CHAPTER ONE

INTRODUCTION

Introduction

Archaeological evidences reveal that cultivation of sunflower began in Arizona and Mexico about 3000 B.C. (Putt, 1997). In the 18th century, sunflower was introduced in The Soviet Union as an ornamental plant but in 1779 in the proceeding of Russian academy the first suggestion of extracting oil from sunflower seeds was .(recorded (Gundaev, 1971

Sunflower (*Helianthus annuus L*) is a member of the family *Compositae*, the largest family of flowering plants. It is widely grown in the U.S.A., Australia, Turkey and Pakistan (Weiss, 1983). The properties of the soils in the Sudan are suitable for commercial production of sunflower. On other hand, requirements of sunflower to water, temperature and soil, generally indicate the central clay plain as potential sunflower growing areas, such as Damazin, Gadarif and El Rank area which are most favorable for growing sunflower under rainfed conditions in The Sudan (Khidir, 1997). In regions such as in Northern State, where high irrigation water cost or scarcity is the principal limiting factor for cultivation, farmers are interested in growing crops that are able to adapt to deficit irrigation .conditions

Recently sunflower has gained greater importance in the Northern state as a promising alternative crop during summer season. The crop has become an important crop for both farmers and consumers; it fits well in the local cropping system and is considered one of the most important potential cash crops in The Sudan, grown as both winter and summer crop. Sunflower is recognized with high potentials that can successfully meet future oil requirements and puts pressure on the decision makers to take full advantage of the crop, especially in the light of .adaptation of the crop with new production areas

Sunflower oil has an ideal combination of saturated and poly-unsaturated fatty acids, which are important for the reduction of high serum cholesterol levels, and its oil cake contains higher amount of protein (40-44%) and balanced amino acids. Sunflower seed contain high oil content ranging from 35-40% with some varieties yielding up to 50% (Skoric and Marinkovic,1986) and oil contain carbohydrates (18.6%), protein (19.8%) and vitamin E .((0.038%) (Mckevith, 2005

Sunflower can be used for many purposes, for its oil extraction, bird feed and human food. The oil is polyunsaturated and high in energy and hence is an extremely important food source for humans. Sunflower oil is better nutritionally and more stable than soybean oil. Also it is used as a salad oil, for cooking and manufacture of margarine (Heiser, 1976). The seed cake left after the oil is pressed from the seeds, is a rich source of protein and is usually used for feeding livestock. The seed hulls used as fuel and the dried stems of sunflower have also been used for fuel (to start fire) and as a source of commercial fiber. In India and Europe sunflower has .(medical uses (Heiser, 1976

Sunflower is a short duration crop and can be fitted well in our present cropping system without making any major changes in its cultivating system. Planting pattern plays a key role in increasing yield of sunflower (Hussain *et al*., 2001). Planting geometry not only affects plant growth and development by balancing the interplant competition (Malik *et al*., 1992) but also determines the distribution pattern of plants over a field; it directly affects solar energy interception and evaporation and indirectly affects water use efficiency. Narrow row spacing ensures more uniform distribution of plant over a given area and makes a plant canopy more effective in intercepting radiant .(energy and shading weeds (Saeed, 1994

Water resources in the Sudan are limited compared to the arable land and the expected large expansion of the cropped areas. In the latest years, scarcity of rainfall led to the initiation of search in irrigation water economy. So, efficient use of irrigation water seems to be of a vital importance. This situation emphasizes the need for using scientifically sound methods for deciding when and how .much to irrigate

It is well known that the type of adopted land preparation practices directly affects soil structure and consequently .soil moisture retention level

Conservation tillage leaves most or part of the crop residues on the soil surface, thus effecting chemical, biological, and physical properties of soil. Soil temperature, water content, bulk density, porosity penetration resistance and aggregate distribution are some of the physical properties affected by tillage .[systems. [Fabrizzi *et al.*, 2005 and Osunbitan *et al*, 2005

Stone et al., (2001) developed a model to explain the effects of water stress on crop development. The general trend in irrigation research is to optimize the yield by minimizing the damage caused by water stress during the crop development stages (Stone et al., 2001).

Deficit irrigation is a strategy that allows a crop to sustain some degree of water deficit in order to reduce costs and potentially increase income. It can lead to increase net income where water costs are high or where water supplies are limited. In the fact when water is limited, alternative strategies must be sought to reduce irrigation use and to improve its efficiency (FAO, 2002). Among these strategies deficit irrigation is getting particular important during the last decades since its aim to optimize agriculture output while saving water for other purposes .((FAO, 2002

In north state of Sudan last recent economic agriculture indicated that the cost of irrigation is 30.2% in large scheme and 33.1% in small scheme from total productivity .(cost of annul crop (Sidahmed, 2008

The overall objective is to help establishing sunflower as .an alternative crop in northern state

Thus, the main objective of the present work is to study the effect of deficit irrigation regimes combined with land preparation packages on yield of sunflower .To achieves these combination water regimes and land preparation .packages are tested

:The specific Objectives

-1 To estimate the irrigation water savings that can be .affected

-2 To study the effect of four tillage packages on soil .water retention capacity

-3 To study the effects of tillage on soil physical properties

-4 To study the combined effect of tillage packages and three levels of water regimes on plant growth and .yield parameters of the crop

CHAPTER TWO

LITERATURE REVIEW

:Introduction 2.1

Tillage, irrigation and sowing methods are important production factors. Tillage and irrigation together represent the most costly items in irrigated agriculture. They need special management practices in the different .climatic, soil and crop conditions

2.2 Sunflower crop:

The origin of the sunflower is South–West of the United States. It was first introduced in Europe as an ornamental, but was established in Eastern Europe and Russia as an oilseed crop. Russian cultivars had immense impact on sunflower as a commercial crop in Europe and in America. At present, sunflower is considered the second most important oilseed crop, after soybean, in world production. Sunflower is adapted to a wide range of climatic conditions (temperate, subtropical and tropical) and is not sensitive to day length. In the tropics it is grown in rotation with maize, sorghum, groundnut and millet. It is tolerant to heat and drought like sorghum and millet. In temperate countries seed yield exceeds 2000 kg/ha, whereas in tropical Africa is as low as 350 kg/ha. European countries import 85% of the crop entering the world trade, and Asian countries about 15% (Pursglove 1982). Sunflower has a tap root system well branched and extends laterally for several meters and makes good use of available moisture in the upper soil profile (Litzenberger 1978). Sunflower (*Helianthus annuus* L.) is an annual crop. It is the source of one of the most important edible oils on a global scale. There is an increasing interest in sunflower production worldwide due to the crop's adaptability and high oil quality (Škorić *et al*, 1986).

2.3 Sunflower in the Sudan:

Sunflower is a promising oilseed in Sudan. The country's oilseed production rests mainly on sesame (*Sesamum indicum* L.), groundnut (*Arachis hypogaea* L.), and cotton

.(.seed (*Gossypium spp*

Extensive commercial production of sunflower was initiated in Sudan in the late 1980s and the early 1990s with the introduction of hybrids such as Hysun-33 from Australia and PAN-7351 from South Africa (El Ahamdi, .(2003; Nour *et al*., 2005

The production was established mainly in rainfed areas of the country and, to a lesser extent, in irrigated conditions. At about the same time, early maturing accessions of two open-pollinated sunflower varieties, Rodio and Bolereo, were released under the names Damazin-1 and Damazin-2, respectively (Adam *et al*, 1989). Since then, nevertheless, sunflower has failed to expand significantly in the country in total area and seed production, which could .be attributed mainly to production constraints

There are many production constraints that are responsible for the fluctuation in area and productivity. These include frequent dry spells, erratic distribution of rainfall, lack of advanced technologies such as hybrid seeds, poor cultural practices, problems with empty seeds, low use of fertilizers, and faulty policies on funding, .processing and marketing

Development of the first sunflower hybrid based on cytoplasmic male sterility in the early 1970s intensified the interest of farmers in growing this crop (Miller, 1999). Thus, the development of sunflower hybrids for Sudanese conditions is an important step towards narrowing down the gap between supply and demand in the seed market and boosting sunflower production and productivity in the country. This will also cut down the time and resources being spent on importations from abroad. Sunflower hybrid seed produced locally is likely to be adopted by the majority of sunflower growers, since the seed source is readily available. Although experimentation of sunflower in Sudan started as early as the 1940s, real concern with it in commercial production started late mainly as rainfed crop. The cultivated area in 1990-1991 reached 293000 feddans mainly in the rainfed area with average yield of 99 .(kg/feddan (appendix 1.1

After the exclusion of castor as a cash crop from the Gash delta in 1987, sunflower was suggested among other cash crops for the Gash delta. It was expected to have a good chance of adaptation in the flood irrigation system because of its well branched tap root system, wide ecological adaptation, and tolerance to .(drought(Dawelbeit, 2012

:Crop water requirement 2.4

Crop water requirement (ET_C) is defined as the depth of water needed to meet the water loss through evapotranspiration of a disease free crop growing in large fields under non-restricting soil conditions, including soil water and fertility and achieving full production potential under the given growing environment (FAO, 2005). Broner and Schneekloth (2003) reported that water requirements of crops depend mainly on environmental conditions. Plants use water for cooling purposes and the driving force of this process is prevailing weather conditions. Different crops have different water use requirements, under the .same weather conditions

The primary objective of irrigation is to apply water to maintain crop evapotranspiration (ET_a) when precipitation is insufficient. The finite total amount of available water is crucial for the economy, health and welfare of a very large part of the developing world. Hess (2005) defined crop water requirements as the total water needed for evapotranspiration, from planting to harvest for a given crop in a specific climate regime, when adequate soil water is maintained by rainfall and/or irrigation so that it does not limit plant growth and crop yield. FAO (2005) :defined crop water requirement (CWR) for a given crop as

$$CWR=\sum_{i=1}^{T} kc\,.\,ETo-P_{eff}$$

-:Where

kc is the crop coefficient of the given crop during the growth stage i

.T is the final growth stage

Each crop has its own water requirements. Net irrigation water requirements (NIWR) in a specific scheme for a given year are thus the sum of individual crop water requirements (CWRi) calculated for each irrigated crop i. Multiple cropping (several cropping periods per year) is thus automatically taken into account by separately computing crop water requirements for each cropping period. Dividing by the area of the scheme (S. in ha), a value for irrigation water requirements is obtained and can be expressed in mm or in m^3/ha (1 mm = 10 m^3/ha). FAO (1992), Smith et al. (1991) and Smith (1992) reported that CROPWAT is meant as a practical tool to help agrometeorologists, agronomists and irrigation engineers to carry out standard calculations for evapotranspiration and crop water use studies, and more specifically the design and management of irrigation schemes. It allows the development of recommendations for improved irrigation practices, the planning of irrigation schedules under varying water supply conditions, and the assessment of production under rainfed conditions or .deficit irrigation

Methods to calculate crop water 2.5 :requirement

Direct measurement of crop 2.5.1 evapotranspiration

:Direct measurement methods for ETc include

aerodynamic method •

detailed soil moisture monitoring •

lysimetry •

plant porometers •

regional inflow-outflow measurements •

All these methods require localized and detailed measurements of plant water use. Detailed soil moisture monitoring in controlled and self-contained devices .(lysimeters) is probably the most commonly used

Little long-term historical data outside of a few ARS and university research stations are available. Use of lysimetry is discussed in more detail. The use of soil moisture ,monitoring devices to monitor crop ET is described in NEH

Estimated crop water requirement ETc 2.5.2

More than 20 methods have been developed to estimate the rate of crop ET based on local climate factors. The simplest methods are equations that generally use only mean air temperature. The more complex methods are described as energy equations. They require real time measurements of solar radiation, ambient air temperature, wind speed/movement, and relative humidity/vapor pressure. These equations have been adjusted for reference crop ET with lysimeter data. Selection of the :method used for determining local crop ET depends on

• Location, type, reliability, timeliness, and duration of ;climatic data

• Natural pattern of evapotranspiration during the year; and

• Intended use intensity of crop evapotranspiration .estimates

The following methods are recommended by the Natural Resources Conservation Service

Temperature method (1)

• FAO Modified Blaney-Criddle

• Modified Blaney-Criddle (SCS Technical Release No. 21). This method is being maintained for historical and in some .cases legal significance

Energy method (2)

• Penman-Monteith method

(3) Radiation method

• FAO Radiation method

(4) Evaporation pan method

The FAO Modified Blaney-Criddle, Penman-Monteith, and FAO Radiation equations represent the most accurate equations for these specific methods. They are most accurately transferable over a wide range of climate conditions. These methods and equations are also widely accepted in the irrigation profession today (FAO,2005).

2.6 Deficit irrigation:

Irrigation, the addition of water to lands via artificial means, is essential to profitable crop production in arid climates. Irrigation is also practiced in humid and sub-humid climates to protect crops during periods of drought. Irrigation is practiced in all environments to maximize production and, therefore, profit by applying water when the plant needs it. In the irrigated areas scarcity of water is also observed due to insufficient water supply. Physiological changes which occur in plant in response to water stress are loss of cell turgor, closing of stomata, and reduction in cell enlargement and reduced leaf surface area. These abnormalities ultimately decrease photosynthesis and respiration (Human *et al*., 1990; Hall *et al*., 1990) and as a result overall production of crop is decreased.

