EFFECT OF SOME TILLAGE SYSTEMS AND SOWING METHODS ON WHEAT PRODUCTION IN THE UPPER TERRACES OF THE NORTHERN STATE (SUDAN)

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A thesis Submitted to the University of Khartoum in Partial Fulfillment of the Requirements for the Degree of Master of Science in Agriculture

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2002
DEDICATION

To my Father and Mother ..... 

To my Wife ........

To my Brothers and my Sister ......

To my all Friends ........

With love
Acknowledgements

I would like to express my deep sincere, thanks, gratitudes and appreciation to my Supervisor Dr. Mohamed Hassan Dahab for his guidance, criticism and supervision and for his visit to the experiment field in the Northern State.

I am deeply grateful to all staff in Dongola Agricultural Research Station for their valuable advices and great help. I am also indebted to my colleagues M.H. Nayile and A. Binnawi for their help and advices. My greatful gratitudes to the ministry of Agriculture of the Northern State for nominating me for the study.

Finally I would like to express my thanks and gratitudes to the general director of Sanabil El Shimal Company Limited Mr. Bilal Othman for his financial assistance and continuous encouragement and help.
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List of Symbols

Hp : Horse power.
DBp : Draw bar power
PTO : Power Take-Off.
A.R.C : Agricultural Research Corporation.
N V R P : Nile Valley Regional Program.
ICARDA : International Centre for Agricultural Research in the Dry Area.
F.A.O. : Food and Agriculture Organization.
F.E. : Field Efficiency.
E FC. : Effective Field Capacity.
S : Speed (forward speed).
W : Width of implement.
D : Depreciation of machine.
P : Purchase price.
R and M : Repair and Maintenance.
A C : Annual Cost of machine.
F C : Fixed Cost of machine.
F : Fuel cost.
O : Oil cost.
L : Labor cost.
T : Tractor cost.
KN : Kilonewton.
Km : Kilometer.
hour:
Km/hr : Kilometer per hour.
R P M : Revolutions per minute.
m² : Meter square.
m/sec : Meter per second.
nm : Newton meter.
Hy. p : Hydraulic power.
Q : Fluid flow rate.
L/sec : Liter per second.
E P : Electric power.
T.C : Total Cost.
V.C : Variable Cost.
ha : Hectare.
ha/hr : Hectare per hour.
SD : Sudanese Dinar.
SD/hr : Sudanese Dinar per hour.
SD/ha : Sudanese Dinar per hour.
SD/Ton : Sudanese Dinar per Ton.
L /ha : Liter per hectare.
L / hr : Liter per hour.
B. D. : Bulk Density.
S A R : Sodium Adsorption Ratio.
E Ce. : Electric conductivity.
Kw : Kilowatt.
C. F. : Conversion factor.
ml : milliter.
M .C.(%) : Moisture Content as percentage.
P H : Hydrogen ion concentration.
Kg / fed. : Kilogram per feddan.
Fig. : Figure.
Sys. : System.
C° : Centigrade.
gm / cc : gram per cubic centimeter.
ANOVA : Analysis of Variance.
(D P) : Disc Plow.
(M P) : Moldboard Plow.
(C P) : Chisel Plow.
(H D H) : Heavy Disc Harrow.
(L D H) : Light Disc Harrow.
(CU) : Cultivator.
(S D) : Seed Drill.
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ABSTRACT

A field experiment was conducted in two successive seasons (2000/2001) and (2001/2002) to investigate the effect of tillage systems and sowing methods on wheat production in the upper terraces of the Northern State. The experiments were carried out at "Jiera Agricultural Cooperative Society, El Dabba Province", 160 km south Dongola city.

The treatment consisted of five tillage systems, namely disc plowing plus light disc harrowing plus leveling, moldboard plowing plus light disc harrowing plus leveling, chisel plowing plus light disc harrowing plus leveling, heavy disc harrowing plus leveling and light disc harrowing plus leveling, in addition to zero tillage as control. Each tillage system included three sowing methods, namely manual broadcasting of seeds plus cultivating (CU), manual broadcasting of seeds plus light disc harrowing (LDH) and seed drilling machine (SD).

The experimental treatments were replicated three times in a split-plot design with the main plots designated to tillage systems and sub-plots to sowing methods.

The measured implements parameters included, effective field capacity, field efficiency, slippage (%) and fuel consumption. Some crop parameters were also measured such as plant height, plant population, fresh and dry weights of plant, grain yield, total biomass and harvest index. Land preparation total costs and sowing costs for the different treatments were also investigated.

The results revealed that the disc plow (DP) plus light disc harrowing and leveling recorded the highest fuel consumption rate for the
two seasons (31.2 L/ha and 30.52 L/ha), highest plant population in the second season (436.56 plants/m²), highest land preparation total costs (12777.8 SD/ha) and highest grain yield costs (3758.2 SD/ton). The disc plow (DP) treatment recorded the lowest field capacity for the two seasons (0.238 and 0.24) respectively.

The moldboard plow (MP) plus light disc harrowing and leveling registered the highest field efficiency in the two seasons (71.83% and 71.81%), highest land preparation costs in SD/hr (5109.57 SD/hr), while the same treatment reported the lowest plant population (381.33 plant/m²) in the second season.

The heavy disc harrow (HDH) indicated the highest slippage (%) in the two seasons (9.1% and 8.8%) highest fuel consumption rate in L/hr in the two seasons (9.0 L/hr and 9.72 L/hr), while it showed the lowest field efficiency in the second season (88.9%).

No significant differences between the effect of sowing methods on the total biomass were observed, but there were significant differences between tillage systems at 5% level. The highest total biomass obtained by both the heavy disc harrowing (HDH) and zero tillage (9.16 Ton/ha), while the lowest value registered by the light disc harrowing (LDH) (7.74 Ton/ha). No significant differences between the effect of tillage systems on plant height, fresh weight, dry weight and grain yield in (Ton/ha) in the two seasons, whereas there were significant differences at 5% level for plant population in the second season. Highly significant differences at 1% level were observed
between sowing methods effect on plant population per m^2. The manual broadcasting with the cultivator (CU) method recorded the highest plant population/m^2 (471.17 plants/m^2), highest total sowing costs in SD/ha and SD/hr giving (3652.2 SD/ha) and (2081.78 SD/hr) respectively.

No significant differences between both tillage systems and sowing methods effect on grain yield in ton/ha were observed, but the method of manual broadcasting plus light disc harrow (LDH) recorded the highest grain yield in the two seasons, while the seed drill (SD) registered the lowest values in the two seasons.

The seed drill (SD) also resulted in the lowest plant population per m^2 in thesecond season (358.17 plants/m2), lowest total sowing costs in SD/ha and SD/hr recording (2740.93 SD/ha) and (1740.49 SD/hr).

The highest harvest index (%) registered by the manual broadcasting plus (LDH) (39.79%), followed by the seed drilling machine (SD) (39.58%) then the manual broadcasting plus the cultivator (CU) (37.82%).

لقد جاء خطأ في هذه الجريمة، حيث أن الجعفة مستمعة، وعندما يتم قراءة جريمة هذه الجريمة، يتم قراءة جريمة الجعتة.

لقد جاء خطأ في هذه الجريمة، حيث أن الجعفة مستمعة، وعندها أن الجعفة مستمعة.
(0,24) أَ (0,38) لِبِلَاءٍ بِذَيَةٍ يُرِبُّ لِرَبِّ لِهُ أَذُوَتُ لِسَبِيلٍ لِسُبُلِّ يُعِيدُ لِعُيُونٍ

(0,24) أَ (0,38) لِبِلَاءٍ بِذَيَةٍ يُرِبُّ لِرَبِّ لِهُ أَذُوَتُ لِسَبِيلٍ لِسُبُلِّ يُعِيدُ لِعُيُونٍ
للمواسم

١٦٥

58.17  نباتات

(1740.49(0 2740.93) كم 1740.49)

للساعة

(2450.93(0 2200.64) (157.82)

للساعة

39.79 (0 37.82)

(133.58(0 120.58) 39.79 (0 37.82)

(39.79(0 37.82) 39.58 (0 37.82) 39.58 (0 37.82) 39.58 (0 37.82)
CHAPTER ONE

INTRODUCTION

Wheat crop

Wheat (*Triticum aestivum*) is a strategic crop in the Sudan, it is the second most important food crop after sorghum. It is grown in some of the irrigated schemes in the central clay plain, but Northern State is the most suitable environmentally. Wheat is a crop of temperate origin, but its cultivation in the Sudan expanded into latitudes lower than 15°N as a winter crop. The minimum temperature for wheat growth is about 3-4°C, the maximum values about 30-32°C and the optimum about 25°C in the Sudan. Wheat production in the Sudan started thousands of years ago on the fertile soils of the River Nile banks. Wheat cultivation spreaded southwards in the central plains of the country at latitudes 14-15°N where there is plenty of land and available water. (Ajeeb *et al.*, 1996).

In the past, demand for wheat in the Sudan was low because the majority of the Sudanese food was based mainly on sorghum, but now wheat consumption has been increased due to urbanization and rising population. The government policy in satisfying the needs draw a policy of horizontal expansion. This led to encourage agricultural cooperatives and establish governmental schemes in the upper terraces. The estimated area suitable for cultivation is about 400,000 feddans in the Northern State.

A little research on wheat production was done before 1965 by the Agricultural Research Corporation (ARC). The wheat research carried out under the Nile Valley Regional Program (NVRP) during the period 1988/89-1994/95 as a cooperative program between (ARC) and
International Centre for Agricultural Research in the Dry Area (ICARDA). The objective of the program was to develop improved technologies and transferring them to the farmers to accomplish productivity and yield stability of wheat (Ajeeb et al., 1996).

The agricultural soils in the Northern State are divided as follows:

1. Gerif lands: those lands extend along the River Nile.

2. Gurare lands: are of light texture and very rich with loams. They are considered as one of the most fertile soil in the Sudan.

3. Basin lands: such lands contain high quantities of precipitated clay and small quantities of salts.

4. Upper terraces (or marginal lands): although they are characterized by high salinity, but they are considered as the future agricultural expansion and development target in the Northern State.

**History of mechanization and implement used**

Many years ago, all crops in the Northern State were produced traditionally. Land preparation was dependant on human power or animal traction. Later, farmers used modern or machine power. The first usage of machinery in the Northern State was in 1940s when Margani El Sayed supplied an iron wheeled tractor powered with gasoline in his private farm at Farjey village near Elgolid, (Personal communication, 2001). The actual beginning of using machinery was in the earliest of 1970s at Elseleim Machinery Service Station by supplying Russian tractors and some plows.
In 1983, FIAT tractors and some implements were brought by “Dongola Inputs and Agricultural Services Company”. Then in 1989, the government supplied fifty of FORD tractors accompanied with disc plows, levelers, and threshers.

In spite of his long experience the farmer in the Northern State is considered as a traditional farmer. He usually used different rural tools or implements. Farmers just take in consideration the minimum cost of operation regardless of scientific methods. The disc plow is used widely in both low lands and high terraces due to its availability irrespective of efficiency. Harrowing was scarcely used after plowing for crumbling the surface because most of the lands are of easy plowed soils. Leveling and smoothing are both done by using back leveler blade. The modified ridger is used on zero tillage land for covering wheat seeds, broad beans and spices after broadcasting them on flat. Chisel plow is used to bury broad beams and some times for wheat seeds.

No research work in the field of land preparation for wheat crop production was done in the Northern State. It is therefore recommended to carry out experiments to achieve the following objectives:

1. Evaluation of some tillage practices and sowing methods on wheat production in upper terraces soil of the Northern State.

2. Comparing the different tillage systems by computing the cost of each system.
3. To optimize the land preparation package for wheat production in the Northern State.
CHAPTER TWO

LITERATURE REVIEW

2.1 Tractors

The tractor is the main source of farm power for operating other machineries. Jones (1966) classified tractors in two common divisions; (a) the steam tractor or an external-combustion engine, (b) the gas tractor or an internal-combustion engine. Liljedahl et al., (1979) mentioned that, early farm tractor was first powered by steam engine, then followed by gas engine or the internal combustion engine. The tractor was developed and adapted to be used for more purposes, such as the general-purpose tractor.

2.1.1 Types of tractors

The tractor types can be grouped into two main classes according to the method of securing and self-propulsion:

2.1.1.1 Track-layer tractors (crawlers)

The crawler tractors are used in such wet soils, and weak sandy soils which require high drawbar pull, (Flatters, 1978). Liljedahl et al., (1979) mentioned that crawlers are used to reduce soil pressure and to increase traction on soft soil surfaces. They have best relative performance due to large ground contact area of the carwlers resulting in a low slippage and higher coefficient of traction.
2.1.1.2 Wheeled tractors

The wheeled tractors as compared to track-layers (crawlers) have greater tractive efficiency, high comfortability, but the traction of the rubber tyres is poor in wet soils or soils that covered with thick crop (Liljedahl et al., 1979). According to the driving system, the wheeled tractors are divided into two types as follows:

a) Two – wheel drive (2 WD tractors).

b) Four – wheel drive (4 WD tractors), these were modified to provide high drawbar power (tractive power).

Jones (1966) reported that tractors can be classified according to utility as follows:

1. General purpose or utility.

2. All purpose or row-crop type.

3. Orchard tractor.

4. Industrial tractor.

5. Garden tractor.

2.1.2 Tractor powers

Jones (1966) reported that the tractor is used to supply power for pulling machines by the drawbar, operating the mechanism of either stationary or mobile machines from a belt pulley or a power take-off (P.T.O)
Hunt (1979) mentioned that the tractor delivers power in several ways. Pulled or loaded implements are powered through the traction of drive wheels, and the pull from the drawbar (linear power). Rotary power is obtained from the power take-off shaft (P.T.O) or from a belt pulley. Both linear and rotary power can be produced by a tractor’s hydraulic system. Some implements require electric power from tractors.

2.1.2.1 Drawbar power

Hunt (1979) reported that drawbar is a function of pull and speed, and can be computed by the following formula:

\[ DBP = \frac{D \times S}{3.6} \]

where: \( DBP \) = Drawbar Power in KN

\( D \) = Pull or Draft force, in KN.

\( S \) = Speed in km/hr.

2.1.2.2 Power take-off shaft power (P.T.O power)

Bowers (1975a) stated that when attaching a tractor and implement, three important factors must be considered:

a) The tractor must not be overloaded.

b) The implement must be pulled at adequate speed or the optimum performance can not be obtained.

c) The soil condition and its effects on machine performance is considered as explained in (Table 2.1). It is a helpful and useful table to calculate needed maximum P.T.O hp when the drawbar
required by an implement is known. Hunt (1979) stated the P.T.O power equation as shown below:

\[
P.T.O = 2\pi \frac{F \cdot R \cdot N}{C}.
\]

\[
= 2\pi \frac{T \cdot N}{C}.
\]

Where:

P.T.O = Power take-off shaft power in KW (HP).

\[F = \text{Tangential force KN.}\]

\[R = \text{Radious of force rotation, M.}\]

\[N = \text{Revolutions per minute or (R.P.M).}\]

\[T = \text{Torque N.M.}\]

\[C = \text{Constant} = 60.\]
Table 2.1.
2.1.2.3 Hydraulic power (Hy.P)

Hunt (1979) reported that the hydraulic power can be represented by

using the equation below:

\[ \text{Hy.P} = \frac{P \cdot Q}{C}. \]


\( P \) = Gauge pressure in KW.

\( Q \) = Fluid flow rate L/sec.

\( C \) = Constant = 1000.

2.1.3 Selection of farm power requirement

There are many factors affect the selection of power such as agricultural conditions, requires of soil and crops, management scale and economic conditions (Depeng et al., 1983). The tractor is the main source of power for all agricultural implements and therefore some important factors should be considered in selection of tractors e.g.,:

a) Availability of maximum engine efficiency.

b) Soil type and it’s resistance to the implement used. This limits the range of power requirements for pulling or drawing.

c) All operation requirements, area, power for work, adaptability, and fitting machine, capacity to field size.
2.2 Tillage

Hunt (1979) described that tillage absorbs over half of the power expended on the farms. It is of great economic importance that the machinery manager should understand the operating characteristics, the applicability, and the performance of the various tillage machines.

2.2.1 Definition of tillage

Kepner et al., (1978) defined tillage as the mechanical manipulation of soil for many purposes. Tillage is also the process of providing a suitable soil environment for seed germination, root growth, weed and moisture control (Deere and Company, 1984) and plaster (1992). Hunt (1979) and Culpin (1981) described tillage as mechanical soil stirring actions carried on for the purpose of nurturing crops. A sound definition of tillage, it is expressed as the operation which includes all practices necessary for land preparation, planting, cultivation and residue management (Mills et al., 1991).

2.2.2 Importance of tillage

Tillage is regarded as an essential feature of mechanized agriculture. It is known as an immense consumer in the cost of crop production. Kuipers (1963) mentioned that the power requirement for tillage is considerably high and may induce technical and economic problem in modern agriculture. According to Smith (1955), an economical seedbed preparation is proposed to:
I. Discourage weed growth.

II. Have a minimum amount of energy expended in its preparation.

III. Cause the least amount of damage to the soil by wheel traffic.

IV. Prepare as a seedbed only the soil adjacent to the eventual seed position.

2.2.3 Objectives and purposes of tillage

According to Smith (1955), the primary objectives and fundamental purposes of tillage are divided into three phases:

a) To prepare a suitable seedbed.

b) To destroy competitive weeds and other pests.

c) To improve the physical condition of the soil.

The basic objectives of tillage as described by Smith (1955), Brady (1974), Kepner et al., (1978), Buckingham (1979) and Mills et al., (1991) are summarized as follows:

1. To create suitable seedbed and root-bed physically, chemically and biologically fitting to the growth of crops. (for seeding and better crop establishment).

2. To add humus to the soil by covering crop residues and manures, to be incorporated in the soil to improve soil fertility.

3. To prevent and destroy weeds or other unwanted vegetation for better seedbed germination.
4. To leave the soil in such condition that air will circulate freely to provide good seed-soil contact.

5. To leave the soil in such condition as to retain moisture from rain and other sources of water (by increasing soil intake rates).

6. To destroy insects as well as their eggs, larvae and the breeding places.

7. To leave the surface in a condition to prevent erosion by winds and water.

8) To establish specific surface configurations for planting, irrigating, drainage, harvesting operations etc.

9) To incorporate and mix fertilizers, pesticides or soil amendments into the soil.

10) To accomplish segregation. This many involve moving soil from one layer to another, removal of rocks and other foreign objects or root harvesting.

2.2.4 Effect of tillage on soil physical properties

2.2.4.1 Effect on soil structure

Soil structure is referred to as the arrangement of soil particles relative to each other. The manner in which these particles are arranged, has a direct influence on the water movement, water retention, aeration and root penetration (Abu Affan, 1960). It can be changed by tillage operations and weather factors such as temperature and rainfall. It affects the soil
factors, the supply of water, air and nutrients, temperature, injurious substance and depth of soil which influence plant growth (Yorder, 1937). Sheikh, et al., (1983) mentioned that tillage practices are performed to break up and pulverize the soil and to allow air and water to move freely in order to promote plant growth. Excessive pulverization by means of heavy equipment affects the soil structure.

The concept of soil tilth involves at least two factors, coarseness or the fineness of the tilth which is concerned with the size distribution of the aggregates (Russell, 1961). Soil particles are made of spaces which may be filled with air or moisture when soils are left uncultivated for long periods. The particles become consolidated and the friable structure of the soil is lost (Culpin, 1981). The principle underlying the method for building a good stable structure is that the soil has to be worked at the minimum moisture content, that allows the soil particles to slip over one another and come into closed packing.

