Schematic illustration of force components in shear test.
Source: Baver et al; (1972)

In the savanna, Kowal and Kassam (1978) noted that ploughing encourages better ramification of roots in the soil, increasing the length and width of the root canopy and also root density in the deeper layer of the soil profile. Their work also confirmed the negative correlation between soil bulk density and root density. Studies with plants grown in glass beds by Hettiarachi (1987) showed that there is also an upper cut-off stresses beyond which root cannot elongate. He observed that when root is unable to extend axially it polarises its growth in a radial direction. This growth in the radial direction relieves stress in the root cap so that axial growth can continue.

In few occassions the restriction of root growth is not always detrimental to crop yield, although in real occasions i.e. in less favourable field conditions of drought. The optimum root system is not always the largest Russel (1978) in Emerson et al. (1978); It is that which ensures the provision of water, nutrients, and hormones by root to the shoot leading to the maximum production of economically important tissues. Root growth outside these requirements as it exists in elaborate tillage system might actually be superficial resulting in wastage of the products of photosynthesis especially in less favourable field condition of drought Russel (1978) in Emerson et al. (1978). Ojeniyi (1990) reported that root length decreased in the order ploughing and harrowing, manual clearing and ridging.

It has been shown that more than 50% of the roots developed by plant remains within the tilled layer Finney and Knight (1973) in Braunack and Dexter (1989). Nicou and Chopart (1979) in Lal and Greenland (1979) mentioned two methods of root sampling. These are:

(a) Samples taken with sharp edged cylindrical probes inserted horizontally or vertically. This method gives the dry root per unit volume of soil in a given horizon in g /dm^3 upon washing in water, sieving in 2mm size sieves and drying for 24hrs at 60°c.

(b) Sampling complete root system, their distribution and proliferation using a root cage which he noted that even though more difficult to conduct, allows for greater precision. This method is also adaptable to study of maximum root depth.

2.10 Tillage Effects On Energy Use And Cost.

Tillage is energy intensive. The amount of energy used is proportional to the volume of soil moved in loosening, pulverising and inverting operations. Jacob and Harrel (1983) reported that in the U.S, it takes up to 60% of the total energy used in crop production. Tractors and implements are still essentially imported items in the less developed countries and therefore unaffordable. When this is combined with high cost of tractorisation where there is no government subsidy, it may constitute a limiting factor on crop production, thus making more and more farmers to result to their time tested, albeit inefficient manual method of tillage. For these groups of farmers, avoidable over tillage means loss of income of farm families.

The determination of cost effects of one pass tillage is realistic only when variable cost are computed as the direct costs per hectare common to all i.e. depreciation, machinery charges, cost of planting, spraying and harvesting are independent of the methods of tillage employed. Phillips (1984) in Phillip and Phillip (1984) reported the longevity of tractors due to the elimination of ploughing and disking, the two operations that required most power. Conversely, no –till has the least energy requirement due to the elimination of these energy outputs. Although he accepted that conservation measures which result in overall decrease in food production or increase labour use would be an unreasonable alternative.

Koronka(1972) remarked that the advantages of No-till can be seen either from the reduction in cost or through the increase achievable on productivity. He noted further that reduced cultivation methods could show up to 40% increase in hectares established over traditional ploughing methods whereas with direct drilling into untilled land the increase is about 500%. But with direct drilling the capital cost of special drills will increase the production cost of this method and a substantial hectarage of cereals will be needed to justify this expenditure. He also noted that non-ploughing techniques increases timelines benefits of sowing near optimum time due to the greater speed of direct drilling and fewer trips across the field.

2.11 Effect of Tillage Technique on Yield.

The effect of various tillage methods on growth and yield using different indicator crops has been studied by many researchers (Kuipers 1985). Sheikh, et al. (1978) used five combination treatments for his experiment of effects of tillage on yield. These combination were given as:

(i) Mouldboard plough, disc harrow, cultivator
(ii) Subsoiler, cultivator, cultivator
(iii) Disc plough, disc harrow, cultivator
(iv) Disc harrow, cultivator, cultivator
(v) Disc harrow – 3 passes.

The crop and soil parameters considered by him were emergence, yield, moisture content, bulk density, penetration resistance, shear strength of soil and emergence force exerted by seedlings. The implements were tested on a sandy loam soil with wheat as an indicator crop.

Experimental results of Sheikh et al. (1978) indicated that the effect of different tillage systems on both the emergence and yield of wheat and on soil physical properties was manifested. His analysis failed however, to establish the superiority of different operations with respect to yield of crop. Suggesting that yield differences can be attributable to changes in the physical and engineering properties of soil brought about by tillage treatments. The study also could not determine the particular soil property that contributed most to yield. In his analysis of the shear strength of soil and the seedling emergence force, the superiority of operation with disc harrow was established since it presented the lowest emergence force 13.4gms (maximum value is 80gms with the second treatment) lower shear strength and highest mean value of wheat yield.

Browning, et al. (1944) and Page et al. (1946) in their independent experiments in Ohio in 1938 and Iowa 1940 respectively used crops yield as the method of assessment. Mouldboard plough, subsurface sweeps and rotary tillers were used as tillage – implement treatments Douglas and Zoufa (1983). The superiority of the mouldboard plough was significant. This was adduced to better incorporation of rich surface soil into the root zone and better pulverisation. Douglas and Zoufa (1983) also compared six such tillage techniques which consisted of :

i) Zero tillage.

ii) Rotary tillage (Rotovating 3 times).

iii) Double ploughing with disc plough and double harrowing with disc harrow.

iv) Ploughing once with disc plough.

v) Ploughing twice with the mouldboard plough followed by two harrowing and

vi) Ploughing once with the mouldboard plough.

They used Maize as the indicator plant. Plant parameters like plant height and grain yield were studied and their result showed that grain yield decrease in the order mouldboard, disc plough rotovator and no-till. Similarly plots ploughed once with the mouldboard produced taller plants than the other tillage treatments.

The superiority of the mouldboard plough in these studies is attributable to better inversion of crumb structured soil, better granulation and creation of large soil clods to forestall wind, water erosion and to improve infiltration. Similar yield increases due to conventional tillage was reported by Osborne et al. (1978) in Emerson et al. (1978) with wheat. However yield reductions due to conventional tillage was also reported in two out of three years of study by Brady (1990). Also more passes of tillage implements have been shown not to influence yield significantly Ojeniyi, (1986, 1989). Other researchers like Triplett, et al. (1964) in Baver, et al. (1972) found no significant differences between the no-till and conventional tillage system. In most instances, tillage systems where the plots were mulched after cultivation gave significantly higher yield, Baver, et al. (1972).

The influence of tillage on yield has been linked to the drainage and weed condition of the farm. Brady (1990) noted that yield from conservation tillage systems generally compares favourably or even greater than that of conventional tillage if the soil is well drained and free from weeds. On soils with restricted drainage, yields with conservation tillage are sometimes inferior to those from conventionally tilled ones. Reasons given for this include higher incidence of pests and diseases prevailing as a result of the higher moisture condition. Foth and Turk (1972) working with sugar beet (Table 3) discovered that yield increases with tillage but this yield could not be sustained with more passes of implement.

The effect of soil structural state on crop yield seems to vary with soil type and crop. Rosenberg (1964) reported that there exists an optimal degree of compaction for a particular soil crop combination. In sandy soil, increased soil compaction was found to increase crop yield. In finer textured soils, compaction usually reduces yield. Also a stronger aggregate structure is known to enhance wheat yield Low, (1972).

Table 3: Beet yield as affected by the number of times field was worked prior to planting.

Time worked	Tons/Acre
None	14
1	16.8
2	16.7
3	15.2
4	14.8
5	14.2
6	14.3

Source: Foth and Turk (1972)

CHAPTER THREE

MATERIALS & METHODS

3.1 Study Area

The study was conducted at the University Teaching and Research Farm in Akure which is located on latitude 7^0 5' N and longitude 5^0 10' E in the rain forest zone of Nigeria. The soil is classified as alfisoil (Ojeniyi, 1989). The soils were developed from basement complex rock under forest vegetation. History of the area indicated that the soil has been left fallow for a 4-year period. It was last planted with cassava. Mean meteorological data obtained from the Ondo State Agro-climatological unit are ambient temperature of 28.13^0 c and 4.9mm rainfall for the month of April 1999. The vegetation in the test farm is predominantly of Siam weed and other shrubs about two to three metres in height. The test farm selected is on a moderate slope to reduce the impact of runoff on the experiment.

Soil textual class analysis from samples taken randomly from the 12 plots indicated that the soil is composed of 71.0-82.2 % of sand 6.58-8.94% of silt, 9.50-19.0 % of clay classified in the range of sandy loam to loamy sand.

3.2 Experimental Design and Procedure

The experimental design was a completely randomised block for each tillage treatment with three replicates each, making a total of 12 plots. There were four tillage treatments which are listed on table 4. Plots are 4.75m in length and 3.25m in breath with a 50m – row border round the perimeter of each plot. This gives a plot size of 15.44m2. Inter plot spacing used was 8.2m on the length and breath side of to allow for stopping and turning of tractor. The total experimental area was 0.129Ha. Vegetation was cleared manually and packed of stones and stumps that may impede the use of farm implement and enhance the taking of measurement. Tillage operations were done according to the treatment used for the study taking due care to ensure no overlap of implements and all operations are single pass. Tillage treatments adopted in the study are shown in Table 4 below.

Treated maize seeds were manually planted in singles at 5cm depth, and at a spacing of 75x25cm which is the recommended spacing for maize Philips (1977). Planting depth was controlled with painted mark on planting pegs at 5cm. 54 seeds were planted, with readings taken from 28 observation units at the centre of the plot. Pre-emergence herbicides Atrazine was sprayed immediately to curtail weed on all the plots while Gramozone was sprayed on the Zero tillage treatments to curb the growth of weeds which were retained on the plots

3.3 Plot Layout

Plot were delineated and pegged according to the experimental plan as shown in Figure 4 and 5. Treatments were assigned randomly to the blocks and independent randomisation was done for each block. To ensure that the variability within blocks is minimised, blocks are kept compact and delineated according to the soil topography.

3.4 Experimental Tools and Machinery.

An MF370, 65HP tractor was used for all tillage operations. Ploughing was done with a 3 furrow mounted disc plough with 66cm diameter plain discs (4 holes). Harrowing was with a mounted tandem disc harrow with alternate serrated and plain edged (32mmm square central holes) discs. Ridging was carried out with a two row disc ridger, the furrow haven been adjusted to produce a spacing of 0.75m instead of the normal 0.9 - 1m spacing. Spraying of herbicides (Atrazine and Gramozone) was done with a Knapsack sprayer.

3.5 Measurement of Physical Properties

Soil Temperature was measured with a soil probe. Readings were taken at 5cm, 10cm being depth of seed/root as recommended by Kohnke (1982) with three replicates each from each depth, randomly selected per plot and mean values determined. The readings were taken in the 8hrs and 16hrs. A total of eight such readings were taken from each plot. Readings were started as soon as tillage treatments were completed and seeds planted because effect of temperature is most critical during the germination and seedlings stage Lal (1974a). Appendix I and II shows the data obtained from field measurement of soil temperature.

The speedy moisture meter model Mc 320 which has been previously calibrated with the gravimetric method was used for the determination of percentage moisture in situ per plot and the data is listed in appendix III. The procedure used for the soil moisture determination is as follows: The soil sample was weighed on balance and mixed with a quantity of calcium carbide. The mixture was then vibrated so that water can be removed in form of acetylene gas through the reaction with the reagent and the percentage moisture determined by the difference in weight was read on the dial scale.