Deficit irrigation practices differ from traditional water supplying practices. The manager needs to know the level of transpiration deficiency allowable without significant reduction in crop yields. The main objective of deficit irrigation is to increase the WUE of a crop by eliminating watering's that have little impact on yield. The resulting yield reduction may be small compared with the benefits gained through diverting the saved water to irrigate other crops for which water would normally be insufficient under traditional irrigation practices. Before implementing a deficit irrigation program, it is necessary to know crop yield responses to water stress, either during defined growth stages or throughout the whole season (Kirda and Nielsen, 1999). Crops or crop varieties that are most suitable for deficit irrigation are those with a short growing season and are tolerant of drought (Stewart and Musick, .(1982

The objective of regulated deficit irrigation is to save water, labor, and in some cases energy, by withholding or skipping irrigation or reducing the amount of water applied per irrigation. The practice leads to some degree of moisture stress on the crop and an effect on crop yield. The water stress results in less evapotranspiration in plants due to closure of the stomata reduced assimilation of carbon and decreased biomass production (Smith et al., 2002). When the water stress is not severe, the reduction of biomass production will have little adverse effect on ultimate yield and can lead to appreciable increase in productivity of water. But when the water stress is severe or occurs at the critical growth stages of a crop, the reduction in yield may be so high that the benefit and .returns for water will be reduced

Effect of irrigation practices on sunflower 2.7 :yield

Browne (1977) concluded that seed yield was increased by 19 percent when final irrigation was applied 22 days after mid flowering, rather than at mid flowering. The higher yield resulted principally from an increase in the number of harvestable seeds. Higher frequency of irrigation further increased seed yield by 9 percent via increase in seed weight. In the second experiment in which all treatments were irrigated at a high frequency seed yield was increased by 30 percent and total oil yield by 48 percent when final irrigation was applied 16 days after mid flowering, rather than at mid flowering. Both seed weight and seed number were increased by the Later irrigation. No further yield improvement was achieved by extending the irrigation season to encompass physiological maturity (a mean 31 days after mid-flowering). There were also frequently irrigated and unirrigated treatments. The frequently irrigated treatments yielded most at equivalent to2.24 t ha^{-1} in sucrose 150 and 3.69 t ha^{-1} in Manchurians, while the corresponding unirrigated water stress reduced shoots dry matter similarly in all species; however water deficits significantly reduced the seed yield. Fereres *et al.,* (2003) evaluated the yield responses to drought of 53 sunflower genotypes. There was substantial variability among genotypes both in dry land yield and in yield potential, estimated as the yield under frequent irrigation.

Water deficit reduced harvest Index (HI). Excellent correlations were found between HI and grain yield under dry land conditions. The reduction in HI due to water deficits was mostly due to adjustments in seed number with less variation in individual seed weight. In turn, the reduction in seed number was due to a combination of reduced head size and of the area having viable seeds. Husain and Ismail, (1994) reported that all growth parameters showed reduction under salt and water stress condition. Salt stress together with moisture stress also adversely affected the growth rate. Sarkar and Chakraborty, (1995) Three irrigations produced significantly maximum head diameter and 1000- seed weight over 2 and 1 irrigations, whereas up to 2 irrigations sole crop of sunflower gave significantly higher values of yield components. Yield of sole sunflower increased with 3 irrigations over 1 irrigation. Debaeke *et al*., (1998) Reported that early sunflower growth was limited when the water availability was reduced during flowering. Full irrigation was effective for maximum grain production, because of a pronounced water deficit during most of the .growing season

Bakhsh *et al*., (1999) study the effect of irrigation .frequencies i.e. 0,2,4,6 and 8

The parameters like plant height, head diameter, number of grains per head, 1000-grain weight and grain yield per hectare were significantly affected by irrigation levels and six irrigations were found optimum for obtaining good yield of sunflower. On the basis of research findings, six irrigations are recommended for sunflower crop to obtain maximum seed yield under irrigated condition. D'Amato *et al*., (1999) reported that limited water irrigations in number of one irrigation, at the "beginning flower stage" (BF) with 686 m3 ha-1, or of two irrigations at "flower bud stage" (FB) and at "beginning flower stage" (BF) with 956 m3 ha^{-1} or at "beginning flower stage" (BF) and at "middle seed growth stage" (MG) with 1155 m^3 ha^{-1}, gave yields of 3.1, 3.3 and 3.5 t ha^{-1} respectively. The yield obtained with three irrigations (volume 1509 m^3 ha^{-1}), distributed in "FB", "BF" and "MG" stages (3.7 t ha^{-1} in achene yield) were higher than the yield obtained with the smaller irrigations volumes (686 and 956 m^3 ha^{-1}). Razi and Assad, (1999) reported that water stress significantly decreased yield and its components; however, oil content did not differ significantly. Genotype and phenotype correlation revealed that seed yield had significant positive correlations with Head diameter, Plant Height, 1000-seed weight and oil yield under normal and limited irrigation. Seed yield had significant correlations with oil content under normal irrigation regime, while these correlations were largely reduced under stress conditions and were not significant. The highest direct effect was exhibited by 1000-seed weight in normal and limited irrigation environments. Direct effect of oil was quite lower than its correlation with seed yield. The lowest direct effect was found for plant height and oil content under normal and stress environments, respectively. Hussain *et al*., (2000) Tested two sunflower genotypes under three moisture level, i.e. 100,50 and 25% of field capacity. Water stress increased the net assimilation rate where as it decrease the leaf area ratio. The water stress had no effect on relative growth rate. A very low and negative correlation was found between net assimilation rate, achene yield and oil yield whereas relative growth rate had a very low and positive correlation with both achene yield and oil yield. Leaf area ratio had positive and significant correlation with achene and oil yield. Khan *et al*., (2001) concluded that a decreasing trend in head diameter, number of achene's per head, 100-achene weight and achene yield per plant to as observed as the level of water stress increased from 100% to 25% of field capacity. Seed oil content was very sensitive to even mild water stress but showed stability .under increasing stress conditions

Aiken and Stockton, (2001) reported that supplemental water treatment were applied to sunflower during vegetative, reproductive, or both growth stages. Seed yield ranged from 2100 to 2700 kg ha^{-1}. Supplemental irrigation increased seed yields by 480 kg ha^{-1} each year. Erdem *et al*., (2001) study the influence of limited irrigation on growth; seed yield and yield components. Five irrigation treatments were applied, designated as T1 full irrigation and T2, T3,T4 and T5 received 75, 50, 25 and 0% of applications of the fully irrigated treatment on the same day. Seed yields averaged highest with full irrigation treatment (T1) and differences between full irrigation and other treatments were significant. Kakar and Soomro (2001) exposed that there were significant differences among the water stress treatment for all the growth and yield parameter, seed yield and seed oil content. Four regular irrigations with 10 days interval and first irrigation after 40 days after sowing (DAS), produced significantly higher seed yield of 931 kg ha^{-1} with 41.81% seed oil content was recorded for four regular irrigations followed by three and two irrigations, giving 918 and 620 kg ha^{-1}, respectively. Oad *et al*., (2001) evaluated that maximum and satisfactory seed yield (2560 kg ha^{-1}) was observed in the V-shaped furrows irrigated with four irrigations as compared with the yield of 1550 and 650 kg ha^{-1} from three and two irrigations. Tahir and Mehdi, (2001) evaluated the field under normal and water stress condition. Head Diameter, 100-achene weight and seed yield per plant were reduced under water stress. Significant but negative correlation of Head diameter with fresh shoot weight was observed under water stress. Positive and significant correlation existed between dry shoot weight and seed yield per plant under water stress conditions. Chimenti *et al*., (2002) found a significant effect of drought on biomass at the end of thesis and at physiological maturity, grain yield, and grain size and harvest index. Yield maintenance under drought conditions was attributable to variations in post-drought shoot biomass increase and HI increase. Flagella *et al*., (2002) reported that yield and its main components were positively affected by irrigation with regard to fatty acid composition, a decrease in oleic and stearic acid and increase linoleic and politic acid were observed under irrigation. The decrease in the oleic/linoleic acid ratio .observed under irrigation

Tahir *et al*., (2002) evaluated inbred lines of sunflower under water stress and normal irrigation. The maximum decrease was observed in yield per plant that was 34.13% when compared with that of under normal irrigation condition followed by 184 leaf area and 100-achene weight with 25.56 and 22.63% decrease under water .stress condition respectively

Calvino *et al.,* (2004) conducted a field trial, in experiment 1 and 2 minor water deficit; water availability accounted for 90% of the crop water requirement. Experiment 3 with more severe water deficit developed around a thesis. Crop in experiment 4 were exposed to mild water deficit in all three critical stages and water stress was most severe in experiment 5. Yield response to narrow row was significant for Zenit in four out of five experiments. The response of grain number paralleled to yield response in Zenit whereas grain number was more responsive to row distance than yield in the long season hybrids. Grain mass was larger in wide row crops in experiment 3-5 and was unaffected by row distance in the remaining trial. In experiment 3 narrow rows significantly reduced yield in Sunflower crop response to narrow rows and highlights the interaction between row spacing and water deficit. For crop with moderate or low deficit, yield did not respond to narrow rows when conditions were conductive to full interception in wide row crops and yield increased up to 15%. Changes in response of grain number to reduce row spacing ranged from nil to 25% increase. Goksoy *et al.,* (2004) reported that seed yield and oil yield increases for the limited irrigation treatments were; 78.7 and 77.4% for H60FM; 77.4 and 78.9% for H40FM; 72.2 and 75% for HF60M; 76.4 and 79.2% for HF40M; 72.7 and 73.6% for HFM60; 77.6 and 76.1% for HFM40. Therefore, we confirm that HFM .irrigation is the best choice for maximum yield

:Definition of soil tillage 2.8

Tillage may be described as the practices of modifying the state of the soil in order to provide conditions favorable to crop growth (Culpin, 1981). It represents the most costly single items in the budget of an arable farmer and is a part of business of farming which remains almost entirely .an art

Hunt (1977) defined tillage as those mechanical soil stirring actions carried out for the purpose of nurturing crops. Also it can be defined as mechanical manipulation of soil for any purpose but in agriculture the term is usually restricted to the changing of soil conditions for crop production (ASAE, 1980) while, Abdalla (1984) define the tillage as any mechanical manipulation of the soil, which is used to maintain, modify or promote change in soil structure in an effort to produce a more desirable environment for crop production. Whereas FAO (1984) defined tillage as the operation of the implements through the soil to prepare seedbed, rootbed, control weed, aerate soil break down of organic meter and minerals to release .plant nutrients

:Tillage objectives 2.9

Culpin (1981) divided the main objectives of tillage as :follows

The production of a suitable tilth or soil structure, the control of moisture, the destruction of weeds, the burning or cleaning of rubbish and the incorporation of fertilizers .into the soil and the distribution or control of pest

The specific objectives of tillage very widely and depend on factors such as soil, climate, crop to be grown and .(prevailing condition (FAO, 1984

:Tillage classes and systems 2.10

Tillage is classified as primary and secondary. Primary tillage constitutes of the initial major soil working operation. It is normally designed to reduce soil strength, .cover plant materials and rearrange aggregates

On the other hand secondary tillage may be described as number of a group of different tillage operations following primary tillage, which are designed to create refined soil conditions before planting. Tillage advantage under one condition or one soil may be a disadvantage under another condition or another soil. The ASAE (1980) and :FAO (1984) divided tillage system into

Conventional tillage: The combined primary and -1
secondary tillage normally performed in preparing a seed bed for given crop in a given geographical area is called .conventional

Conservation tillage: Any tillage sequence that reduces -2
soil or water loss relative to conventional tillage is called conservation tillage. It is often a form of non-inversion of the soil that retains protective amounts of crop residues on the surface. Conservation tillage is usually relies on management of surface residues to minimize soil and .water losses

Minimum tillage: The minimum soil manipulation -3
necessary for crop production or meeting tillage requirement under existing soil and climate conditions is .(called minimum tillage (FAO, 1984

No tillage: A procedure whereby is made directly into an -4
essentially unprepared seedbed. No tillage is a method of planting crops that involves no seedbed preparations other than opening the soil for the purpose of placing seeds at the intended depth. It usually involves opining a small slit or punching a hole in the soil including chemical use for weed control. It’s also called slot planting, zero .(tillage or drilling (FAO, 1984

Optimum tillage: Optimum tillage is an idealized system, -5
which permits a maximized net return for given condition .((ASAE, 1980

Reduced tillage: It’s a system in which the primary tillage -6
operation is performed in conjunction with special planting

procedure in order to reduce or eliminate secondary tillage .(operation (ASAE, 1980

7- Strip tillage: This is a system in which only isolated bands .(of soil are tilled (ASAE, 1980

8- Bedding or Ridging: It is a tillage operation, which mounds .(soil into a specific configuration (ASAE, 1980

9- Stubble mulching: is a system of tillage that retains the stubble of crops or crop residues on the land, thus providing a protective surface cover before the during seedbed preparation and at least partially during the .(growing season of the succeeding crop (ASAE, 1980

2.11 Effect of tillage on soil physical :properties

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

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

On the other hand, conservation tillage methods often result in decreased pore space (Hill, 1990), increased soil strength (Bauder *et al.,* 1981) and stable aggregates (Horne *et al.,* 1992). The pore network in conservationally tilled soil is usually more continuous because of earthworms, root channels and vertical cracks. Therefore, conservation tillage may reduce disruption of continuous pores. Whereas, conventional tillage decreases soil penetration resistance and soil bulk density (Khan *et al.,* 1999). This also improves porosity and water holding .capacity of the soil

Ploughing treatment directly and indirectly affects bulk density. The direct effect of ploughing is that soil is pulverized, disturbed and its volume increased at which the bulk density is decreased. On the other hand the indirect effect of ploughing happens when heavy machinery and equipment pass over the soil which compact it and its bulk density is increased (Johnson *et al.*, .(1989

Tillage is one of the most influential management practices affecting soil physical and hydraulic characteristics (Lal and Shulka 2004). Strip tillage (ST) was performed using a single operation with special equipment that provided alternating 30-cm wide strips of tilled and untilled soil while conventional tillage (CT) consisted of six to seven separate operations using different tillage implements following the harvest of one crop in .preparation for the next crop

Two of the most commonly measured soil physical properties affecting hydraulic conductivity are the soil bulk density and effective porosity as these two properties are also fundamental to soil compaction and related .(agricultural management issues (Strudley et al. 2008

:Effect of tillage on soil infiltration rate 2.12

Lal *et al.*(2004) described the infiltration as the process of water entry into the soil profile due to gravitational and surface suction forces. While Michael, (1999) defined infiltration as the movement of water from the surface .vertically downward into the soil

Infiltration rate as described by Michael, (1999) is a soil characteristic determining the maximum rate at which water can enter the soil under specific condition including the presence of excess water. Infiltration rate decreases during irrigation. The rate of decrease is rapid initially and the infiltration rate tends to approach to a constant value. The nearly constant rate develops as time has elapsed from the start of irrigation and is called the basic infiltration rate and the total quantity of water that enters the soil in a given time is called accumulated infiltration. Israelsen and Hansen (1962) stated that infiltration rate varies with many factors including depth of water on the surface, temperature of water and soil, soil structure and .texture, and initial moisture content of the soil