Krause, et al., (1984) reported that soil tillage under irrigated farm should improve the soil conditions and accomplished a high infiltration capacity, good internal drainage and good capacity for removing surplus water. Colvin et al., (1984) mentioned that soil conditions are optimum if the structural units of the soil in the root zone are small enough to promote infiltration and aeration.
The breaking of larger clods into smaller ones is easy for light soils, while it is a much more difficult process in case of medium to heavy soils, requiring proper use of cultivation implements (Russell, 1961). Boone and Kuipers (1970), listed three different aspects in the effect of main tillage operations e.g loosening, crumbling and mixing. Loosening effect of main tillage operation were considerable, but variability of pore space in one field is affected by crumbling and mixing. Dexeter (1979) stated that soils tend to be most friable. Large clods crumbled into smaller aggregates and structural damage may be accelerated when tillage is carried out at moisture content near the lower plastic limit.

2.2.4.2 Effect on soil moisture content (%)

All different types of tillage are concerned with adjustment of the soil moisture content to the need of the crop. Heavy soils are usually operated deeply and left the surface rough and open, were the rain may easily penetrate and quickly pass down into the drains. It may be also desirable at seeding time to obtain at the surface the smaller particles of the soil structure which will keep any moisture deposit in the upper layers. Sometimes when tillage is applied early on a wetter soil, it may be necessary to produce a rough broken surface by the use of a cultivator so as to induce partial drying of the surface layer (Culpin, 1981).

Hakimi and Kachrue (1976) reported that tillage was also found to influence nutrient relationships and fertilizer placement through it’s effect
on water content in the surface soil layers and the effective volume of soil it presents to root system.

Lal (1976) found that the soil moisture content and crop yield increased with no tillage and minimum tillage practices. Johnson et al., (1984) reported that minimum tillage system increase soil moisture content hydrological properties and increasing water by improving water infiltration. That is due to the advantageous effect of higher soil moisture content, which is refered to:

a) Mulching increases water infiltration, reduces evaporation and run-off.

b) Increases of the earth worms, microbial and termite activity, which improve soil structure.

c) Heavy trashes which prevent rain from breaking down soil aggregates.

Singh et al., (1978) found that deep plowing with moldboard plow and tandem disc caused better storage of soil moisture in the upper 30 cm soil layer when compared with shallow plowing. No much variation in the soil moisture content at the depth of (30-50cm), when different tillage implements were used, whereas chiseling was found to increase water transmission. The maximum total available soil moisture was found at the depth (10-50cm) when the chisel plow is used. The tillage method affects soil moisture by altering root distribution and if the other factors being constant, plant available water in soil managed by conservation tillage is
likely to be greater than in plow-till soil (Ojeniyi, 1986 and Heilman, 1988).

Tayler and Overton (1982) stated that the availability of soil moisture can be enhanced under no-tillage and this agreed with the finding of Lal (1976) where it was observed that no-tillage plots of an experiment had higher moisture content especially at the (0-10cm) depth, than the plowed plots, particularly during drought stresses. No-tillage treatments showed higher volumetric water content to a depth of 60 cm during most of the growing season. At depth over 60 cm, the tillage system had little influence on soil moisture during the growing season. The reduction in evaporation and the ability of water storage under no-tillage insure a greater water reservation. This can help the crop to overcome short drought periods and moisture stresses (Belvins et al., 1971).

2.2.4.3 Effect on soil infiltration rate

Richard (1952) defined the infiltration rate as the maximum rate at which soil in a given condition and at a given time can absorb water. Quantitatively, the infiltration rate is defined as the volume of water passing into the soil per unit area and time. Initially, infiltration rate decreases rapidly and tends to approach a constant value during irrigation (Michael, 1978). Infiltration rate is affected by porosity of soil which is changed by cultivation or compaction cultivation influences infiltration rate by increasing the porosity of surface soil and breaking the surface seals.
George et al., (1975) found that infiltration rate associated with chiseling treatment was approximately half of the rotary tillage treatments. (FAO, 1984). Ahmed and Maurya (1989) reported that after three to four years of crop cultivation under normal conventional tillage, the positive effects of deep tillage finished and that was due to it’s high impact on infiltration and increasing of water and nutrient losses from the root zone resulting in the dilution of the soil fertility.

Many investigations have been carried out by a large number of workers such as Horton (1940), Musgrave (1955) in identifying factors that influence infiltration rate. These factors can be summarizing in the following:

1. Soil type and soil profile.
2. Biologic and macro structures within the soil.
3. Vegetal cover.

The main factors affecting the rate of intake of water by soil are:

I. **Surface conditions and the amount of protection against the impact of rains.**

II. Internal characteristics of soil mass such as pore, size, depth or thickness of permeable parts degree of swelling of clay and colloids, organic matter and aggregation.

III. Soil moisture content and degree of saturation.

**2.2.4.4 Effect on soil bulk density**
Bulk density is the ratio of soil mass to its volume (including pore size). It is expressed in terms of gm/cc. Bulk density is a highly variable quantity since it depends upon the degree of aggregation and porosity of soil. Most of tillage practices are performed to minimize soil density, increase porosity and hence increase water holding capacity within the tilled zone.

Bushman et al., (1973) mentioned that bulk density is affected directly or indirectly by plowing. Direct impact is that the soil is disturbed and its volume increased and as a result, the bulk density decreases, while the indirect impact happens when heavy machinery and equipment compacted the soil. This decreases soil volume and accordingly the soil bulk density is increased. Sheikh et al., (1978) mentioned that different tillage operations had different effect on soil physical properties as bulk density, moisture content and penetration resistance.

Lal (1992) stated that properly implemented no-tillage system in some soil, increases the homogeneity of soil structure and maintains relatively lower bulk density. Johnson et al., (1989) noticed that both disc and rotary plows decreased the value of bulk density when compared to unplowed soils. On the other hand, Tahan et al., (1992) stated that lower values of bulk density were obtained when using the disc plow and moldboard plow compared with high values obtained when using the chisel plow. A field experiment was
carried out over six years to obtain the effect of different plowing practices on bulk density. It was found that before secondary cultivation, remarkable differences in soil properties resulted from the primary tillage treatments and smaller but significant differences continued throughout the growing season. Shallow plowing also gave a slight lower bulk densities in the top (15cm) soil than the deep plowing, while the additional loosening effect of deep tillage was clear between (21-33cm) depth. Chisel plowing resulted an intermediate value of bulk density between that of moldboard and zero-tillage in the top (10cm) soil depth (Soane and Pidgeon, 1975).

2.2.5 Effect of tillage on crop yield

Ishag et al., (1987) mentioned that good tillage is a determinant factor for crop yield, as it helps in controlling weeds, uptake of moisture and plant nutrients. Sorour et al., (1950) identified the influence of tillage methods on growth and yield of corn and found no significant differences in number, length and yield of ears due to tillage treatment. Tillage increased crop yields primarily by facilitating early planting, germination, growth, weed content and moisture conservation (Richey et al., 1973).

A field experiment was done by Barker (1963) in a large term comparison of plowing, rotary cultivation, cultivating and discing on an easy working soil at Cambridge. It was found that:

a) The cereals yield after root crops was independent of basic cultivations.
b) For wheat after fallow, yield dependent on controlling regrowth of rye grass and plowing was most effective.

c) For potatoes, sugar beet and wheat after, fallow plowing was best, discing worst and rotary cultivation and cultivating were intermediate.

Reddy and Dakshinamurti (1971) studied the effect of different tillage treatments, Viz. deep plowing, moldboard plowing, discing, disc harrow and local “desi” plowing on root growth factors, soil structure and yield of maize followed by wheat. They reported that all factors studied in both crops were significantly higher with deep plowing, followed by moldboard plowing. They also mentioned that the penetration of roots was better due to improve soil structure in the phizosphere.

Mohamed (1980) determined the effect of both chisel plow, disk plow followed by harrowing and harrowing on the yield of groundnut.

Chisel plow gave higher yield than the other treatments.

Abdalla (1984) studied the influence of subsoiling, chiseling, disc plowing and disc harrow on the production of alfalfa forage crop grown under a saline-sodic clay soil. He reported that the analysis of variance for the crop yield and crop height showed no significant difference between various tillage treatments.

Five different tillage operations in a vertisol soil of Rahad Agricultural Scheme were carried out by Ahmed and Haffar (1993) to determine the influence of tillage on cotton yield. The study included heavy
disc harrow, chisel plow, subsoiler, disc plow and light disc harrow. The plots in which they used deep plowing did not provide any significant yield advantages over shallow ones.

2.2.6 Effect of sowing methods on wheat production

Broadcasters and seed drills (SD) are the two main seeding machines used for crop planting in the Sudan. The most popular seeder is the wide level disc (WLD).

Studies of different mechanized agricultural operations showed that the increase of production depends upon proper land preparation, using the proper implement in the proper time. This leads to good seedbed, good seedling, equal and regular plant growth and leads finally to a congenial harvesting. Three seeding machines were evaluated at New Halfa: WLD without hoses WLD with hoses and a seed drill (ICARDA, 1987). The seed drill (SD) had a positive effect on crop establishment but none of the seeding machines had a significant effect on grain yield.

On-farm studied conducted at Rahad to compare the vicon spreader plus 40cm ridger; vicon speader plus disc harrow and (WLD). The results showed that WLD increased yield over the vicon by 10-12% (Babiker and El Hassan, 1990b). The method of sowing (40 and 60cm ridges, 120cm beds) did not affect grain yield significantly. This is in agreement with the results reported by Ghorashi (1990, 1992). Other studies in Gezira and Managil, sowing on 40cm and 60 cm rides improved water management
and reduced flooding hazards, but did not increase yields significantly when compare to sowing on flat. (Salih and Musa, 1989) and (Salih et al., 1990, 1994). The same results were obtained at the white Nile Scheme where 40cm and 80cm ridges and chisel plowing were used after seed broadcasting. No significant effect was observed on grain yield but ridges improved water management (Satti, 1990).

Planting on wet soil is a practical method of controlling weeds and avoiding flooding hazards associated with the first irrigation, especially on inadequately leveled fields. Salih (1989) reported that maximum germination was obtained at 39% soil moisture, while no germination took place when the soil moisture content was below 22%.

Sowing on wet soil increased grain yield significantly (P<0.05) compared to sowing on dry soil as reported by Babiker et al., (1991) and Ghorashi (1992).

Studies of four different seeding machines: seed drill (SD), wide level disc (WLD) with tubes, WLD without tubes and broadcasting (BC) plus ridger at New Hafa and Rahad during two seasons showed that, for the two seasons there were no significant differences in yield except the seed drill (SD) which had a positive effect on crop establishment at New Hafa (ICARDA, 1987) and (Dawelbeit et al., 1993).

A study of the effect of seeding machines included (SD) and (WLD) and two seed rates (95 and 143 kg/ha) on wheat yield was conducted at
Gezira and Rahad (Abdel Wahab et al., 1994a). The result at Gezira showed no significant differences on yield between the treatments. At Rahad, the results showed that lower grain yield were obtained with lower seed rates in both locations. The seed drill (SD) was superior to the (WLD) and more effective to shift from using low seed rates compared to the WLD. When applying 143 kg/ha, the seed drill (SD) out yielded the wide level disc (WLD) by 11.4% but when the seed rate was lowered to 95kg/ha, the increase was 22.2% and was significant at (P<0.05).

2.2.7 Tillage and sowing methods interaction

A study comparing and evaluating the effect of different tillage systems on wheat was conducted in Gezira for four seasons (Salih and Musa 1987, 1988, 1989; Salih, 1990). The study included: 3-bottom disc plow, chisel plow, disc harrow, cultivator and ridger, in addition to seeding on 40cm ridges and on flat by buring with disc harrow after broadcasting in the two seasons. The result showed that harrowing twice significantly increased grain yield in 1987/88, while ridging slightly increased grain yield over flat in the two tested seasons. It was found to improve crop establishment and increase sorghum yields in Gedarif area (Sim Sim Dryland Farming Project, 1989), the procedure of pressing the soil with a harrow packer (screw shaped roller with additional weight on its frame) after placing and covering the seed is called harrow packing (HP). The
result of this operation led to better water absorption by the seeds and hence better seed germination and seedling emergence.

On-farm evaluation in the Gezira Scheme showed that harrow packing (HP) made the first irrigation easier and faster. In the first season there was a 7% increase in yield due to harrow packing (HP), while no differences were observed in the second season (Dawelbeit, 1992, 1993). Investigations at New Halfa on three levels of pressing with the harrow packer (0, 1250 and 1550 kg/m² as additional weights per unit area) and wide level disc (WLD). The results showed no significant differences in yield (Abdel Gadir, 1992). Similarly, at Rahad, harrow packing at the three levels mentioned above and with three seeding machines: seed drills (SD), wide level disc (WLD) and broadcasters (BC) resulted in no significant differences in yield. (Mohamed and Dawelbeit, 1992). A study done by Babiker et al., (1991) for testing three seeders: (a) with tine furrow openers (6cm depth of seeding), (b) disc furrow opener (4cm depth of seeding) and (c) broadcasting using two land preparation systems: (i) chisel plowing plus harrowing and leveling and (ii) disc harrowing. Results showed that seeding with the tine furrow opener drill gave the highest yield which significantly (P<0.05) out-yielded the other two machines.

2.2.8 Tillage And Machinery Performance

Machinery performance measures are the rate and quality at which the operations are accomplished. It is affected by many factors including
the soil implement and power sources. Tillage equipment moving in a soil at a uniform velocity is under three main forces Kepner et al., (1978).

i- Gravity force action upon the implement (weight of machine).

ii. The soil force action upon the implement.

iii -Pull applied by the power unit to maintain motion.
2.2.8.1 Field efficiency (Time Efficiency)

Field efficiency is generally expressed as the ratio of output/input.

Time efficiency is the ratio of the effective operating time to the total time the machine is used for the operation. It is the effective operating time expressed in hour per feddan. The total time taken is equal to the effective operating time plus the lost time in the field. The lost time included:

- Turning time at the end of the field. (One)
- Time to load and unload the machine if not done on-the-go. (Two)
- Machine adjustment time, if not done on-the-go. (Three)
- Maintenance time, included refilling the fuel tank lubrication, tightening bolts-etc if not done on-the-go. (Four)
- Repair time (the time spent in replacing or renewing parts. (Five)

It is the ratio of the theoretical field time to the total time taken or spent in the field. Where the theoretical field time is the operating time by the machine in the field at an optimum forward speed and performing over its full width of action.

2.2.8.2 Effective field capacity

According to Hunt (1979), Culpin (1981) and Razzag (1991) the effective field capacity is the actual average working rate of an implement or machine. It is the product of speed, width and field efficiency.

An equation for effective field capacity can be determined as follows:
\[ EFC = \frac{SWE}{C} \]

Where:

- \( EFC \) = Effective field capacity in hectare per hour.
- \( S \) = speed Km/hr.
- \( W \) = rated width of implement, m.
- \( E \) = field efficiency as a decimal.
- \( C \) = constant = 10.

### 2.2.8.3 Theoretical field capacity

Kepner (1978) defined that theoretical field capacity is the area cover per hour if the machine were effectively in operation all the time 100% at an optimum foreyard speed and optimum rated width of action with 100% efficiency. Razzag (1991) on the other hand expressed the theoretical field capacity calculated on the basis of width of each machine and average working speed.

### 2.2.8.4 Fuel consumption

Liljedahl et al (1979) calculated the average fuel consumption in liters/hour for a tractor with maximum P.T.O horse power is expressed by the equation below.

\[ Q = \frac{(0.54 P)}{(KW-H/L)} \]

Where:

- \( Q \) = average fuel consumption in liters/hour
P = maximum P.T.O power of the tractor in Kw

Some diesel tractors were tested at Nebraska in 1976, the average Hp-hr per gallon was 12.63 Hp-hr/gal and the Kw-hr per liter was 2.43 Kw-hr /L. Accordingly the above equation becomes:

\[ Q = \frac{0.54P}{2.43} = 0.22P \text{ L/hr.} \]

Kepner et al., (1978) stated that there are many factors affecting fuel consumption of machine, such as load, soil conditions and operating speed. Gordon (1991) reported that the disc plow consumes more fuel than the moldboard plow, while Abdalla (1995) reported that chiseling consumed more fuel in l/ha than ridging. On the other hand Badi (1997) found that the disc plow was consumed lesser fuel followed by chisel plow and finally moldboard plow. Dawelbeit (1997) reported that, high fuel consumption when using the disc plow due to the low working (low output).

### 2.2.8.5 Draft (pull) of implement

Kepner et al (1978) defined draft as the horizontal component of pull parallel to the line of motion, and expressed in Kilonewton. The draft is dependent on the plow size, plowing depth, plowing speed, disc and tilth angles, and soil type Kepner et al (1978) (Hunt, 1979), while Baloch et al (1991) reported that the pull increase as the depth and width of cut increase.
When the disc angle is about 42°-43°, the total draft increases disc angle, the total draft becomes slightly reduced, while at 45° (Bukhari et al, 1992). Kepner et al., (1978), mentioned that the relation between the speed and draft is represented by the equation below

\[ D_s = D + KS \]

Where:

\( D_s \) = Draft as speed S.

\( D \) = static component of draft, independent of speed.

\( S \) = forward speed

\( K \) = constant whose value is related to implement type and design, and to the soil condition.

### 2.2.9 Tillage Costs

Machinery cost into two categories fixed costs and variable costs.

#### 2.2.9.1 Fixed costs of operating machines

Fixed costs are independent of the use of the machine. This portion remains relatively constant, regardless of the annual use. Fixed costs include depreciation, insurance, interest on investment, taxes and shelter or housing for machines.

##### 2.2.9.1.1 Depreciation

Depreciation is expressed as the loss in the value of the machine with the passage of time, whether the machine is used or not. That is due to
wear, expensive operation costs, excessive repair costs, low capacity or obsolescence, availability of anew or more efficient machines, changing in the enterprise size. The amount of depreciation is the difference between the value of machine at the start of the year and it is value at the end of each year. +Five method may be used to determine the annual value of depreciation.

Estimated value method. It is a most realistic determination of (One) depreciation.

Straight-line method. It is the most practical and the most (Two) common. The straight line method is also simple and gives a constant annual charge for depreciation which is expressed by the following equation.

\[ D = \frac{P - S}{L} \]

Where:

- \( D \) = annual depreciation
- \( P \) = purchase price
- \( S \) = salvage or selling price
- (year) \( L \) = time between selling and purchasing

For general application in which the real value of (S) salvage price is not available, 10%of the purchase price may be appropriately used

(c) Declining balance method (Constant percentage).
A constant rate is applied each year to the remaining value (include selling price) of the machine at the beginning of the year. The depreciation value is different for each year among the machine life. The equation below expressed the relationship.

\[ D = V_n - V_{n+1} \]

\[ V_n = P \left( 1-x \right)^n, \quad V_{n+1} = P \left( 1-x \right)^{n+1} \]

Where:

\( D \) = Amount of depreciation for year \((n+1)\).

\( N \) = Number of representing age of the machine in years, at the beginning of year in equation.

\( V \) = Remaining value at any time.

\( X \) = Ratio of depreciation rate used to that of the straight-line method.

(X may have any value between 1 and 2).

(If \( X = 2 \), that method is called a double – declining balance method. For used machine the maximum rate is, \( X = 1.5 \).