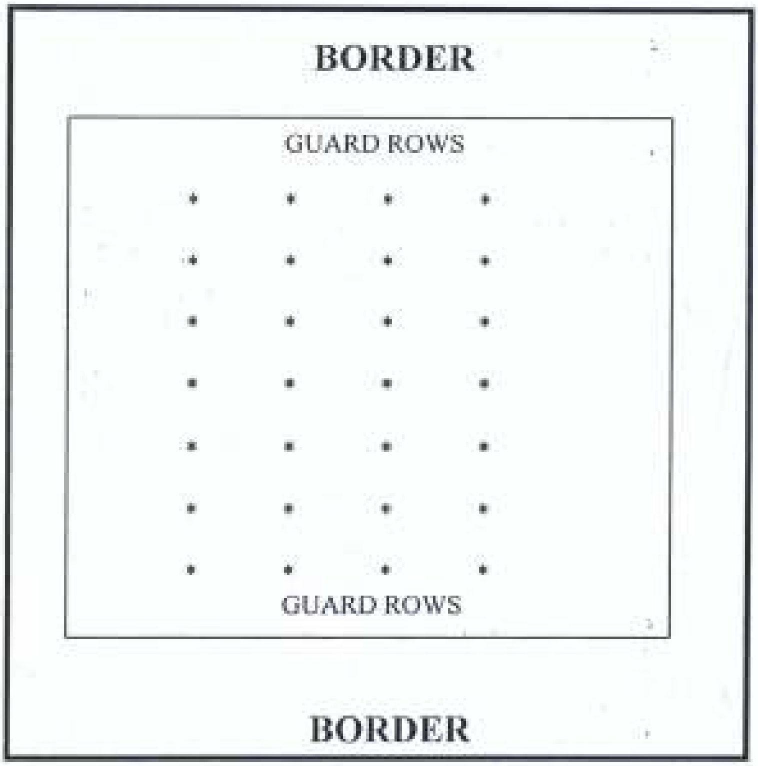

Fig. 4 : Layout of the Experimental Plot.

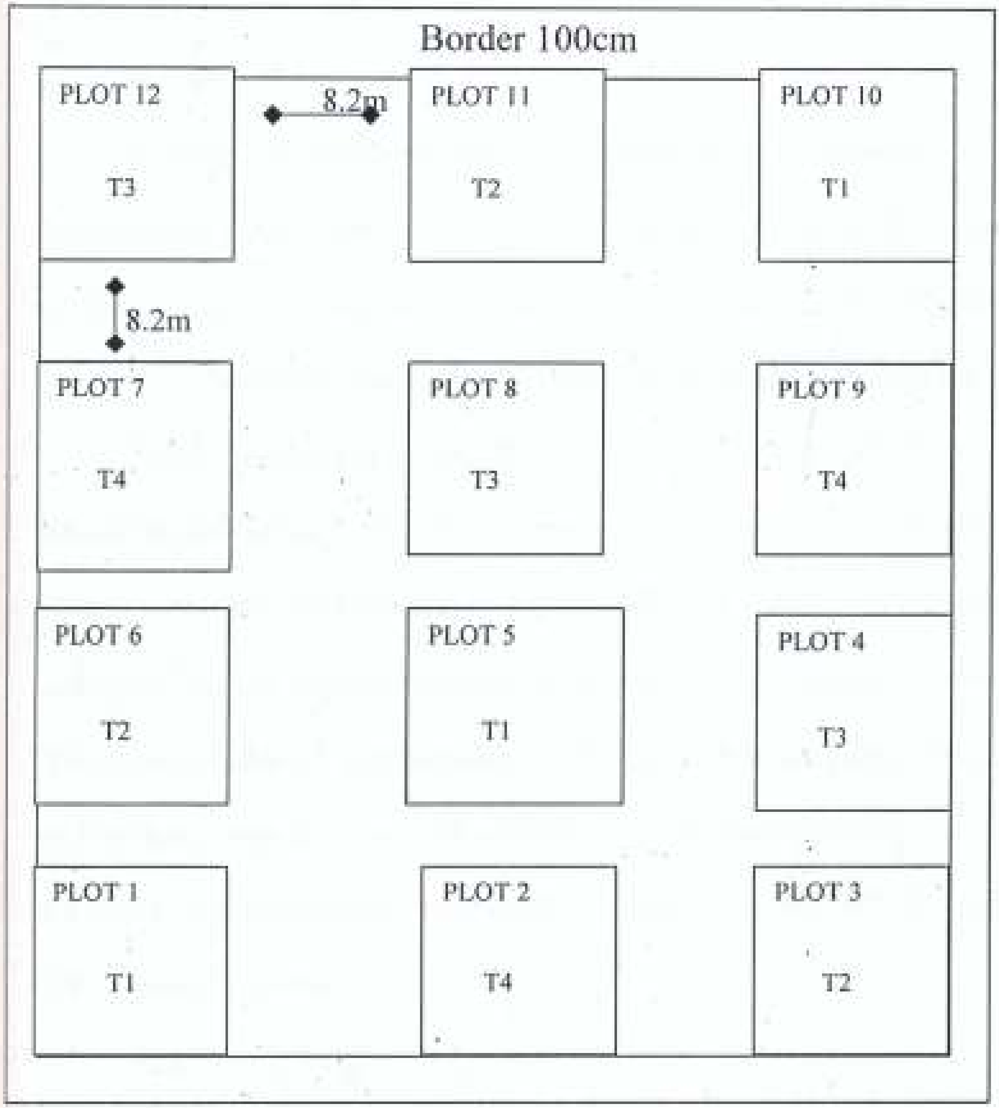

Fig 5: Plots Layout on the Experimental Farm.

Kohnke (1982) noted that this method is recommended as an approximation for most fieldwork. The method he said was accurate within 5% on most materials.

Total pore space was obtained from the relationship adopted from Foth and Turk (1972) as :

Total pore space = $100- (\rho_b / \rho_p \times 100)$ ……………………………………………………(5).

The data obtain ,

Where,

ρ_b = Bulk density

ρ_p = Particle density ed from these relationship is on appendix IV, V, VI.

To determine the size distribution of soil aggregates from the tillage treatment, dry sieving method of aggregate analysis was used and the results expressed as the mean weight diameter (MWD) as described in Sighn (1989), Biswas and Mukherjee (1987) and Hillel (1980b).

Seven size rages of sieves 0.425, 0.85, 2.00, 2.36mm 3.35 (Numbers 40, 20, 10, 8, 6, by ASTM standards), 6.7mm, 9.5mm were used. The sieves have a uniform diameter of 20cm. They were covered on top and the bottom with a pan and installed on a rotary shaker and bolted and the machine operated for 10 minutes. Soil samples obtained from each fraction was collected and weighted. Three replicates of each treatment were done to reduce experimental error and mean values obtained. 200g and 400g of soil per replicate were used for the dry and wet sieving respectively(Appendix VII and VIII). The MMD is defined by the following equation:

MWD = $\sum X_i W_i$…………………………………………………………………(6)

Where,

X_i = Mean diameter of any particular Size range of aggregates in a fraction

W_i = Weight of aggregates in that size range, As a fraction of the total dry weight of sample analysed

Table 4: Tillage Treatments.

OPERATIONS		PLOTS	
		Number	Designation
1.	Zero Tillage (ZT): Slashing and Planting	1,5,10	T_1
2.	Ploughing (PL): Slashing, ploughing	3,6,11	T_2
3.	Ploughing Harrowing (PH): Slashing Ploughing and Harrowing	4,8,12	T_3
4.	Ploughing, Harrowing & Ridging (PHR) Slashing, Ploughing Harrowing & Ridging	2,7,9	T_4

Bulk density measurements were taken with core cylindrical samplers of 166 cm^3. The cylindrical sampler was pushed gently and uniformly into the soil to minimise compression and shattering. Samples are taken from two depths of the soil profile 0-10cm, 10-20cm. Two replicates were taken per plot for each soil depth samples were dried at 105°c for 24hrs and their dry weight taken (Appendix VII and VIII). For seedling emergence force, wet density was also determined.

$$\rho_w = W_{ws} / V_{ws} \quad \text{.......} (7)$$

Where:

ρ_w = Wet density.

W_{ws} = Wt of wet soil

V_{ws} = Volume of wet soil.

Samples for determination of the soil shear strength were collected in a box having a square cross section, 60mm x 60mm x 60mm for the shear box.

Residual direct shear box machine and its accessories consisting of a box measuring 60mm x 60mm x 60mm and weighing balance was used. Three replicates were collected per plot from 0-10cm soil depth. Moisture content was also determined for each replicate and treatment. Core cutters were fabricated from a 3.81cm flat bar and worked into a sharp edge for easy penetration into the soil. The method used in the measurement includes:

The equipment was prepared and three specimens measuring 60mm x 60mm x 30mm were trimmed out of the sample and weighted in order to determine its bulk density. One of the specimen was gently inserted into the box with the two halves of the box held together by means of two screws. The box was placed in the jacket of the machine, loading yoke was placed over the box and a normal stress of $5kN/m^2$ was applied to the first specimen. Thereafter the shear load was applied and dial readings were obtained at regular intervals until failure occurred and the specimen was removed.

The second, third and fourth specimen were tested in the same manner but with increased normal stress of $10kN/m^2$, $20kN/m^2$, and $30kN/m^2$ The results obtained from measurements are recorded in Appendix IX.

3.6 Measurement of the Crop Parameters

For root length determination four samples per plot were randomly and carefully selected and dug up in 20cm circular diameter root cage to eliminate damage to the roots. The samples were soaked in water overnight and washed in a 2mm slide to ensure complete removal of soil and then dried at 60°c. The length of each root and the total number of main roots were measured and recorded.

The number of seedlings germinating from the plots were physically counted daily and recorded in Appendix XI

Stem diameter of samples collected for the root size measurement were measured with veneer calliper, at the lowest inter-node. The force exerted by seedling was calculated from the mathematical relationship used by Sheikh et al. (1978):

$$F = \mu'' D\,(2CL \tan(45^\circ + 2\theta) + WL/2 - \tan^2(45^\circ + 2\theta) \quad \text{.............................(8)}$$

Where,

F = force exerted by seedling (gms)

μ = Coefficient of friction between seedling and soil (assume 0.25)

D = Mean stem diameter of seedling (cm)

L = Depth of planting (cm)

C = Cohesion of soil (gms/cm^3)

θ = Angle of internal friction of soil in degree

W = Wet density of soil (gms/cm^3).

3.7 Cost of Tillage Treatments

Cost of tractor and implement Hiring service charged was assumed to be 25% of total operating costs per hectare. Machinery hiring rates at the National Agricultural Land

Development Authority (NALDA) on table 5 were obtained to facilitate comparison of monetary benefit of choosing different tillage treatments.

The National Agricultural Land Development Authority does not render mechanical planting due to the non-availability of planters or direct drilling implements. All cost items include cost of fuel, lubrication and materials.

The method used in Wingate –Hill (1978) in Emerson et al. (1978) was adopted to determine the gross margin for each treatment(Table 5).

$Gm = T_r - T_{dc}$……………………………………………………………………(9)

And $T_{dc} = D_c + C_c$………………………………………………………………(10)

Where:

G_m = Gross Margin.

T_r = Total returns.

T_{dc} = Total direct costs.

D_c = Direct costs.

C_c = Cultivating costs.

Total returns was based on yield of 2t ha^{-1} (Phillip, 1977) and N17, 000 t^{-1} (assumed).

Table 5: Cost of Tillage Operations.

Particulars	Rate
i) Cultivating costs	N
(a) Cost of slashing	1,500 per ha
(b) Cost of ploughing	2,000 per ha
(c) Cost of harrowing	1,300 per ha
(d) Cost of ridging	1,300 per ha
(ii) Direct costs	
(a) Cost of manual planting on that tilled soil	900,00
(b) Cost of manual planting on untilled soil	1,500.00
(c) Cost of manual planting on ridges	800.00
(d) Cost of manual spraying	1,800.00

CHAPTER FOUR

RESULTS AND DISCUSSION.