Effect of tillage on soil moisture 2.13 :content

Areerak(1988) mentioned that soil moisture content for deep tillage practices was high when compared to no-tillage and conventional tillage practices. Whereas Vajdai (1991) stated that using various tillage methods (heavy disc, heavy cultivators, medium-deep loosener) he found that there was no significant difference in moisture content due to the use of various tilling tools for the 0-20cm soil layers whereas in the 20-40cm layer all the .treatments resulted in significantly high moisture content While Abdalla (1995) found that the moisture content for chiseling was greater than those for ridging and no tillage. This was mainly attributed to the fact that chiseling the soil to a greater depth. The results of a comparative study of tillage implements including disc harrow, disc plough, mouldboard plow and field cultivator made by Fabrizzi *et al.* (2005) revealed a significant difference between the levels of soil moisture at a specified depth of 15cm for the .different tillage operations

Effect of tillage on crops yield 2.14

Tillage is one of the most influential management practices affecting soil physical and hydraulic characteristics (Lal and Shulka 2004). Strip tillage (ST) was performed using a single operation with special equipment that provided alternating 30-cm wide strips of tilled and untilled soil while conventional tillage (CT) consisted of six to seven separate operations using different tillage implements following the harvest of one crop in .preparation for the next crop

Two of the most commonly measured soil physical properties affecting hydraulic conductivity are the soil bulk density and effective porosity as these two properties are also fundamental to soil compaction and related agricultural management issues (Strudley et al. 2008). Saturated hydraulic conductivity is considered one of the most important parameters for water flow and chemical transport phenomena in soils (Reynolds and Elrick 2002). About 60% of consumed energy in agriculture is related to tillage operation. It is very important to take attention to the application and number of operation of tillage .(equipments (Mahmoudi and Mohammadi- Nashali, 2007

Effect of tillage on sunflower yield 2.15

Results of different tillage methods (Moldboard plowing, disking, harrowing and minimum tillage) on sunflower yield showed that, maximum (1840kg/ha) and minimum

(1360kg/ha) of sunflower yield was related to disking and .(moldboard plowing, respectively (Bonciarelli, 1991

The impact on soil compaction on crop growth is a complex process. Soil mechanical constraints might impair root system's growth; this alteration leads to a decrease in sunflower yield. These results in a reduction of the above ground plant growth (which also leads to an alteration of the root system), and finally to a global loss of yield (Lipiec and Hatano, 2003; Sadras et al., 2005). Concerning sunflower cropped under soil compaction, literature has reported decreases in (1) leaf area, (2) above ground biomass, (3) plant height, (4) growth rate, (5) rooting depth and (6) final yield (Bayhan et al., 2002; Botta et al., 2006; Diaz-Zorita, 2004). Even though no interaction has been observed between crop health and tillage practices (Lecomte and Quere, 2005), the reduction of traditional soil tillage practices (leaving stubble during winter) has led to increases of disease infections (Debaeke and Peres, .(2003; Taverne, 2005; Seassau et al., 2010

:Sowing methods 2.16

Ahmad *et al*., (2000) planted crop on three sowing method i.e. ridge, furrow and flat land. Results indicated that sowing method showed no significant effect on the emergence m^{-2}, plant height. Head diameter, 1000-grain weight, grain yield and oil yield (kg ha^{-1}) were significantly affected by different sowing methods. Maximum of 18.67 cm head diameter, 68.43 g 100-grain weight, 2229.74 kg ha-1 grain yield and 931.34 kg ha^{-1} oil yield were obtained from ridge sown crop while furrow method had the lowest values for these variables. Mahal *et al*., (2000) investigated the effect of three levels of flood water, two methods of plantation (flat and ridge) and two levels of N (120 and 150 kg ha^{-1}). They concluded that sowing on ridges reduced the adverse effect of flooding and gave .9.9% more yield than flat sowing

CHAPTER THREE
MATERIALS AND METHODS

-:3.1The experimental site

The study was conducted in the Northern State of Sudan and lies between latitude 16°- 22°N and longitudes 20° - 32°E. The state lies in the arid and semi-arid zones, where the annual rainfall is less than 100mm. the climate is characterized by distinct seasons where summer extends from April to the end of September. The maximum temperature in summer reaches 45°C. Winter extends from October to the end of March and it is the cold season. The maximum winter temperature is about 30°C, while the (minimum temperature is around 5°C (appendix 1

-:Soil of the experimental site 3.2

A profile was dug in the experimental site and described according to the standard soil survey procedure. The physical and chemical proprieties of this soil are reported .((appendix 1.3

Profile description 3.2.1

cm: Brown (10YR6/3) dry, dark brown (10YR3/3) 15 – 0 moist, fine granular to blocky, sandy loam, slightly .sticky, slightly plastic smooth boundary, pH 7.6

cm: light yellowish to brown (10YR6/4) dry, dark 35 – 15 brown (10YR4/3) moist slightly sticky, plastic, loam, weak platy structure, hand dry, firm moist, few tubular pare , many CaCo3 modules, very strong calcareous matrix, .smooth boundary, pH 8.9

55cm Gray to Brown (10YR5/2) moist and dray, sandy–35 loam, weak granular, medium sticky and plastic. Few fine pores, sand grains, gray CaCo3 nodules, smooth .boundary, and pH 7.3

75cm. very pale brown (10YR7/3) dry, dark grayish to–55 brown (10YR4/2) moist, loam , weak medium and fine sub angular ,blocky , slightly sticky , slightly plastic. Firm moist hard dry, many CaCo3 nodules and non-creations gradual .smooth brownish, pH 7.4

cm light brownish to gray (10YR6/2) dry , dark 95 –75 brown (10YR4/3) moist, weak ,platy structure , slightly, sticky and plastic , sandy loam, friable moist , hard dry , few CaCo3 , white concretion , PH 7.6

cm brown (10YR6/3) ,moist and dry , sand clay 150 –95 loam , moderate granular, hard , non-sticky and non-plastic, soft dry , non-calcareous matrix , abrupt to smooth boundary PH 7.3

120cm dark grayish to brown (10YR4/2) moist and dry , sandy , very hard , granular , non-sticky and non-plastic , . loose moist loose dry , non-calcareous matrix , PH7.5

:Experimental design and treatments 3.3

A strip – spilt plot design was used with four replications and 24 treatments applied on it, the size of plot is (4×3) m. The treatment is a three tillage packages and no tillage :(as the main plots (plate 1

Three-body disk plow (T_1) plate 2-1

Chisel plow (T_2) plate 3 -2

Heavy disk harrowing (T_3) plate 4-3

(No tillage (T_0-4

:Sub-plot consisted of two sowing methods

Flat (F) plate 5-1

Ridge (R) plate 6-2

:Sub-sub plot consisted of three levels of irrigation water

(ETc (W_1 75%-1

(ETc (W_2 85%-2

(ETc (W_3 100%-3

N

Canals

Road

Rep.4

Rep.1

Rep.2

Rep.3

75% **R 1** **ETc**

expermental unit

experimental unit

sub plot

85% ETc

T1

100% ETc

strip1

75% **F** **ETc**

85% ETc

1005% ETc

T_2

T_2

strip2

T_3

strip3

strip4

T_0

Plate 1 Experimental layout

Plate 2: Three-body disc plow

Plate 3: Heavy disc harrow

Plate 4: Chisel plow

Plate 5: Ridge plot

Plate 6: Flat plot

:Cultural practices 3.4

:The seed 3.4.1

Sunflower hybrid Hysun 33, was recommended by the agriculture research corporation were selected for purpose .of this study

:Sowing 3.4.2

Sowing is on the shoulder of the ridges and rows. The rate of 2 seed per hole thinning to one plant after two weeks. Hand weeding is carrying out three times, just before .irrigation

:Sowing date 3.4.3

.The date of sowing in the two seasons was on late May

:Irrigation water measured 3.4.4

The irrigation water quantity is calculated according to the crop water requirement, which is estimated from meteorological data using the modified Penman method described by Doorenbos and Pruitt (1977), with help by .ETo software program. The irrigation interval is 10 days

The parshall flume (2in) plate 7 is the most commonly used as flow measuring device in open channel irrigation systems. In this study parshall flume and Skogerboe *et al*, (1967) table together with the general free flow equation :were used to measure the water discharge, as follows

$$(Q_f = C_f \times (h_d)^{nf} \qquad (1$$

:Soil parameters 3.5

.Soil moisture contents 3.5.1

Soil moisture content was determined by gravimetric method; the soil samples were taken one day before irrigation for the depth 0-20, 20-40, and 40- 60cm using soil auger. Small cans were used for taking the wet samples which are weighed and then put in an oven at .105°c for 24 hours

A sensitive electrical balance is used to determine the wet and dry weights of the soil samples. Then the soil :moisture (%) is determined as follows

$$\text{Soil moisture (\%)} = \frac{wet\ weight - oven\ dry\ weight}{oven\ dry\ weight} \times 100$$

((2

:Infiltration characteristic 3.5.2

A double ring cylinder infiltrometer were installed randomly in the central area of each three plot in each strip as described by Michael (1978) after land preparation .before sowing plate 8

The infiltrometer consist of two cylinders made of 2mm thickness rolled steel. Each cylinder is 25 cm height, the inner cylinder from which the infiltration measurement are taken is 30cm in diameters, while the outer cylinder which is used as a buffer to prevent any lateral movement of water in the soil are 60cm in diameter. The cylinders are driven concentrically into the soil at depth of 10cm using a hammer on a wood plank placed on the top of the cylinder .to prevent damage to the edges of the cylinders

A plastic sheet is use to cover the soil surface in the inner cylinder before filling with water and starting reading. The level of water is maintained by refilling using a measuring cylinder. The water level in the inner cylinder is measured using a graduated scale. Readings are taken every 5minutes interval until a constant infiltration rate. The .average infiltration rate in cm/hour is determined

:Bulk density 3.5.3

The bulk density of soil is measure using the paraffin wax method as described by Jonson (1945). The bulk density for a clod is found by determining the mass of the clod in air the mass is then divided by volume of the same clod which is determine after being coated it with paraffin wax .and weighting the coated clod submerged in water

$$(\text{Bulk density} = \frac{\text{the mass of the clod}}{\text{the volume of the same clod}} \ \text{gm/cm}^3 \quad (3$$

:Particle density 3.5.4

Particle density of the soil is determined by using the .(cylinder method as described by Blake (1965

It is found by determining the mass of the soil sample. The mass is then divided by the volume of the soil sample, which is determine by the measuring the increase in the water column in the measuring cylinder after pouring the .soil sample in it

$$\text{Particle density} = \frac{mass\ of\ the\ soil\ sample}{volume\ of\ the\ same\ sample}$$

((4

:Soil porosity 3.5.5

The soil porosity is calculated by using the following :equation

$$Porosity(\ ) = \left[1 - \frac{Bulk\ density}{Particle\ density}\right] \times 100$$

:Vegetative plant growth parameters 3.6

:Plant height 3.6.1

Plant height is measuring using meter stick at 40, 50, 70 and 90day after sowing. Three plants from each subplot are randomly selecting and tagging. The height of each plant is measuring from the soil surface to the tip of the .youngest leaf. The mean of each treatment is obtained

:Stem diameter 3.6.2

The stem diameters are measuring at 70 and 90days from sowing using vernia. Three tagged plant are selected from each subplot and the stem diameters are measuring from .the soil level

:(Leaf area index (L.A.I 3.6.3

L.A.I is estimating using the punch method (Waston and :Waston, 1953) the leaf area is calculated as follows

$$\frac{Total\,area\,of\,leaf\,discs \times total\,dry\,weight\,of\,leaf}{dry\,weight\,of\,leaf\,discs} \qquad (6)$$

:Then the leaf area index is calculating as follows

$$L.A.I = \frac{leaf\,area\,per\,plant}{plant\,ground\,area}$$

((7

:Yield parameters 3.7

:(Head diameters (cm 3.7.1

Measurements with meter tape across the center of the head. Two or three measurement are taken in different direction and means head diameter is obtained for each .treatment

:Number of seed per head 3.7.2

Three heads are taken from each subplot and the total number of seeds is counting, hence the mean number of .seeds per head is obtained

:Thousand seed weights 3.7.3

Thousand seed are counting from the bulk seed yield of each subplot weighting and the mean thousand yields per .weight is found

:Seed yield per feddan 3.7.4

Seed yield per feddan are obtaining by harvesting all heads in an area of $0.7m^2$ from the middle ridge or row in each subplot the seed are cleaning and weighting and the .seed yield per feddan are calculating

:Statistical analysis 3.8

Analysis of variance was used to analyze the data (ANOVA) appropriate strip spilt plot design was used according to Gomeze. and Gomeze (1976). Means separation was carried out using the Duncan multiple range tests help .with MSTATC software program

Plate 7: Parshall flume 2inch

Plate 8: Double ring cylinder infiltrometer

CHAPTER FOUR
RESULTS AND DISCUSSIONS
:Effect of tillage on Soil parameters 4.1
:Bulk density 4.1.1

Table 4.1 shows the results of bulk density in g/cm^3 (mean values) for each tillage treatment at the upper soil surface (0.0 – 0.25m) in seasons 2011 and 2012. The analysis of variance shows significant differences in bulk density between tillage treatments at $P \leq 0.05$. The harrowing treatment represented lowest values in both seasons, followed by chiseling disking and the highest values were obtained under no-tillage treatment. The decrease the bulk density resulting from harrowing treatment might be due to improvement of soil structure, which resulted in .(greater micro pore spaces as reported by Mahgoub (1999

:Porosity percentage 4.1.2

Table 4.12 shows the mean values of porosity % at the upper soil layer (0.0 – 0.25cm) for each tillage treatments for the 2011 and 2012 seasons. The highest porosity % values were obtained under harrowing and chiseling in both seasons. The results of porosity % showed that all tillage treatments gave higher porosity percentages than no-tillage treatment (control). This might be due to the action of cutting, inverting and mixing which increased soil volume and this resulted is increasing the porosity %. The harrowing land preparation treatment was found superior in improving soil physical properties through directly improving soil moisture retention capacities, porosity and .bulk density as shown in chapter four