\( L \) = time between selling and purchasing, \((year)\).

The digits of the estimated number of years of life are added together. This sum is divided in to the number of years of life remaining from the machine including the year in equation. This value of depreciation can be expressed by the following formula.
D = \frac{L - n (p - s)}{YD}.

Where:

D = \text{annual depreciation}

YD = \text{sum-of-the-year digits (1+2+3----)}

L = \text{number of year between selling and purchasing.}

n = \text{age of the machine at the beginning of the year in equation}

p = \text{purchase price}

s = \text{salvage or selling price}

(e) Sinking-fund method:

Hunt (1979) recorded that, this method used by engineering economists. It considers the problem of depreciation as one of establishing a fund that will draw compound interest uniform annual payments to this fund are of such a size that by the end of the life of the machine, the fund and their interest have accumulated to an amount that will purchase equivalent machine. By the equations below, values of the sinking – fund annual payment (SFP) and the value of the year n (Vn), are:
\[ SFP = P - S \quad (i) \quad \frac{(1+i)^{L} - 1}{(1+i)^{L} - 1} \]

\[ V_n = P - S (1+i)^{L} - (1+i)^{n} \quad \frac{(1+i)^{L} - 1}{(1+i)^{L} - 1} \]

Where:

\( SFP = \) sinking fund annual payment.

\( V_n = \) value at the end of year (n)

\( P, S, L, n = \) as explained before

\( i = \) interest rate.

### 2.2.9.1.2 Interest on investment

The rate of interest is stated by Hunt (1979) 8% but other rates may be more appropriate. When the straight-line method of depreciation is used, it is accomplished by making an annual interest charge on the on the average investment in the machine over it fuel life. The amount invested in a machine is greater during its early life than during later years since an amount is written off each year as depreciation. Liljedahl et al (1979) reported that where operating costs are concerned, it is desirable to calculate interest charge by a method that result in constant or equal yearly charges throughout the machine life.

\[ I = (P + S \cdot r) \quad r \]

Where:

\( I = \) Annual interest charge
200

P = Purchase price.

S = Salvage value.

R = rate of interest, as percentage.

2.2.9.1.3 Taxes, insurance and sheltering (housing) (T.I.S)

The annual cost of taxes would be about 1.5% of the purchase price when spread over a ten year life. The annual charge for insurance would be between 0.25-0.5% of the original price. The shelter is between 0.2-1.2% of the purchase price of the machine Bowers (1975) and Hunt (1979). More over the charge for housing cost depend on the size of the machine and usually ranges from 0.5 – 1% of the purchase price Kepner et al (1978).

2.2.9.2 Variable Costs

The variable costs increase with the amount of operation and hours of use of the machine. Variable costs include repair and maintenance, labor, fuel, oil and lubricants costs, Hunt (1979).

2.2.9.2.1 Repair and maintenance costs

Repair and maintenance cost have received greater consideration than other items of the variable cost. This is because of its difficulty to estimate and since it is one of the largest items in the total cost. Hunt (1979) recorded that repair and maintenance costs are varied from one part of the country to another, due to differences in soils, weather
and crop condition. As well as differences in the operator skills and the value of machine.

Dawelbeit and Ahmed (1987) mentioned that in most of agricultural schemes in the Sudan especially in Rahad and Gezira schemes, machinery maintenance, especially preventive maintenance was given so little attention. And therefore about 40% of the agricultural machinery were out of work. The repair costs increase with machine age, this indicate the optimal time for replacing the machinery. Witney and Saadoun (1989).

The logarithmic equation which best describes the typical trend in the total accumulated repair and maintenance costs, TAR, was first proposed some 30 years ago and later modified by Rotz (1987) to include the average operating speed compensation for accumulated machine use

\[
\frac{TAR}{PP} = RA \left( \frac{XV_1}{V_0} \right)^{RB}
\]

Where: \( pp = \) per purchase price.

**TAR** = Total accumulated repair and maintenance.

\( RA, RB = \) repair constant and exponent.

\( X = \) accumulated used, \( h \times 10^3 \)

\( V_0, V_1 = \) typical and actual average operation speed Km/hr.

**Speed compensation ensure that the fewer hour of accumulated use for a high speed operation do not resulted in lower repair costs than for a lower speed operation with the same machine.**
According to Culpin (1981), the estimations of annual costs of spares and repairs as percentage of purchase price at various levels of use of farm machinery are as in Table (2.2).

### 2.2.9.2.2 Labor cost

Kepner *et al* (1978) stated that labor charges should be based upon the prevailing wage rates. The labor cost per unit area is inversely proportional to the field capacity of the machine. That means, the use of a large implement in wide areas decreases the annual labor costs per unit area, but increase the machine total fixed costs per unit area.

### 2.2.9.2.3 Fuel, oil and Lubricants costs

Fuel and lubricants costs are variable according to the use of the machine. Fuel costs will depend on the type of work done, and the factor power and load. They can be satisfactorily estimated when accurate records are lacking. About 20-30 % of the total machine annual costs for fuel and lubricants Bowers (1975a).

**ASAE (1980) defined oil consumption as a volume per hour of engine crank case oil replaced as recommended by the company. For tractors the following formula is applied.**

Table 2.2.

\[
\text{Oil consumption ( L/hr )} = 0.00059 \times P + 0.02169
\]

Where:

\[P = \text{rated engine power in Kw. hr}\]
Lonnemark (1967) mentioned that according to the surveys done in
U.S.A which indicated that the average consumption of oil in tractors is 2.5
– 3 % of fuel consumption, and that the cost of oil and filter can be taken as
15% of the cost of fuel used. The allowance is usually 15% of fuel cost for
lubricant and oil in Nigeria according to Kaul (1985).

2.2.9.3 Total costs of Performing field Operation

The annual total costs for any operation are given either per unit
area, or unit production basis. Kepner (1978) The determination of the
costs per unit of work involves the factors below

Annual use of implement, in hours or hectares (One)

Effective field capacity of implement, in hectares per hour. (Two)

Total annual fixed cost. (Three)

Total operation cost per hour. (Four)

Cost per hour or per hectare for the tractor power required by (Five)

implements that are not self – propelled.

Labor cost per hour. (Six)

Hunt (1979) reported that the possibility of combining the costs of
depreciation, interest on investment, taxes, shelter, and insurance into a
single percentage of the purchase price called (the annual fixed cost
percentage) and estimated between (15% - 17%) of the purchase price for
To obtain the annual total cost for a field machine, one must add to
the above mentioned definition the yearly cost of repair and maintenance,
fuel, oil and labor as a variable cost

The total cost per year for field machine can be as follows:

\[ AC = (FC\%) P + \frac{CA}{SWE} (R&M) P + F + O + L + T \]

Where:

\( AC \) = annual cost of operating machine.

\( FC\% \) = annual fixed cost percentage.

\( P \) = purchase price of machine.

\( C \) = constant, 10.

\( A \) = annual area use in ha.

\( S \) = forward speed, Km / hr.

\( W \) = effective width of action of machine, m.

\( E \) = field efficiency, decimal.

\( R&M \) = repair and maintenance costs, decimal of purchase price per

\( F \) = fuel cost per hour.

\( O \) = oil cost per hour.

\( L \) = labor rate per hour.

\( T \) = cost of tractor use by the machine per hour

\( (T = \text{zero, if self – propelled }. \)
The total annual cost of operating a tractor per year can be as follows:

\[ Ac = (FC\%) P + \text{Annual hours of use ( R&M )} P + F+O+L \]

Letters in this equation as that mentioned before.
CHAPTER THREE

MATERIALS AND METHODS

3.1 Materials

3.1.1 Experiment site

Two experiments were carried out during seasons 2000/2001 and 2001/2002 at the farm of “Jiera agricultural cooperative society” El Dabba Province. The location of the site was about 160 km south Dongola town, in an area of 3240 m². The soil is sandy clay soil. The details of the soil properties is given in (Appendix A, Table A.1). Climate is deserty, arid cold in winter and sun shining with high temperature in summer. The average annual rainfall is less than 100mm. The air temperatures range from a minimum of 5°C in January to a maximum of 47°C in June. Humidity is less than 20%. (Dongola weather forecast station).

3.1.2 Tractors and equipments

3.1.2.1 The tractor

One tractor “FORD-6610” was used for determining machinery parameters measurements. The specifications of the tractor used are given in (Appendix A, Table A.2).
3.1.2.2 Implements used

Three primary tillage implements; a standard disc plow, (DP) moldboard plow (MP) and chisel plow (CP); and two secondary tillage implements namely; a trailed heavy off-set disc harrow (HDH) and a mounted light off-set disc harrow (LDH) were used to carry out the experimental treatments. A rear blade leveler was used for leveling operations. In addition to these implements seed drill machine for sowing practices, a cultivator and light dist harrow were used. The specifications of these implements were used are shown in (Appendix A, Table A.3).

3.1.2.3 Other equipments used

1. Ranging poles for surveying the experimental area.

2. Measuring-tape of 30 meters length for measuring field distances and dimensions to calculate the slippage and speed.

3. Wood pegs for marking distances during the experiment.

4. Hand watch with stop-watch facility for recording the time required.

5. Piece of chalk: for making a mark point on the rear wheel of the tested tractor for measuring slippage ratio.

6. Graduated container (one of four liters capacity), it was used to refill the tractor fuel tank to determine fuel consumption in each operation carried out.

7. Fuel container of 4 gallons capacity to keep the diesel fuel in the field for refilling the fuel tank after each operation.
8. Measuring-tape of 2 meters length to measure the width of cut and the depth of work for each implement.

9. Double ring infiltrometer; for determining the infiltration rate for each treatment Fig. (3.1).

10. Graduated scale (ruler) 30cm length, for measuring the level of the water in the inner cylinder of the infiltrometer.

11. An auger of 140cm length and of five scales of depth, 20, 40, 60, 80 and 100cm for soil sampling.

12. A square shaped steel with dimensions of (1mx1m) to count the population per one meter square when it was dropped randomly into the plot.

13. Sensitive balance to represent the fresh and the dry weight of plants.

14. Weighing balance was used to calculate the total grain yield in a limited harvested area (15m²) and also the total biomass of wheat crop.

15. Shot pipes of 15cm inside diameter for measuring water flow.

3.1.3 Crop inputs

Urea fertilizer at a rate of 80 kg/fed., super-phosphate at 40 kg/fed. Wadi Elneil seeds variety for sowing at a rate of 50 kg/fed (120 Kg /ha).
Fig. 3.1
3.2 Methods

3.2.1 Experimental design

The experiment was designed to compose six main blocks (tillage systems) and three sub-blocks (sowing methods) for each tillage system. The area was arranged in split plot design with three replicates, giving a total of fifty-four plots, each plot was of 5mx12m = 60m².

The total area = 121 m x35 m = 4235 m²

There were spaces between the plots, each of one meter width and two meters spacing between replicates. The irrigation channels are of one meter width.

Actual cultivated area = 0.77 feddan.(54 x60 m² =3240 m² )

The plots randomly distributed in each replicate, they were done from the low land to the upper land (vertically to the River Nile direction). The experimental field layout is shown in (Fig. 3.2).

a) The tillage systems included:

1. Disc plowing plus disc harrowing plus leveling.
2. Moldboard plowing plus disc harrowing plus leveling.
3. Chisel plowing plus disc harrowing plus leveling.
4. Trailed heavy off-set disc harrowing plus only leveling.
5. Mounted, light off-set disc harrowing plus only leveling.
6. Zero tillage area for control and comparison.
b) Sowing methods treatments included:

fig. 3.2.

A. Manual broadcasting plus cultivator (CU).

B. Manual broadcasting plus light disc harrow.(LDH).

C. Seed drilling machine.(SD).

3.2.2 Experiment land preparation and sowing

The experimental area was divided according to the design and after that each tillage treatment was assigned to its location as follows:

Treatment 1: Plowing by a three disc blades standard disc plow, (Plate 1) to 0.22m working depth followed by disc harrowing and leveling.

Treatment 2: Plowing by a three bottom moldboard plow, (Plate 2) to 0.25m working depth, followed by disc harrowing and leveling.

Treatment 3: Plowing by a chisel plough of five tools in two rows, (Plate 3) to 0.18m working depth followed by disc harrowing and leveling.

Treatment 4: Using a trailed heavy off-set disc harrow of 14 discs, (Plate 4) for plowing to the depth of 0.20m, followed by leveling.

Treatment 5: Using a mounted light off-set disc harrow of 20 discs (Plate 5) for tillaging to the depth of 0.15m, followed by leveling. Using a reer blade leveler (Plate 8).

Treatment 6: Zero tillage area as control without any tillage.

Three different sowing methods were used as follows:
Plate 1&2.
Plate 3&4.

a) Manual broadcasting of the seed followed by cultivator (CU), (ridger without wings), (Plate 6) row spacing of 0.4m.

b) Manual broadcasting of the seed followed by light disc harrowing (LDH).

c) Sowing by using seed drill machine (SD) of 12.6cm row spacing and 1.64m width of work. (Plate 7)

The crop was sown in 20th November 2000 in the first season and in 27th November 2001 in the second season.

3.2.3 Fertilizing application

Urea was distributed manually and directly before watering. It was applied at a rate of 80kg/fed. in two doses; the first dose of 40kg/fed.before the second irrigation, while the second dose was applied before the fourth irrigation. Super-phosphate fertilizer was also supplied to the experimental area at a rate of 40 kg/fed in one dose before plowing.

3.2.4 Irrigation water measurement

Measurement of water flow rate is essential for calculating the exact quantity of irrigation water. Many ways are used for measuring water flow rate in the field, but direct methods included short pipes, weirs (90V notch weir) and parshall flume.
The irrigation water for wheat crop according to Izz Eldien et al. (2000), Appendix A, Table (A.4) was measured for each plot with a Plate 5&6. Plate 7&8.
of 15cm inside diameter and 120cm length), which was (concrete pipe
installed at the off-take of Abu-sitta ditch which was needed to irrigate the
plot.

The discharge of the pipe in liter per second (L/sec) was obtained by .1
collecting it in a graduated container of 17 liter capacity.

A constant head was used in Abu-Eshrin to keep the discharge of the .2
pipe to give the same rate within the flow time.

A pit was dug in the bed of Abu-setta ditch, just near the off-take .3
point, to put the measuring container.

Water discharged in the container was collected and recorded. .4
The same procedure was repeated three times in each irrigation and .5
the mean was taken to represent the discharge for the particular
constant head. Appendix A (Tables A.5 and A.6) show the crop
water requirement for one plot in liter per irrigation, and the time
consumed to add the water required for that plot in the two seasons.

3.2.5 Tractor Parameters Measurements

3.2.5.1 Forward Speed

A distance of 39m was measured along the length of the replicate. The
tractor was linked with each tillage implement. The tractor
started then plowing at the first high gear. Time in seconds was
recorded for each 39 m distance (length of stroke).
The plowing was repeated three times for the 39m distance. The total time was recorded, then the mean of time taken to travel the 39m distance was obtained. Traveling speed (m/sec) was calculated as follows:

\[
\text{Speed (m/sec)} = \frac{\text{distance (m)}}{\text{time taken (sec)}} = \frac{39 \text{ m}}{\text{time required to cover it (sec)}}
\]

### 3.2.5.2 Measurement of wheel slippage

The slippage of the rear wheel of the tractor was expressed in percentage. It was calculated for each implement as follows:

- the rear wheel was marked at a portion tangent to the ground surface by a piece of chalk.
- The distance traveled by five revolutions of the rear wheel when the tractor without load was measured (D1).
- The distance covered by the same number of revolutions was measured, when the tractor was loaded with the implement, (D2).
- The procedure mentioned in item (2 and 3) was repeated three times with each implement, then the mean distance for D1 and D2 was computed.

\[
\text{Slippage \%} = \frac{D_1 - D_2}{D_1} \times 100
\]

Where:

\[D_1 = \text{distance traveled without load in (m)}\]
D_2 = distance traveled with load in (m).

3.2.6 implement Parameters Measurements:

3.2.6.1 measurement of field efficiency

Field efficiency measured in percentage is the effective time (productive time) over the total time (effective time + lost time taken in the field).

\[
\text{Field efficiency \%} = \frac{\text{Effective time (Te)}}{\text{Total time taken (T0)}} \times 100
\]

or

\[
\text{Field efficiency \%} = \frac{T_e}{(T_e + T_{in} + T_t)} \times 100
\]

Where:

\( T_e = \text{Effective time or (productive time), is that actual time consumed in the field by the tractor and the linked implement while plowing a unit of area; computed with stop-watch.} \)

\( T_0 = \text{Total time taken} = \text{effective time (Te)} + \text{lost time in the field.} \)

\( \text{Lost time} = \text{time of interruption (T_{in})} + \text{time of turning (T_t)} \)

\[
\therefore T_0 = T_e + (T_{in} + T_t)
\]

3.2.6.2 Effective field capacity measurement

The effective field capacity was calculated according to Hunt (1979) as follows:

\[
C_E = S \times W \times \frac{E}{C_F}
\]

Where:

\( C_E = \text{Effective field capacity (ha/hr).} \)

\( S = \text{Travel speed of the machine (Km/hr).} \)
W = Effective width of cut in metres.

E = Field efficiency %.

CF = Conversion factor, for ha = 10.

### 3.2.6.3 Fuel consumption rate measurement

The fuel consumption was calculated in liter /ha and liter /hr as follows:

A/ Fuel consumption rate (L/ha) = \[
\frac{\text{Reading of cylinder ml} \times 10000}{\text{Area of the plot m}^2 \times 1000}
\]

B/ Fuel consumption rate (L/hr) = \[
\frac{\text{Reading of cylinder ml} \times 60 \times 60}{1000 \times \text{Time required (sec)}}
\]

The tested tractor started working in the plot with its full tank. 1

After finishing to plow the plot, the tank was refilled with the 2

graduated cylinder.

The amount of fuel which was used to refill the tank was recorded 3

in liters.

The time taken to finish the plot (as a total time) was recorded by 4

using the stop watch.

### 3.2.7 Soil Parameters Measurements

#### 3.2.7.1 Soil Sampling

Sampling before plowing: .a
Soil samples were taken before plowing from each replicate in a randomly selected location (station). From each station in an increment of 0.2m from the surface to a depth of one meter below the surface was taken to find out the soil bulk density of each depth, gravimetric moisture content and other soil analysis.

Sampling before planting and at any irrigation:

Other soil samples were taken before planting and at any irrigation from two replicates of each tillage system at randomly selected locations. Samples were collected as outlined above, and similarly prepared and kept in plastic bags to compute the percentage of moisture content.

3.2.7.2 Soil Moisture Content %

Samples of soil which were collected from five depths (0-0.2, 0.2-0.4, 0.4-0.6, 0.6-0.8, 0.8-1.0m). Portions of samples were taken and immediately, kept in plastic bags and weighed. They were then dried in an oven at temperature of 110-115° C for 24 hours. The samples were reweighed again. Soil moisture content percentage on dry weight basis was calculated as follows:

\[
\text{soil moisture content \%} = \frac{W_1 - W_2}{W_2} \times 100
\]

Where:

\[W_1 = \text{Wet sample weight in gm.}\]
\[W_2 = \text{Dry sample weight in gm.}\]
3.2.7.3 Soil Infiltration rate

Infiltration was measured by using “double ring infiltrometer”. Fig. (3.1).