4.1 Physical Characteristics

Result of the physical characteristics obtained are quite variable, while the soil moisture and soil temperature did not show a significant influence of tillage treatments which confirm earlier results by Ojeniyi (1985), (1986), Ojeniyi and Dexter (1975) at the 10 cm or 10 – 20 cm soil depth . The soil density (dry basis) was significantly altered by tillage(Table 6). The result of the soil moisture retention shows that average percentage of soil moisture fall within a maximum range of 9.59% in T_4 and minimum of 8.61% for T_1. Treatments two and three have 8.9% and 9.92% respectively.

Result of the analysis of variance for the same experiment shows that $P< 0.05$ for tillage treatments, indicating that there is no much differences between the plots. This insignificant result is contrary to the results of Ojeniyi (1985); Phillips and Phillips (1984) but comparatively it agrees with Ojeniyi (1989) which suggested that the larger the macro-porosity, the smaller the soil water content because voids larger than 8mm as present in zero tillage soils are responsible for water loss in tilled soils.

These previous studies have found that No-till plots looses less water and that volumetric water content is increased with Bulk density. The current results might be due to the manual slashing and packing of organic mater on the plots before planting, which has left very little organic matter to serve as mulch. It tends to support the view that the more the micro-porosity as with more tillage the better the water conservation when there is no surface mulch. Temperature readings taken in the morning show that mean temperature at 5cm depth were 25.59 °C, 25.53 °C, 25.76 °C, 25,62 °C for treatments one, two, three and four while at the 10 cm depth, mean value of 25.79 °C, 25.53 °C, 25.89 °C, and 25.53 °C were obtained.

Table 6 : Soil Physical properties

Treatments	Soil temperature (° C)		Dry Density g/cm^3		Soil Porosity (%)		Soil Moisture (%)
	5cm	10cm	0-10cm	10-20cm	0-10cm	10-20cm	0-10cm
ZT	25.59	25.79	1.40	1.48	40.43	39.09	8.60
PL	25.52	25.53	1.24	1.33	45.58	39.02	8.90
PH	25.76	25.89	1.25	1.47	42.96	36.15	9.22
PHR	25.62	25.53	1.31	1.32	44.23	35.76	9.59

Comparatively the readings in the evenings (Appendix II) showed mean value of 34.22°C, 35.14°C, 34.38°C, 35.14°C for the same treatments at the 5cm depth and 33.05°C, 33.36°C, 33.26°C, 34.64°C at the 10cm depth.

Soil Temperature is generally lower at the 10cm in the evenings, conversely, morning temperature at 10 cm, showed results which are equal to or higher than that at the 5cm except for treatment four. The no-till plots presented the lowest value of soil temperature probably because of mulching and canopy formation which reduces direct solar radiation on the top soils.

The soil density (dry basis) for 0 - 10cm soil depth revealed that the zero tillage plots are denser than others, averaging 1.40g/cm^3. This is followed by treatment four with 1.31 g/cm^3, treatments three and two at 1.25 g/cm^3 and 1.24 g/cm^3 respectively. The apparent significantly high density of treatment four is probably due to the finer particles that are broken down which are pushed into existing macro-pores thus clogging them. The inconsistent and insignificant result of density on treatment at the 10 - 20cm depth in Table 10 might be due to the difficulty of maintaining a constant depth of operation during tillage. However, the no-till plots are still denser, at 1.48 g/cm^3 than the others treatments. Predictably all treatments are denser in the 10 - 20 cm depth. This may be due to the reduction in the soil organic matter content at the depth.

The results of the soil porosity (Tables 11 and 12) are obtained by a mathematical relationship (equation 6) using bulk density and particle density as parameters. At the 0 - 10 cm depth, treatment two has the largest mean pore space of 45.58% followed by treatments four, three and one. Treatment one appears to be the most densely packed because with time the particles have been naturally consolidated. The high significant effects of treatment on the total pore space might be due to the presence of macro-pores within the sampled soil left by decaying organic matter which was turned in during ploughing. At the 10 - 20cm depth, the results of the porosity are also not significant although it tend to have a reverse relationship when compared with the other treatments (except for treatment two) at the shallower depth. Treatment one has the highest percentage of pore space while the least is treatment four followed by T_2 and T_3 in that order

4.2 Aggregate Stability:

The evaluation of the effects of tillage treatment on soil structure by using data from dry sieving experiment (Table 7) revealed an average MWD of 6.54mm for T_1, 6.18mm for T_2, 4.79mm T_3 and 4.81mm for T_4. These results are significant at the 95% confidence interval. It showed that the tillage implements used did influenced the breakdown of the soil peds into smaller units with the exception of Treatment four which showed a marginally higher value than the preceding treatment. This might probably be due to the fact that ridging operation is more of an aggregate forming operation than the preceding operations which are for inversion and disintegration.

During wet sieving results recorded also showed that soil peds were broken down by the action of water to 2.995mm for treatment one and 2.362mm, 1.818 and 1.812 for T_2, T_3 and T_4 respectively. This shows that tillage intensity contributes to the formation of water stable aggregates of smaller MWD than the zero tillage.

To determine the degree of stability of soil in the different tillage treatments, a ratio of wet/dry sieving was used. Although the result of the ANOVA was not significant at the 5% level. The values of F calculated is 1.231 against F critical of 4.346. This indicates that the differences within the treatments are small.

Higher values of stability ratio as in treatment one, signifies the better stability against

Table 7: Stability index of tillage techniques

Treatment	MWD (Wet Sieving)	MWD (Dry Sieving)	Stability. Index
1	2.995	6.543	0.471
2	2.362	6.182	0.384
3	1.818	4.790	0.379
4	1.812	4.816	0.388

destructive forces of rain or wind erosion, suggesting that, with more cultivation, stability is reduced. This agrees with Osborne, et al. (1978). This is probably due to the weakening of bonding between soil mineral particles as found out by Chan (1988) or the disintegration of soil organic matter which also enhances aggregate formation.

4.3 Crop Parameters.

ANOVA results of the experimental evidence of root measurements taken showed that $P > 0.05$ both for the mean number of roots developed per treatment and the mean root length of measured roots . The maximum number of main roots developed are 13, 18, 13 and 14, for the T_1, T_2 , T_3 and T_4. The minimum number of roots are 7,8,8 and 9 for the same treatments respectively. Treatment two developed an average of 12.4 main roots (Table 8 and Fig. 6) followed by treatment four which is 10.4 in number. Treatments one and three recorded root numbers that were marginally fewer than treatment four. This result seem not to follow any clear pattern with tillage intensity as found out in Ojeniyi (1989).

The mean root length of the treatment three with two tillage operations is 12.98 cm followed by 11.57 cm on the treatment with one tillage operation and 11.03cm for treatment Four. The Zero tillage recorded the least developed average root length considering the number of roots developed, with 8.75 cm long roots on average. This can be due to the influence of the soil density on the root elongation confirming the negative correlation between these two parameters as reported by previous researchers. This has been proved to affect crop growth negatively (Trouse, 1974) if moisture and nutrients cannot be periodically replenished after depleting the available moisture in the soil zones on which they grow. Such root system will fail to meet the demand of crops. The current result was however not able to predict accurately the critical density at which the root growth is limited.

Table 8 : Crop Parameters.

Treatment	Mean Root length (cm)	No of roots (No)	Stem Diameter (cm)	Actual emergence (No)
ZT	8.79	10.00	0.37	25.00
PL	11.57	12.44	0.44	26.00
PH	12.98	10.00	0.41	24.67
PHR	11.03	10.44	0.34	24.00

4.4 Stem Diameter;

The results of the ANOVA on the data used to study the influence of tillage treatments on stem diameter at 95% confidence interval. The analysis showed that the differences between the treatments are not significant. Explanation for this might be that despite the shortage in number and length of roots in some of the treatments, nutrients, water , air and other growth ingredients have not reached a critical level of scarcity that will lead to reduction in growth of the root system and then the stem. Average diameter of stems measured are 0.37 cm for T_1, 0.34cm for treatment four 0.41 for treatment three and 0.44 for treatment two.

4.5 Emergence of Seedlings

Although the result of experiment showed that the emergence was higher after five days in T_3 (Fig 7).This is probably due to better contract of seed with soil and moisture resulting from the production of smaller mean void size by tillage treatments. In T_3 a maximum of 72.58% of seeds have emerged at the fifth day. This result also shows that denser tilths restrict emergence in T_4 and T_1. Thus confirming the findings of Wingate -Hill (1978). Treatment two has 63.56%, followed by 45.1%in T_1 and 34.5% in T_4. This pattern was not followed by the actual emergence after seven days as all treatments show appreciable emergence of over 85% of seeds.

Although, the ANOVA for the actual emergence shows that this result is not significant at $\propto = 0.05$. Seedlings emerged in the order 26, 25, 24, 66 and 24, seedling for T_2, T_1, T_3 and T_4 out of the 28 observation units.

4.6 Cost Analysis

From the cost analysis (Table 9) it can be seen that intensive tillage cannot be justified based on cost consideration alone if it does not lead to commensurate increases in crop yield.