Table 4.1 Mean values of bulk density in g/cm^3 at 0.0 – 0.25m depth for the 2011 and 2012 seasons for the four :tillage treatment

Bulk density in g/cm^3 at 0.0 – 0.25m depth		Treatment
Season 2012	Season 2011	
1.358^{bc}	1.418^{b}	Disking
1.283^{c}	1.263^{c}	Harrowing
1.467^{b}	1.285^{c}	Chiseling
1.795^{a}	1.750^{a}	No-tillage(control(
5.95	4.6	%C.V
0.1431	0.01	LSD
0.045	0.032	±SE

Means values followed by the same letter within a column are not significantly different at P ≤ 0.05 according to .Duncan multiple range test

Table 4.2 Mean values of porosity % at 0.0 – 0.25m depth for the 2011 and 2012 seasons for the four tillage :treatment

Porosity % at 0.0 – 0.25m depth		Treatment
Season 2012	Season 2011	
40.46^{ab}	39.17^{b}	Disking
44.59^{a}	47.42^{a}	Harrowing
40.10^{ab}	44.48^{a}	Chiseling
27.65^{c}	24.89^{c}	No-tillage(control (
12.63	7.03	%C.V
13.2	4.393	LSD
4.131	1.373	±SE

:Infiltration rate 4.1.3

The statistical analysis showed that there were no significant differences in infiltration values (P ≤ 0.05) between tillage treatments at initial stage, but they all .gave significantly higher values than the control

Fig 4.1 and 4.2 showed the average infiltration rate in cm and the average cumulative infiltration in cm for all tillage treatments. It is clear that tillage increased infiltration rate compared with the control. Chiseling treatment gave the highest infiltration rate at the beginning and was followed by disking, harrowing and control. In this study chiseling was found to give higher infiltration rates at the beginning that drops steeply to flat compared to other tillage treatments but in soil moisture retention capacity it showed no superiority. This justifies its lower yield compared to harrowing. This result is in agreement with .(results reported by Mhgoub, (1999

:Crop water requirement 4.1.4

Crop water requirement and crop coefficients were calculated throughout plant growth stages using the .computer program (Cropwat) appendix 5

:Water demand 4.1.5

The results shows that the amount of applied water in m^3/fed/watering for each irrigation treatment in 2011 and 2012 seasons increased as irrigation proceed up to the 8^{th} watering, and then decreased in the final or late stage .appendix 6

Fig 4.1 infiltration rate in cm for the different tillage treatment

(Cumulative Infiltration (cm

Fig 4.2 cumulative infiltration (cm) for the different tillage treatment

:Moisture content 4.1.6

Table (4.3) is a summarizing of analysis of variances and explains the effect of treatments and their interactions on .soil moisture content

Table 4.4 shows the mean values of soil moisture content in different depth. It is clear that harrowing treatment resulted in the highest value of moisture content in depth (0 – 20) cm in both seasons when compared with disking, chiseling and no-tillage treatment. In depth (20-40) cm the disking treatment gave the lowest values in both seasons but in depth (40-60). The analysis of variance showed a significant difference between treatments. In season 2011 the harrowing gave a highest value of moisture content while the no-tillage gave the lowest value and there were no significant difference between disking and chiseling. According to season 2012 a significant difference was .existed between types of tillage compared with no-tillage

On the other hand, the effect of sowing methods (ridge and flat) on soil moisture content can be explained in table 4.5, and it is obvious that there was no significant difference in all depths for both seasons except in first .season for depth40-60cm

The third factor which was the irrigation water levels (75%ETc, 85%ETc and 100%ETc) on soil moisture content in two seasons can be seen in table 4.6. The analysis of variance explained a significant difference due irrigation water levels (75%ETc, 85%ETc and 100%ETc) treatments, the level of 100%ETc gave the highest value in all depths .for both seasons

Regarding the above factors the results showed the significant differences on soil moisture content in both .(seasons due to combined effect Appendix (4.7 to 4.10

Table 4.3: F values from ANOVA table for soil moisture contents in both seasons

60 – 40		40 – 20		20 - 0		Source of variation
S2	S1	S2	S1	S2	S1	
*13.61	169. *8	17.4 *4	58.9 *8	42.56 *	*9.85	T
2.45^{ns}	53.9 *9	1.91^{n} s	0.22^{n} s	0.85^{ns}	4.69^{ns}	S.M

2.75ns	12.1*5	2.63ns	27.4*1	2.54ns	*6.91	T×S.M
*39.17	115.*2	10.1*2	132.*7	*4.7	*65.1	A.W
*2.43	*8.23	*4.86	*3.82	*4.78	*3.27	T×A.W
*1.29	*2.95	1.19ns	11.9*9	0.83ns	*3.65	S.M×A.W
0.39ns	*6.05	*2.38	*3.08	*3.31	*5.61	T×S.M ×A.W

Key: T**:** Tillage, S.M: Sowing Methods, I.W.L: ,Irrigation Water Levels
(S1: first season (2011) and S2: second season (2012

Table 4.4 Effect of tillage treatments on soil moisture .(content for both seasons (2011 and 2012

Incremental depth cm						Treatment
40-60		20-40		0-20		
S2	S1	S2	S1	S2	S1	
a 19.78	20.91 a	15.43 a	14.94 a	14.69 a	6.38 a	Harrowing
a 18.94	16.96 b	14.69 a	c 5.83	14.14 a	5.9 abc	Discing
a 18.68	16.85 b	14.39 a	15.39 a	14.12 a	6.28 ab	Chiseling
14.53 b	c 12.16	b 9.04	b 8.94	b 7.66	5.01 c	No-tillage

10.68	5.68	22.63	15.16	23.79	24.62	%C.V
2.04	0.88	2.245	1.09	1.63	0.965	LSD
0.637	0.28	0.702	0.34	0.51	0.299	±SE

Means values followed by the same letter within a column are not significantly different at P ≤ 0.05 according to .Duncan multiple range test

Key: T_1**:** Harrowing, T_2: Disking, T_3: Chiseling, T_0: No-tillage

Table 4.5 Effect of sowing method (Ridge and Flat) treatments on soil moisture content for both season 2011 .and 2012

Incremental depth cm						Treatment
40-60		20-40		0-20		
S2	S1	S2	S1	S2	S1	
18.16a	10.07b	13.64a	18.57a	13.00 a	5.08a	R
17.8a	11.98a	13.13a	18.87a	12.30 a	5.71a	F
10.68	5.68	22.63	15.16	23.79	24.62	%C.V

.**Key:** R**:** Ridge basin, F: Flat basin__

Table 4.6 Effect of applied water levels treatment on soil .moisture content for both season 2011 and 2012

Incremental depth cm						Treatment
40-60		20-40		0-20		
S2	S1	S2	S1	S2	S1	
c 16.01	c 7.98	12.24 b	c 16.62	11.99 b	c 3.76	W1
17.70 b	10.80 b	12.58 b	18.59 b	11.98 b	b 4.96	W2
a 20.23	14.31a	15.35 a	20.95 a	13.98 a	a 7.48	W3
10.68	5.68	22.63	15.16	23.79	24.62	%C.V
0.965	0.84	1.52	0.53	1.51	0.67	LSD
0.34	0.42	1.159	0.48	1.22	0.24	±SE

Key: I.W.L: irrigation water levels_
.W_1**:** 75%ETc , W_2: 85%ETc, W_3: 100%ETc

Effect of the different treatments on 4.2 :Vegetative growth parameters

Table 4.7 explains that there were significant differences on vegetative parameters due to treatments and their .interactions as shown blow, except on stem diameters

:Irrigation water levels 4.2.1

The irrigation water levels applied were influenced on all vegetative parameters except the stem diameters, the analysis of variance sowed there were significant differences between treatment, the level of 100%ETc gave a highest value and the level of 75%ETc gave lowest value in all parameters, in season one (2011) there were no significant differences obtained between 100%ETc and 85%ETc these results is due to water stress caused considerable reduction reduced all vegetative parameters this result is agreement with those reported by (El-Naim, . (1992, and Badr El Din, 2003

Plant height parameters in season one indicated that there were no significant differences between 100% and 85% irrigation water levels but there was a significant differences when compare it with 75%ETc irrigation water levels, in the other hand in season two there were no significant differences between 75%ETc and 85%ETC irrigation water levels but there was a significant differences when compare it with 100%ETc irrigation water levels, in both seasons the highest value was obtained by 100%ETc level

In stem diameters there were no significant differences obtained due to irrigation water levels. The same result of plant height was obtained by number of leaf per plant and leaf area index (LAI). All these result was tabulated in .table 4.8

Leaf area (index (LAI		No of leaf/plant		Stem diameters		Plant height		Source of variation
S2	S1	S2	S1	S2	S1	S2	S1	
24.3 *9	19.4 *1	*17.39	76.4 *2	*6.94	16.3 *8	39.4 *9	*9.52	T
2.65^{n} s	3.95^{n} s	0.93^{ns}	2.14^{n} s	4.05^{n} s	5.55^{n} s	5.51^{n} s	8.65^{n} s	S.M
1.05^{n} s	0.35^{n} s	0.003^{n} s	0.24^{n} s	0.19^{n} s	1.2^{ns}	0.15^{n} s	*5.06	T×S.M
50.8 *8	14.6 *8	*14.19	10.2 *2	0.46^{n} s	0.47^{n} s	12.2 *4	*8.10	A.W
*5.15	0.94^{n} s	*2.32	0.78^{n} s	0.4^{ns}	2.09^{n} s	1.12^{n} s	1.57^{n} s	T×A.W
2.77^{n} s	*7.45	0.13^{ns}	*5.05	0.49^{n} s	2.14^{n} s	1.49^{n} s	1.05^{n} s	S.M×A.W
*5.74	*3.06	*2.51	*3.01	*1.73	*6.09	0.63^{n} s	1.45^{n} s	T×S.M ×A.W

Table 4.7 F value for vegetative parameters in both seasons

Table 4.8 Effect of irrigation water levels treatments on vegetative parameters of sunflower (*Helianthus annuus L)* for both seasons

Leaf area	No of	Stem	Plant height	I.W.L

(index(LAI		leaf/plant		diameters				
S2	S1	S2	S1	S2	S1	S2	S1	
1.30c	1.35b	16.13c	15.66b	0.99a	1.47a	63.97b	56.97b	W1
1.99b	1.91a	18.47b	17.59a	1.11a	1.47a	67.56b	66.75a	W2
2.51a	1.99a	21.22a	17.53a	1.12a	1.44a	74.69a	67.84a	W3
24.80	21.83	20.58	11.52	23.99	12.25	12.83	18.64	%C.V
0.24	0.254	1.925	0.981	0.132	0.09	4.43	5.98	LSD
0.085	0.089	0.677	0.344	0.046	0.032	1.56	2.10	±SE

:Sowing methods 4.2.2

The statistical analysis indicated there were no significant differences on vegetative parameters (plant height, stem diameters, number of leaf per plant and leaf area index) .due to tillage types these result is obtained in table 4.10

:Tillage types 4.2.3

Table 4.11 shows the mean values of all vegetative parameters and how they affected by different tillage type .in both seasons

The analysis of variance shows a significant difference in plant height due to tillage. The harrowing treatment gave highest values in both seasons followed by disking, .chiseling and no-tillage

Stem diameters show significant differences due to tillage treatments compared with no- tillage in both seasons but there was no significant difference between types of .tillage

The analysis of variance indicated significant differences between tillage treatments on number of leaf/plant in season 2011 disking treatment gave highest value followed by harrowing but there were no significant differences between chiseling and no-tillage in both seasons, in season 2012 the harrowing treatment gave the .highest value followed by disking treatment

Table 4.11 showed significant differences on LAI in both season effected by tillage treatments. The analysis of variance explained no significant differences between harrowing and disking but there was significant difference .If compare it with chiseling and on-tillage

Table 4.9 Effect of sowing methods treatments on vegetative parameters of sunflower (*Helianthus annuus L)* for both seasons

Leaf area (index(LAI		No of leaf/plant		Stem diameters		Plant height		S.M treatments
S2	S1	S2	S1	S2	S1	S2	S1	
1.99a	1.61a	18.23a	16.27a	1.04a	1.50a	66.75a	67.21a	R
1.88a	1.84a	18.98a	17.58a	1.15a	1.42a	70.73a	60.5a	F
24.80	21.83	20.58	11.52	23.99	12.25	12.83	18.64	%C.V

Table 4.10 Effect of tillage treatments on vegetative parameters of sunflower (*Helianthus annuus L)* for both seasons

Leaf area (index(LAI		No of leaf/plant		Stem diameters		Plant height		Tillage treatments
S2	S1	S2	S1	S2	S1	S2	S1	
2.79a	2.15a	23.88a	18.13b	1.29a	1.63a	84.67a	76.04a	T_1
1.96b	1.98a	20.25b	19.25a	1.16a	1.57a	71.46b	70.75a	T_2
1.52c	1.43b	16.50c	15.5c	1.08a	1.45a	61.25c	58.54b	T_3
1.47c	1.46b	13.79c	14.83c	0.85b	1.31b	57.58c	59.08b	T_0
24.80	21.83	20.58	11.52	23.99	12.25	12.83	18.64	%C.V
0.395	0.272	3.375	0.714	0.22	0.124	6.18	6.24	LSD
0.124	0.085	1.055	0.223	0.069	0.04	1.93	1.95	±SE

Effect of treatments Combination on 4.2.4
:Vegetative parameters

The result showed the significant differences on vegetative parameters in both seasons due to treatments combination except the combination of tillage and sowing .methods table 4.16

The combination effect of tillage and sowing methods on vegetative parameters were shown in table 4.12. There were no significant differences in all vegetative .parameters in both seasons

The combination effect of tillage and amount of water applied on vegetative parameters were shown in table

4.13. In plant height there were significant differences between treatments, the highest value were obtained by harrowing with 100%ETc (76.75,88.13)cm in both season .(2011, 2012) respectively