The infiltration rate was obtained by measuring the depth of ponded water inside the inner cylinder at certain time intervals. Water is maintained in the area between the two cylinders. Infiltration rate was measured three times as follows:

1. Before plowing: from three stations (replicates), one station for each replicate.
3. At harvest: the infiltration rate was determined twice in each treatment.
4. The average was taken to represent the infiltration rate for each treatment.

3.2.7.4 Soil bulk density

The soil bulk density was measured by using the paraffin wax method or (clod method) as described by (Black, 1965). Two locations were selected randomly before plowing in the experimental field. Five samples were taken from each location with 0.2m interval, (0-0.2, 0.2-0.4, 0.4-0.6, 0.6-0.8, 0.8-1.0m). A soil clod sample about 5cm in diameter was used to determine the bulk density. The clod bulk density was found by determining the mass of the cold in the air, the mass was then divided by...
the volume of the same clod, which was determined after being coated with paraffin wax and weighing the coated clod submerged in water. The bulk density was calculated in grams per cubic centimeter, Appendix A (Table A.1) using the following expression:

\[
BD = \frac{W - (W_a - W_w)}{D_w} - \frac{(W_a - W)}{D_c}
\]

Where: BD = Bulk density of the soil (gram/cc).

\( W \) = Weight of soil sample before wax coating (gm).

\( W_a \) = Weight of soil sample with wax coating (gm).

\( W_w \) = Weight of soil sample with wax in water (gm).

\( D_w \) = Density of water = 1 gram/cc.

\( D_c \) = Density of paraffin wax = 0.9 (gm/cc).

3.2.8 Plant parameters measurements

3.2.8.1 Plant population

A square shaped steel (1mx1m) in dimensions was dropped randomly into each plot at plant age of 85 days and the plants inside this area were counted and the average was taken from three replicates to find out the plant population per one meter square.

3.2.8.2 Grain yield (Ton/ha)

An area of \((1.5m \times 10m = 15m^2)\) was selected randomly inside each plot, then the plants were cut (after the crop was completely matured) from the ground surface and left for 10 days to dry. Each sample was threshed and...
manually and the clean grains were collected separately and weighed. The final grain yield is expressed in (Ton/ha).

\[ \text{Grain yield (Ton/ha)} = \frac{W \text{ kg}}{15 \text{ m}^2 \times 1000} \times 10000 \]

3.2.8.3 Total biomass (Ton/ha)

Samples harvested from the 15m\(^2\) area in each plot (section 3.2.8.2) were weighed before threshing to obtain the total biomass. The weight was finally expressed in Ton/ha for each treatment.

3.2.8.4 Harvest index %

The harvest index is the percentage of total grain yield to the total biomass. It was calculated for each treatment as follows:

\[ \text{Harvest index (\%)} = \frac{\text{grain yield}}{\text{total biomass}} \times 100 \]

3.2.9 Cost of production

The production costs include seeds price, chemical fertilizers price, irrigation cost, land preparation cost, sowing cost, weeding cost (if done) and harvest cost. In the study five tillage systems and three methods of sowing were used, in addition to zero tillage system as control.

3.2.9.1 Land preparation costs

Land preparation cost in Sudanese Dinars included plowing, disc harrowing and leveling for each treatment. It contained annual fixed costs and variable costs. Appendix (F.1)
The annual fixed costs was calculated as percentage of purchase price. It was taken as 16% of purchase price. The annual hours of use for the tractor and implement were taken as 1200 hours and 250 hours respectively (Hunt, 1979). The fixed costs were computed per hour as follows:

\[
\text{Total fixed costs/hr for tractor} = \frac{\text{Annual fixed costs in Dinars}}{1200 \text{ hr}}
\]

\[
\text{Total fixed costs/hr for each implement} = \frac{\text{Annual fixed costs in Dinars}}{250 \text{ hr}}
\]

Variable costs: included repair and maintenance (R and M), fuel, oil and labor costs.

1. Annual repair and maintenance costs were calculated from records of tractor in Sudanese Dinars for the last two years, then computed per hour as follows:

\[
\text{R and M costs per hour for tractor} = \frac{\text{Annual R + M costs for tractor (or avg. Costs of two years)}}{1200 \text{ hr}}
\]

or = 9% of purchase price (Table 2.2).

\[
\text{R and M costs per hour each implement} = \frac{\text{Annual R + M costs for implement}}{250 \text{ hr}}
\]

or = 7.5% of purchase price (Hunt, 1979).

2. Fuel costs: It was measured from calculated fuel consumption rate (L/hr) for each implement, then computed in Sudanese Dinars as follows:
Fuel costs per hour = fuel consumption rate (L/hr) x fuel price in Dinars.

3. Lubricants costs: They were computed as 15% of fuel cost (Kepner et al., 1978).

4. Annual labor costs = labor monthly salary in Dinars x 12 months.

Monthly working hours = 30 x 8 = 240 hrs.

Labor cost per hour = Annual labor cost

\[
\text{1200 hr}
\]

Labor cost SD/ hr = Labor monthly salary (SD) /240 hrs.

3.2.9.2 Sowing costs

Sowing cost for each method was used as actually recorded from the field. Appendix F (Tables F.1 and F.2).

3.2.9.3 Harvest costs

The harvest cost included the manual cutting cost, threshing cost and empty sacks price. They were computed according to the present price during each season. Appendix F (Tables F.1 and F.2).
CHAPTER FOUR
RESULTS AND DISCUSSION

4.1 Effect of Tillage Systems On Some Soil Parameters

4.1.1 Effect on soil infiltration rate in (cm/hr)

The experimental means of infiltration rate data in cm/hr for the
second season before plowing, before planting (after plowing) and at
harvest are given in Appendix B (Tables B.1, B.2 and B.3) and shown in
Figs. (4.1, 4.2 and 4.3) respectively. It is clear that before planting the
highest initial infiltration rate was recorded by the disc plow (33 cm/hr)
followed by the light disc harrow (30 cm/hr), the moldboard plow (28.8
cm/hr), the heavy disc harrow (28.2 cm/hr) and the chisel plow (24.6
cm/hr).
The highest value of steady infiltration rate in cm/hr before planting
was registered by the light disc harrow (LDH), followed by the disc plow
(DP), the moldboard plow (MP), the heavy disc harrow (HDH) and the
chisel plow (CP) and they recorded (9.0 cm/hr), (8.2 cm/hr), (7.6 cm/hr),
(7.4 cm/hr) and (5.8 cm/hr) respectively, Appendix B (Table B-1) and Fig
(4.3).

Before planting, the steady infiltration rate in cm/hr was observed
after (60 minutes) for the (DP), the (MP), and the (LDH), while it was
observed after (75 minutes) for the (CP) and the (HDH) and after 30 mins.

For zero tillage, Appendix B (Table B-1), Fig. (4.1).

Means of infiltration rate data in cm/hr at harvest are shown in Appendix B (Table B-2) and (Fig.4.2). The results showed that the disc plow (DP) recorded the highest initial infiltration rate in cm/hr followed by the heavy disc harrow (HDH), the chisel plow (CP), zero tillage, the moldboard plow (MP) and the light disc harrow (LDH) and they recorded 39 cm/hr, 37.8 cm/hr, 36.0 cm/hr, 34.8 cm/hr, 30 cm/hr and 24 cm/hr respectively. The highest value of steady infiltration rate in cm/hr at harvest was recorded by the (CP), followed by zero tillage, the heavy disc harrow (HDH), the (DP) and (MP) and the (LDH) and they recorded (13.2 cm/hr), (12 cm/hr), (10.2 cm/hr), (6.6 cm/hr) and (5.2 cm/hr) respectively.

At harvest, the steady infiltration rate in cm/hr was observed after 45 minutes for the (MP) and (HDH), after 60 minutes for the (DP) and zero tillage and after 75 minutes for the (CP) and the (LDH), (Fig. 4.2)

The average accumulative intake (in cm) as affected by the tillage systems before planting (after plowing) and at harvest are shown in Appendix B (Tables B-4 and B-5) respectively. The greatest value of accumulative intake (in cm) before planting was recorded by the (LDH) (after 105 minutes from beginning; at steady intake) followed by the (DP), the (HDH) zero tillage, the (MP) and the (CP) and they recorded 19.65 cm, 18.30 cm, 17.35 cm, 17.35 cm, 16.55 cm and 13.90 cm respectively,
Appendix B (Table B-4). Average accumulative intake trends as affected by different tillage systems before planting are shown in Fig. (4.4) as with different equations.

At harvest, the (CP) recorded the greatest value of average accumulative intake (in cm) after 105 minutes from beginning (at steady intake), followed by zero tillage, the (HDH), the (DP), the (MP) and the (LDH) and they recorded (26.8 cm), (24.3 cm), (21.25 cm), (15.9 cm), (14.6 cm) and (11.85 cm) respectively, (Fig. 4.5).

The disc plow tillage (DP) recorded the highest initial infiltration before planting and at harvest. The increase in the initial infiltration rate in cm/hr obtained from the disc plowing could be due to the increase in the porosity and the aggregation of the surface soil. These results agreed with (Michael, 1978).

Zero tillage recorded (28.8 cm/hr) and (34.8 cm/hr) before planting and at harvest respectively due to the high ratio of sand in the experimental soil Appendix A (Table A.1). It was known that the upper terraces soils are easy to plow and they contained lumpy of sand which differs in its distribution from place to another.

Fig. 4.4.

Fig. 4.5.
All tillage systems, used in this study, showed a decrease in steady infiltration rate and increase in the initial infiltration rate before planting and at harvest, (Figs. 4.1 and 4.2).

4.1.2 Effect on soil moisture content in Percentage

The experimental data of soil moisture content (%) for the first season and the second season are given in Appendix C (Table C-1 and Table C-2) respectively.

The analysis of variance of results for soil moisture content (%) at any irrigation for the first and the second seasons are shown in Tables (4.1) and (4.2) respectively. Duncan's multiple range test for soil moisture content (%) as affected by tillage systems at any irrigation for the two seasons are given in Tables (4.3) and (4.4) respectively.

It is clear that the lowest soil moisture content (%) for the two seasons before plowing, before planting (after plowing) and at any irrigation was recorded at the top surface (0-20) cm depth which could be due to the fact that the surface layer is subjected to drying more quickly because of the direct exposure to air and sun.

In the two seasons the highest values of soil moisture content (%) before plowing, before planting and at any irrigation were observed at (40-60) cm depth. The analysis of variance (ANOVA) showed insignificant differences between the tillage systems at 5% and 1% levels in the first Table 4.1.
season at all depths, (Table 4.1), while the second season showed significant differences between the tillage treatments at 5% level for depths (0-20) cm and (60-80) cm in the seventh irrigation (Table 4.2). Duncan’s multiple range test for soil moisture content (%) as affected by different tillage systems in the two seasons showed that no significant differences between treatments before planting and at any irrigation except those at the 7th irrigation in the second season (Table 4.4).

The results of soil moisture distribution before plowing and before planting; in zero tillage plots (at the first irrigation) for the two seasons are shown in Figs. (4.6 and 4.8).

It can be observed that the highest soil moisture content (%) before plowing for the two seasons was recorded at (40-60 cm) and (20-40 cm) depths giving values of 2.17%, 1.26% for the first season and 2.96%, 2.77% for the first and the second season in sequence.

The highest soil moisture content (%) before planting (at the first irrigation) for the two seasons was also recorded at (40-60) cm and (20-40) cm depths for all tillage systems, (Figs 4.6 and 4.8). At
the first irrigation (Before planting) for the first season, it was observed that the chisel plow (CP) recorded the highest moisture content (%) at (40-60) cm depth (2.22%), while the lowest moisture content (%) at the same depth was registered by the heavy disc harrow (HDH) and the light disc harrow (LDH) and they both gave the value of (2.16%). At (20-40) cm depth the highest value of moisture content was recorded by the (HDH) (1.36%) and the lowest moisture content (1.25 %) was indicated by the moldboard plow (MP) and the chisel plow (CP).

In the second season before planting (at the first irrigation) the highest moisture content (%) was registered by the moldboard plow (MP) and the heavy disc harrow (HDH) at (40-60) cm and (20-40) cm depths in sequence, giving values of (3.15%) and (3.07%) respectively. On the other
hand, the chisel plow (CP) and the disc plow (DP) showed the lowest value of soil moisture content (%) at (40-60) cm and (20-40) cm depths giving values of (2.76%) and (1.83%) respectively.

The results of soil moisture distribution before any irrigation for both seasons (from the 2nd irrigation to the last irrigation) are shown in (Figs. 4.7 and 4.9) for the first season and the second season respectively. The trends of soil moisture distribution for all tillage systems in the two seasons were increased moisture content (%) with the increase in depth till (40-60) cm depth and then decreased again.

It can be observed that at all irrigations (except the fifth one) for the first season, the moldboard plow (M.P) recorded the highest moisture content (%) at (40-60) cm depth giving values 12.23 %, 12.53 %, 12.89 %, 13.97 % and 15.50 % at the second, the 3rd, the 4th, the 6th and the 7th irrigations respectively; at the same time, the chisel plow (CP) showed the highest value at the 5th irrigation (13.53 %). However the lowest value of
soil moisture content (%) at (40-60) cm depth was recorded by the light disc harrow (LDH) at the 2\textsuperscript{nd}, the 3\textsuperscript{rd} and the 4\textsuperscript{th} irrigations giving values of 11.93 %, 12.20 % and 12.45 % respectively. The lowest values registered by the heavy disc harrow (HDH) at the same depth at the 5\textsuperscript{th}, the 6\textsuperscript{th} and the 7\textsuperscript{th} irrigations giving values of 12.91 %, 13.5 % and 14.17 % in sequence.

In the second season the results showed that the chisel plowing system (CP) registered the highest soil moisture content (%) at (40-60) cm depth giving values of 12.88 %, 12.98 %, 13.63 %, 13.90 %, 14.32 %, 14.64 % and 14.92 % at the 2\textsuperscript{nd}, the 3\textsuperscript{rd}, the 4\textsuperscript{th}, the 5\textsuperscript{th}, the 6\textsuperscript{th}, the 7\textsuperscript{th} and the 8\textsuperscript{th} irrigations respectively. The lowest soil moisture content (%) at (40-60) cm depth was recorded by the light disc harrow system (LDH) at the 2\textsuperscript{nd} to the 8\textsuperscript{th} irrigation giving values of 12.08 %, 12.26 %, 12.38 %, 13.07 %, 13.51 %, 13.68 % and 13.98 % respectively.

It was observed that zero tillage system registered the highest soil moisture content (%) at (0-20) cm depth than the plowed plots giving values of 1.18 % and 1.20 % in the two seasons respectively. These results are in line with (Lal, 1976) and (Tyler and Overton, 1982).

The highest values of soil moisture content (%) recorded by the moldboard plow (MP) in the first season at (40-60) cm and (20-40) cm depths at all irrigations can be due to its greater depth of cut. The highest values of soil moisture content (%) were obtained by the chisel plow (CP) in the second
season at the same depths as mentioned above for all irrigations could be attributed to the fact that chiseling was found to increase water transmission. The results are in agreement with the findings of Singh et al., (1978).

Generally, it can be concluded that the moisture content (%) increases with time and therefore the values of soil moisture content (%) for the different tillage systems at the different depths were greater at last irrigation than those that found before plowing.

The soil moisture distribution in the two seasons was found to increase with depth at any irrigation till the depth of (40-60) cm then decreased.

4.2. Effect of Tillage Systems on Machinery Parameters:

4.2.1. Effect on field efficiency

The results of field efficiencies as affected by the type of tillage implement are given in Tables (4.5 and 4.6) for the two seasons. In the first season, the moldboard plow resulted in the highest field efficiency, followed by the disc plow, the chisel plow, the heavy disc harrow and the
Table 4.6.
light disc harrow and they recorded 71.83%, 71.34%, 70.59%, 69.23% and 65.12% respectively.

The lowest field efficiency obtained from the light disc harrow could be due to its lowest time of stroke in seconds (28 sec.) taken to travel 39 m with load in the field, and also its lowest total lost time during turning at the end of the field. In the second season the moldboard plow also recorded the highest field efficiency, followed by the disc plow, the light disc harrow, the chisel plow, and the heavy disc harrow and they recorded 71.8%, 70.8%, 69.1%, 68.57% and 68.09% respectively. The lower value of field efficiency obtained from the heavy disc harrow could be due to its high total time in relation to the effective time taken. These results are in line with the findings of (Hunt, 1979).

4.2.2. Effect on effective field capacity

The results of effective field capacity are given in Tables (4.5) and (4.6) for the two seasons respectively. The highest effective field capacity in the first season was recorded by the light disc harrow, followed by the chisel plow, the heavy disc harrow, the moldboard plow, and the disc plow. They recorded 0.685 ha/hr, 0.50 ha/hr, 0.32 ha/hr, 0.284 ha/hr and 0.238 ha/hr respectively.

In the second season, the highest effective field capacity was also given by the light disc harrow, followed by the chisel plow, the heavy disc
harrow, the moldboard plow, and the disc plow and they recorded 0.73 ha/hr, 0.49 ha/hr, 0.36 ha/hr, 0.28 ha/hr and 0.24 ha/hr respectively.

The lowest value of effective field capacity which was recorded by the disc plow in both seasons could be due to it's smaller width of cut. While the highest value which was given by the light disc harrow may be due to the larger width of cut and higher forward speed. These results are in agreement with the finds of Hunt (1979).

4.2.3. Wheel slippage % as affected by tillage systems

The results of tractor wheel slippage % as affected by tillage systems are presented in Tables (4.5) and (4.6) for the two seasons respectively. The highest wheel slippage was given by the heavy disc harrow in the first season, followed by the moldboard plow, the disc plow, the chisel plow and the light disc harrow which recorded 9.1%, 8.6%, 8.5%, 5.3%, and 1.4% respectively. In the second season the same sequence with almost similar slippage values were observed 8.8%, 8.52%, 8.37%, 5.02% and 2.39% respectively.

In both seasons the highest value of slippage (%) obtained from the heavy disc harrow may be due to the higher draft force exerted by the implement, while the lower value of wheel slippage recorded by the light disc harrow could be attributed to the smaller working depth (0.15) m. These results are in line with the findings of Baloch et al. (1991) and Hunt (1979).
Fuel consumption rate (L/ha, L/hr) as affected by tillage systems

The results of fuel consumption rate in L/ha and L/hr for the two seasons are shown in Tables (4.5) and (4.6). The highest value of fuel consumption in L/ha for the two seasons was recorded by the disc plow, followed by the moldboard plow, the heavy disc harrow, the chisel plow and the light disc harrow. In the same order the values were 31.2 L/ha, 28.94 L/ha, 27.8 L/ha, 14.71 L/ha, and 12.21 L/ha respectively in the first season, and recorded 30.52 L/ha, 29.24 L/ha, 27.12 L/ha, 16.8 L/ha and 12.21 L/ha respectively in the second season. The highest value of fuel consumption rate in L/hr for the first season was recorded by the heavy disc harrow, followed by the light disc harrow, the moldboard plow, then the disc plow and the chisel plow, and they recorded 9.0 L/hr, 8.36 L/hr, 8.24 L/hr, 7.44 L/hr, 7.40 L/hr in sequence. In the
second season, the highest fuel consumption rate in L/hr was also reported by the heavy disc harrow, followed by the light disc harrow, the moldboard plow and the chisel plow, and lastly the disc plow and they recorded 9.72 L/hr, 8.89 L/hr, 8.24 L/hr, 8.24 L/hr and 7.4 L/hr respectively.

The highest value of fuel consumption rate in L/hr, given by the heavy disc harrow for the two seasons, could be due to its higher draft force (high load). These coincide with the results of Gordon (1991) and Dawelbeit (1997).