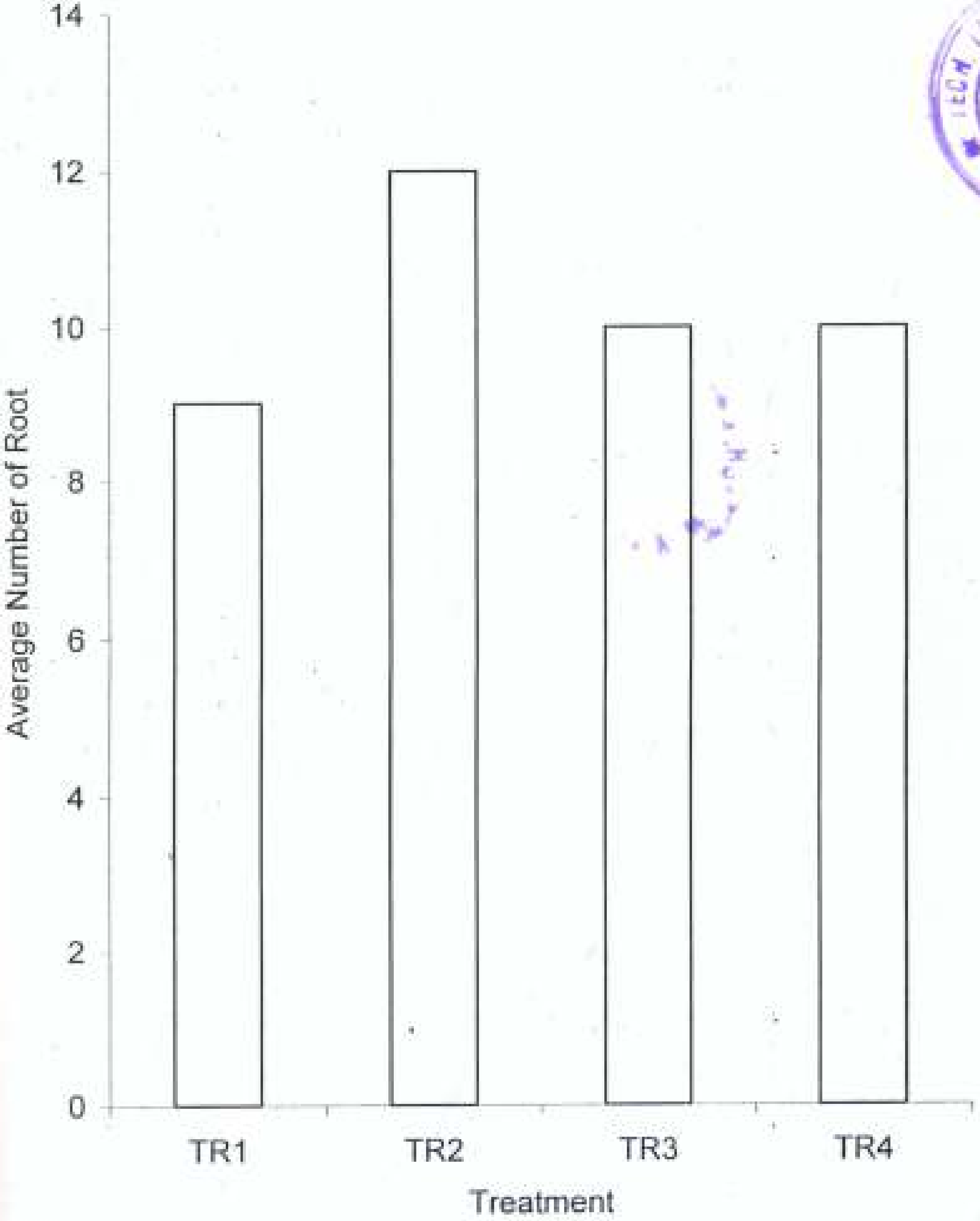

Fig.6 : Average Number of Roots Developed per Treatment

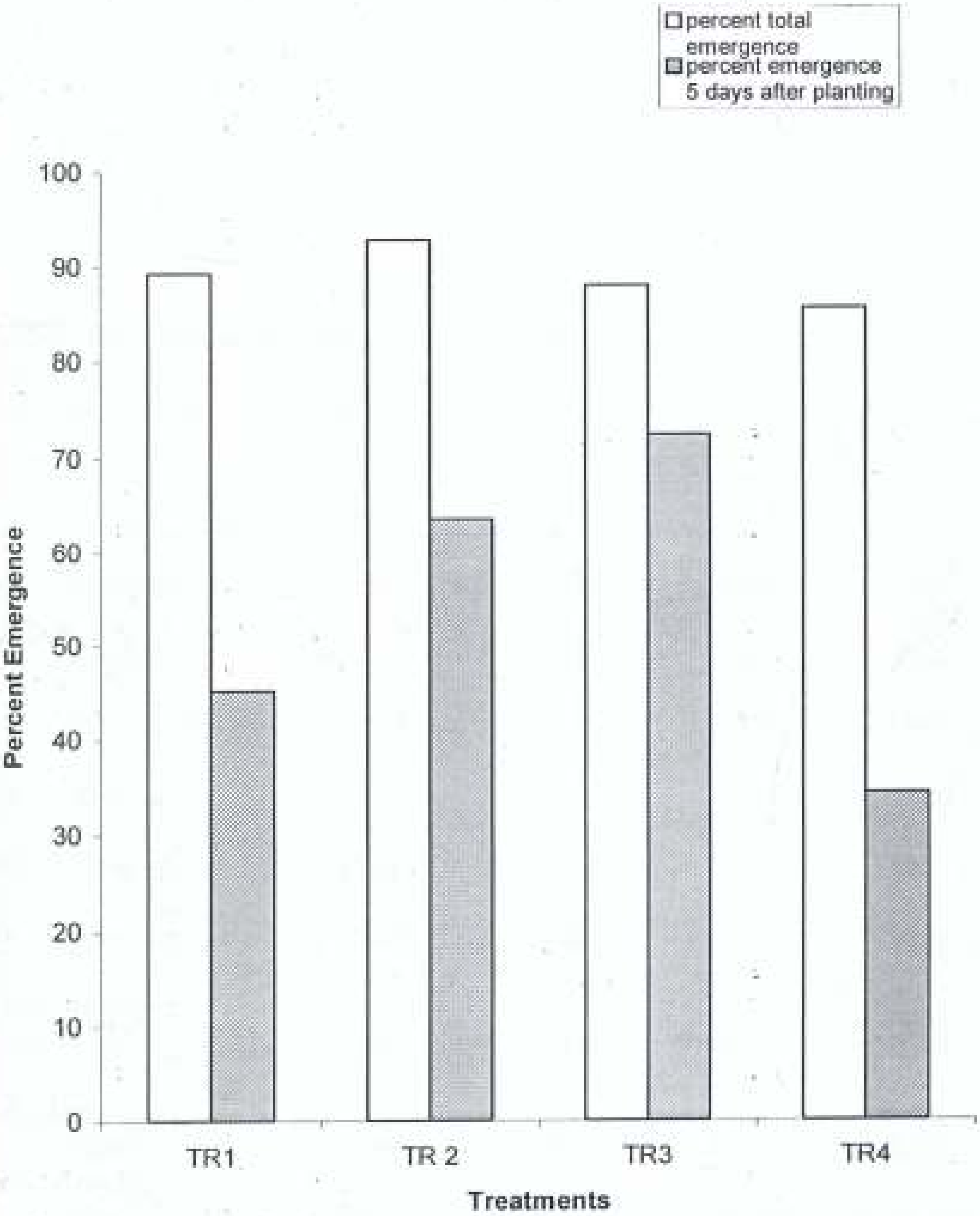

Fig.7 : Percent Emergence 5 Days After Planting and Total Emergence

Table9 : Comparison of Cost Items of Tillage Systems.

Operations \ Costs	T1	T2	T3	T4
	N	N	N	N
(a) Slashing	1500	1500	15000	1500
(b) Ploughing		2000	2000	2000
(c) Harrowing			1300	1300
(d) Ridging				1300
(e) Planting	1500	900	900	800
(f) Spraying	2800	1800	1800	1800
Total Cultivating Costs N ha^{-1}	1500	3500	4800	6100
Total Direct Costs (Nha^{-1}	5800	6200	7500	8700
Cross merging Nha^{-1}	28,200	27,800	26,500	25,300

Costs are at 75% Government subsidy.

4.7 Effect of Soil Shear Strength.

Result of the direct soil shear box test revealed that soil strength is highest in the uncultivated soil. As previously discussed, the effect can be attributed to the stronger organic bonding inherent in the soil organic matter and mineral particles. As soil strength increases it logically follows that resistance to the growth of crops increases. The following predictive values were got from the linear regression analysis (Table 10 and Figure 8) for the shear tests. From Coulomb law the shear force in soil was expressed as:

$\tau = C + \sigma \tan \theta$ ....(11)

This was used to model the shear test data.

The regression statistic showed that a high positive correlation exists between the normal stress and the shear stress for all treatments (Table 11) except treatment four. Values of R are 0.76 for T_1 and 0.92, 0.78, 0.39 for T_2, T_3 and T_4 respectively. The standard errors obtained are 2.71, for T_1, 1.22 for T_2, 2.51 and 7.66 for T_3 and T_4.

The analysis of variance also showed that these results are significant at the 95% confidence interval as the F calculated was found to be higher than the F tabulated in each case.

The soil shear strength decreases directly with tillage in treatments two, three, and four. This result seems to favour the third and fourth tillage treatments being the ones with the least shear strength. However the effect of soil strength on seedlings depends not only on the crust strength but also on extraneous factors like, the size of seedlings, vigour of seedlings (Hillel, 1980b).

4.8 Emergence Force.

The emergence force computed from the mathematical formula (Equation 7) used by Sheikh, et al. (1978) using data from various physical and crop parameters extracted into Table 12 The force was lowest in treatment four and increase directly with less tillage. Average values are 10.63kN, 9.22kN, 8.96kN and 8.85kN for T_1, T_2, T_3 and T_4. Results of the analysis of variance for these are significant at the 95% confidence interval. The F. calculated was found to be 852,42 against the tabulated values of 4,07. This result means that tillage treatments used influenced the emergence force exerted by the seedlings.

Table 10: Model of Soil Shear Strength.

	Treatment	θ (°)	C kN/m^2	Model.
1	2T	16.86	23.31	y = 0.3032x +23.315
2	PL	15.7	21.15	y = 0.2813x + 21.149
3	PH	17.36	16.81	y = 0.2969x + 16.808
4	PHR.	17.36	16.65	y = 0.312 x + 16.651

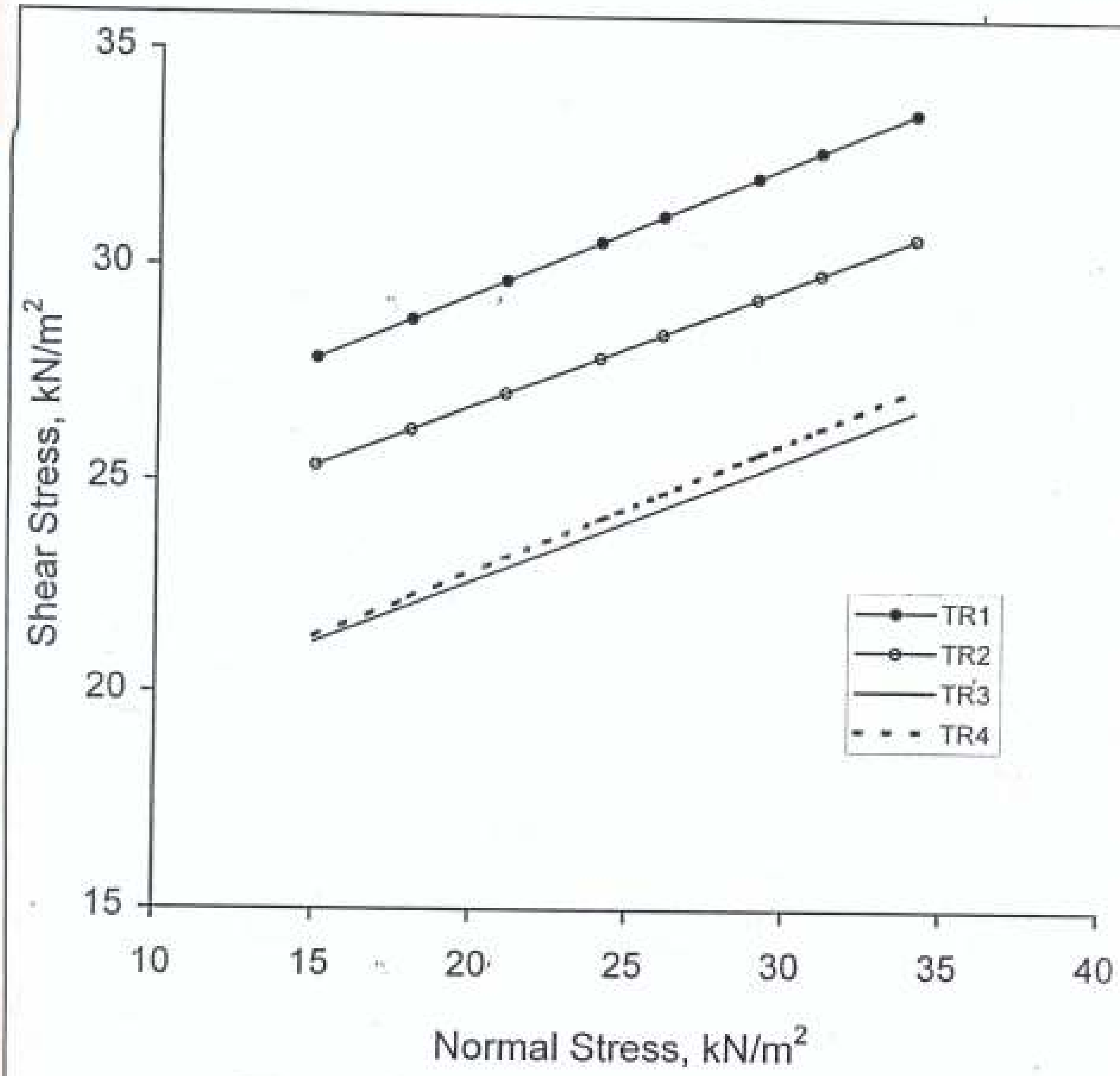

Figure 8 : Shear stress linear regression graphs for the four different treatments

Table 11: Regression statistic for linear regression model.