In number of leaf per plant the highest value were obtained by the harrowing with 100%ETc (20.63, 29.13) in both season (2011, 2012) respectively and there were no significant differences on stem diameters for both .seasons

In leaf area index the highest value were obtained by the disking with 100%ETc (2.40) in first season and by .harrowing with 100%ETc (3.35) in second seasons

The combination effect of sowing methods and amount of irrigation water applied on vegetative parameters were shown in table 4.14 below. The highest value in plant height were obtained by ridge with 100%ETc (73.44) cm is first season and by flat with 100%ETc (76.44) cm in second .seasons

In number of leaf per plant, stem diameters and leaf area index the highest value were obtained by flat with 100%ETc (19.06, 21.88), (1.57,1.25) cm and (2.37, 2.60) .respectively

The combination effect between tillage, sowing methods and amount of water applied on vegetative parameters were shown in table 4.15. Significant differences obtained in plant height parameters in both seasons. In number of leaf per plant parameters the highest value were obtained by harrowing with flat with 100%ETc (21.75, 29.75) in both .season respectively

In stem diameters parameter the highest value were obtained by disking with ridge with 100%ETc (1.80) cm in first seasons and by disking with flat with 100%ETc (1.50) .cm in second seasons

In leaf area index (LAI) parameter the highest value were obtained by harrowing with ridge with 85%ETc (2.83, 3.74) .in both seasons respectively

Table 4.11 Interaction effect of (tillage and sowing methods) on vegetative .parameters

Treatments		Vegetative parameters							
Tillage	S.M	Plant height		.Leaf no		(Stem. D (cm		LAI	
		S1	S2	S1	S2	S1	S2	S1	S2
T_1	R	71.5a	81.0a	18.58a	23.42 a	1.67a	1.26 a	2.19a	2.89a
T_1	F	62.58 a	88.33a	19.92a	24.33 a	1.58a	1.32 a	2.12a	2.68a
T_2	R	78.33 a	70.0a	17.50a	19.92 a	1.66a	1.06 a	2.11a	2.18a
T_2	F	63.17 a	72.92a	18.75a	20.58 a	1.48a	1.25 a	1.84a	1.75a
T_3	R	58.83 a	60.42a	14.00a	16.17 a	1.38a	0.98 a	1.44a	1.47a
T_3	F	59.33 a	62.08a	15.67a	16.83 a	1.31a	1.17 a	1.48a	1.56a
T_0	R	60.17 a	55.58a	15.00a	13.42 a	1.30a	0.84 a	1.28a	1.46a
T_0	F	56.92 a	59.58a	16.00a	14.17 a	1.33a	0.87 a	1.58a	1.47a
%C.V		18.64	12.83	11.52	2.58	12.25	23.9 9	21.83	24.80
LSD		6.88	14	1.369	4.906	0.18	0.45	0.472	0.516
±SE		2.15	4.38	0.428	1.534	0.055	0.14 1	0.148	0.161

.Table 4.12 Interaction effect of (tillage and irrigation water level) on vegetative parameters

Treatment	Vegetative parameters

Tillage	I.W.L	Plant height		Leaf no./plant		Stem diameters ((cm		LAI	
		S1	S2	S1	S2	S1	S2	S1	S2
T_1	W1	56.63cd	78.13b	17.00cd	19.13de	1.58a	1.21a	1.79bcd	1.75bc
T_1	W2	67.75abc	87.75a	19.00abc	23.38bc	1.60a	1.28a	2.48a	3.25a
T_1	W3	76.75a	88.13a	20.63a	29.13a	1.70a	1.37a	2.19ab	3.35a
T_2	W1	61.88bcd	66.25cd	17.75bc	17.38def	1.56a	1.02a	1.42def	1.16de
T_2	W2	74.13ab	68.75c	18.38abc	19.63cd	1.55a	1.14a	2.12abc	1.83bc
T_2	W3	76.25a	79.38ab	19.38ab	23.75b	1.59a	1.31a	2.40a	2.89a
T_3	W1	50.38d	59.63cde	14.38e	15.88def	1.34a	1.01a	1.03f	1.37cde
T_3	W2	66.25abc	56.25ef	15.25de	16.00def	1.50a	1.08a	1.46def	1.35cde
T_3	W3	60.63cd	67.88c	16.88cd	17.63def	1.20a	1.14a	1.79bcd	1.83bc
T_0	W1	59.0cd	51.88f	13.50e	12.13g	1.44a	0.73a	1.16ef	0.92e
T_0	W2	58.88cd	57.13def	15.50de	14.88efg	1.24a	0.95a	1.60cde	1.53bcd
T_0	W3	57.75cd	63.75cde	15.50de	14.38fg	1.26da	0.89a	1.61cde	1.95b
%C.V		18.64	12.83	11.52	20.58	12.25	23.99	21.8	24.8
LSD		11.97	8.869	1.961	3.85	0.18	0.264	0.509	0.482
±SE		4.21	3.119	0.690	1.354	0.063	0.093	0.179	0.170

Table 4.13 Interaction effect between (sowing methods X irrigation water amount) on vegetative parameters

Treatment		Vegetative parameters							
S.M	I.W.L	Plant height		.Leaf no		(S.D (cm		LAI	
		S1	S2	S1	S2	S1	S2	S1	S2
R	W1	58.25c	63.75b	15.75c	15.88c	1.44ab	0.97c	1.49cd	1.45d
R	W2	69.94ab	63.56b	17.6bc	18.25bc	1.50ab	1.03bc	1.86bc	2.14bc
R	W3	73.44a	72.94a	16.0c	20.56ab	1.44ab	1.11abc	1.64bc	2.41ab
F	W1	55.69c	64.19b	15.56c	16.38c	1.39b	1.01bc	1.21d	1.15d
F	W2	63.56bc	71.56a	18.13ab	18.69bc	1.44ab	1.19ab	1.97b	1.85c
F	W3	62.25bc	76.44a	19.06a	21.88a	1.57a	1.25a	2.37a	2.60a
%C.V		18.64	12.83	11.52	20.58	12.25	23.99	21.8	24.8
LSD		8.426	6.27	1.387	2.722	0.13	0.178	0.36	0.341
±SE		2.976	2.205	0.487	0.957	0.045	0.066	0.127	0.12

Table 4.14 Effect of interaction between tillage, sowing methods and irrigation water levels on .vegetative parameters

Vegetative parameters			Vegetative parameters							
Tillage	S.M	I.W.L	Plant height		.Leaf no		(S.D (cm		LAI	
			S1	S2	S1	S2	S1	S2	S1	S2
T_1	R	W1	60.00a	80a	18.00bc	18.25cde	1.75ab	1.28abc	1.83cde	1.8efg
T_1	R	W2	68.25a	80a	19.50ab	23.50bc	1.60bcd	1.2abcd	2.83a	3.74a
T_1	R	W3	86.25a	83a	15.00cde	28.50ab	1.65abc	1.3abc	1.68def	1.14ab
T_1	F	W1	53.25a	76.25a	16.00cde	20.00cd	1.40cde	1.15abcd	1.76cde	1.70efg
T_1	F	W2	67.25a	96.25a	18.50bc	23.25bc	1.60abcd	1.36abc	2.13abc	2.77bc
T_1	F	W3	67.25a	92.50a	21.75a	29.75a	1.75ab	1.44abc	2.69ab	3.57a
T_2	R	W1	63.75a	66.25a	16.75cde	16.75de	1.48bcd	1.09abcd	1.45fg	1.02hij
T_2	R	W2	78.75a	66.25a	19.5ab	19.75cd	1.70ab	0.98cef	1.89defg	2.35cde
T_2	R	W3	92.50a	77.50a	19.5ab	23.25bc	1.80a	1.13abcd	2.17bcde	3.16ab
T_2	F	W1	60.00a	66.25a	18.75abc	18.00cde	1.65abc	0.95cef	1.39fgh	1.31fgh
T_2	F	W2	69.50	71.25a	21.75a	19.50c	1.40cd	1.30ab	2.35ab	1.32fg

			a			d	e	c	cd	h
T_2	F	W3	60.00a	81.25a	19.25ab	24.25abc	1.38cde	1.5a	2.63abc	2.63bcd
T_3	R	W1	49.25a	60a	14.75de	16.50de	1.50abcd	0.93cde	1.47fg	1.96def
T_3	R	W2	69.75a	53.75a	14.75de	16.25de	1.60abcd	1.05bcd	1.27gh	1.10ghi
T_3	R	W3	57.50a	67.50a	15.50cde	15.75de	1.05h	0.98def	1.10gh	1.34fgh
T_3	F	W1	51.50a	59.25a	14.00de	15.25de	1.18fgh	1.10abcd	0.59h	0.77j
T_3	F	W2	62.75a	58.25a	15.75cde	15.75de	1.40cde	1.11abcd	1.66def	1.60efg
T_3	F	W3	63.75a	68.25a	18.25bc	19.50cd	1.35cde	1.30abc	2.50abcd	2.32cde
T_0	R	W1	60.00a	48.75a	13.50e	12.00e	1.55abcd	0.60f	1.22gh	1.02hij
T_0	R	W2	63.00a	54.25a	14.5de	13.50de	1.10gh	0.90def	1.48fg	1.38fgh
T_0	R	W3	57.50a	63.75a	14.00bcd	14.75de	1.25efg	1.03cdef	1.62efg	2.00def
T_0	F	W1	58.00a	55a	13.50e	12.25e	1.33defg	0.85def	1.10fgh	0.83ij
T_0	F	W2	54.75a	60a	16.5cde	16.25de	1.38cde	1.00bcd	1.73def	1.69efg
T_0	F	W3	58.00a	63.75a	17.00bcd	14.00de	1.2efg	0.75ef	1.61efg	1.90def
%C.V			18.64	12.83	11.52	20.58	12.25	23.99	21.8	24.8

±SE	5.95	4.411	0.975	1.915	0.089	0.131	0.253	0.240

Effect of different treatments on yield 4-3 :parameter

:4.3.1Effect of Irrigation water levels

The significant differences were obtained in yield parameters due to irrigation water levels in both seasons, except on number of seed per plant. The head diameters result showed significant differences between the three water level in season one but in season two the result obtained showed no significant differences between 75%ETc and 85%ETc irrigation water levels. The significant differences obtained were found when compared to 100%ETc irrigation water levels, the highest values in both seasons were obtained under 100%ETc irrigation water levels (6.2, 9.68) cm respectively fig 4.3. The head diameter was sensitive to water stress. Similar results were found by D Andria *et al*, (1995), Mekki *et al*, (1999) and Bader El Din, (2003) how indicated the reduction in head diameters .when imposed to water stress

Fig 4.4 showed the number of seed per head was not affected by tillage treatments, water stress and sowing methods it seems that these characters are genetically control rather than environmentally affected. This result compares well with those .(reported by Eljak, (1990

In thousand seed weight there were no significant differences between 75%ETc and 85%ETc irrigation water levels. Significant differences were obtained with 100%ETc irrigation water levels in both seasons. The highest values obtained under 100%ETc irrigation water levels were (50.5, 86.03) gms10^{-3} respectively .show fig 4.5

The results of thousand seed weight indicated that thousand seed weight was highly sensitive to water stress. Supporting evidence was reported by many workers D Andiria, 1995, Khan .(*et al*, (1996), shouk, (1999), and Bader El Din, (2003

Fig 4.6 showed the effect of irrigation water levels on yield kg\fed followed the same pattern as manifested in head diameters results. In yield The highest values obtained in the two seasons under 100%ETc irrigation water levels were (487.25, 507.83) kg\fed respectively. This results is in agreement with those reported by D Andria *et al*, (1995) who stated that sunflower is both sensitive to water deficit and capable of bearing high yield in response to irrigation inputs. It is clear that sunflower seed yield is positive directly affected by . .irrigation water levels

Significant differences were showed due to irrigation water levels on percentage of empty seed per head. The highest percentage in two seasons was obtained under 100%ETc irrigation water levels. Sunflower is well known for its empty seeds problem. 100% ET_c irrigation water levels showed no improvement in the reduction of the number of empty seeds but on the reverse the number of empty increased show fig 4.7. This implies that the number of empty phenomenon is associated with level of irrigation at a certain growth stages of the plant life time. This complies well with (Kirda and Nielsen, 1999 and D'Amato *et al*., 1999). All result of effect of water levels was tabulated in appendix 1.11

:Effect of sowing methods 4.3.2

Result showed that there were no significant differences on yield parameters due to sowing method treatments in both .seasons fig 4.3to 4.7 and appendix 1.12

:The effect of tillage types 4.3.3

Fig 4.3to 4.7 showed the effect of tillage treatments on yield parameters, there were significant differences in head diameter (cm), thousand seed weight and yield kg/fed and there were no significant differences in number of seed per head. In head diameter (cm) the lowest values were obtained with no-tillage in both seasons (4.71and 7.58) cm and the highest values were obtained under harrowing treatment (8.69and 10.51). The statistical analysis showed there were no significant differences between harrowing, disking and chiseling but there were significant differences when we compare it with no-tillage in season 2011, in season 2012 there were no significant differences between harrowing and disking but there were significant differences when we compare it with chiseling and no-tillage and no significant differences between chiseling and no-tillage. In number of seed per head the highest values were obtained under disking tillage (241.75 and 243.08) in first and second seasons respectively. In thousand seed weight the heights values were obtained under harrowing tillage (84.58 .and 61.5) grams in first and second seasons respectively

In yield heights values were obtained under discing tillage (419.67 and 593.63) kg/fed in first and second seasons respectively, but there was no significant differences obtained .on percentage of empty seed per head

Analysis of variance, in both seasons, showed significant differences due to tillage treatments the highest values in yield were obtained under harrowing treatment and lowest values were obtained under no- tillage treatment. This may be attributed to the fact that sunflower plant is a tap rooted plants that penetrate well in tilled soils. All results were tabulated in .appendix 1.13