**Effect Of Tillage Systems And Sowing Methods on Some Plant Parameters**

**Effect on plant height (cm)**

Plant height data for the two seasons are shown in (Appendix E Table E-1) and Table (4.16). The analysis of variance for plant height in the two seasons are shown in Tables (4.7) and (4.8) respectively. The analysis of variance indicated no significant differences between all treatments in the two seasons. Duncan's multiple range test for the effect of tillage
Table 4.7.
Table 4.8.
systems and sowing methods on plant height for the two seasons are given in Table (4.9).

The sowing method which includes manual broadcasting plus light disc harrowing resulted in the greater overall mean plant height for the two seasons, followed by the manual broadcasting plus cultivating then seed drilling machine and they recorded 91.55 cm, 91.08 cm and 89.27 cm in the first season, and 97.22 cm, 96.61 cm and 95.44 in the second season respectively.

The insignificant differences between the treatments in the two seasons could be due to the light structure of the experimental soil. The soil was also easy to plow, so there was no influence of tillage practices and sowing methods observed on most of plant parameters.

4.3.2. Effect on plant fresh weight in (gm/plant)

The fresh weight data as affected by different treatments are shown in Appendix E (Table E-2), Table (4.16). Duncan's multiple range test and the analysis of variance for the plant fresh weight in the two seasons are given in (Tables 4.10, 4.7 and 4.8) respectively.

No significant differences between the treatments in the two seasons were observed. Generally in both seasons, manual broadcasting plus cultivating resulted in the highest plant fresh weight, followed by
Table 4.9.

Table 4.10.

Table 4.10.

Manual broadcasting plus light disc harrow then the seed drill machine, and they recorded (4139.2 gm/m²), (3852.2 gm/m²) and (3454.2 gm/m²) in the first season and (4047.4 gm/m²), (3490.5 gm/m²) and (3119.7 gm/m²) in the second season respectively.

The highest fresh weight in the first season obtained by the light disc harrowing (4133.6 gm/m²) and in the second season by the disc plowing (3793.7 gm/m²), while the lowest fresh weight recorded by the heavy disc harrowing (3516.4 gm/m²) and the light disc harrowing (3354.7 gm/m²) in the first and the second seasons respectively.

4.3.3. Effect on plant dry weight (gm/m²)

Plant dry weight data for the two seasons are given in Appendix E (Table E-3), Table (4.16). Duncan's multiple range test and analysis of variance for plant dry weight as affected by different treatments in the two seasons are given in (Table 4.11) and (Tables 4.7 and 4.8) respectively. No significant differences between the treatments in the two seasons were observed. It is clear that in both seasons, the manual broadcasting plus cultivating (CU) recorded the highest plant dry weight in gm/m² followed by manual broadcasting plus the light disc harrowing (LDH) then
the seed drill machine (SD) and they registered (1526.3 gm/m²), (1425.5 gm/m²) and (1250.9 gm/m²) in the first season, and (1545.4 gm/m²), (1351.4 gm/m²) and 1210.6 gm/m²) in the second season respectively.

The highest dry weight given by the light disc harrowing (1538.4 gm/m²) and the disc plowing (1497.4 gm/m²) in the first and the second seasons respectively, while the lowest dry weight registered by the moldboard plowing (1288.7 gm/m²) and the light disc harrowing (1294.5 gm/m²) in the first and the second seasons respectively.

4.3.4. Effect on plant population per m²

Plant population data for the two seasons are given in (Appendix E Table E-4), Table (4.16). Duncan's multiple range test for the effect of tillage systems and sowing methods on plant population and analysis of variance for the two seasons are given in Table (4.12) and Tables (4.7) and (4.8) respectively.

No significant differences between treatments was observed in the first season, while in the second season significant differences between tillage systems at 5% level was observed, Table (4.8). This could be due to weeds influence on crop growth.
In the second season the disc plowing plus harrowing and leveling resulted in the highest plant population, followed by the chisel plowing plus harrowing and leveling, the heavy disc harrowing plus leveling, zero tillage, the light disc harrowing plus leveling, and the moldboard plowing plus harrowing and leveling and they recorded (436.56) plants/m², (427.78) plant/m², (410.56) plant/m², (407.44) plant/m², (394.67) plants/m² and (381.33) plant/m² respectively. Highly significant differences between sowing methods at \( P \leq 0.01 \) was observed in the second season, Table (4.8). This might be due to deep placing of seeds by both the disc harrow and the seed drill in the sandy soil, which affect the germination rate of plants.

The manual broadcasting plus cultivating resulted in greater plant population per meter square, followed by the manual broadcasting plus light disc harrowing, then the seed drilling machine and they recorded (471.17) plant/m², (399.83) plant/m² and (358.27) plant/m² respectively. Generally, plant population values of the second season were higher than those of the first season.

The greater plant population by the disc plowing plus harrowing plus leveling may be attributed to the good soil pulverization obtained by the disc plow. Also the greater plant population accrued by the manual broadcasting plus cultivating could be due to the good seedbed preparation.
and irrigation management and that resulted in high tillering and improved the germination percentage.

The lowest values of plant population which was recorded by seed drilling. This may be due to deep placing of seeds by the machine compared to the other depths used by the cultivator and the light disc harrow which might affect the germination percentage of plants. These results are in line with the findings of Richey et al. (1973) and Hakimi and Kachrue, (1976).

### 4.3.5. Effect on grain yield ton/ha

The grain yield data for the two seasons is given in (Appendix E Table E-5) and Table 4.17). Duncan's multiple range test (Table 4.13) and the analysis of variance, Tables (4.7) and (4.8) showed no significant differences between the treatments of tillage and sowing for the two seasons. The grain yield as affected by tillage systems and sowing methods for the first and the second seasons are shown graphically in Fig. (4.10) and (4.11) respectively.

The values of grain yield (Ton/ha) for the first season are greater than those of the second season by (22.4%), (14.2%), (18.9%), (9.7%) and (16.7%) for the disc plowing (DP), the moldboard plowing (MP), the chisel plowing (CP), the heavy disc harrowing (HDH) and the light disc harrowing (LDH) respectively, whereas zero tillage showed the greater value of grain yield for the second season than of the first season by 7.1 %.
The higher grain yield values obtained in the first season could be due to the reduced weeds influence on crop growth. Also the mechanical analysis for the second season showed high sand percentage of the different depths than those in the first season and these may affected on plant nutrients and water holding capacity at the root zone of the crop.

In the first season, the highest value of grain yield by tillage systems recorded by the disc plowing (DP) 4.16 Ton/ha, followed by the chisel plowing (CP) 4.02 Ton/ha, the heavy disc harrowing (HDH) 3.96 Ton/ha, the light disc harrowing (LDH) 3.91 Ton/ha, the moldboard plowing (MP) 3.85 Ton/ha and zero tillage 3.36 Ton/ha.

The lowest grain yield obtained by zero tillage could be due to the slow emergence of crop stand, which was affected by weeds. These results are agreed with the finds of Harimi and Kachrue (1976).

In the second season the highest grain yield was given by the heavy disc harrowing (HDH) followed by zero tillage, he disc plowing (DP), the chisel plowing (CP), the moldboard plowing (MP) and the light disc harrowing (LDH) and they recorded 3.61 Ton/ha, 3.60 Ton/ha, 3.40 Ton/ha, 3.38 Ton/ha, 3.37 Ton/ha and 3.35 Ton/ha in sequence.
In case of sowing methods, the highest grain yield in the first season is given by manual broadcasting plus light disc harrowing 4.0 Ton/ha followed by the manual broadcasting plus the cultivating (3.87 Ton/ha) then the seed drilling machine (3.76 Ton/ha), while in the second season the results followed the same trend of the first season of sowing and they recorded (3.51 Ton/ha), 3.49 Ton/ha and 3.36 Ton/ha respectively.

It is clear that the values of grain yield (Ton/ha) affected by sowing methods for the first season are greater than those of the second season.

These results are agreed with the findings of Dawelbeit et al. (1993).

The ANOVA, (Tables 4.7 and 4.8) showed no significant differences between the tillage systems. These results are in line with the findings of Ahmed and Haffar, (1993) and Abdalla, (1984).

4.3.6. Effect on total biomass in Ton/ha

The total biomass data (only for the second season) is given in (Appendix E Table E.6), Table (4.17). Duncan's multiple range test (Table 4.14) and the analysis of variance for total biomass as affected by tillage systems and sowing methods for the second season are shown in Table.

The analysis of variance showed significant differences between the tillage systems at 5% level. Duncan's multiple range test also showed significant differences between tillage system, Table (4.14).
The highest values of total biomass were obtained by both the heavy disc harrowing (HDH) and zero tillage, followed by the disc plowing, the chisel plowing, the moldboard plowing, and the light disc harrowing and they recorded 9.16 Ton/ha, 9.16 Ton/ha, 8.85 Ton/ha, 8.29 Ton/ha, 7.98 Ton/ha and 7.74 Ton/ha respectively. No significant differences were observed between sowing methods (Tables 4.8 and 4.14). The highest
Table 4.14.
biomass value was observed by the manual broadcasting plus the (LDH) (8.74 Ton/ha), followed by the manual broadcasting plus the cultivating (CU) (8.73 Ton/ha) and seed drilling machine (SD) (8.12 Ton/ha).

The lowest value of total biomass was obtained from the light disc harrowing plus leveling and the moldboard plowing plus harrowing and leveling. This could be due to the lower values of plant population/m² which was affected by weeds in these plots.

4.3.7. Effect on harvest index(%)  

The harvest index data (only for the second season) is shown in (Appendix E :Table E-7) and Table (4.17). Duncan's multiple range test for the effect of tillage systems and sowing methods on the harvest index for the second season is given in Table (4.15). The analysis of variance for harvest index is shown in Table (4.8). The analysis of variance showed no significant differences between the tillage systems, but there is significant differences between sowing methods at 5% level. Duncan's multiple range test showed significant differences between the different sowing treatments.

Manual broadcasting plus the light disc harrowing (LDH) resulted in higher percentage of harvest index, followed by the seed drilling machine
Table 4.17.

(SD), then the manual broadcasting plus the cultivating (CU) and they recorded 39.79%, 39.58% and 37.82% respectively (Tables 4.8 and 4.15).

The highest percentage of harvest index obtained from the manual broadcasting plus the light disc harrow may be due to it's highest grain yield (Ton/ha)

4.4. Land Preparation Costs Of Tillage Systems

4.4.1 The calculated costs

The calculations of cost analysis for different tillage systems used for the experimental land preparation are shown in Appendix F (Table F-1).

The results of the actual land preparation costs for different type of tillage, sowing methods and harvesting practices costs in SD/ha for the two seasons are given in. Appendix F (Tables F.3 and F.4) respectively.

Results of the calculated total cost (in SD/hr and SD/ha) of the different field operations, and the total costs for each tillage system are given in Tables (4.18) and (4.19) respectively.

The highest value of the calculated total costs in SD/hr was recorded by the heavy disc harrow, followed by the light disc harrow, the moldboard plow and the chisel plow, the disc plow and the blade leveler, and they recorded 2381.39 SD/hr, 1848.74 SD/hr, 1799.68 SD/hr, 1799.68 SD/hr, 1712.77 SD/hr and 1461.15 SD/hr respectively. (Table 4.18).
Table 4.19.
The highest costs in SD/hr for the heavy disc harrow could be due to its high purchase prices (800,000 SD) and fuel consumption rate (9.72 L/hr). Also the high cost in SD/hr for the light disc harrow may be due to the high fuel consumption rate (8.89 L/hr).

The highest total costs in SD/ha obtained from the disc plow may be attributed to its lower effective field capacity and the lower width of working, while the lowest total costs in SD/ha obtained from the light disc harrow could be due to its higher effective field capacity and the large width of cut (Table 4.18). These results are agreed with the findings of Hunt (1979).

The calculated total costs of land preparation in SD/hr are shown in Table (4.19). The highest value of land preparation costs in SD/hr resulted by both the moldboard plowing and the chisel plowing plus light disc harrowing plus leveling followed by the disc plowing plus light disc harrowing plus leveling, the heavy disc harrowing plus leveling, and the light disc harrowing plus leveling. They recorded 5109.57 SD/hr, 5109.57 SD/hr, 5022.66 SD/hr, 3842.54 SD/hrs and 3309.89 SD/hr in sequence. The highest total costs of land preparation in SD/ha was registered by the disc plowing plus light disc harrowing plus leveling, followed by the moldboard plowing plus light disc harrowing plus leveling, the heavy disc harrowing plus leveling, the chisel plowing plus light disc harrowing plus leveling and the light disc harrowing plus leveling and they recorded
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12777.8 SD/ha, 12068.7 SD/ha, 9723.77 SD/ha, 9314.1 SD/ha, and 5641.3 SD/ha respectively.

Land preparation total costs in SD/Ton of grain yield are shown in Table (4.19). It can be observed that the highest costs in SD/Ton was recorded by the disc plowing + disc harrowing + leveling, followed by the moldboard plowing + disc harrowing + leveling, the chisel plowing + disc harrowing + leveling, the heavy disc harrowing + leveling and the light disc harrowing + leveling and they recorded 3758.2 SD/Ton, 3581.2 SD/Ton, 2755.7 SD/Ton, 2693.6 SD/Ton, and 1684.0 SD/Ton in sequence. These results indicated that the light disc harrowing plus leveling was more economic compared to the other types of tillage followed by the heavy disc harrowing plus leveling. The lowest costs in SD/Ton given by the light disc harrowing plus leveling, could be due to its lowest value of total costs in SD/ha, while the lower costs in SD/Ton obtained by the heavy disc harrowing plus leveling may be due to its higher grain yields in Ton/ha, Table (4.19).

The results of calculated total costs in SD/ha, SD/hr and SD/ton of tillage systems and sowing methods interaction are shown in (Table 4.20). The highest values of the calculated total cost in (SD/ha) and (SD/ton) of tillage systems and sowing methods interaction were recorded by the disc Table 4.20.plowing + disc harrowing + leveling with the manual 4804.68 SD/ton broadcasting + the cultivator (1A) 16430 SD/ha and
respectively. The lowest values in SD/ha and SD/ton were recorded by zero
tillage with seed drill machine (6c) 2740.93 SD/ha and 801.44 SD/ton respectively, followed by the light disc harrowing + leveling with seed drill
machine (5c) 8382.23 SD/ha and 2485.44 SD/ton in sequence. The highest calculated total costs in (SD/hr) of tillage systems and
sowing methods interaction were registered by both the moldboard plowing
+ disc harrowing + leveling with manual broadcasting + light disc harrow
(2b) and the chisel plowing + disc harrowing + leveling with also manual
broadcasting + light disc harrow (3b), giving 7451.07 SD/hr. The lowest
value in (SD/hr) was recorded by zero tillage with seed drill machine (6c)
1740.49 SD/hr followed by the light disc harrowing + leveling with seed
drill machine (5c) 5050.38 SD/hr, (Table 4.20).

4.4.2 The actual costs

The calculations of actual costs of land preparation and sowing
methods costs in SD/ha for the two seasons are shown in (Appendix F
(Table F.3 and F.4). The results registered in these appendices were based
on the price shown in Appendix F (Table F-2).

The highest value of the actual costs of land preparation is given by
the disc plowing + disc harrowing + leveling, (13470 SD/ha), while the
lowest value recorded by the light disc harrowing (LDH) plus leveling
(3915 SD/ha).
The comparison between the calculated and actual total costs of land preparation are given in Table (4.21), Fig. (4.12). It can be concluded that the highest values of calculated and actual total land preparation costs in SD/ha, SD/hr and SD/Ton were registered by the deep plowing systems, while the lowest values were recorded by the light disc harrowing.

4.5. Costs of Sowing Methods

The highest actual cost of sowing in SD/ha was recorded by cultivating (CU) after manual broadcasting the seeds and the seed drilling machine (SD), then manual broadcasting plus light disc harrowing (LDH) which recorded 2400 SD/ha, 2400 SD/ha, and 2115 SD/ha respectively, Appendix F (Table F.4). The values of the cultivator (CU) and the seed drill (SD) machine sowing methods are both greater than the value obtained by the light disc harrow (LDH) sowing method by (13.5%). Results of calculated total costs in SD/ha for each sowing method are recorded in Appendix F (Table F-1) and Table (4.19). The highest total costs in SD/ha were given by the manual broadcasting plus cultivating (3652.2 SD/ha), followed by the manual broadcasting plus the light disc harrowing (3207.5 SD/ha) and the seed drilling machine (2740.93 SD/ha).
Fig. 4.12.
The highest value of total costs in SD/ha obtained from the cultivating method could be due to its lower effective field capacity. Total costs of sowing in SD/Ton of final grain yield for each method are shown in Table (4.19). The highest costs in SD/Ton recorded by the manual broadcasting plus cultivating (1046.48 SD/Ton) followed by the manual broadcasting plus the light disc harrowing (913.82 SD/Ton), and the seed drilling machine (801.44 SD/Ton).

The above results indicated that the seed drilling machine was more economic compared to the other methods of sowing, as it recorded the lowest cost of sowing.

The comparison between the calculated and actual total costs of sowing methods is given in Table (4.22). From this it can be concluded that the highest actual and calculated total sowing costs in SD/ha and SD/Ton were recorded by manual broadcasting plus cultivating (CU), and in SD/hr by manual broadcasting plus the light disc harrowing, while the lowest total sowing costs in SD/ha, SD/hr and SD/Ton were registered by the seed drilling machine.

Table 4.22.
CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The following conclusions can be drawn:

1. All tillage systems increased the initial infiltration rate, but the basic infiltration rate was decreased.

2. The moisture content (%) of all treatments increased with depth and with increasing in water movement downwards of sandy soils.

3. The highest field efficiency in the two seasons was recorded by the moldboard plow (71.83% and 71.8%) respectively, while the lowest values were registered by the light disc harrow in the first season (65.12%) and by the heavy disc harrow in the second season (68.09%).

4. The highest effective field capacity in the two seasons was registered by the light disc harrow (0.685 ha/ hr and 0.728 ha/ hr), while the lowest value capacity was recorded by the disc plow (0.238 ha/ hr) and 0.24 ha/ hr) respectively.

5. The heavy disc harrow recorded the highest wheel slippage (%) in the two seasons (9.1% and 8.8%), while the light disc harrow registered the lowest wheel slippage % (1.4% and 2.39%) in the two seasons.
6. The disc plow recorded the highest fuel consumption rate in the two seasons (31.2 L/ha and 30.5 L/ha), while the light disc harrow recorded the lowest rate (12.21 L/ha) in both seasons.

7. The ANOVA result showed no influences of tillage systems and sowing methods were observed on most of plant parameters.

8. The disc plow tillage system with the manual broadcasting plus (LDH) and the heavy disc harrow tillage system with the manual broadcasting plus cultivating recorded the highest grain yield in ton/ha in the first and the second seasons giving values of 4.38 ton/ha and 3.71 ton/ha respectively.

9. The highest land preparation calculated total cost in SD/hr was recorded by both the (MP) system and the (CP) system (5109.57 SD/hr), while the (LDH) system recorded the lowest value of land preparation costs (3309.89 SD/hr)

10. The highest land preparation calculated total costs in SD/ha and in SD/Ton of grain yield were given by the disc plowing system (DP) (12777.8 SD/ha) and (3758.2 SD/Ton) while the lowest costs were recorded by the light disc harrowing (LDH) system (5641.3 SD/ha and 1683.97 SD/Ton) in the two seasons respectively.