Treatment	No of Observation	Correlation Coefficient (R)	Coefficient of Determination (R^2)	Standard Error	F Observed	F Critical
ZT	12	0.76	0.58	2.71	13.79	0.00
PL	12	0.92	0.85	1.22	58.52	1.74
PH	12	0.78	0.61	2.51	15.51	0.00
PHR	12	0.39	0.16	7.66	1.84	0.20

Table 12: Emergence Force Exerted by Seedlings.

S/N	Treatment	Stem Diameter D (cm)	Wet Density W (g/ cm^3)	Angle of Internal Friction θ (°)	Cohesion C (kN/ m^2)	Emergence Force F (kN)
1	2T	0.364	1.63	16.86	23.31	10.63.
2	PL	0.442	1.44	15.7	21.15	9.22
3	PH	0.409	1.42	17.36	16.81	8.96
4	PHR	0.386	1.54	17.36	16.65	8.85

A follow up test was carried out to determine if the differences between each treatment is significant with the Fisher's least significant difference (Table13). The result showed that there were significant differences between the emergence force exerted by the treatments. This significant result is seen primarily as the influence of the soil strength on the seedlings. The emergence force was found to increase directly with soil strength.

Table 13: Fisher's Least Significant Difference for Emergence Force Exerted.

LSD Result.

Groups	Average.
Tr_1	10.86a
Tr_2	9.22b
Tr_3	8.96c
Tr_4	8.85d

4.8 Model of emergence Force

A multiple linear regression model was fitted for each of the treatments with emergence force as the dependent variable and other physical and crop parameter as the independent variable. Such parameters are: Cohesion (C), Angle of a internal friction (θ), Wet density (W), Mean weight diameter (D), Root length (RL) and Root number (RN) for each treatment. The summary statistic of regression analysis and the analysis of variance are presented on table 14. The models are:

$$F_1 = -11.98 + 0.05C + 0.25\theta + 1.39W + 0.62D + 0.15RL + 0.0016RN \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (12)$$

$$F_2 = -5.62 + 0.23C - 0.85\theta + 5.56W + 0.93D + 0.11RL + 0.0015RN \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (13)$$

$$F_3 = 1.90 - 0.019C - 0.069\theta - 0.34 + 0.17D - 0.031RL + 0.031RN \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (14)$$

$$F_4 = -42.82 + 2.21C - 1.52\theta + 28.05W - 4.22D + 1.14RL - 0.14RN \ldots\ldots\ldots\ldots\ldots\ldots\ldots (15)$$

Where:

C = Cohesion

θ = Angle of Internal Friction.

W = Wet Density.

D = Mean Weight Diameter.

RL = Root Length.

RN = Root Number.

Result indicated that a good fit exists between the variables. Both the correlation coefficient (R) and the coefficient of determination (R^2) are very high for the individual treatments (Table 14). The standards errors were also low, indicating that there are common factors between the relationships. The R^2 are 0.84 for T_1 0.83 for T_2, 0.88 for T_3 and 0.96 for T_4. The R are 0.92, 0.91, 0.92 and 0.98 for the same treatments. The standard error was lowest in T_3 where it was 0.081 followed in ascending order by 0.11 in T_4, 0.21 in T_2 and 0.26 in T_4. These results indicate that the independent variables are accurate parameters for the prediction of the emergence force exerted by the maize seedling and vice versa.

To test whether in these results such a high R^2 occurred by chance the F statistic was used For all cases the F – observed statistic in greater than the F critical value using ∞ values of 0.05 and 6 degree of freedom. This shows that the regressions equation is useful in predicting the values of the emergence force exerted by the maize seedling

Table 14 : Regression statistic for multiple linear regression models.

Treatment	No of Observation	Correlation Coefficient (R)	Coefficient of Determination (R^2)	Standard Error	F Observed	F Critical
ZT	9	0.92	0.84	0.23	1.80	0.40
PL	9	0.91	0.83	0.21	1.67	0.42
PH	9	0.94	0.88	0.08	2.52	0.31
PHR	9	0.98	0.96	0.11	8.60	0.11

CHAPTER FIVE.

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The research gave enough evidence that the soil structural condition as modified during tillage, affects the soil physical properties and some crop properties of the soil using maize as an indicator crop. The influence of cultivation on the soil temperature, moisture retention, total porosity appear not significant. But the soil density was significantly altered by the tillage treatments used.

These findings, agrees with previous works reported by Osborne, et al. (1976) and Chan (1988). While cultivation may prove advantageous in the reduction of stress on the penetrating roots as it searches for moisture and vital nutrients, it has been seen that as cultivation increases up to a point, the density of the soil will increase after the initial loosening action. This might be attributable to the observations of Chan, (1988) that soil strength is increased by the amount of dispersible clay caused by cultivation.

Ridging operation mainly reduces erosion risks and improves water conservation for crop use as observed in Kowal and Kassam (1978), otherwise it might be considered superflous for cultivation of grains as no obvious advantage has been found of its use in the study. Based on the result, it is doubtful if significant increase can be made on yield of crops on the ridged plots (on the long run) given the early growth data obtained on root growth and stem diameter. The suitability of such operations for root crops cultivation might be acceptable in view of the wide spread use Kowal and Kassam, (1978).

Also the experiments have also shown that intensive cultivation decreases the aggregate stability of the soil tested in the different tillage treatments. This suggests serious harmful consequences to the uncovered soil during the rainy season. Expectedly, the zero tillage plots had highest emergence force which reduces as tillage is increased. This might be responsible for the decrease in stands with less tillage relative to the third and fourth treatments in the current study that has earlier been reported by Phillips and Phillips (1984). For these reasons, a higher seed rate might be recommended as tillage is reduced to make up for the short fall and to guarantee maximum stands. The experiment was not able to determine the critical soil strength that might completely hinder the growth of the seedlings.

The total cultivating costs per hectare was maximum for T_4 (N6100) and lowest for T_1 at N1500. Treatments two and three recorded an amount of N3500 and N4800 respectively.

The total direct costs followed the same trend, establishing the economy of reduced tillage treatments over others. The number of main roots and the average length of the roots sampled in the experiment was also significantly affected by treatments and both showed the superiority of a single pass disc ploughing operation. Actual emergency was over 85% for all treatments. Emergence was earlier on the treatments with reduced tillage and no tillage. The emergence force was found to increase directly with soil strength. From a minimum value of 8.85 kN in treatment four to a maximum of 10.63 kN in treatment one.

5.2 Recommendation.

The optimum tillage practice is the tillage that is necessary for maximization of returns to the farmer which is obtainable over a long period of time i. e. with minimum soil destruction. Although it is difficult to statistically say one tillage technique is the optimum, as no definite rules can be laid down recommending what implements are needed to produce the best result in all circumstances. However considering the general influence of all parameters measured and cost implication, it is recommended that

i) One ploughing is adequate for the growth of maize planted under similar condition of this test. This is adequate to satisfy the demands of the crops, soil conservation and mechanization.

ii) The no-till system is not advantageous except there is adequate mulch cover over seedling to improve soil moisture conservation, also a more frequent supply of either organic or inorganic fertilizer might be required to compensate for the inability of the root system to penetrate deeper and denser tilth in search for fresh nutrients. Problem of environmental hazard of herbicides and difficulty in mechanization are also strong points against zero tillage.

From the result it is evident that the reduced shear strength and emergence force obtained with more tillage operations was not translated to increase in the crop parameters studied.

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APPENDIXES

Appendix I: Mean Soil Temperature (am)

PLOT	DEPTH	1	2	3	4	5	6	7	8	MEAN
1	5	24.3	26.3	24.3	25.7	26.7	25	25.3	26	25.45
	10	25	26.3	25.3	25.7	26.3	25.7	25.7	27	25.875
2	5	23.7	26.3	24.3	25.7	26	25	25.3	26	25.288
	10	23.3	26.7	25	25	26	24.7	25.3	26	25.25
3	5	23.7	26.3	23.3	25.3	26.3	25.7	25.3	25	25.113
	10	23.7	26.3	25.3	25.3	25.7	25	25	26	25.288
4	5	25	26.3	23.3	26	26	25.7	25	26	25.413
	10	25.3	26.3	24.7	25.3	26	25.7	25.7	27	25.75
5	5	24.7	26.3	24.3	25.7	26.3	25.3	26	26	25.575
	10	25	26.3	25.3	25	26	25.3	26	27	25.738
6	5	24	26.3	24	27	26.7	25.7	25.7	26	25.675
	10	25	26.3	25	26.3	26.3	25.3	25.7	27	25.863
7	5	23.3	26.3	24	28	26.3	25.7	26	25	25.575
	10	23.7	26.3	25.3	27	26.8	25.7	25.7	25	25.688
8	5	24	26.7	24.7	27.3	26.7	26	25.7	26	25.888
	10	25	26.3	25.7	26	26.7	25.3	26	27	26
9	5	23.7	27.3	24.3	28.3	27	25.7	25.7	26	26
	10	24	27	25.3	26	26.3	25	25.7	26	25.663
10	5	24.3	27.7	24	26.7	26.7	25.3	25.3	26	25.75
	10	24.3	27.3	25	26	26.3	24.3	26	27	25.775
11	5	24.3	26.3	24	27	27	25.7	26	26	25.788
	10	24.3	26.3	25	26	26	24.7	25.3	26	25.45
12	5	24.7	27	24.3	27.3	26.3	26.3	26	26	25.988
	10	25	26.7	25.3	26	26.3	25	26	27	25.913

Appendix II: Mean Soil Temperature (pm)

PLOT	DEPTH	1	2	3	4	5	6	7	MEAN
1	5	33	36.7	37	29.7	36.7	36	31.3	34.343
	10	31	35.7	35	29.7	35	34.7	30.3	33.057
2	5	40	37.7	36	29.3	34	35.3	31.3	34.8
	10	38	36.3	35	29.3	32.3	35.3	30.7	33.843
3	5	41	38.7	35	29	37	35.7	31	35.343
	10	38	37	34	29	34	35	30.7	33.957
4	5	38	38	35	29.3	36.3	34.3	30.7	34.514
	10	36	36	33	29	35	34.7	30	33.386
5	5	33	40	35	29	33.7	37	31.3	34.143
	10	30	37.3	34	28.3	35	36	31.7	33.186
6	5	38	39	35	29.3	37.7	35.3	31.7	35.143
	10	36	37	34	29.3	32.3	35	31.3	33.557
7	5	39	39	37	29	34.7	36	31.7	35.2
	10	36	37	36	29	34	35	31	34
8	5	38	38	36	29.3	35	37	29	34.614
	10	35	35.7	35	27	33.7	34	30	32.914
9	5	38	39	38	29.3	37	36.7	30	35.429
	10	35	38	37	28.3	35.7	36	30	34.286
10	5	35	37.3	35	30	36	36	30.3	34.229
	10	32	35.7	34	27.7	34.7	36	30.3	32.914
11	5	38	39	38	29	34.7	35.3	30.7	34.957
	10	26	37.7	37	27	34	34.7	30.7	32.443
12	5	36	36	36	29.3	35.3	36	29.7	34.043
	10	36	36	36	27.3	33.7	35.3	30	33.471

Appendix III: Moisture Content.