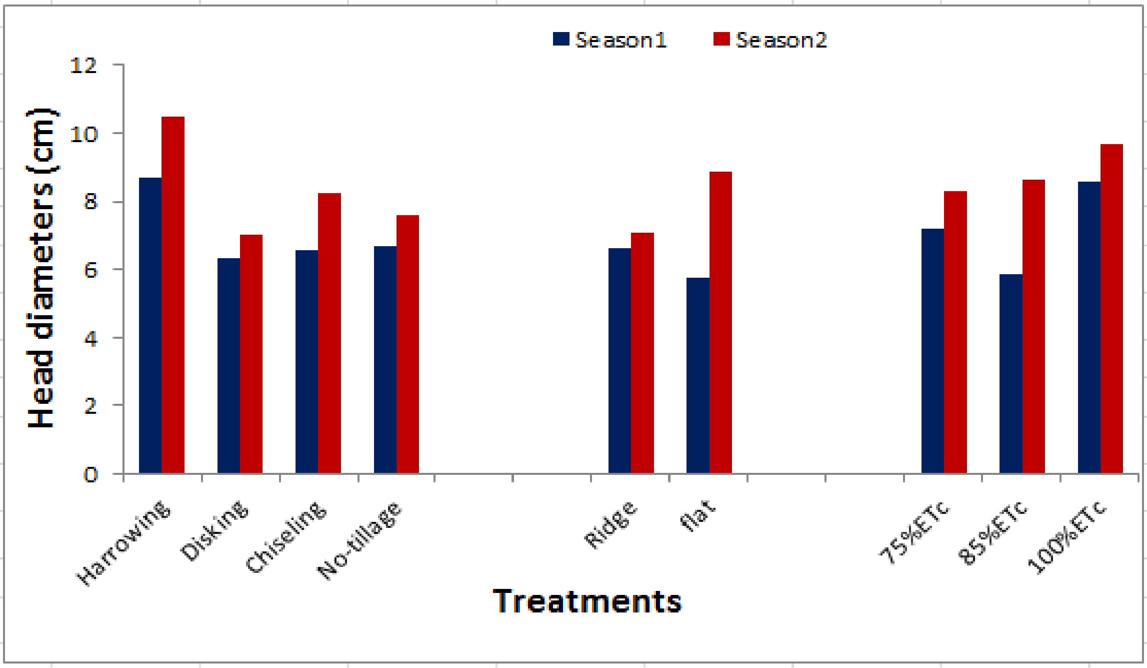

Fig 3: Effect of treatments on head diameters of sunflower (*Helianthus annuus L*) for both seasons

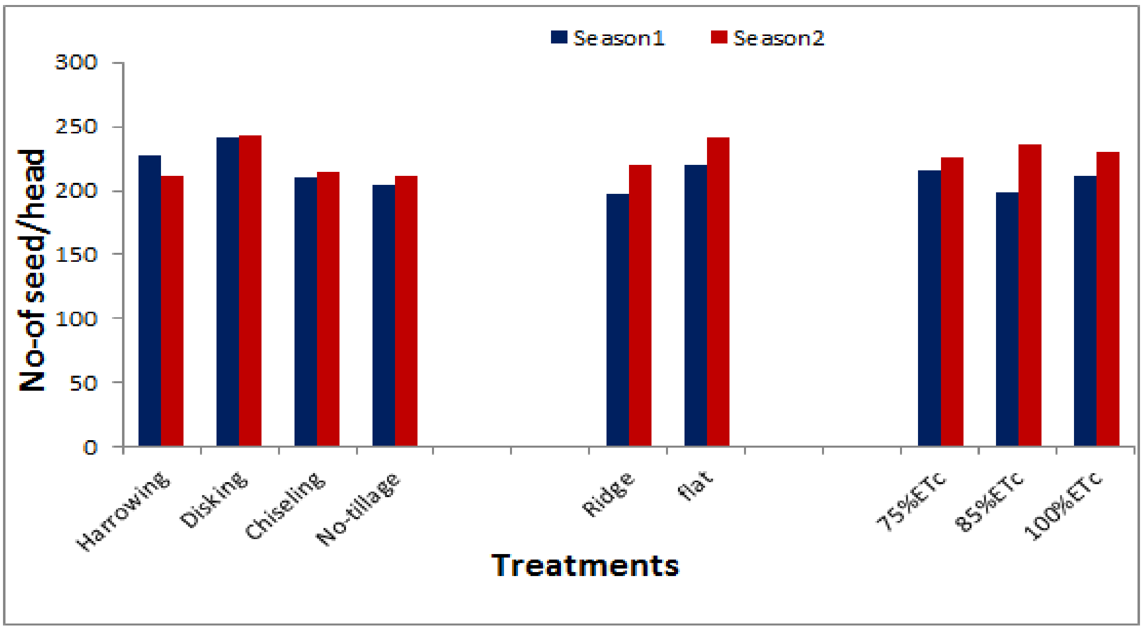

Fig 4: Effect of treatments on number of seed/head of sunflower *(Helianthus annuus L)* for both seasons

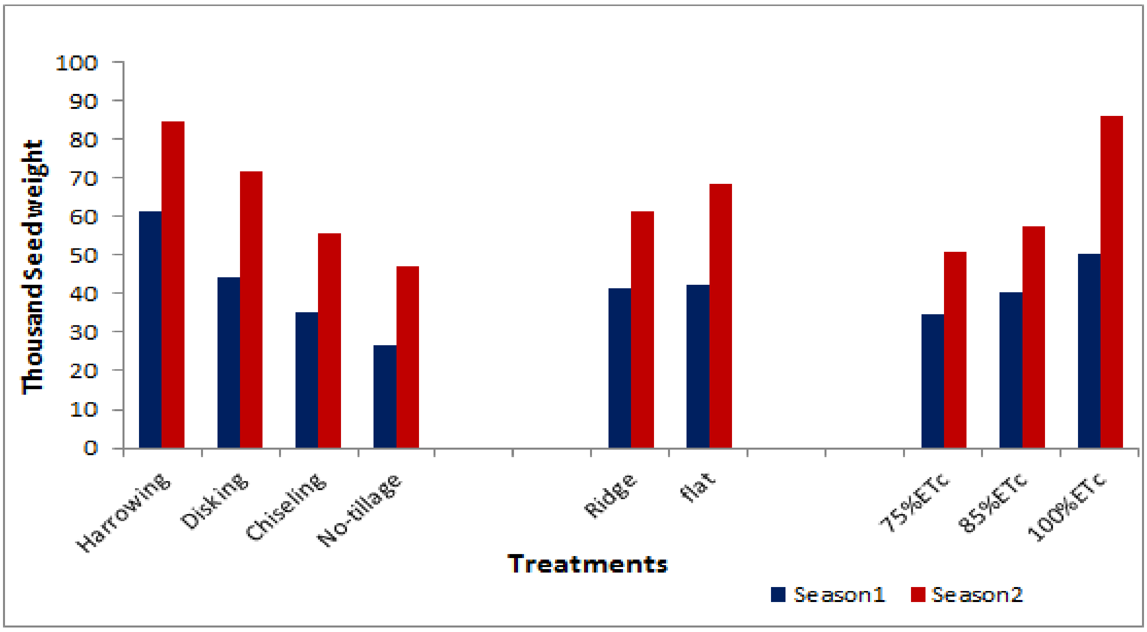

Fig 5: Effect of treatments on thousand seed weight of sunflower *(Helianthus annuus L)* for both seasons

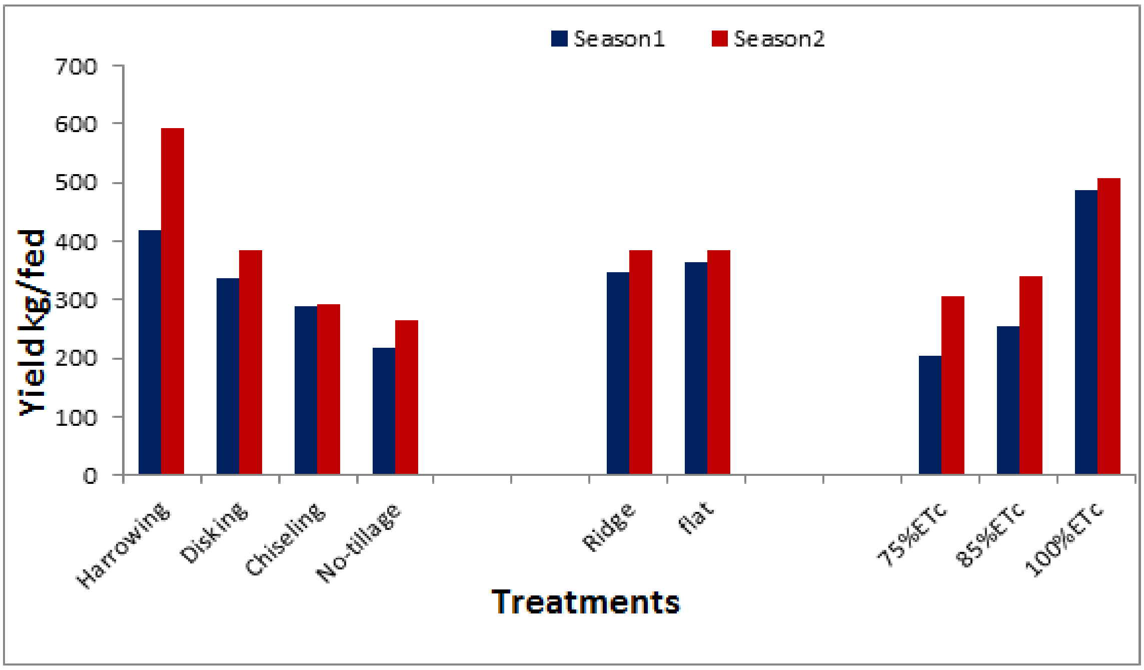

Fig 6: Effect of treatments on yield kg/fed of sunflower *(Helianthus annuus L)* for both seasons

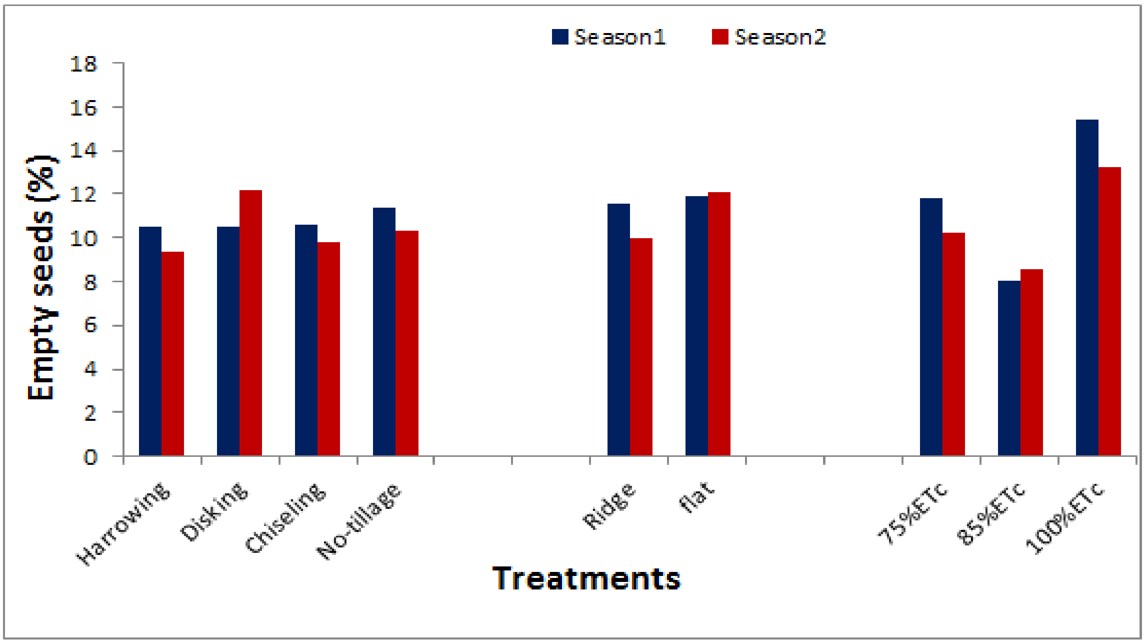

Fig 7: Effect of different treatments on percent empty seeds/head of sunflower *(Helianthus annuus L)* for both seasons

Effect of different treatment Combinations on 4.3.4 :yield parameters

The result showed a significant difference in yield parameters for treatments combination in both seasons, except in the number of seed per plant, in the irrigation water levels and sowing methods combination table 4.19 showed the F value for .all treatment and their interactions

The combination effect of tillage and sowing methods on yield parameters are shown in table 4.15. Head diameters showed significant differences between treatments, the highest value were obtained by disking with flat in season 2011and harrowing with flat in season 2012. Whereas, in thousand seed weight the statistical analysis gave no significant differences in both seasons. However, the effect of these combinations on number of seeds per head indicated that the best combination is disking with flat sowing in season 2012 but in season 2011 the .best combination was harrowing with flat sowing

Significant differences in yield (kg/fed) were obtained by combination of tillage and sowing methods the highest value were obtained by harrowing with flat sowing and the lowest .value obtained by no-tillage with flat sowing in both seasons

The combination effect of tillage and irrigation water levels on yield parameters are shown in table 4.16. Head diameters, showed significant differences between treatments, the heights value were obtained by disking with 100%ETc in both season .((2011, 2012

Highest value for thousand seeds weight and number of seeds per head were obtained by harrowing with 100%ETc in both seasons (2011, 2012). In yield (kg/fed) the highest value were obtained by the disking with 100%ETc in both seasons. The result of empty seed percentage showed no significant differences for tillage and sowing methods but there was a significant difference due to irrigation water levels. The lowest percentage is obtained under 85%ETc and the highest value .was given by 100%ETc

The combination effect between sowing methods and irrigation water levels on yield parameters were shown in table 4.17. There were no significant differences in number of seed per head. The highest value in head diameters, thousand seed weight and yield (kg/fed) were obtained by flat with 100%ETc in .both seasons

The combination effect between tillage, sowing methods and irrigation water levels on yield parameters were shown in table 4.18. In yield (kg/fed) the best combination is obtained by .harrowing with flat under 100%ETc

.Table 4.15 Interaction effect between (tillage and sowing methods) on yield parameters