11. Manual broadcasting plus cultivating method recorded the highest calculated total costs of sowing 3652.2 SD/ha, while the seed drill machine registered the lowest value 2740.93 SD/ha.
12. Manual broadcasting plus light disc harrowing method recorded the highest calculated total costs of sowing in SD/hr 2341.5 SD/hr, while the seed drill machine recorded the lowest value 1740.49 SD/hr.

5.2 Recommendations

1. The light disc harrow plus leveling recorded the lowest land preparation total cost in (SD/ha), (SD/hr) and in SD/Ton of grain yield. Therefore the light disc harrow plus leveling can be recommended as an economic tillage system for wheat land preparation in these areas.

2. Seed drilling machine recorded the lowest costs of sowing and therefore can be recommended as the economic sowing method for the wheat crop.

3. More studies should be made to investigate the effect of harrow packing (the procedure of pressing the soil after placing and covering wheat seeds) on grain yield especially in sandy and light soils of the Northern State.
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# Table (4-1) Analysis of variance of results for soil moisture content % at any irrigation First season

<table>
<thead>
<tr>
<th>Sample before</th>
<th>Source of variation</th>
<th>F. calculated</th>
<th>F. tabulated</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>0-20 cm</td>
<td>20-40 cm</td>
</tr>
<tr>
<td>First irrigation</td>
<td>Tillage sys.</td>
<td>0.33</td>
<td>1.05</td>
</tr>
<tr>
<td>2nd irrigation</td>
<td>Tillage sys.</td>
<td>1.06</td>
<td>1.37</td>
</tr>
<tr>
<td>3rd irrigation</td>
<td>Tillage sys.</td>
<td>1.25</td>
<td>0.45</td>
</tr>
<tr>
<td>4th irrigation</td>
<td>Tillage sys.</td>
<td>1.80</td>
<td>1.81</td>
</tr>
<tr>
<td>5th irrigation</td>
<td>Tillage sys.</td>
<td>0.59</td>
<td>2.13</td>
</tr>
<tr>
<td>6th irrigation</td>
<td>Tillage sys.</td>
<td>0.56</td>
<td>0.74</td>
</tr>
<tr>
<td>7th irrigation</td>
<td>Tillage sys.</td>
<td>0.54</td>
<td>0.70</td>
</tr>
<tr>
<td>8th irrigation</td>
<td>Tillage sys.</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
Table (4-2) Analysis of variance of results for soil moisture content % at any irrigation Second season

<table>
<thead>
<tr>
<th>Sample before:</th>
<th>Source of variation</th>
<th>F. calculated</th>
<th>F. tabulated</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>0-20 cm</td>
<td>20-40 cm</td>
</tr>
<tr>
<td>0-20 cm</td>
<td>0.73</td>
<td>2.41</td>
<td>0.35</td>
</tr>
<tr>
<td>20-40 cm</td>
<td>0.90</td>
<td>0.43</td>
<td>0.48</td>
</tr>
<tr>
<td>40-60 cm</td>
<td>0.97</td>
<td>0.42</td>
<td>0.92</td>
</tr>
<tr>
<td>60-80 cm</td>
<td>0.81</td>
<td>0.90</td>
<td>1.34</td>
</tr>
<tr>
<td>80-100 cm</td>
<td>0.74</td>
<td>3.21</td>
<td>1.26</td>
</tr>
<tr>
<td>1st irrigation.</td>
<td>Tillage sys.</td>
<td>0.73</td>
<td>2.41</td>
</tr>
<tr>
<td>2nd irrigation.</td>
<td>Tillage sys.</td>
<td>0.90</td>
<td>0.43</td>
</tr>
<tr>
<td>3rd irrigation.</td>
<td>Tillage sys.</td>
<td>0.97</td>
<td>0.42</td>
</tr>
<tr>
<td>4th irrigation.</td>
<td>Tillage sys.</td>
<td>0.81</td>
<td>0.90</td>
</tr>
<tr>
<td>5th irrigation.</td>
<td>Tillage sys.</td>
<td>0.74</td>
<td>3.21</td>
</tr>
<tr>
<td>6th irrigation.</td>
<td>Tillage sys.</td>
<td>2.29</td>
<td>1.66</td>
</tr>
<tr>
<td>7th irrigation.</td>
<td>Tillage sys.</td>
<td>6.61*</td>
<td>0.79</td>
</tr>
<tr>
<td>8th irrigation.</td>
<td>Tillage sys.</td>
<td>0.19</td>
<td>4.90</td>
</tr>
</tbody>
</table>

* = significant.
** = highly significant.
<table>
<thead>
<tr>
<th>Implements</th>
<th>Parameters</th>
<th>Field Efficiency %</th>
<th>Effective field capacity ha/hr</th>
<th>Slippage %</th>
<th>Fuel consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Disc plow</td>
<td>71.34</td>
<td>0.238</td>
<td>8.5</td>
<td>31.2</td>
<td>7.44</td>
</tr>
<tr>
<td>Moldboard plow</td>
<td>71.83</td>
<td>0.284</td>
<td>8.6</td>
<td>28.94</td>
<td>8.24</td>
</tr>
<tr>
<td>Chisel plow</td>
<td>70.59</td>
<td>0.50</td>
<td>5.3</td>
<td>14.71</td>
<td>7.40</td>
</tr>
<tr>
<td>Heavy off- set</td>
<td>69.23</td>
<td>0.32</td>
<td>9.1</td>
<td>27.8</td>
<td>9.00</td>
</tr>
<tr>
<td>Disc harrow</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Light off- set</td>
<td>65.12</td>
<td>0.685</td>
<td>1.4</td>
<td>12.21</td>
<td>8.36</td>
</tr>
<tr>
<td>Disc harrow</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table (4-5) effect of tillage systems on some machinery parameters In the first season 2000-2001.
## Table (4-6) effect of tillage systems on some machinery parameters In the second  season 2001-2002

<table>
<thead>
<tr>
<th>Implement</th>
<th>Field Efficiency %</th>
<th>Effective field capacity ha/hr</th>
<th>Slippage %</th>
<th>Fuel consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disc plow</td>
<td>70.8</td>
<td>0.24</td>
<td>8.37</td>
<td>30.52</td>
</tr>
<tr>
<td>Moldboard plow</td>
<td>71.8</td>
<td>0.28</td>
<td>8.52</td>
<td>29.24</td>
</tr>
<tr>
<td>Chisel plow</td>
<td>68.57</td>
<td>0.49</td>
<td>5.02</td>
<td>16.8</td>
</tr>
<tr>
<td>Heavy off- set Disc harrow</td>
<td>68.09</td>
<td>0.36</td>
<td>808</td>
<td>27.12</td>
</tr>
<tr>
<td>Light off- set Disc harrow</td>
<td>69.1</td>
<td>0.73</td>
<td>2.39</td>
<td>12.21</td>
</tr>
</tbody>
</table>
Table (4-7) Analysis of variance result for plant parameters in the first season 2000/2001.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Source of variation</th>
<th>F. calculated</th>
<th>F. tabulated*</th>
<th>5%</th>
<th>1%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height of plant (cm)</td>
<td>Tillage system</td>
<td>1.57</td>
<td>3.33</td>
<td>5.64</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sowing method</td>
<td>2.71</td>
<td>6.94</td>
<td>16.69</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Tillage x sowing</td>
<td>1.18</td>
<td>2.35</td>
<td>3.37</td>
<td></td>
</tr>
<tr>
<td>Fresh weight (gm)</td>
<td>Tillage system</td>
<td>0.69</td>
<td>3.33</td>
<td>5.64</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sowing method</td>
<td>1.62</td>
<td>6.94</td>
<td>16.69</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Tillage x sowing</td>
<td>0.89</td>
<td>2.35</td>
<td>3.37</td>
<td></td>
</tr>
<tr>
<td>Dry weight (gm)</td>
<td>Tillage system</td>
<td>1.39</td>
<td>3.33</td>
<td>5.64</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sowing method</td>
<td>1.01</td>
<td>6.94</td>
<td>16.69</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Tillage x sowing</td>
<td>1.39</td>
<td>2.35</td>
<td>3.37</td>
<td></td>
</tr>
<tr>
<td>Population (plants/m²)</td>
<td>Tillage system</td>
<td>0.39</td>
<td>3.33</td>
<td>5.64</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sowing method</td>
<td>2.95</td>
<td>6.94</td>
<td>16.69</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Tillage x sowing</td>
<td>0.29</td>
<td>2.35</td>
<td>3.37</td>
<td></td>
</tr>
<tr>
<td>Grain yield (ton/ha)</td>
<td>Tillage system</td>
<td>0.77</td>
<td>3.33</td>
<td>5.64</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sowing method</td>
<td>1.83</td>
<td>2.94</td>
<td>16.69</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Tillage x sowing</td>
<td>0.76</td>
<td>2.35</td>
<td>3.37</td>
<td></td>
</tr>
</tbody>
</table>

Tillage x sowing = Interaction.
Table (4-8) Analysis of variance result for plant parameters in the second season 2001/2002.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Source of variation</th>
<th>F. calculated</th>
<th>F. tabulated***</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>5%</td>
</tr>
<tr>
<td>Height of plant (cm)</td>
<td>Tillage system</td>
<td>3.10</td>
<td>3.33</td>
</tr>
<tr>
<td></td>
<td>Sowing method</td>
<td>2.00</td>
<td>6.94</td>
</tr>
<tr>
<td></td>
<td>Tillage x sowing</td>
<td>0.79</td>
<td>2.35</td>
</tr>
<tr>
<td>Fresh weight (gm)</td>
<td>Tillage system</td>
<td>1.67</td>
<td>3.33</td>
</tr>
<tr>
<td></td>
<td>Sowing method</td>
<td>0.58</td>
<td>6.94</td>
</tr>
<tr>
<td></td>
<td>Tillage x sowing</td>
<td>0.88</td>
<td>2.35</td>
</tr>
<tr>
<td>Dry weight (gm)</td>
<td>Tillage system</td>
<td>0.48</td>
<td>3.33</td>
</tr>
<tr>
<td></td>
<td>Sowing method</td>
<td>2.25</td>
<td>6.94</td>
</tr>
<tr>
<td></td>
<td>Tillage x sowing</td>
<td>0.74</td>
<td>2.35</td>
</tr>
<tr>
<td>Final Population (plants/m2)</td>
<td>Tillage system</td>
<td>5.22*</td>
<td>3.33</td>
</tr>
<tr>
<td></td>
<td>Sowing method</td>
<td>56.47**</td>
<td>6.94</td>
</tr>
<tr>
<td></td>
<td>Tillage x sowing</td>
<td>1.61</td>
<td>2.35</td>
</tr>
<tr>
<td>Grain yield (ton/ha)</td>
<td>Tillage system</td>
<td>0.65</td>
<td>3.33</td>
</tr>
<tr>
<td></td>
<td>Sowing method</td>
<td>0.21</td>
<td>2.94</td>
</tr>
<tr>
<td></td>
<td>Tillage x sowing</td>
<td>0.20</td>
<td>2.35</td>
</tr>
<tr>
<td>Total Biomass (ton/ha)</td>
<td>Tillage system</td>
<td>4.34*</td>
<td>3.33</td>
</tr>
<tr>
<td></td>
<td>Sowing method</td>
<td>1.19</td>
<td>2.94</td>
</tr>
<tr>
<td></td>
<td>Tillage x sowing</td>
<td>0.63</td>
<td>2.35</td>
</tr>
<tr>
<td>Harvest index (%)</td>
<td>Tillage system</td>
<td>0.60</td>
<td>3.33</td>
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<td></td>
<td>Sowing method</td>
<td>11.30*</td>
<td>2.94</td>
</tr>
<tr>
<td></td>
<td>Tillage x sowing</td>
<td>0.27</td>
<td>2.35</td>
</tr>
</tbody>
</table>

* = significant  
Tillage x sowing = Interaction.
** = highly significant.  *** F.tabulated: Source = Thomas and Jackson Hills (1978).
Table (4.10): Duncan’s multiple range test for the effect of tillage sys. and sowing methods on fresh weight gm.

First Season.

<table>
<thead>
<tr>
<th>Type of tillage</th>
<th>A</th>
<th></th>
<th>B</th>
<th></th>
<th>C</th>
<th></th>
<th>Overall mean</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Gm/m²</td>
<td>Gm/plant</td>
<td>Gm/m²</td>
<td>Gm/plant</td>
<td>Gm/m²</td>
<td>Gm/plant</td>
<td>Gm/m²</td>
<td>Gm/plant</td>
</tr>
<tr>
<td>1 (DP)</td>
<td>4997.9</td>
<td>12.26a</td>
<td>3527.4</td>
<td>8.93a</td>
<td>3487.95</td>
<td>10.11a</td>
<td>3995.1</td>
<td>10.44a</td>
</tr>
<tr>
<td>2 (MP)</td>
<td>3922.8</td>
<td>9.23a</td>
<td>3714.4</td>
<td>8.83a</td>
<td>3255.6</td>
<td>8.53a</td>
<td>3628.8</td>
<td>8.87a</td>
</tr>
<tr>
<td>3 (CP)</td>
<td>4427.8</td>
<td>10.73a</td>
<td>3768.5</td>
<td>9.63a</td>
<td>3590.0</td>
<td>10.00a</td>
<td>3923.2</td>
<td>10.12a</td>
</tr>
<tr>
<td>4 (HDH)</td>
<td>3115.7</td>
<td>8.86a</td>
<td>3881.97</td>
<td>9.00a</td>
<td>3500.9</td>
<td>10.43a</td>
<td>3516.4</td>
<td>9.43a</td>
</tr>
<tr>
<td>5 (LDH)</td>
<td>4051.4</td>
<td>9.93a</td>
<td>4753.3</td>
<td>11.50a</td>
<td>3611.2</td>
<td>10.23a</td>
<td>4133.6</td>
<td>10.56a</td>
</tr>
<tr>
<td>6 Zero tillage</td>
<td>4352.5</td>
<td>9.96a</td>
<td>3446.7</td>
<td>8.20a</td>
<td>3223.2</td>
<td>9.66a</td>
<td>3684.2</td>
<td>9.28a</td>
</tr>
</tbody>
</table>

Overall mean 4139.2 | 10.17a | 3852.2 | 9.35a | 3454.2 | 9.83a |

Gm /m² = From Appendix E (Table E.2) and (Table 4.12) First season.

Type of tillage
1 = Disc plowing + Disc Harrowing + Leveling
2 = Moldboard plowing + Disc Harrowing + Leveling
3 = Chisel plowing + Disc Harrowing + Leveling
4. Heavy disc harrowing + Leveling
5 = Light disc harrowing + Leveling
6 = Zero tillage.
Sowing methods

A = Manual broadcasting + **cultivating**

B = Manual broadcasting + Light disc harrowing

C = Seed drill
Table (4.10): second season.

<table>
<thead>
<tr>
<th>Type of tillage</th>
<th>A ( \text{gm/m}^2 )</th>
<th>A ( \text{Gm/plant} )</th>
<th>B ( \text{gm/m}^2 )</th>
<th>B ( \text{Gm/plant} )</th>
<th>C ( \text{gm/m}^2 )</th>
<th>C ( \text{Gm/plant} )</th>
<th>Overall mean ( \text{gm/m}^2 )</th>
<th>Overall mean ( \text{Gm/plant} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (DP)</td>
<td>4355.7</td>
<td>8.26a</td>
<td>3840.6</td>
<td>9.13a</td>
<td>3131.96</td>
<td>8.66a</td>
<td>3793.7</td>
<td>8.69ab</td>
</tr>
<tr>
<td>2 (MP)</td>
<td>3930.4</td>
<td>8.96a</td>
<td>3291.9</td>
<td>8.61a</td>
<td>2874.7</td>
<td>8.90a</td>
<td>3363.3</td>
<td>8.82ab</td>
</tr>
<tr>
<td>3 (CP)</td>
<td>4255.7</td>
<td>8.35a</td>
<td>2994.1</td>
<td>7.90a</td>
<td>3315.1</td>
<td>8.40a</td>
<td>3516.4</td>
<td>8.22b</td>
</tr>
<tr>
<td>4 (HDH)</td>
<td>4188.9</td>
<td>9.22a</td>
<td>3855.9</td>
<td>9.60a</td>
<td>3136.8</td>
<td>8.35a</td>
<td>3719.7</td>
<td>9.06a</td>
</tr>
<tr>
<td>5 (LDH)</td>
<td>3466.4</td>
<td>8.15a</td>
<td>3743.7</td>
<td>8.47a</td>
<td>2811.9</td>
<td>8.88a</td>
<td>3354.7</td>
<td>8.50ab</td>
</tr>
<tr>
<td>6 Zero tillage</td>
<td>4046.8</td>
<td>8.58a</td>
<td>3247.97</td>
<td>8.70a</td>
<td>3418.6</td>
<td>9.06a</td>
<td>3577.3</td>
<td>8.78ab</td>
</tr>
<tr>
<td>Overall mean</td>
<td>4047.4</td>
<td>8.59a</td>
<td>3490.5</td>
<td>8.73a</td>
<td>3119.7</td>
<td>8.71a</td>
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<td></td>
</tr>
</tbody>
</table>

\( \text{Gm/m}^2 \) = From Appendix E (Table E.2) and Table 4.12) Second season.

Type of tillage
1 = Disc plowing + Disc Harrowing + Leveling
2 = Moldboard plowing + Disc Harrowing + Leveling
3 = Chisel plowing + Disc Harrowing + Leveling
4 = Heavy disc harrowing + Leveling
5 = Light disc harrowing + Leveling.
6 = Zero tillage.
Sowing methods

A = Manual broadcasting + cultivating

B = Manual broadcasting + Light disc harrowing

C = Seed drill
Table (4.11): Duncan’s multiple range tests for the effect of tillage systems and sowing method on dry weight (gm)/plant and (gm /m²).

First Season.

<table>
<thead>
<tr>
<th>Type of tillage</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>Overall mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Gm/m²</td>
<td>Gm/plant</td>
<td>Gm/m²</td>
<td>Gm/plant</td>
</tr>
<tr>
<td>1 (DP)</td>
<td>1907.8</td>
<td>4.68a</td>
<td>1323.3</td>
<td>3.35a</td>
</tr>
<tr>
<td>2 (MP)</td>
<td>1423.8</td>
<td>3.35a</td>
<td>1388.2</td>
<td>3.30a</td>
</tr>
<tr>
<td>3 (CP)</td>
<td>1485.6</td>
<td>3.60a</td>
<td>1354.0</td>
<td>3.46a</td>
</tr>
<tr>
<td>4 (HDH)</td>
<td>1160.5</td>
<td>3.30a</td>
<td>1371.6</td>
<td>3.18a</td>
</tr>
<tr>
<td>5 (LDH)</td>
<td>1574.9</td>
<td>3.86a</td>
<td>1810.4</td>
<td>4.38a</td>
</tr>
<tr>
<td>6 Zero tillage</td>
<td>1630.0</td>
<td>3.73a</td>
<td>1315.6</td>
<td>3.13a</td>
</tr>
<tr>
<td>Overall mean</td>
<td>1526.3</td>
<td>3.75a</td>
<td>1425.5</td>
<td>3.46a</td>
</tr>
</tbody>
</table>

Gm /m² = From Appendix E (Table E.3) and (Table 4.12) First season.