PLOT	1	2	3	4	5	6	7	8	MEAN
1	2	6.5	9	16	4.5	12.5	13.5	9.8	8.75714
2	2.75	6	11.4	15.8	6	13	15.5	12.5	10.3688
3	4.75	7.95	12.3	13.6	4	9.7	13.8	12.7	9.85
4	7.1	2	5.5	0.5	3	10.5	13	13.5	6.8875
5	3.6	5.5	5	13.5	4.5	9	16.2	8.5	8.225
6	2.3	10.5	7.6	16	12.5	6.5	14.5	11.3	10.15
7	1.4	10.5	9.5	13.5	10.2	10.5	11.8	12.6	10
8	1.4	9.5	9.4	15.2	1.2	9.1	16.4	12.5	9.3375
9	1.1	3	9	12.5	9.5	9.6	12	10.6	8.4125
10	3	6.5	4.8	16	6	6.7	13.5	10.5	8.375
11	2.5	10.1	5	14.5	8.5	12	14	11.5	9.7625
12	1.5	11.5	11.6	17.1	7.5	6	14.6	14.1	10.4875

Appendix IV. Particle Density.

P.-1-10cm

P'-10-20cm

PLOT	Vol. of soil (cm^3)	Wt of soil (g)	P.density ($g|cm^3$)
P1	4	9.48	2.37
P1'	6	15.12	2.52
P2	6	15	2.5
P2'	6.5	15.73	2.42
P3	8	8.3	2.29
P3'	8.5	16.15	1.9
P4	7	15.89	2.27
P4'	7	6.38	2.34
P5	5	13.68	2.28
P5'	6	13.68	2.47
P6	6	13.84	2.31
P6'	5	13	2.6
P7	6	14.5	2.42
P7'	5.5	12.98	2.36
P8	7	134.86	1.98
P8'	7	14.9	2.13
P9	7	14.98	2.14
P9'	7	15.96	2.28
P10	8	19.36	2.42
P10'	4.5	10.39	2.31
P11	6	13.32	2.22
P11'	8	17.76	2.22
P12	7	16.9	2.4
P12'	4	9.88	2.47

Appendix V: Soil Physical Characteristics (DEPTH: 0-10cm)

	Wt Of Core	Wt Of Wet Soil	Wt Of Dry Soil	Dry Density	Wet Density	Particle Density	Total Porosity	% Moisture
P1	252.58	278	237.38	1.43	1.67			17.4
				1.41	1.64	2.37	40.5	16.2
	249.38	268	230.74	1.39	1.61			11
P2	253.05	243.2	219.12	1.32	1.47			
				1.33	1.48	2.5	46.8	12.3
	253.78	249.8	222.44	1.34	1.5			16
P3	248.73	233	200.84	1.21	1.4	2.29	46.28	
				1.23	1.45			18.1
	251.1	242.8	205.84	1.24	1.46			12.8
P4	246.19	232.4	219.54	1.32	1.4			
				1.31	1.46	2.27	42.29	16
	252.81	252.3	217.46	1.31	1.52			
P5	252.72	264.8	229.08	1.38	1.59	2.28	39.9	15.6
				1.37	1.59			
	251.36	261.7	227.42	1.37	1.58			15.1
P6	257.2	242.05	208.58	1.25	1.46			16
				1.24	1.46	2.31	46.32	
	250.25	245	209.16	1.26	1.47			17.3
P7	250.3	242.5	214.14	1.29	1.46			13.2
				1.28	1.46	2.42	47.11	
	251.94	242	210.82	1.27	1.46			14.8
P8	255.18	244	212.48	1.28	1.47			15
				1.28	1.47	1.98	35.35	
	255.67	243	212.48	1.28	1.47			14.5
P9	254.68	251.8	219.12	1.32	1.5			14.9
				1.31	1.7	2.14	38.78	10.1
	254.18	239	217.46	1.31	1.44			18.5
P10	224.43	289.9	244.63	1.47	1.47	2.42	40.91	
				1.43	1.67			17.4
	250.91	268.9	229.08	1.38	1.6			
P11	250.1	229.5	203.98	1.23	1.38	2.22	44.14	12.5
				1.24	1.41			
	254.56	239.7	207.5	1.25	1.44			15.5
P12	254.2	245.5	212.5	1.28	1.48	2.4	51.25	15.7
				1.17	1.34			
	255.36	199	176	1.06	1.2			13.3

Appendix VI: Soil Physical characteristics (DEPTH: 10-20cm)

	Wt of Core	Wt of Wet Soil	Wt of Dry Soil	Dry Density	Wet Density	Particle Density	Total Porosity	% Moisture
P1	252.75	289.81	247.02	1.49	1.75			17.3
				1.45		2.52	42.46	
	249.22	273.73	233.02	1.4	1.65			17.5
P2	253.32	277.87	239.55	1.44	1.67			16
				1.39		2.42	42.56	
	254.63	264.26	220.94	1.33	1.54			19.6
P3	251.1	281.96	241.78	1.46	1.7			16.6
				1.4		1.9	26.32	
	248.85	261.57	222.7	1.34	1.58			17.5
P4	249.41	292.37	252.36	1.52	1.76			15.9
				1.51		2.34	35.89	
	252.49	288.2	249.51	1.5	1.74			15.5
P5	250.79	294.87	251.42	1.51	1.78			17.3
				1.51		2.47	38.87	
	254.94	290.22	222	1.51	1.75			15.5
P6	253.53	226.22	188.12	1.13	1.36			20.3
				1.2		2.6	53.8	
	254.78	255.84	208.65	1.26	1.54			22.6
P7	245.75	218.85	187.55	1.13	1.32			16.7
				1.18		2.36	50	
	250.39	242.41	203.24	1.22	1.46			19.3
P8	256.98	312.62	269.98	1.63	1.88	2.13	27.23	15.8
				1.55				
	250.92	283.77	243.86	1.47	1.71			16.4
P9	251.77	270.54	230.24	1.39	1.63	2.28	14.72	17.5
				1.39	1.63			18.9
	253.41	272.6	229.15	1.39	1.64			
P10	250.22	272.33	244.82	1.47	1.86			12.5
				1.48				
		292.2	247.3	1.49	1.76	2.31	35.93	
P11	252.26	283.28	243.48	1.47	1.71			16.3
				1.4		2.22	36.94	
	251.5	261.68	219.78	1.32	1.58			19.1
P12	253.5	270.36	235.27	1.42	1.63			14.9
				1.35		2.47	45.34	
	255.3	251.58	211.63	1.27	1.52			18.9

Appendix VII: Dry Sieving.

	SIEVE SIZE	MEAN (MM)	R1	R2	R3	MEAN	%	XiWi (mm)
Plot 1								
1	.00-.425	0.213	1.2	1.5	1.8	1.57	0.01	0.0016
2	.425-.85	0.638	7	8.1	6.9	7.46	0.04	0.0236
3	.85-2.00	1.425	26.5	15.1	16.1	19.43	0.1	0.1382
4	2.00-2.36	2.18	25.4	15.8	13.2	18.13	0.09	0.1984
5	2.36-3.35	2.945	20.3	21.4	21.8	21.17	0.11	0.3092
6	3.35-6.70	5.025	37.9	25.6	27.4	30.3	0.46	2.2864
7	6.70-9.5	8.1	44.6	45.6	43.2	44.41	0.22	1.798
8	.> 9.5	9.5	65.9	66.5	68.9	67.1	0.34	3.192
								7.947
Plot 2								
1	.00-.425	0.213	8.9	11.2	16	12	0.06	0.0129
2	.425-.85	0.638	20.1	12.5	15	15.8	0.08	0.0504
3	.85-2.00	1.425	25	24	25	25.13	0.13	0.1795
4	2.00-2.36	2.18	22	25	19	22.7	0.11	0.2474
5	2.36-3.35	2.945	27.6	25.3	23	25.3	0.13	0.374
6	3.35-6.70	5.025	28	30	26.5	28.67	0.14	0.7185
7	6.70-9.5	8.1	31	30	35	32.06	0.16	1.298
8	.> 9.5	9.5	36	47.9	36	40.2	0.2	1.9
								4.78
Plot 3								
1	.00-.425	0.213	3.6	1.3	5.3	3.4	0.02	0.0036
2	.425-.85	0.638	7.5	11.4	9.6	9.5	0.05	0.0306
3	.85-2.00	1.425	18	11	13	14.8	0.07	0.1055
4	2.00-2.36	2.18	18.2	12.6	14.4	13.4	0.07	0.1461
5	2.36-3.35	2.945	23.4	25	24.5	24.3	0.12	0.3622
6	3.35-6.70	5.025	31	30	23	28.33	0.14	0.7135
7	6.70-9.5	8.1	54	30	41	35.56	0.18	1.442
8	.> 9.5	9.5	67	66	67	67	0.34	3.182
								5.985
Plot 4								
1	.00-.425	0.213	4.7	6.3	5	5.33	0.03	0.0055
2	.425-.85	0.638	11	10.1	10.2	10.43	0.05	0.0332
3	.85-2.00	1.425	20.1	21.8	33.9	25.26	0.13	0.1795
4	2.00-2.36	2.18	16.4	21.3	10.6	16.1	0.02	0.1766
5	2.36-3.35	2.945	20.2	26.8	27	42.67	0.12	0.3622
6	3.35-6.70	5.025	27.7	32.9	27.5	29.36	0.15	0.7336
7	6.70-9.5	8.1	52.3	42.6	41.9	45.6	0.23	1.847
8	.> 9.5	9.5	47.6	38.2	43.8	43.2	0.22	2.052
								5.389
Plot 5								
1	.00-.425	0.213	1	4.5	3.2	2.9	0.02	0.0032
2	.425-.85	0.638	1.1	2.5	4.9	2.83	0.01	0.0089
3	.85-2.00	1.425	15	16	12	14.7	0.07	0.1055
4	2.00-2.36	2.18	16.5	18.2	12.7	15.8	0.08	0.1722
5	2.36-3.35	2.945	25	24.3	26.1	25.13	0.13	0.3711
6	3.35-6.70	5.025	31.9	39.6	31.8	34.43	0.17	0.8643
7	6.70-9.5	8.1	51.2	50.4	55	52.43	0.26	2.106
8	.> 9.5	9.5	54.6	53.1	48.4	51.9	0.03	2.375
								6.006
Plot 6								
1	.00-.425	0.213	2.8	1.9	2.3	2.33	0.01	0.0026