Treatment		Yield parameters									
Tillage	S.M	(D.D(cm		Seed 1000 Weight		No of Seed/ head		Yield Kg/fed		Empty seeds (%)	
		S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
T_1	R	5.5b	10.13ab	77.33ab	59.67a	227.08bc	214bcd	273.17c	536.83ab	9.75a	8.64a
T_1	F	5.88b	10.89a	102.5a	63.33a	227.92b	269.5a	563.5a	650.45a	11.32a	10.12a
T_2	R	5.25b	8.56bcd	66.67a	42.17a	179.08bc	184.75d	275.83c	352.35bcd	11.92a	10.76a
T_2	F	7.42a	9.83abc	65.33a	46.33a	307.08a	237.67abc	401.33b	418.68bc	17.17a	11.13a
T_3	R	6.3b8	8.45cde	47.08a	33.33a	202.42bc	220bcd	286c	322.63cd	11.04a	9.15a
T_3	F	5.71b	8.05de	63.75a	36.83a	178.83bc	208.17cd	290c	263.5cd	10.17a	10.19a
T_0	R	5.42b	8.38cde	53.58a	29.67a	179.83bc	263.17ab	227.67c	332.61cd	13.58a	12.4a
T_0	F	4c	6.79e	40.83a	23.83a	168.75c	250.83abc	207.17c	198.12d	9.1a	12.14a
%C.V		18.4	24.12	18.51	18.66	23.7	21.37	22.41	23.02	14.15	18.25
LSD		1.04	1.55	29.64	12.79	53.61	45.55	93.15	179.9	9.53	5.44
±SE		0.324	0.49	9.27	4.00	16.76	14.24	29.12	56.24	2.98	2.63

.Table 4.16 Interaction effect between (tillage and irrigation water levels) on yield parameters

Treatment		Yield parameters									
tillage	I.W.L	(D.D(cm		Seed 1000 Weight		No of Seed/ disk		Yield Kg/fed		Empty seeds (%)	
		S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
T_1	W1	4.69e	9.1b	61.88cd	43.13cde	184.13bcd	230.63a	255efg	280.5def	13a	11.01a
T_1	W2	6.00bcd	10.94a	60cde	62.63b	203.75bcd	271.13a	285.5ef	342.48cd	6.73a	9.71a
T_1	W3	6.38abc	11.49a	92.88ab	78.75a	294.63a	223.5a	471.25bc	533.58b	11.88a	14.48a
T_2	W1	4.94de	8.23bcd	68.75bc	35def	257.5ab	209.13a	227.5fgh	425bc	9.88a	6.21a
T_2	W2	6.75ab	8.73bc	90ab	45cd	221.38abc	192.88a	384.25cd	540.8b	8.88a	7.18a
T_2	W3	7.31a	10.64a	95a	52.75bc	250.38abc	231.63a	647.25a	815.125a	12.11a	14.13a
T_3	W1	5.56cde	8.86bc	40.63def	40cde	231.25abc	230.75a	173.00gh	349.32cd	11a	11.6a
T_3	W2	6.31abc	7.48cd	41.88def	29.25efg	176.88cde	200.38a	210.25fgh	214.7ef	8.69a	89.63a
T_3	W3	6.25abc	8.41bcd	83.75abc	36def	163.75de	211.13a	480.75b	318.19cdf	12.13a	13.17a
T_0	W1	4.81e	7.06d	31.63f	21g	192.75bcd	235a	160gh	174.61f	13.21a	11.43a
T_0	W2	4.44e	7.5cd	37.5ef	24.75fg	195.38bcd	280.63a	142.5h	257.05def	8.56a	8.09a
T_0	W3	4.88de	8.19bcd	72.5abc	34.5def	134.75e	255.38a	349.75de	364.43cd	12.25a	14.27a
%C.V		18.4	24.12	18.51	18.66	23.7	21.37	22.41	23.02	14.1	18.25

									5	
LSD	1.05	1.26	21.92	13.21	67.24	86.88	90.92	110.2	10.76	9.14
±SE	0.37	0.44	7.71	4.65	23.65	30.55	31.97	38.77	3.78	3.92

Table 4.17 Interaction effect between (Sowing methods and Irrigation water levels) on .yield parameters

Treatment		**Yield parameters**									
S.M	**I.W.L**	(D.D (cm		Seed 1000 Weight		No of Seed/ disk		Yield Kg/fed		Empty seeds (%)	
		S1	**S2**	S1	**S2**	S1	**S2**	S1	**S2**	S1	**S2**
R	W1	5.38c	8.79 b	48.31 c	36.69 b	227.06a	225.63a	210.63d	332.06 bc	12.44 ab	13.23 ab
R	W2	5.5bc	8.48 bc	48.13 c	37.94 b	180.56a	232.69a	204.75d	288.88 c	9.06b	11.42 ab
R	W3	6.03a bc	9.36 ab	87.06 a	49a	203.69a	203.13a	381.63b	537.39 a	13.22 ab	16.08 a
F	W1	4.63d	7.83 c	53.13 bc	32.88 b	205.75a	227.13a	197.13d	282.66 c	11.17 ab	14.26 ab
F	W2	6.25a b	8.84 b	66.56 b	42.88 ab	238.13a	239.81a	306.5 c	388.64 b	7.07b	8.02b
F	W3	6.38a	10.01a	85.00 a	52a	218.06a	257.69a	592.88a	478.27 a	17.63 a	16.24 a
%C.V		18.4	24.12	18.51	18.66	23.7	21.37	22.41	23.02	14.15	18.25
LSD		0.74	0.89	15.5	9.34	47.55	61.43	64.29	77.95	7.6	6.87
±SE		0.26	0.31	5.45	3.27	16.72	21.6	22.61	27.41	2.67	2.43

Table 4.18 Interaction effect between tillage, sowing methods and irrigation water levels on .yield parameters

Treatment			Yield parameters									
Tillage	S.M	I.W.L	(D.D (cm		Seed Weight 1000		No of Seed/ disk		Yield Kg/fed		% Empty seeds	
			S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
T_1	R	W1	4.88bcd	9.13def	68.75bcd	43.75def	195.75cde	204.75abc	170kl	386.7def	9.5a	12.23a
T_1	R	W2	5.5bcd	10.25bcd	50cde	57.75bcd	127.5efg	219abc	255.5fgh	379.6def	7a	7.5a
T_1	R	W3	6.13bcd	11abc	113.25a	77.5ab	358.0ab	218.25abc	402cde	786.5ab	12.75a	13.25a
T_1	F	W1	4.5abc	9.08def	55cde	42.5def	172.5cde	256.5abc	285fgh	463.3cde	16.5a	4.5a
T_1	F	W2	6.5bc	11.63abc	70cde	67.5abc	280bc	323.25ab	513bcd	702ab	6.45a	8.75a
T_1	F	W3	6.63b	11.98ab	72.5bcd	80a	231.25cde	228.75ab	892.5a	844.2a	11a	13.5a
T_2	R	W1	5.25bcd	9.03def	37.5def	41.5def	256.25bcd	194.75ab	273.5fgh	352.4def	12.75a	11.93a
T_2	R	W2	4.75cde	7.93fgh	65bcd	40def	167.75cde	152.5c	196.5jkl	262.7fgh	9.5a	16.38a
T_2	R	W3	5.75bcd	8.73efg	97.5ab	45def	113.25fg	207c	349.5efg	441.95def	13.5a	9.5a
T_2	F	W1	4.63def	7.43hij	100ab	28.5efg	258.75bcd	223.5c	236.5ghk	208.6hij	7a	13.5a
T_2	F	W2	8.75a	9.53def	115a	50cde	275.00bc	233.25c	374.5def	422.25def	8.25a	7a
T_2	F	W3	8.88a	12.55a	92.5ab	60.5abc	387.5a	256.25c	593b	625.2bc	13.5a	8.25a
T_3	R	W1	6bc	9.78cef	43.75cde	40def	256.25bcd	257.5c	195jkl	397.9def	12a	11.5a

T_3	R	W2	6.63b	7.5ghi	30ef	27.5efg	175cde	222.5c	151.5kl	326.2ghi	9a	12.3a
T_3	R	W3	6.5b	8.08fgh	67.5bcd	32.5efg	176cde	180bc	336.5efg	333.8efg	12.13a	9.45a
T_3	F	W1	5.13bcd	7.95fgh	37.5def	40def	206.25cde	204bc	125l	300.73efg	10.25a	10.13a
T_3	F	W2	6bc	7.45hij	53.75cde	31efg	178.75cde	178.25bc	133.5kl	193.2jk	7a	10.7a
T_3	F	W3	6bc	8.75efg	100ab	39.5def	151.5def	242.25bc	363efg	302.58efg	13.25a	7.4a
T_0	R	W1	5.38bcd	7.25ij	43.25cde	21.5gh	200cde	245.5bc	204ijk	191.23jk	15.5a	9.5a
T_0	R	W2	5.13bcd	8.25efg	47.5cde	26.5fgh	172cde	336.75a	215.5ijk	277fgh	10.75a	16.5a
T_0	R	W3	5.75bcd	9.63def	70bcd	41def	167.5cde	207.25bc	438.5hij	529.6cd	14.5a	10.3a
T_0	F	W1	4.25efg	6.88j	20f	20.5h	185.5cde	224.5bc	142cde	158k	10.93a	13.75a
T_0	F	W2	3.75g	6.75j	27.5f	23fgh	218.75cde	224.5bc	205kl	237.1ghi	6.38a	6.5a
T_0	F	W3	4fg	6.75j	75bc	28efg	102g	303.5ab	523bc	199.25ijk	10a	14.5a
%C.V			18.4	24.12	18.51	18.66	23.7	21.37	22.41	23.02	14.15	18.25
LSD			1.48	1.79	31	18.69	95.09	122.9	128.6	155.9	15.22	13.25
±SE			0.52	0.63	10.9	6.57	33.44	43.21	45.22	27.41	5.35	3.04

Table 4.19 F value for yield parameters in both seasons

Empty seed (%)		Yield kg/fed		Thousand seed weight(gra (ms		No-of seed/head		Head diameters		Source of variation
S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	
ns 1.34	0.69 ns	83.7 *2	*43.6	16.48 *	4.36 *	1.84 ns	*6.48	28.97 *	*9.48	T
ns 2.04	0.03 ns	0.07ns	*49.5	0.26ns	1.73 ns	5.42 ns	5.78ns	0.015 ns	0.99ns	S.M
ns 0.76	0.95 ns	1.45ns	11.68 *	0.72ns	3.22 ns	3.61 ns	*8.81	3.44ns	*11.74	T×S.M
*4.21	*3.8	43.2 *3	*88.9	11.75 *	23.7 *	0.10 ns	0.54ns	10.25 *	*11.46	I.W.L
ns 1.09	1.13 ns	*7.35	*2.93	*3.42	1.22 ns	0.60 ns	*3.57	*3.34	*2.49	T× I.W.L
ns 1.89	0.86 ns	*4.09	12.34 *	0.97ns	1.83 ns	0.91 ns	*4.48	*3.73	*4.46	S.M× I.W.L
ns 2.03	1.22 ns	*4.01	*1.2	0.87ns	3.41 *	1.29 *	*4.85	*3.48	*2.62	T×S.M × I.W.L

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

- The results indicated that tillage treatments had considerable effects on most of the vegetative, productive and soil parameters attributes measured .in this study
- The harrowing land preparation treatment was found superior in improving soil physical properties through directly improving soil moisture retention capacities, .porosity and bulk density
- In this study chiseling was found to give higher infiltration rates at the beginning that drops steeply to flat compared to other tillage treatment but in soil moisture retention capacity it showed no superiority. .This justifies its lower yield compared to harrowing
- The results of sowing methods (flat, ridge) showed that there was no significant differences in all .parameters measured in this study
- The results obtained showed that the irrigation water level treatments significant differences in most of the vegetative and yield parameters attributes measured in this study. The number of seed per head was not affected by tillage treatments, water stress and sowing methods it seems that this character is genetically control rather than environmentally .affected

- The results of thousand seed weight indicated that thousand seed weight was highly sensitive to water .stress
- Analysis of variance, in both seasons, showed significant differences due to tillage treatments the highest values in yield were obtained under harrowing treatment and lowest values were .obtained under no- tillage treatment
- The results obtained from this study, indicated that harrowing tillage with 100%ETc had a significantly better effect on growth and yield attributes, as .compared to the other treatments
- Sunflower is well known for its empty seeds problem. 100% ETc irrigation water levels showed no improvement in the reduction of the number of empty seeds but on the reverse the number of empty increased. This implies that the number of empty seeds phenomenon is associated with level of .irrigation at a certain growth stages of the plant life

RECOMMENDATIONS

Based on the results obtained in this study it -1
seems that this crop yield better at 100%ETc,
therefore it's recommended to be given its full
.irrigation water requirement

Effect of deficit irrigation on empty seeds -2
phenomenon should be studied further specially at
.plant mid stages of growth

Sunflower performs better if grown in harrowed -3
.soils

Although this study did not touch on sunflower -4
harvesting methods studies aiming at establishing
sunflower as a summer cash crop in the Northern
State should be accompanied with mechanical
.harvesting studies

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APPENDICES

:(Appendix (1

Appendix 1.1

Area under sunflower, production, and yield from 1987/88 .season to 2011/12 season in Sudan

Yield Kg/fed	PROD Ton ,000’	AREA fed ,000’	SEASON	Yield Kg/fed	PROD Ton ,000’	AREA fed ,000’	SEASON
308	4	13	2000/01	150	39	260	1987/88
154	4	26	2001/	125	46	367	1988/

			02				89
621	18	29	2002/ 03	152	22	145	1989/ 90
462	6	13	2003/ 04	98	23	234	1990/ 91
520	13	25	2004/ 05	147	11	75	1991/ 92
611	44	72	2005/ 06	181	40	221	1992/ 93
479	73	147	2006/ 07	222	32	144	1993/ 94
338	100	296	2007/ 08	274	48	175	1994/ 95
338	247	730	2008/ 09	227	25	110	1995/ 96
393	46	118	2009/ 10	274	20	73	1996/ 97
602	124	206	2010/ 11	185	12	65	1997/ 98
387	92	238	2011/ 12	217	10	46	1998/ 99
				163	8	49	1999/ 00

Source: Ministry of Agriculture and Forestry, Department .of Agriculture Statistics

:**Appendix 1.2**

(Climate of Northern State (desert climatic zone

3800	[Sun light duration [hr/year
23.1	[Solar radiation [Mj/m^2/day
[July] 43	[Maximum Temperature [°C

[.Jan] 8	[Minimum Temperature [°C
35	[Temperature Range [°C
100 >	[Rain fall [mm\annum
2500	[Evap. [mm\annum

Source: حسين سليمان آدم (2002) المناخ الزراعي دار جامعة الجزيرة للطباعة والنشر. الطبعة الثانية.