Type of tillage
1 = Disc plowing + Disc Harrowing + Leveling
2 = Moldboard plowing + Disc Harrowing + Leveling
3 = Chisel plowing + Disc Harrowing + Leveling
4 = Heavy disc harrowing + Leveling
5 = Light disc harrowing + Leveling
6 = Zero tillage.
Sowing methods

A = Manual broadcasting + cultivating

B = Manual broadcasting + Light disc harrowing

C = Seed drill
Table (4.11): second season.

<table>
<thead>
<tr>
<th>Type of tillage</th>
<th>Sowing methods A</th>
<th>Sowing methods B</th>
<th>Sowing methods C</th>
<th>Overall mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>gm/m²</td>
<td>Gm/plant</td>
<td>Gm/m²</td>
<td>Gm/plant</td>
</tr>
<tr>
<td>1 (DP)</td>
<td>1666.4</td>
<td>3.16a</td>
<td>1526.99</td>
<td>3.63a</td>
</tr>
<tr>
<td>2 (MP)</td>
<td>1517.8</td>
<td>3.46a</td>
<td>1322.9</td>
<td>3.46a</td>
</tr>
<tr>
<td>3 (CP)</td>
<td>1697.2</td>
<td>3.33a</td>
<td>1140.8</td>
<td>3.01a</td>
</tr>
<tr>
<td>4 (HDH)</td>
<td>1508.4</td>
<td>3.32a</td>
<td>1498.2</td>
<td>3.73a</td>
</tr>
<tr>
<td>5 (LDH)</td>
<td>1318.5</td>
<td>3.10a</td>
<td>1440.9</td>
<td>3.26a</td>
</tr>
<tr>
<td>6 Zero tillage</td>
<td>1570.6</td>
<td>3.33a</td>
<td>1194.7</td>
<td>3.20a</td>
</tr>
<tr>
<td>Overall mean</td>
<td>1545.4</td>
<td>3.28a</td>
<td>1351.4</td>
<td>3.38a</td>
</tr>
</tbody>
</table>

Gm/m² = From Appendix E (Table E.3) and (Table 4.12) Second season.

Type of tillage
1 = Disc plowing + Disc Harrowing + Leveling
2 = Moldboard plowing + Disc Harrowing + Leveling
3 = Chisel plowing + Disc Harrowing + Leveling
4 = Heavy disc harrowing + Leveling
5 = Light disc harrowing + Leveling
6 = Zero tillage.
Sowing methods

A = Manual broadcasting + cultivating

B = Manual broadcasting + Light disc harrowing

C = Seed drill
Table (4.16): Mean plant parameters measurement data for the first season.

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Plant height (cm)</th>
<th>Fresh weight (gm)</th>
<th>Dry weight (gm)</th>
<th>Final plant population (plants /m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tillage Sys..</td>
<td>Sowing Method</td>
<td>Sowing Method</td>
<td>Sowing Method</td>
<td>Sowing Method</td>
</tr>
<tr>
<td>1 (DP)</td>
<td>A 94.7 B 95.7 C 92.3</td>
<td>A 12.3 B 8.9 C 10.1</td>
<td>A 4.68 B 3.35 C 3.87</td>
<td>A 408 B 395 C 346</td>
</tr>
<tr>
<td>2 (MP)</td>
<td>A 95.5 B 89.3 C 92.2</td>
<td>A 9.2 B 8.8 C 8.5</td>
<td>A 3.35 B 3.3 C 2.8</td>
<td>A 425 B 421 C 382</td>
</tr>
<tr>
<td>3 (CP)</td>
<td>A 89 B 90.2 C 90.3</td>
<td>A 10.7 B 9.6 C 10</td>
<td>A 3.6 B 3.47 C 3.57</td>
<td>A 413 B 392 C 359</td>
</tr>
<tr>
<td>4 (HDH)</td>
<td>A 88.7 B 88.8 C 85</td>
<td>A 8.9 B 9.7 C 10.4</td>
<td>A 3.3 B 3.18 C 3.9</td>
<td>A 352 B 432 C 336</td>
</tr>
<tr>
<td>5 (LDH)</td>
<td>A 91.2 B 94 C 83.8</td>
<td>A 9.9 B 11.5 C 10.2</td>
<td>A 3.87 B 4.38 C 3.57</td>
<td>A 408 B 414 C 357</td>
</tr>
<tr>
<td>6 Zero tillage</td>
<td>A 87.5 B 91.3 C 92</td>
<td>A 9.97 B 8.2 C 9.7</td>
<td>A 3.37 B 3.13 C 3.67</td>
<td>A 437 B 421 C 334</td>
</tr>
</tbody>
</table>

Type of tillage
1 = Disc plowing + Disc Harrowing + Leveling
2 = Moldboard plowing + Disc Harrowing + Leveling
3 = Chisel plowing + Disc Harrowing + Leveling
4 = Heavy disc harrowing + Leveling
5 = Light disc harrowing + Leveling
6 = Zero tillage.
Sowing methods

**A = Manual broadcasting + cultivating**

**B = Manual broadcasting + Light disc harrowing**

C = Seed drill
Table (4-16): Mean plant parameters measurement data for the second season

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Plant height (cm)</th>
<th>Fresh weight (gm)</th>
<th>Dry weight (gm)</th>
<th>Final plant population (plants /m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (DP)</td>
<td>97</td>
<td>98</td>
<td>95</td>
<td>8.3</td>
</tr>
<tr>
<td>2 (MP)</td>
<td>95</td>
<td>96</td>
<td>95</td>
<td>9.0</td>
</tr>
<tr>
<td>3 (CP)</td>
<td>97</td>
<td>100</td>
<td>95</td>
<td>8.3</td>
</tr>
<tr>
<td>4 (HDH)</td>
<td>99</td>
<td>97</td>
<td>97</td>
<td>9.2</td>
</tr>
<tr>
<td>5 (LDH)</td>
<td>94</td>
<td>97</td>
<td>95</td>
<td>8.2</td>
</tr>
<tr>
<td>6 Zero tillage</td>
<td>97</td>
<td>95</td>
<td>96</td>
<td>8.6</td>
</tr>
</tbody>
</table>

Type of tillage
1 = Disc plowing + Disc Harrowing + Leveling
2 = Moldboard plowing + Disc Harrowing + Leveling
3 = Chisel plowing + Disc Harrowing + Leveling
4 = Heavy disc harrowing + Leveling
5 = Light disc harrowing + Leveling
6 = Zero tillage.

Sowing methods
A = Manual broadcasting + cultivating

B = Manual broadcasting + Light disc harrowing

C = Seed drill
Table (4.17): Mean Crop parameters measurement data for the two seasons.

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Season One</th>
<th>Season Two</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Grain yield (ton/ha)</td>
<td>Grain yield (ton/ha)</td>
</tr>
<tr>
<td>Tillage sys.</td>
<td>Sowing Method</td>
<td></td>
</tr>
<tr>
<td></td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>1 (DP)</td>
<td>4.07</td>
<td>4.38</td>
</tr>
<tr>
<td>2 (MP)</td>
<td>4.07</td>
<td>3.69</td>
</tr>
<tr>
<td>3 (CP)</td>
<td>4.05</td>
<td>3.90</td>
</tr>
<tr>
<td>4 (HDH)</td>
<td>4.12</td>
<td>3.91</td>
</tr>
<tr>
<td>5 (LDH)</td>
<td>3.85</td>
<td>4.43</td>
</tr>
<tr>
<td>6 Zero tillage</td>
<td>3.05</td>
<td>3.69</td>
</tr>
</tbody>
</table>

Harvest index = Total Grain Weight x 100 / Total Biomass

Type of tillage
1 = Disc plowing + Disc Harrowing + Leveling
2 = Moldboard plowing + Disc Harrowing + Leveling
3 = Chisel plowing + Disc Harrowing + Leveling
4 = Heavy disc harrowing + Leveling
5 = Light disc harrowing + Leveling
6 = Zero tillage.

Sowing methods
A = Manual broadcasting + cultivating

B = Manual broadcasting + Light disc harrowing

C = Seed drill
Table (4.18): Result of the calculated costs (SD/hr) and SD/ha of different field implements used

<table>
<thead>
<tr>
<th>Implements</th>
<th>Total Costs SD / hr</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fixed cost</td>
</tr>
<tr>
<td>Disc plow (DP)</td>
<td>709.33</td>
</tr>
<tr>
<td><strong>Moldboard plow MP</strong></td>
<td>725.33</td>
</tr>
<tr>
<td>Chisel plow (CP)</td>
<td>725.33</td>
</tr>
<tr>
<td>Heavy D. harrowing</td>
<td>1045.33</td>
</tr>
<tr>
<td>Light D. harrowing</td>
<td>725.33</td>
</tr>
<tr>
<td>Levelling</td>
<td>661.33</td>
</tr>
<tr>
<td>Cultivating (CU)</td>
<td>725.33</td>
</tr>
<tr>
<td>Seed drilling (SD)</td>
<td>789.33</td>
</tr>
</tbody>
</table>
Table (4.19): Result of the calculated Total costs (SD/hr) and SD/ha) for each tillage system and sowing method sed.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Operations</th>
<th>Grain yield ton/ha</th>
<th>Total costs of treatments</th>
<th>Cost in SD/ton</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>SD/ha</td>
<td>SD/fed</td>
</tr>
<tr>
<td>1</td>
<td>Disc plow + disc harrowing + leveling</td>
<td>3.40</td>
<td>12777.8</td>
<td>5324.1</td>
</tr>
<tr>
<td>2</td>
<td>Moldboard plow + disc harrowing + leveling</td>
<td>3.37</td>
<td>12068.7</td>
<td>5028.6</td>
</tr>
<tr>
<td>3</td>
<td>Chisel plow + disc harrowing + leveling</td>
<td>3.38</td>
<td>9314.1</td>
<td>3080.9</td>
</tr>
<tr>
<td>4</td>
<td>Heavy disc harrowing + leveling</td>
<td>3.61</td>
<td>9723.77</td>
<td>4051.6</td>
</tr>
<tr>
<td>5</td>
<td>Light disc harrowing + leveling</td>
<td>3.35</td>
<td>5641.3</td>
<td>2350.5</td>
</tr>
<tr>
<td>A</td>
<td>Manual broadcasting + cultivating</td>
<td>3.49</td>
<td>3652.2</td>
<td>1512.75</td>
</tr>
<tr>
<td>B</td>
<td>Manual broadcasting + light disc harrowing</td>
<td>3.51</td>
<td>3207.5</td>
<td>1336.46</td>
</tr>
<tr>
<td>C</td>
<td>Seed drilling machine</td>
<td>3.42</td>
<td>2740.93</td>
<td>1142.05</td>
</tr>
</tbody>
</table>
Table (4.20): Interaction effect of tillage systems and sowing methods on calculated total costs in (SD/ha), (SD/hr) and (SD/ton).

<table>
<thead>
<tr>
<th>Tillage system</th>
<th>Sowing method</th>
<th>A</th>
<th>A</th>
<th>B</th>
<th>B</th>
<th>C</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>SD/hr</td>
<td>SD/hr</td>
<td>SD/hr</td>
<td>SD/hr</td>
<td>SD/hr</td>
<td>SD/hr</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td>16430</td>
<td>7104.44</td>
<td>4804.68</td>
<td>15985.3</td>
<td>7364.16</td>
<td>4672.02</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>15720.9</td>
<td>7191.35</td>
<td>4627.68</td>
<td>15276.2</td>
<td>7451.07</td>
<td>4495.02</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>12966.3</td>
<td>7191.35</td>
<td>3802.18</td>
<td>12521.6</td>
<td>7451.07</td>
<td>3669.52</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>13375.97</td>
<td>5924.32</td>
<td>3740.08</td>
<td>12931.27</td>
<td>6184.04</td>
<td>3607.42</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td>9293.5</td>
<td>5391.67</td>
<td>2730.48</td>
<td>8848.8</td>
<td>5651.39</td>
<td>2597.82</td>
</tr>
<tr>
<td>6</td>
<td></td>
<td>3652.2</td>
<td>2081.78</td>
<td>1046.48</td>
<td>3207.5</td>
<td>2341.5</td>
<td>913.82</td>
</tr>
</tbody>
</table>

Tillage systems:
1 = Disc plowing + Disc Harrowing + Leveling
2 = Moldboard plowing + Disc Harrowing + Leveling
3 = Chisel plowing + Disc Harrowing + Leveling
4 = Heavy disc harrowing + Leveling
5 = Light disc harrowing + Leveling
6 = Zero tillage.

Sowing methods
A = Manual broadcasting + cultivating

B = Manual broadcasting + Light disc harrowing

C = Seed drill
Table (4-21): Comparison between the calculated and actual total costs of land preparation

<table>
<thead>
<tr>
<th>Tillage systems</th>
<th>Land preparation total costs SD/ha</th>
<th>Difference in percentage on actual cost basis</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Actual costs</td>
<td>calculated costs</td>
</tr>
<tr>
<td>1. (DP) + disc harrowing and leveling</td>
<td>13470</td>
<td>12777.8</td>
</tr>
<tr>
<td>2. (MP) + disc harrowing and leveling</td>
<td>12525</td>
<td>12068.7</td>
</tr>
<tr>
<td>3. (CP) + disc harrowing and leveling</td>
<td>8430</td>
<td>9314.1</td>
</tr>
<tr>
<td>4. (HDH) plus only leveling</td>
<td>8268</td>
<td>9723.77</td>
</tr>
<tr>
<td>5. (LDH) plus only leveling</td>
<td>3915</td>
<td>5641.3</td>
</tr>
</tbody>
</table>

1. DP = Disc plowing
2. MP = Moldboard plowing
3. CP = Chisel plow
4. HDH = Heavy disc harrow
5. LDH = Light disc harrow
Table (4-22) comparison between the calculated and actual total costs of sowing methods.

<table>
<thead>
<tr>
<th>Sowing methods</th>
<th>Total swing cost SD/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Actual costs</td>
</tr>
<tr>
<td>A. manual broadcasting + (MR)</td>
<td>2400</td>
</tr>
<tr>
<td>B. manual broadcasting + (LDH)</td>
<td>2115</td>
</tr>
<tr>
<td>C. seed drilling machine (DS)</td>
<td>2400</td>
</tr>
</tbody>
</table>

MR = Modified ridger.

LDH = Light disc harrow.

Table (2.1): The soil conditions and their effects on machine performance.

<table>
<thead>
<tr>
<th>Condition of soil</th>
<th>Usable drawbar hp as a percentage of maximum P.T.O horse power</th>
<th>Ratio of max. P.T.O hp to useable drawbar hp.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Firm</td>
<td>67%</td>
<td>1.5</td>
</tr>
<tr>
<td>Tilled</td>
<td>56%</td>
<td>1.8</td>
</tr>
<tr>
<td>Soft or sandy</td>
<td>48%</td>
<td>2.1</td>
</tr>
</tbody>
</table>
Table (2.2): The annual cost of spares and repairs as percentage of purchase price at various levels of use of farm machinery.

<table>
<thead>
<tr>
<th>Approx. annual use (hours)</th>
<th>Additional use</th>
<th>500</th>
<th>750</th>
<th>1000</th>
<th>1500</th>
<th>100 hrs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tractors</td>
<td></td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td>5</td>
<td>6.7</td>
<td>8</td>
<td>10.5</td>
<td></td>
<td></td>
<td>0.5</td>
</tr>
<tr>
<td>Other machines and implements</td>
<td></td>
<td>50</td>
<td>100</td>
<td>150</td>
<td>200</td>
<td>Per 100 hrs</td>
</tr>
<tr>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td>Combines and P.T.O driven thresher</td>
<td>1.5</td>
<td>2.5</td>
<td>3.5</td>
<td>4.5</td>
<td>2.0</td>
<td></td>
</tr>
<tr>
<td>Pick up baler, potato harvester</td>
<td>3.0</td>
<td>5.0</td>
<td>6.0</td>
<td>7.0</td>
<td>2.0</td>
<td></td>
</tr>
<tr>
<td>sugar cane harvester Group 1 normal ploughs, cultivator, tooth harrow, hoes, elevators, potato diggers</td>
<td>4.5</td>
<td>8</td>
<td>11</td>
<td>14</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Group 2 rotary cultivators, mowers, binders, pea cutters</td>
<td>4</td>
<td>7</td>
<td>9.5</td>
<td>12</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Group 3 disc harrow fertilizers combine drill, spreaders, sprayers</td>
<td>3</td>
<td>5.5</td>
<td>7.5</td>
<td>9.5</td>
<td>4.0</td>
<td></td>
</tr>
<tr>
<td>Group 4 swath turners side delivery rakes, forage harvesters semi-automatic potato planter trans planter</td>
<td>2.5</td>
<td>4.5</td>
<td>6.5</td>
<td>8.5</td>
<td>4.0</td>
<td></td>
</tr>
<tr>
<td>Group 5 corn drill, milking machines, hydraulic loaders, simple potato planting attachments</td>
<td>2.0</td>
<td>4.0</td>
<td>5.5</td>
<td>7.0</td>
<td>3.0</td>
<td></td>
</tr>
<tr>
<td>Group 6 grain dryers and cleaners</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: (Culpin, 1981).
Table (4.3): Duncan’s multiple range test for soil moisture content % as affected by tillage systems in the first season at any irrigation.

Table (4.3): First irrigation (First Season)

<table>
<thead>
<tr>
<th>Depth cm Tillage</th>
<th>0 – 20 cm</th>
<th>20 – 40 cm</th>
<th>40 – 60 cm</th>
<th>60 – 80 cm</th>
<th>80 – 100 cm</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (DP)</td>
<td>1.14a</td>
<td>1.34a</td>
<td>2.19ab</td>
<td>1.21a</td>
<td>1.15a</td>
<td>1.41a</td>
</tr>
<tr>
<td>2 (MP)</td>
<td>1.14a</td>
<td>1.25a</td>
<td>2.18ab</td>
<td>1.19a</td>
<td>1.13a</td>
<td>1.38a</td>
</tr>
<tr>
<td>3 (CP)</td>
<td>1.15a</td>
<td>1.25a</td>
<td>2.22a</td>
<td>1.17a</td>
<td>1.15a</td>
<td>1.38a</td>
</tr>
<tr>
<td>4 (HDH)</td>
<td>1.13a</td>
<td>1.36a</td>
<td>2.16b</td>
<td>1.15a</td>
<td>1.14a</td>
<td>1.38a</td>
</tr>
<tr>
<td>5 (LDH)</td>
<td>1.14a</td>
<td>1.34a</td>
<td>2.16b</td>
<td>1.19a</td>
<td>1.14a</td>
<td>1.39a</td>
</tr>
<tr>
<td>6 zero tillage</td>
<td>1.18a</td>
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Table (4.3): Second irrigation (first season)

<table>
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<th>Depth cm Tillage</th>
<th>0 – 20</th>
<th>20 - 40</th>
<th>40 - 60</th>
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<th>80 - 100</th>
<th>Overall</th>
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<td>12.23a</td>
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<td>6.60a</td>
<td>8.56a</td>
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<td>8.58a</td>
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<td>12.18a</td>
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Table (4.3): Third irrigation (first season)

<table>
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<th>40 - 60</th>
<th>60 - 80</th>
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<th>Overall</th>
</tr>
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<td>9.05a</td>
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<td>8.92a</td>
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<td>8.91a</td>
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<tr>
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<td>12.43a</td>
<td>8.79a</td>
<td>7.34a</td>
<td>9.19a</td>
</tr>
</tbody>
</table>

Figures that share the same letter are not significantly different.