2	.425-.85	0.638	16.8	11.7	14.6	14.37	0.07	0.0459
3	.85-2.00	1.425	17.4	10	15	37.06	0.01	0.1924
4	2.00-2.36	2.18	13.2	12.6	15.8	13.87	0.07	0.1504
5	2.36-3.35	2.945	23.5	28.6	25.7	25.93	0.13	0.3799
6	3.35-6.70	5.025	35	42	33	37.06	0.19	0.9296
7	6.70-9.5	8.1	42	44	44	43.13	0.22	1.742
8	.> 9.5	9.5	48.7	46.8	50.9	48.8	0.24	2.318
								5.761
Plot 7								
1	.00-.425	0.213	2.2	4.3	9.4	2.63	0.01	0.0027
2	.425-.85	0.638	12.1	6.6	7.5	8.73	0.04	0.0274
3	.85-2.00	1.425	18.3	22	20.3	20.36	0.1	0.1454
4	2.00-2.36	2.18	16.7	29	30	25.7	0.13	0.3248
5	2.36-3.35	2.945	32	21.9	30	28.26	0.14	0.4152
6	3.35-6.70	5.025	30.1	36.1	34	33.86	0.17	0.8492
7	6.70-9.5	8.1	43.6	43.1	33.3	40	0.2	1.62
8	.> 9.5	9.5	44.2	31.9	37.4	37.83	0.19	1.295
								4.6797
Plot 8								
1	.00-.425	0.213	3.7	2.4	2.5	2.87	0.01	0.0029
2	.425-.85	0.638	13.7	10.6	18.1	14.13	0.07	0.0453
3	.85-2.00	1.425	29.5	28	33.3	30.27	0.05	0.2152
4	2.00-2.36	2.18	36.6	32.3	24.6	31.17	0.16	0.3401
5	2.36-3.35	2.945	26.3	30.5	24.9	27.23	0.14	0.4005
6	3.35-6.70	5.025	24.7	28.2	26.5	26.47	0.13	0.6633
7	6.70-9.5	8.1	34.6	32.7	33.6	33.67	0.17	1.361
8	.> 9.5	9.5	30.8	36.2	36.2	34.4	0.17	1.634
								4.662
Plot 9								
1	.00-.425	0.213	3.1	4.5	3.6	3.73	0.02	0.0038
2	.425-.85	0.638	13	40.2	13.7	13.63	0.07	0.0433
3	.85-2.00	1.425	33.2	36.8	29.9	33.3	0.17	0.2365
4	2.00-2.36	2.18	18.1	19.5	13	16.89	0.08	0.1831
5	2.36-3.35	2.945	25.4	24.4	25.5	25.1	0.13	0.3711
6	3.35-6.70	5.025	22.4	20.4	28.6	23.8	0.12	0.5979
7	6.70-9.5	8.1	42.5	41.1	41.5	41.7	0.21	1.693
8	.> 9.5	9.5	36	37.1	44.2	29.1	0.2	1.862
								4.99
Plot 10								
1	.00-.425	0.213	4	2.7	3.5	3.4	0.02	0.0036
2	.425-.85	0.638	13.7	15.2	10.4	13.1	0.07	0.0421
3	.85-2.00	1.425	15.3	18	15	16.27	0.08	0.1154
4	2.00-2.36	2.18	15.8	20.3	15.2	17.1	0.09	0.1875
5	2.36-3.35	2.945	20.3	30.1	23	24.67	0.12	0.3622
6	3.35-6.70	5.025	38.5	30.66	29.8	32.97	0.17	0.8291
7	6.70-9.5	8.1	39.3	30	42	37.6	0.19	1.523
8	.> 9.5	9.5	51.7	51.8	61	55.07	0.28	2.613
								5.676
Plot11								
1	.00-.425	0.213	3	3.1	3.6	3.23	0.02	0.0034
2	.425-.85	0.638	4.4	2.7	4	3.7	0.02	0.0121
3	.85-2.00	1.425	14	17	12	14.76	0.07	0.1055
4	2.00-2.36	2.18	12.3	11.4	15.2	12.97	0.07	0.1417
5	2.36-3.35	2.945	10.1	11.1	10.8	10.67	0.05	0.1561
6	3.35-6.70	5.025	25.1	30	23.9	26.33	0.13	0.6583
7	6.70-9.5	8.1	81.1	46.1	43.2	46.8	0.23	1.895
8	.> 9.5	9.5	78	77	86	80.27	0.4	3.828

6.8

Plot 12

1	.00-.425	0.213	14.3	14.1	15.6	14.67	0.07	0.0155
2	.425-.85	0.638	24.8	20.9	17.5	21.06	0.11	0.0669
3	.85-2.00	1.425	26.8	28.2	25.7	26.9	0.14	0.1924
4	2.00-2.36	2.18	22.2	23.5	25.6	23.77	0.12	0.2572
5	2.36-3.35	2.945	19.6	27.7	23.4	23.57	0.12	0.3445
6	3.35-6.70	5.025	22.5	26.6	30.4	26.5	0.13	0.6683
7	6.70-9.5	8.1	34.3	25.1	33.6	31	0.16	1.256
8	> 9.5	9.5	35.4	33.7	28.2	32.07	0.16	1.52
								4.321

Appendix VIII: Wet Sieving

PLOT 1

S/n	Sieve Size	Mean Dia. (mm)	R1 (g)	R2 (g)	R3(g)	Mean (w) (g)		XiWi (mm)
1	.00-.425	0.213	73.5	74.3	72.43	73.43	24.2	0.052
2	.425-.85	0.638	45.6	43.3	41.5	43.46	9.23	0.059
3	.85-2.00	1.425	67.3	68.7	67.9	67.79	21.5	0.306
4	2.00-2.36	2.18	46.1	45.1	46.4	46.1	10.6	0.23
5	2.36-3.35	2.945	50.5	51.4	52.3	51.4	13.2	0.389
6	3.35-6.70	5.025	31.7	31.8	31.2	31.57	3.28	0.165
7	6.70-9.5	8.1	39.8	38.6	39.4	39.27	7.14	0.578
8	> 9.5	9.5	45.2	46.8	48.4	46.8	10.9	1.036
								2.815

PLOT 2

S/n	Sieve Size	Mean Dia (mm)	R1 (g)	R2 (g)	R3(g)	Mean (w) (g)		XiWi (mm)
1	.00-.425	0.213	75.1	75.4	74.6	75.3	25	0.053
2	.425-.85	0.638	44.8	44.9	45.3	45	10	0.064
3	.85-2.00	1.425	67.9	67.6	67.8	67.77	21.4	0.305
4	2.00-2.36	2.18	44.2	44.4	44	44.2	9.6	0.209
5	2.36-3.35	2.945	51.9	51.7	51.6	51.73	13.3	0.392
6	3.35-6.70	5.025	33.1	33.7	33.3	33.33	4.18	0.21
7	6.70-9.5	8.1	38.8	38.3	38.6	38.57	6.79	0.55
8	> 9.5	9.5	44.2	44.1	44.8	44.37	2.68	0.255
								2.038

PLOT 3

1	.00-.425	0.213	72.7	70.9	74.9	72.83	23.9	0.051
2	.425-.85	0.638	50.1	47.9	45.7	47.9	11.5	0.073
3	.85-2.00	1.425	70.4	72.8	71.4	71.53	23.3	0.332
4	2.00-2.36	2.18	50.9	50.4	49.3	50.2	12.6	0.275
5	2.36-3.35	2.945	59.1	60.5	59.9	59.5	17.3	0.508
6	3.35-6.70	5.025	30.5	29	29.5	29.67	2.33	0.117
7	6.70-9.5	8.1	34.1	35.2	32.9	34.09	4.54	0.368
8	> 9.5	9.5	32.2	34.3	36.4	34.3	4.65	0.442
								2.166

PLOT 4

S/n	Sieve Size	Mean Dia (mm)	R1 (g)	R2 (g)	R3(g)	Mean (w) (g)		XiWi (mm)
1	.00-.425	0.213	88.3	89.8	91.2	89.77	22.4	0.048
2	.425-.85	0.638	70.7	70.9	70.6	70.73	12.9	0.082
3	.85-2.00	1.425	100.9	100.3	100.5	100.57	27.8	0.395
4	2.00-2.36	2.18	69.3	69.4	69.7	69.47	12.2	0.267
5	2.36-3.35	2.945	73.5	75.2	73	73.9	14.5	0.426
6	3.35-6.70	5.025	51.1	50.3	50.4	50.6	2.8	0.141
7	6.70-9.5	8.1	52	51.6	53.5	53.4	4.2	0.34
8	> 9.5	9.5	54.2	52.5	53.5	53.4	4.2	0.399
								2.098

PLOT 5

S/n	Sieve Size	Mean Dia (mm)	R1 (g)	R2 (g)	R3(g)	Mean (w) (g)		XiWi (mm)
1	.00-.425	0.213	63.8	63.3	69.7	65.6	20.3	0.043
2	.425-.85	0.638	44.6	42.7	43.7	43.66	9.33	0.059

3	.85-2.00	1.425	69.4	69	67.6	68.07	21.8	0.311
4	2.00-2.36	2.18	45.1	44.7	44.3	44.7	9.85	0.215
5	2.36-3.35	2.945	53.9	56.5	51.2	53.87	14.4	0.425
6	3.35-6.70	5.025	34.5	34.8	34.2	34.5	4.75	0.239
7	6.70-9.5	8.1	40.3	40	40.6	40.3	7.65	0.619
8	.> 9.5	9.5	48.4	49	48.7	48.1	11.9	1.125
								3.036

PLOT 6

S/n	Sieve Size	Mean Dia (mm)	R1 (g)	R2 (g)	R3(g)	Mean (w) (g)		XiWi (mm)
1	.00-.425	0.213	72.5	72.4	73	72.63	23.8	0.051
2	.425-.85	0.638	48.4	44.1	52.6	48.37	11.7	0.075
3	.85-2.00	1.425	68.9	78.5	73.7	73.7	24.4	0.348
4	2.00-2.36	2.18	45.6	44.9	44.8	45.1	10.1	0.219
5	2.36-3.35	2.945	50.4	52	48.7	50.37	12.7	0.373
6	3.35-6.70	5.025	30.5	27.5	30.1	29.37	2.18	0.11
7	6.70-9.5	8.1	39	35.4	34.9	36.43	5.72	0.463
8	.> 9.5	9.5	44.7	45.2	42.2	44.03	9.51	0.903
								2.542

PLOT 7

S/No.	Sieve Size (mm)	Mean(xi) Dia(mm)	R1(g)	R2(g)	R3(g)	Mean(w) 100(g)	%	XiWi
1	.00-.425	0.213	97.1	97.1	97.1	94.57	34.8	0.074
2	.425-.85	0.638	49.4	48.8	50.1	49.43	12.2	0.078
3	.85-2.00	1.425	73.4	77.2	75.3	75.3	25.2	0.358
4	2.00-2.36	2.18	46.4	44.9	43.8	45.04	10	0.218
5	2.36-3.35	2.945	44.9	44.4	47.5	45.6	10.3	0.303
6	3.35-6.70	5.025	27.4	28.5	27.9	27.93	1.47	0.074
7	6.70-9.5	8.1	29.5	30.3	30.9	30.23	2.62	0.211
8	.> 9.5	9.5	31.9	31.7	32.1	31.9	3.45	0.327
								1.643

PLOT 8

1	.00-.425	0.213	79.2	76.1	110.6	79.63	27.3	0.058
2	.425-.85	0.638	50.1	50.3	50.4	50.27	12.6	0.081
3	.85-2.00	1.425	77.7	82.1	79.9	79.9	27.5	0.391
4	2.00-2.36	2.18	52.1	53.7	50.4	52.07	13.5	0.295
5	2.36-3.35	2.945	57.6	54.8	52.1	54.83	14.9	0.439
6	3.35-6.70	5.025	26.7	26.5	27.6	26.93	0.97	0.049
7	6.70-9.5	8.1	27.5	28	27.9	27.8	1.4	0.113
8	.> 9.5	9.5	29.1	28.5	28.1	28.57	1.78	0.169
								1.595

PLOT 9

1	.00-.425	0.213	95.4	96.5	94.3	95.4	35.2	0.075
2	.425-.85	0.638	44.7	45.1	46.4	45.4	10.2	0.065
3	.85-2.00	1.425	67.3	70.6	69.95	69.28	22.1	0.315
4	2.00-2.36	2.18	47.3	46.7	46.9	46.97	11	0.239
5	2.36-3.35	2.945	50.8	49.9	51	50.54	12.8	0.376
6	3.35-6.70	5.025	30.9	28	29.05	29.32	2.16	0.109
7	6.70-9.5	8.1	31.2	31.7	30.7	31.2	3.1	0.251
8	.> 9.5	9.5	32.4	31.5	31.7	31.86	3.45	0.325
Total								1.755

PLOT 10

S/n	Sieve Size	Mean Dia (mm)	R1 (g)	R2 (g)	R3(g)	Mean (w) (g)		XiWi (mm)
1	.00-.425	0.213	65.5	66.6	65.3	65.8	20.4	0.043
2	.425-.85	0.638	44.4	43.8	44.2	44.13	9.57	0.061