<u>Appendix 1.3</u>

The physical and chemical properties of a typical soil profile from the experimental site

$CaCo_3$	ESP	Soil texture			CEC	S.P	SAR	(Soluble anions (mg/L				Soluble captions				ECe	PH	Depth cm
		Silt	Clay	Sand				$^{-}SO_3^{-}$	^{-}CL	HCO_3	$^{-}CO_3^{-}$	++K	+Mg+	Ca+	+Na			
5.4	25.9	24.5	22.2	53.3	27.7	42.9	67.8	112.6	55.5	11.5	0.0	0.009	2	11.8	176.3	19.3	7.6	15 – 0
4.8	31.5	19.2	30.9	49.9	55	53.5	66.3	123.8	178.5	13.9	0.0	0.15	7.9	26.7	278.5	31.6	8.9	– 15 35
6.4	42.9	16.3	24.5	58.7	57	49.5	40.1	140.3	88.5	10.2	0.0	0.017	6.3	18.2	197.5	23.9	7.3	– 35 55
6.2	40.4	30.5	27.3	42	57.5	46.6	62.3	136.5	122.6	12.9	0.0	0.009	5.8	22.5	236.8	27.2	7.4	– 55 75
6	32.5	12.4	17.8	69.8	36.5	35.4	48	56.2	71.5	8.5	0.0	0.005	3.5	9.3	119.9	13.6	7.6	– 75 95
4.3	26.5	17.7	19.5	62.8	23	38.9	84.6	130.7	80.6	11.7	0.0	0.0012	1.5	9.7	211.5	22.3	7.3	– 95 120
3.1	17.8	8.2	2.3	89.5	5.2	32.7	49.2	45.2	63.2	9.6	0.0	0.0015	3	8.6	105.7	11.8	7.5	+ 120

Appendix 1.4 Mean value of infiltration rate in cm for :the 2011- 2012 seasons under different tillage treatment

Treatment	Infiltration rate cm			
	min 5	10min	20min	30min
Disking	1.5[a]	[a] 0.8	0.8[b]	[a] 1.63
Harrowing	[a] 1.2	[a] 0.9	[a] 1.93	0.96[bc]
Chiseling	[a] 1.23	[a] 1.07	[a] 1.96	1.26[b]
No-tillage	0.6[b]	0.42[b]	0.6[c]	0.7[c]
%C.V	14.41	16.46	11.87	13.3
LSD	0.328	0.26	0.32	0.3
±SE	0.0948	0.0753	0.0913	0.0876

Appendix 1.5 The length of plant stage, crop coefficient value/stage and monthly ETo/season

ETo	Month	Kc value	Stage length	Stage
10.76	May	0.35	20	Initial
11.29	June	0.75	30	Development
9.76	July	1.12	35	Med
10.16	August	0.75	20	Late
10.76	September			

.**Appendix 1.6**: Applied water m^3/Fed/watering for irrigation treatment in seasons 2011 and 2012

Volume of water applied m^3/watering/Fed										
Total	9th	8th	7th	6th	5th	4th	3rd	2nd	1est	Treatment
338.9	338.9	329.5	477.9	477.9	468.51	307.4	307.4	331.6	165.9	100% Etc
288.07	288.07	280.08	406.22	406.22	398.23	261.29	261.29	281.86	141.02	Etc 85%
254.18	254.18	247.13	358.43	358.43	351.38	230.55	230.55	248.7	124.43	Etc 75%

Appendix 1.7 Combination effect between (tillage X sowing methods) on soil moisture content for different depths.

Treatment		Incremental depth cm					
		20 – 0		40 - 20		60 – 40	
Tillage	S.M	S1	S2	S1	S2	S1	S2
T_1	R	5.14 bc	7.82a	21.51 ab	a 8.90	7.78d	19.52 a
T_1	F	7.63 a	7.50a	20.31 bc	a 9.18	10.12 c	20.04 a
T_2	R	5.87 b	16.18 a	14.58 g	16.89 a	5.89e	19.50 a
T_2	F	5.97 b	12.09 a	19.35 cd	12.49 a	5.76e	18.38 a
T_3	R	4.15 c	12.81 a	16.25 f	13.6a	14.97 a	19.43 a
T_3	F	4.42 c	15.34 a	17.44 ef	15.19 a	15.82 a	17.93 a
T_0	R	5.18 bc	15.19 a	21.94 a	15.18 a	11.64 b	14.18 a
T_0	F	4.84 bc	14.19 a	18.38 d	15.67 a	16.23 a	14.87 a
%C.V		24.62	23.79	5.68	22.63	15.16	10.68
LSD		1.09	3.90	1.54	3.71	1.33	1.53
±SE		0.34	1.22	0.48	1.16	0.42	0.477

Appendix 1.8 Combination effect between (tillage X irrigation water amount) on soil moisture content for different depths.

Treatments	Incrementa

							l depth cm
					20 – 0	- 20 40	– 40 60
Tillage	I.W.L	S1	S2	S1	S2	S1	S2
T_1	W1	5.20bcd	8.36f	19.27bc	9.11f	7.03de	17.71cd
T_1	W2	4.7cde	7.96f	21.37a	8.76f	7.78de	19.09bc
T_1	W3	9.255a	14.66bcd	22.10a	9.25f	12.03c	22.54a
T_2	W1	3.49ef	12.05de	14.81e	12.62de	3.99f	16.94d
T_2	W2	6.06bc	11.72e	16.23d	11.27ef	6.06e	19.15bc
T_2	W3	8.81a	18.65a	19.82b	20.17a	7.43de	20.73ab
T_3	W1	2.95f	14.66bcd	14.06e	13.51cde	12.54c	16.88d
T_3	W2	3.94def	12.22cde	16.97d	13.38cde	14.44b	18.04cd
T_3	W3	5.96bc	15.50abc	19.51b	16.29bc	19.2a	21.12ab
T_0	W1	3.41ef	12.90bcd	18.34c	13.72bcd	8.34d	12.51f
T_0	W2	5.13bcd	16.03ab	19.78b	16.90b	14.90b	14,51e
T_0	W3	6.48b	15.14bcd	22.37	15.67bcd	18.56a	16.55d
%C.V		24.62	23.79	5.68	22.63	15.16	10.68
LSD		1.34	3.03	1.07	3.05	1.68	1.93
±SE		0.47	1.06	0.38	1.07	0.59	0.48

Appendix 1.9 Combination effect between (sowing methods X irrigation water amount) on soil moisture .content for different depths

Treatment		Incremental depth cm					
		20 – 0		40 - 20		60 – 40	
S.M	I.W.L	S1	S2	S1	S2	S1	S2
R	W1	3.43 e	12.85a	16.44 e	13.00 a	7.60 d	16.58 bc
R	W2	5.10 c	12.27a	17.81 d	12.97 a	9.49c	17.86 b
R	W3	6.73 b	13.88a	21.47 a	14.96 a	13.12b	20.03 a
F	W1	4.10 de	11.13a	16.80 e	11.48 a	8.35cd	15.44 c
F	W2	4.81 cd	11.69a	19.37 c	12.19 a	12.10b	17.54 b
F	W3	8.23 a	14.09a	20.43 b	15.73 a	15.49a	20.43 a
%C.V		24.62	23.79	5.68	22.63	15.16	10.68
LSD		0.94	2.139	0.76	2.15	1.19	1.37
±SE		0.33	0.75	0.27	0.76	0.42	0.48

Appendix 1.10 Combination effect between (tillage X sowing methods X irrigation water amount) on .soil moisture content for different depths

Treatment			Incremental depth cm					
			0-20		40 – 20		60 – 40	
Tillage	S.M	I.W.L	S1	S2	S1	S2	S1	S2
T_1	R	W1	e 4.93	f 7.28	19.84cd	d 7.71	e 6.93	cde 17.93
T_1	R	W2	e 4.16	7.27f	bc 21.82	d 8.03	e 7.05	cde 18.5
T_1	R	W3	c 6.33	8.90f	b 22.88	10.97cd	cd 9.37	ab 22.13
T_1	F	W1	d 5.47	9.45f	e 18.70	cd 10.51	e 7.12	cde 17.5
T_1	F	W2	d 5.24	8.65f	c 20.92	cd 9.49	d 8.52	bcd 19.68
T_1	F	W3	a 12.18	4.41f	bc 21.31	d 7.54	b 14.68	a 22.95
T_2	R	W1	2.71f	14.66bc	f 11.88	bc 15.17	f 5.01	cde 17.83
T_2	R	W2	c 6.28	13.74cd	f 13.02	bc 13.98	f 5.81	bcd 19.93
T_2	R	W3	b 8.64	20.14a	18.84 de	a 21.52	e 6.87	abc 20.75
T_2	F	W1	e 4.28	f 9.43	ef 17.75	cd 10.08	f 2.98	e 16.05
T_2	F	W2	cd 5.84	f 9.69	d 19.50	d 8.56	ef 6.31	cde 18.38
T_2	F	W3	bc 7.78	abc 17.16	c 20.80	ab 18.82	cd 7.99	abc 20.70
T_3	R	W1	f 3.08	cde 13.74	f 14.27	bc 13.52	c 11.18	cde 17.58
T_3	R	W2	4.87e	cde 12.81	f 15.18	bc 13.57	b 14.84	18.77cde
T_3	R	W3	e 4.51	ef 11.89	d 19.31	bc 13.70	a 18.88	ab 21.93
T_3	F	W1	ef 2.83	abc 15.58	f 13.85	bc 13.50	b 13.90	e 16.18
T_3	F	W2	f 3.01	ef 11.62	e 18.76	bc 13.18	b 14.04	de 17.3
T_3	F	W3	bc 7.42	ab 19.10	19.71	ab 18.89	a 19.53	ab 20.3
T_0	R	W1	f 3.00	abc 15.73	cd 19.77	bc 15.62	e 7.30	f 13.00
T_0	R	W2	de 5.11	abc 15.26	bc 21.23	bc 16.29	cd 10.26	f 14.23
T_0	R	W3	bc 7.43	bcd 14.58	a 24.84	bc 13.65	a 17.36	f 15.33
T_0	F	W1	ef 3.82	f 10.07	f 16.92	c 11.83	cd 9.39	f 12.03
T_0	F	W2	de 5.16	abc 16.79	e 18.33	ab 17.51	a 19.54	f 14.80

T_0	F	W3	d 5.54	abc 15.70	cd 19.89	ab 17.68	a 19.77	cde 17.78
%C.V			24.62	24.75	5.68	22.63	15.16	10.68
LSD			1.89	4.28	1.51	3.31	2.38	7.73
±SE			0.66	1.51	0.53	1.52	0.84	0.96

Appendix 1.11 Effect of irrigation water level treatments on sunflower (*Helianthus annuus L)* yield parameters for two seasons

Empty seed (%)		Yield kg/fed		Thousand seed weight		No-of seed/head		Head diameters		I.W.L
S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	
10.2ab	11.8 b	307.34 b	203.88 c	50.72b	34.78 b	226.38a	216.41a	8.31 b	5.00 c	W_1
8.6b	8.04 c	338.76 b	255.63 b	57.34b	40.41 b	236.25a	199.34a	8.66 b	5.88 b	W_2
13.2a	15.4 a	507.83 a	487.25 a	86.03a	50.5a	230.41a	210.88a	9.68 a	6.20 a	W_3
18.4	24.12	18.51	18.66	23.7	21.37	22.41	23.02	14.15	18.25	C.V %
4.3	3.1	55.12	45.46	10.96	6.61	43.44	33.62	0.63	0.52	LSD
1.98	2.185	19.38	15.99	3.86	2.32	15.28	12.25	0.22	0.18	±SE

Means values followed by the same letter within a column are not significantly different at P ≤ 0.05 according to Duncan multiple range

Appendix 1.12 Effect of sowing methods treatments on yield parameters of sunflower for both seasons

Empty seed (%)		Yield kg/fed		Thousand seed weight		No-of seed/head		Head diameters		S.M
S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	
9.98a	11.57 a	386.1 a	345.7a	61.17a	41.21a	220.48 a	197.10a	7.06 a	6.64 a	R
12.06a	11.94 a	383.2 a	365.5a	68.23a	42.58a	241.54 a	220.65a	8.89 a	5.75 a	F
18.4	24.12	18.51	18.66	23.7	21.37	22.41	23.02	14.15	18.25	C.V %

Appendix 1.13 Effect of tillage treatments on yield parameters of sunflower (*Helianthus annuus L)* for both seasons

Empty seed (%)		Yield kg/fed		Thousand seed (weight(grams		No-of seed/head		Head diameters ((cm		Tillage
S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	

9.4a	10.5 a	385.52b	337.25b	84.58 a	61.5a	211.21 a	227.5 a	10.51 a	8.69 a	T_1
12.2a	10.5 a	593.63a	419.67a	71.58 ab	44.25 b	243.08 a	241.75a	9.9ab	6.33 a	T_2
9.8a	10.6 a	294.07c	288c	55.42 b	35.08 bc	214.08 a	210.63a	8.25c	6.54 a	T_3
10.4a	11.3 a	265.36c	217.42d	47.21 b	26.75 c	212.00 a	204.29a	7.58c	4.71 b	T_0
18.4	24.12	18.51	18.66	23.7	21.37	22.41	23.02	14.15	18.25	%C.V
3.56	4.23	75.84	10.65	25.55	11.74	52.15	40.4	0.75	0.73	LSD
0.78	1.03	23.71	12.7	7.99	3.67	16.3	12.52	0.24	0.23	±SE