* Type of tillage

1 = Disc plowing + Disc Harrowing + Leveling
2 = Moldboard plowing + Disc Harrowing + Leveling
3 = Chisel plowing + Disc Harrowing + Leveling
4 = Heavy disc harrowing + Leveling
5 = Light disc plowing + Leveling
6 = Zero tillage.
Table (4.3): Fourth irrigation (first season)

<table>
<thead>
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<th>Depth cm</th>
<th>0 – 20 cm</th>
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<th>60 – 80 cm</th>
<th>80 – 100 cm</th>
<th>Overall</th>
</tr>
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<td>9.38a</td>
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<td>12.89a</td>
<td>8.65b</td>
<td>7.71a</td>
<td>9.52a</td>
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<td>12.47a</td>
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<td>7.33a</td>
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<td>7.56a</td>
<td>9.60a</td>
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<td>12.45a</td>
<td>9.45a</td>
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<td>9.77a</td>
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Table (4.3): Fifth irrigation (first season)

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<th>80 - 100</th>
<th>Overall</th>
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<td>13.19a</td>
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<tr>
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<td>10.84a</td>
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<td>10.53a</td>
<td>9.15a</td>
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<tr>
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Table (4.3): Sixth irrigation (first season)

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<th>40 – 60</th>
<th>60 - 80</th>
<th>80 - 100</th>
<th>Overall</th>
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<td>10.31a</td>
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Table (4.3): Seventh irrigation (first season)

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<th>80 - Overall</th>
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<td>9.27a</td>
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<td>10.03a</td>
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<tr>
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<td>9.34a</td>
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<td>9.91a</td>
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<td>cm 2</td>
<td>cm 3</td>
<td>cm 4</td>
<td>cm 5</td>
</tr>
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<td>------</td>
<td>------</td>
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<td>------</td>
<td>------</td>
</tr>
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<td>12.44a</td>
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Tillage Systems: See irrigations before in the first season
Table (4.4): Duncan’s multiple range test for soil moisture content % as affected by tillage systems in the second season at any irrigation.

<table>
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<tr>
<th>Depth cm</th>
<th>0 – 20 cm</th>
<th>20 – 40 cm</th>
<th>40 – 60 cm</th>
<th>60 – 80 cm</th>
<th>80 – 100 cm</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (DP)</td>
<td>0.89a</td>
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<td>1.30a</td>
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<td>1.6a</td>
</tr>
<tr>
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<td>3.15a</td>
<td>1.41a</td>
<td>1.08a</td>
<td>1.7a</td>
</tr>
<tr>
<td>3 (CP)</td>
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<td>2.76a</td>
<td>1.35a</td>
<td>1.28a</td>
<td>1.68a</td>
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<td>2.82a</td>
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<td>1.27a</td>
<td>1.77a</td>
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Figures that share the same letters are not significantly different.

Table (4.4): Second irrigation (second season).

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<th>0 – 20</th>
<th>20 – 40</th>
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<th>60 – 80</th>
<th>80 – 100</th>
<th>Overall</th>
</tr>
</thead>
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<td>6.71a</td>
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<td>12.38a</td>
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<td>6.62a</td>
<td>8.66a</td>
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<td>12.88a</td>
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<td>6.29a</td>
<td>8.58a</td>
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Table (4.4): Third irrigation (second season).

<table>
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<th>40 – 60</th>
<th>60 – 80</th>
<th>80 – 100</th>
<th>Overall</th>
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Table (4.4): Fourth irrigation (second season).
<table>
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<th>60 – 80 cm</th>
<th>80 – 100 cm</th>
<th>Overall</th>
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Tillage Systems See Table (4.3)

Table (4.4): Fifth irrigation (second season).

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<th>60 – 80 cm</th>
<th>80 – 100 cm</th>
<th>Overall</th>
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<td>10.20a</td>
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<tr>
<td>5</td>
<td>7.31a</td>
<td>10.09a</td>
<td>13.07a</td>
<td>10.22a</td>
<td>8.63a</td>
<td>9.86a</td>
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<tr>
<td>6</td>
<td>7.93a</td>
<td>11.51a</td>
<td>13.59a</td>
<td>10.32a</td>
<td>8.43a</td>
<td>10.37a</td>
<td></td>
</tr>
</tbody>
</table>

Figures that share the same letters are not significantly different.

Table (4.4): Sixth irrigation (second season).

<table>
<thead>
<tr>
<th>Depth cm</th>
<th>Tillage</th>
<th>0 – 20 cm</th>
<th>20 – 40 cm</th>
<th>40 - 60</th>
<th>60 – 80</th>
<th>80 - 100</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>8.24a</td>
<td>11.47a</td>
<td>13.62a</td>
<td>11.9a</td>
<td>9.37a</td>
<td>10.76a</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>8.01a</td>
<td>11.39a</td>
<td>13.74a</td>
<td>10.33a</td>
<td>9.65a</td>
<td>10.62a</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>8.21a</td>
<td>11.86a</td>
<td>14.32a</td>
<td>11.27a</td>
<td>9.48a</td>
<td>11.03a</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>8.86a</td>
<td>11.44a</td>
<td>13.72a</td>
<td>11.35a</td>
<td>9.17a</td>
<td>10.91a</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>8.76a</td>
<td>10.22a</td>
<td>13.51a</td>
<td>10.69a</td>
<td>9.28a</td>
<td>10.49a</td>
<td></td>
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<tr>
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<td>8.46a</td>
<td>11.59a</td>
<td>13.87a</td>
<td>10.68a</td>
<td>9.85a</td>
<td>10.89a</td>
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</tr>
</tbody>
</table>

Table (4.4): Seventh irrigation (second season).

<table>
<thead>
<tr>
<th>Depth cm</th>
<th>Tillage</th>
<th>0 – 20</th>
<th>20 – 40</th>
<th>40 - 60</th>
<th>60 – 80</th>
<th>80 - 100</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>9.68ab</td>
<td>11.01a</td>
<td>13.71a</td>
<td>9.49a</td>
<td>8.39b</td>
<td>10.46b</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>11.28a</td>
<td>10.46a</td>
<td>13.78a</td>
<td>12.02a</td>
<td>9.99a</td>
<td>11.51a</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>8.86a</td>
<td>12.30a</td>
<td>14.64a</td>
<td>9.23a</td>
<td>8.96ba</td>
<td>10.80b</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>8.56b</td>
<td>12.10a</td>
<td>14.49a</td>
<td>10.19a</td>
<td>9.55a</td>
<td>10.98a</td>
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</tbody>
</table>
### Table (4.4): Eighth irrigation (second season).

<table>
<thead>
<tr>
<th>Depth cm</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0 – 20</td>
</tr>
<tr>
<td>1</td>
<td>9.85a</td>
</tr>
<tr>
<td>2</td>
<td>9.93a</td>
</tr>
<tr>
<td>3</td>
<td>9.22a</td>
</tr>
<tr>
<td>4</td>
<td>9.11a</td>
</tr>
<tr>
<td>5</td>
<td>9.49a</td>
</tr>
<tr>
<td>6</td>
<td>9.53a</td>
</tr>
</tbody>
</table>

Tillage Systems: See Table (4.3).
Table (4.9): Duncan’s multiple range test for the effect of tillage systems and sowing method on plant height (cm)

**First season.**

<table>
<thead>
<tr>
<th>Type of tillage</th>
<th>Sowing methods</th>
<th>Overall mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>1 (DP)</td>
<td>94.66a</td>
<td>95.66a</td>
</tr>
<tr>
<td>2 (MP)</td>
<td>95.50a</td>
<td>89.33a</td>
</tr>
<tr>
<td>3 (CP)</td>
<td>89.00a</td>
<td>90.16a</td>
</tr>
<tr>
<td>4 (HDH)</td>
<td>88.66a</td>
<td>88.83a</td>
</tr>
<tr>
<td>5 (LDH)</td>
<td>91.16a</td>
<td>94.00a</td>
</tr>
<tr>
<td>6 Zero tillage</td>
<td>87.50a</td>
<td>91.33a</td>
</tr>
<tr>
<td>Overall mean</td>
<td>91.08a</td>
<td>91.55a</td>
</tr>
</tbody>
</table>

**Second season.**

<table>
<thead>
<tr>
<th>Type of tillage</th>
<th>Sowing methods</th>
<th>Overall mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>1 (DP)</td>
<td>97.33a</td>
<td>97.66a</td>
</tr>
<tr>
<td>2 (MP)</td>
<td>95.00a</td>
<td>96.33a</td>
</tr>
<tr>
<td>3 (CP)</td>
<td>97.00a</td>
<td>99.66a</td>
</tr>
<tr>
<td>4 (HDH)</td>
<td>99.33a</td>
<td>97.33a</td>
</tr>
<tr>
<td>5 (LDH)</td>
<td>94.33a</td>
<td>97.33a</td>
</tr>
<tr>
<td>6 Zero tillage</td>
<td>96.66a</td>
<td>95.00a</td>
</tr>
<tr>
<td>Overall mean</td>
<td>96.61a</td>
<td>97.22a</td>
</tr>
</tbody>
</table>

Type of tillage:

1 = Disc plowing + Disc Harrowing + Leveling
2 = Moldboard plowing + Disc Harrowing + Leveling
3 = Chisel plowing + Disc Harrowing + Leveling
4 = Heavy disc harrowing + Leveling
5 = Light disc harrowing + Leveling
6 = Zero tillage.

Sowing methods
A = Manual broadcasting + cultivating

B = Manual broadcasting + Light disc harrowing

C = Seed drill
Table (4.12): Duncan’s multiple range test for the effect of tillage systems and sowing method on population (plants/m²).

First season.

<table>
<thead>
<tr>
<th>Type of tillage</th>
<th>Sowing methods</th>
<th>Overall mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>1 (DP)</td>
<td>407.66a</td>
<td>395.00a</td>
</tr>
<tr>
<td>2 (MP)</td>
<td>425.00a</td>
<td>420.66a</td>
</tr>
<tr>
<td>3 (CP)</td>
<td>412.66a</td>
<td>391.33a</td>
</tr>
<tr>
<td>4 (HDH)</td>
<td>351.66a</td>
<td>431.33a</td>
</tr>
<tr>
<td>5 (LDH)</td>
<td>408.00a</td>
<td>413.33a</td>
</tr>
<tr>
<td>6 Zero tillage</td>
<td>437.00a</td>
<td>420.33a</td>
</tr>
<tr>
<td>Overall mean</td>
<td>407.00a</td>
<td>412.00a</td>
</tr>
</tbody>
</table>

**Legend:**

1 = Disc plowing + Disc Harrowing + Leveling  
2 = Moldboard plowing + Disc Harrowing + Leveling  
3 = Chisel plowing + Disc Harrowing + Leveling  
4 = Heavy disc harrowing + Leveling  
5 = Light disc harrowing + Leveling  
6 = Zero tillage.

A = Manual broadcasting + cultivating  
B = Manual broadcasting + Light disc harrowing  
C = Seed drill

Second season.

<table>
<thead>
<tr>
<th>Type of tillage</th>
<th>Sowing methods</th>
<th>Overall mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>1 (DP)</td>
<td>527.33a</td>
<td>420.66a</td>
</tr>
<tr>
<td>2 (MP)</td>
<td>438.66a</td>
<td>382.33a</td>
</tr>
<tr>
<td>3 (CP)</td>
<td>509.66a</td>
<td>379.00a</td>
</tr>
<tr>
<td>4 (HDH)</td>
<td>454.33a</td>
<td>401.66a</td>
</tr>
<tr>
<td>5 (LDH)</td>
<td>425.33a</td>
<td>442.00a</td>
</tr>
<tr>
<td>6 Zero tillage</td>
<td>471.66a</td>
<td>373.33a</td>
</tr>
<tr>
<td>Overall mean</td>
<td>471.17a</td>
<td>399.83b</td>
</tr>
</tbody>
</table>

1 = Disc plowing + Disc Harrowing + Leveling  
2 = Moldboard plowing + Disc Harrowing + Leveling  
3 = Chisel plowing + Disc Harrowing + Leveling  
4 = Heavy disc harrowing + Leveling  
5 = Light disc harrowing + Leveling  
6 = Zero tillage.
Table (4.13): Duncan’s multiple range test for the effect of tillage systems and sowing method on grain yield (Ton/ha).

**First season.**

<table>
<thead>
<tr>
<th>Type of tillage</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>Overall mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (DP)</td>
<td>4.07a</td>
<td>4.38a</td>
<td>4.04a</td>
<td>4.16a</td>
</tr>
<tr>
<td>2 (MP)</td>
<td>4.07a</td>
<td>3.69a</td>
<td>3.81a</td>
<td>3.85a</td>
</tr>
<tr>
<td>3 (CP)</td>
<td>4.05a</td>
<td>3.90a</td>
<td>4.11a</td>
<td>4.02a</td>
</tr>
<tr>
<td>4 (HDH)</td>
<td>4.12a</td>
<td>3.91a</td>
<td>3.85a</td>
<td>3.96a</td>
</tr>
<tr>
<td>5 (LDH)</td>
<td>3.85a</td>
<td>4.43a</td>
<td>3.45a</td>
<td>3.91a</td>
</tr>
<tr>
<td>6 Zero tillage</td>
<td>3.05a</td>
<td>3.69a</td>
<td>3.34a</td>
<td>3.36a</td>
</tr>
<tr>
<td>Overall mean</td>
<td>3.87a</td>
<td>4.00a</td>
<td>3.76a</td>
<td></td>
</tr>
</tbody>
</table>

1 = Disc plowing + Disc Harrowing + Leveling
2 = Moldboard plowing + Disc Harrowing + Leveling
3 = Chisel plowing + Disc Harrowing + Leveling
4 = Heavy disc harrowing + Leveling
5 = Light disc harrowing + Leveling
6 = Zero tillage.

**Second season.**

<table>
<thead>
<tr>
<th>Type of tillage</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>Overall mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (DP)</td>
<td>3.42a</td>
<td>3.51a</td>
<td>3.27a</td>
<td>3.40a</td>
</tr>
<tr>
<td>2 (MP)</td>
<td>3.41a</td>
<td>3.46a</td>
<td>3.26a</td>
<td>3.37a</td>
</tr>
<tr>
<td>3 (CP)</td>
<td>3.35a</td>
<td>3.51a</td>
<td>3.29a</td>
<td>3.38a</td>
</tr>
<tr>
<td>4 (HDH)</td>
<td>3.71a</td>
<td>3.58a</td>
<td>3.53a</td>
<td>3.61a</td>
</tr>
<tr>
<td>5 (LDH)</td>
<td>3.39a</td>
<td>3.37a</td>
<td>3.31a</td>
<td>3.35a</td>
</tr>
<tr>
<td>6 Zero tillage</td>
<td>3.70a</td>
<td>3.63a</td>
<td>3.47a</td>
<td>3.60a</td>
</tr>
<tr>
<td>Overall mean</td>
<td>3.49a</td>
<td>3.51a</td>
<td>3.36a</td>
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</tbody>
</table>
A = Manual broadcasting + cultivating

B = Manual broadcasting + Light disc harrowing

C = Seed drill
Table (4.14): Duncan’s multiple range test for the effect of tillage systems and sowing method on total biomass (Ton/ha) in the second season.

<table>
<thead>
<tr>
<th>Type of tillage</th>
<th>Sowing methods</th>
<th>Overall mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>1 (DP)</td>
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<td>2 (MP)</td>
<td>7.96a</td>
<td>8.31a</td>
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<td>3 (CP)</td>
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<td>9.03a</td>
</tr>
<tr>
<td>4 (HDH)</td>
<td>9.60a</td>
<td>9.08a</td>
</tr>
<tr>
<td>5 (LDH)</td>
<td>7.76a</td>
<td>8.26a</td>
</tr>
<tr>
<td>6 Zero tillage</td>
<td>9.70a</td>
<td>8.86a</td>
</tr>
<tr>
<td>Overall mean</td>
<td>8.73a</td>
<td>8.74a</td>
</tr>
</tbody>
</table>

1 = Disc plowing + Disc Harrowing + Leveling
2 = Moldboard plowing + Disc Harrowing + Leveling
3 = Chisel plowing + Disc Harrowing + Leveling
4 = Heavy disc harrowing + Leveling
5 = Light disc harrowing + Leveling
6 = Zero tillage.

**A = Manual broadcasting + cultivating**

**B = Manual broadcasting + Light disc harrowing**

C = Seed drill
Table (4.15): Duncan’s multiple range test for the effect of tillage systems and sowing methods on harvest index (%) in the second season.

<table>
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<th>Type of tillage</th>
<th>Sowing methods</th>
<th>Overall mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>1 (DP)</td>
<td>36.84a</td>
<td>39.59a</td>
</tr>
<tr>
<td>2 (MP)</td>
<td>37.19a</td>
<td>38.80a</td>
</tr>
<tr>
<td>3 (CP)</td>
<td>39.32a</td>
<td>38.91a</td>
</tr>
<tr>
<td>4 (HDH)</td>
<td>38.72a</td>
<td>39.49a</td>
</tr>
<tr>
<td>5 (LDH)</td>
<td>37.73a</td>
<td>41.67a</td>
</tr>
<tr>
<td>6 Zero tillage</td>
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<td>40.26a</td>
</tr>
<tr>
<td>Overall mean</td>
<td>37.82b</td>
<td>39.79a</td>
</tr>
</tbody>
</table>

* Type of tillage
1 = Disc plowing + Disc Harrowing + Leveling
2 = Moldboard plowing + Disc Harrowing + Leveling
3 = Chisel plowing + Disc Harrowing + Leveling
4 = Heavy disc harrowing + Leveling
5 = Light disc harrowing + Leveling
6 = Zero tillage.

** Sowing methods
A = Manual broadcasting + cultivating

B = Manual broadcasting + Light disc harrowing

C = Seed drill.

Fig. (4.4): Average accumulative intake (cm) as affected by tillage systems before planting.

Tillage systems and equations:
1. (DP), $I = 2.195t^{-0.47}$
2. (MP), $I = 2.08t^{-0.43}$
3. (CP), $I = 1.796t^{-0.43}$
4. (HDH), $I = 2.291t^{-0.46}$
5. (LDH), $I = 2.489t^{-0.37}$
6* Zero tillage (before plowing), $I = 1.944t^{-0.46}$

Fig. (4.5): Average accumulative intake (cm) as affected by tillage systems at harvest.
Tillage systems and equations:
1. (DP), \( I = 2.15t^{0.5} \)
2. (MP), \( I = 1.855t^{-0.047} \)
3. (CP), \( I = 3.04t^{-0.36} \)
4. (HDH), \( I = 2.537t^{-0.43} \)
5. (LDH), \( I = 1.40t^{0.5} \)
6. Zero tillage (at harvest), \( I = 2.982t^{-0.29} \)
6* Zero tillage (before plowing), \( I = 1.944t^{-0.46} \)

<table>
<thead>
<tr>
<th>Accumulative intake (cm)</th>
<th>Time (min)</th>
<th>Scale 1 ( \equiv ) 10min</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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<table>
<thead>
<tr>
<th>Accumulative intake (cm)</th>
<th>Time (min)</th>
<th>Scale 1 ≡ 10min</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
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</tbody>
</table>
Plate (1): Three disc blades standard disc plow.

Plate (2): Three bottom moldboard plow.
Plate (3): Chisel plow. (with five tools in two rows)

Plate (4): Trailed, heavy off-set disc harrow.
Plate (5): Mounted, light off-set disc harrow.

Plate (6): Four bottom cultivator
Plate (7): Seed drill machine (14 tubes).

Plate (8): Reer blade leveler.