3	.85-2.00	1.425	70.7	66.2	68.4	68.43	21.7	0.309
4	2.00-2.36	2.18	45.2	46.1	45.4	45.57	10.3	0.224
5	2.36-3.35	2.945	50.1	49.6	49.2	49.63	12.3	0.363
6	3.35-6.70	5.025	33.6	34	34.3	33.97	4.48	0.225
7	6.70-9.5	8.1	40.4	39.5	41.2	40.37	7.68	0.622
8	.> 9.5	9.5	50.1	54.1	54.2	52.1	13.6	1.287
								3.134

PLOT 11

S/No.	Sieve Size (mm)	Mean xi Dia(mm)	R1(g)	R2(g)	R3(g)	Mean(w) 100(g)	%	XiWi
1	.00-.425	0.213	75.3	84.1	80	79.8	27.4	0.058
2	.425-.85	0.638	45.8	45.6	45.4	45.6	10.3	0.066
3	.85-2.00	1.425	79.2	73.3	79.4	77.3	26.2	0.373
4	2.00-2.36	2.18	49.7	48.1	48.9	48.9	12	0.262
5	2.36-3.35	2.945	54	56.7	53.5	55.03	15	0.442
6	3.35-6.70	5.025	32.5	29.4	29.3	30.73	2.86	0.146
7	6.70-9.5	8.1	31	29.8	30.4	30.4	2.7	0.347
8	.> 9.5	9.5	31.6	33	32.1	32.24	3.62	0.684
								2.378

PLOT 12

S/No.	Sieve Size (mm)	Mean(Xi) Dia(mm)	R1(g)	R2(g)	R3(g)	Mean(W) 100(g)	%	XiWi(mm)
1	.00-.425	0.213	74.6	82.9	91.1	82.87	28.9	0.062
2	.425-.85	0.638	51.1	47.9	50.3	49.77	12.4	0.079
3	.85-2.00	1.425	83.5	74.4	78.9	78.93	27	0.384
4	2.00-2.36	2.18	49.7	47.1	44.4	47.07	11	0.241
5	2.36-3.35	2.945	50.3	54.7	45.9	50.3	12.7	0.373
6	3.35-6.70	5.025	29	30.2	28.6	29.26	2.13	0.107
7	6.70-9.5	8.1	31.5	31.8	31.2	31.5	3.25	0.263
8	.> 9.5	9.5	30.3	31	29.6	30.3	2.65	0.252
								1.761

Appendix IX : Soil Shear Test.

Summary of result

General information

(1) Dimensions 60mm x 60mmx60mm

(2) Area of s 0.0036m3

(3) Load Ring 0.0009Kn/div.

	Normal Stress.	Max. Dial Reading.	Shear Load	Shear Stress.	
NO 1	5	106	0.0957	26.6	
	10	113	0.102	28.3	C=25
	20	126	0.1138	31.6	0=18.3
	30	140	0.1256	34.9	
2	5	39	0.0349	9.7	
	10	46	0.041	11.4	C=8
	20	60	0.0536	14.9	0=19
	30	73	0.0659	18.3	
3	5	94	0.0849	23.6	
	10	100	0.0896	24.89	C=22.4
	20	110	0.0986	27.38	0=14
	30	119	0.1075	29.87	
4	5	89	0.0799	22.2	
	10	94	0.0846	23.5	C=21
	20	104	0.0932	25	0=14
	30	114	0.1026	28.5	
5	5	86	0.0774	21.5	
	10	91	0.0824	22.9	C=20
	20	104	0.0932	25.9	0=16.4
	30	115	0.1037	28.8	
6	5	93	0.0839	23.3	
	10	99	0.0893	24.8	C=21.9
	20	110	0.0994	27.6	0=16
	30	122	0.1098	30.5	
7	5	110	0.0986	27.4	
	10	116	0.104	28.9	C=26
	20	127	0.1141	31.7	0=16
	30	138	0.1246	34.6	
8	5	65	0.0583	16.2	
	10	71	0.0641	17.8	C=14.6
	20	84	0.0759	21.1	0=18
	30	97	0.0875	24.3	
9	5	70	0.063	17.5	
	10	76	0.0687	19.1	C=16
	20	88	0.0796	22.1	0=17
	30	101	0.0907	25.2	
10	5	105	0.095	26.4	
	10	111	0.1001	27.8	C=25
	20	123	0.1105	30.7	0=15.8
	30	142	0.1278	33.5	

11	5	83	0.0729	20.7	
	10	89	0.0918	22.3	C=19.2
	20	101	0.1305	25.3	0=17
	30	114	0.1681	28.4	
12	5	66	0.0598	16.6	
	10	73	0.0655	18.2	C=15
	20	86	0.0774	21.5	0=18
	30	98	0.0882	24.7	

Appendix X: Root Parameters

TREATMENT 1: ZERO TILLAGE

	Plot 1			Plot 5			Plot10		
	a	b	c	a	b	c	a	b	c
Root length (cm)/ No	10	10	9	13	10	10	12	9	7
1	8.5	8.4	7.1	8.1	5.7	9.2	7.3	9.1	5.5
2	12	5.3	5.5	13.1	27.1	3.5	9.6	4.2	4.3
3	7.4	15.4	8.2	4.3	12.3	4.8	3.4	7.2	12
4	12	4.3	7.5	12.6	7.9	5.5	7.7	7.5	11
5	11	12.1	11.7	11.5	13.3	11.4	11.2	8.1	5.6
6	12.5	10	7.9	4.2	4.2	6.8	5.8	5.2	4.5
7	12.3	7.6	7.7	13.2	12.1	4.4	6.8	6.1	7.2
8	6.2	6.4	10.5	11	11.5	7.1	8.1	7.1	
9	8.9	5.3	12.5	10.3	9.2	13.5	4.6	10.1	
10	13.2	6.1		11.3	16	11.7	7.1		
11				11.4			7.3		
12				17			6.9		
13				12.8					
14				6					
15									
TOTAL (cm)	104	80.9	78.6	146.8	119.3	77.9	85.8	64.6	50.1
MEAN	10.4	8.09	8.73333	10.4857	11.93	7.79	7.15	7.17778	7.15714
Stem (D)	0.3	0.4	0.1	0.3	0.6	0.5	0.3	0.4	0.4

TREATMENT 2.

		PLOT 3			PLOT 6			PLOT 11	
	R1	R2	R3	R1	R2	R3	R1	R2	R3
Root Length(cm) /No	8	11	18	14	13	14	13	10	11
1	8.9	7	3.1	14	6.8	7	6	10	36
2	9.1	3.4	12.5	12.7	16	2	16.2	15	14.5
3	5.6	9.6	10	13	14.7	18	8.5	4.7	23.7
4	10.2	12.2	12.5	10.7	14.8	12.7	16.8	6.4	2.5
5	5.1	0.9	4.2	8.3	14.1	13.4	8.9	15	21
6	6.1	8.6	4.5	14.9	14.2	12.1	9	13.6	22
7	5.7	0.7	10	6.7	8	15	11	14.6	11
8	6.9	6.9	3.1	12.8	13.2	24.2	13.1	23.7	36
9		11.1	13	9	19.4	14.5	8	2.5	36.1
10		10	5.8	1	11.4	17.5	22.1	20.5	24
11		6.1	4.2	10.5	12.8	14.7	23		17
12		6.7	8.3	12.4	12.9	19.7	14.5		
13			8.5	8	20.4	8.8	19.2		
14			10.1	15.2		4.1			
15			10.2						
16			10.9						
17			4.6						
18			10.9						
TOTAL (cm)	57.6	83.2	146.4	149.2	178.7	183.7	176.3	126	243.8
MEAN	7.2	6.93333	8.13333	10.6571	13.7462	13.1214	13.5615	12.6	22.1636
STEM(D)	0.3	0.6	0.4	0.6	0.4	0.5	0.6	0.1	0.4

Treatment 3.

Plots			Plot 4			Plot 8			Plot 12
	a	B	c	a	b	c	a	b	c
Root length (cm) / No	10	11	12	13	9	9	9	8	9
1	4	24.2	13.2	5	12.2	11.5	8	14.3	10.4
2	10.1	12.6	11.1	10.4	32	5	6.1	3.9	9.5
3	14.15	10	10	5	12	15.5	5.2	10.2	15.4
4	3.7	6.5	9.7	7	10	11.9	8.3	20.6	14.3
5	16.9	8.5	7.2	9.5	14.5	26.4	17.1	18.5	16.4
6	8.3	10.8	10.1	8.3	6.2	8.5	23.5	18.7	3.7
7	8.5	4.2	7.9	10.4	7.1	14.6	16.3	17	5.5
8	10	15.6	9.5	10.5	13	17.9	115	22.8	10.2
9	6	11	15.4	5.7	17.4	6.2	14.5		11.2
10	21.5	10	8.4	10.4					
11		6.7	4.2	6.1					
12			17.2	10.1					
13									
14									
15									
16									
17									
Total (cm)	103.15	120.1	123.9	98.4	124,4	117.5	214	126	96.6
Mean	10.315	10.9182	10.325	8.2	13.8222	13.0556	23.7778	15.75	10.7333
Stem (D)	0.4	0.3	0.5	0.5	0.5	0.4	0.3	0.5	0.3

Treatment 4.

Plots	Plot7				Plot 2			Plot 9	
	a	b	c	a	b	c	a	b	c
Root length(cm)/No	10	10	11	10	14	9	10	9	11
1	9.7	22.2	10.8	14.2	12.8	9.2	9.7	10.4	17.7
2	19.3	2.5	4.6	12.9	8	7.7	16.8	6.9	11
3	7.2	14	28.7	5.6	12.9	13	14.8	15.7	5.1
4	6.9	4.3	11.9	12	19.1	5.9	18	7.9	14.7
5	20.4	3.3	8.8	5	11.9	10.6	10.6	5.7	11.3
6	13.8	22.1	19.1	11	13.7	10.9	6.6	1	10
7	10.6	28	6.9	6.7	14	9.1	16.6	7.2	9.2
8	16.8	2.2	10.7	12.9	11.8	14.9	5.9	15.2	4.9
9	18.2	8.8	4.1	3.1	16.2	15.2	17.4	7.2	12.1
10	13,7	9.9	0.4	3.3	12.8		4		7.9
11			14.1		5.3				15.7
12					10.5				
13					5.7				
					14.7				
Total	136.6	117.3	120.1	86.7	169.4	96.5	120.4	77.2	119.6
MEAN	13.66	11.73	10.92	8.67	12.1	10.72	12.04	8.57	10.87
Stem (cm)	0.4	0.5	0.3	0.4	0.5	0.4	0.3	0.3	0.4

Appendix XI: Germination Count.

DAYS. PLOTS.	4TH	5TH	6TH	7TH	25%	50%	70%	MEAN EMERGENCE	EMERGENCE AFTER 5 DAYS (%)	TOTAL EMERGENCE
1	2	7	10	4	5	6	7	5.25	32	23/28
2	3	7	8	4	5	6	7	5.5	35.7	22/28
3	11	9	4	3	4	5	5	6.75	71.4	27/28
4	9	10	4	2	4	5	6	6.25	67.8	25/27
5	3	13	9	1	6	5	6	6.5	57	26/28
6	12	8	6	1	4	5	5	6.75	71.4	27/28
7	4	8	10	4	5	6	6	6.5	42.8	26/28
8	12	10	2	1	4	6	5	6.25	71.4	25/28
9	3	4	9	8	5	6	7	6	25	24/28
10	8	5	12	2	4	6	6	6.5	46.4	26/28
11	10	11	3	-	4	5	5	6	47.97	24/28
12	13	9	0	3	4	5	5	6	78.54	24/28