Chapter One

Introduction

Sudan is a large country = 1.861sq km = 717.945 sq miles. (www.Indexmundi. Com/Sudan/area./ htm), dominated by arid and semi-arid tropical regions that favor the formation of salt affected soils. Saline soils occur on both banks of the White Nile within the arid and semi-arid regions. Most of the salt accumulations occurred at soil depth, of 0.3 -0.6 meters, top—soil salinity rarely occurred. (Nachtergaele,1976). Khartoum State is an important area for fodder production to satisfy the requirement of increasing animal numbers for meat and dairy products, the demand for which is continuously increasing due to normal population growth and mass immigration of rural communities to the capital towns and other settlements. In addition to this, a remarkable activity for cattle and sheep for export has resulted in increasing the area of fodder crops. Irrigation cost and management, no doubt, plays an important role for the production of fodder crops. Efficient utilization of the land water resources will therefore be reflected directly to the interest of the farmers, the consumer, and also to the interest of export trade, so that the irrigation interval can be added to the original Penman Montieth Model which was recommended by Food and Agriculture Organization of the United Nations .FAO (1984). The area under Abu Sabein is estimated to be about 6300 ha (15000 Fadden) / year, (Abu Swar., 2005). This fodder is usually cut and transported to dairy animals, fattening or export animals before their journey abroad. This fodder is usually consumed as fresh matter. The fodder is a rich source of nutrient containing 5% crude Protein and 55 % total digestible nutrient (Osman *et al* 1968).

A series of experiments started since 1975 and continued to 2005, to give complementary information relating crop productivity to irrigation level and variation to climate (Saeed, and EL.Nadi, 1988). Most of the salt affected soils of Sudan have a relatively low nutrient content. The Potassium (K) content is considered adequate but sodium bicarbonate and extractable Phosphorus are deficient for most important agricultural crops, (Mustafa 1986). Response of barley to water stress at different growth stages at various levels of soil salinity resulted in significant ($P<0.05$), variations in both the above ground and root dry weights between different treatments at each sampling data. In addition, the interaction between level of salinity and water stress was also significant (Al khafaf, *et al.*, 1990). It is not always possible or practical to eliminate all salt from the soil, but managing the soil may reduce salt effects. The most effective way of using saline land and saline water is to use tolerant plants. The choice of tolerant crop is essential for successful crop production (Rastegari, and Farahangisabet, 2006). Crops differ in the ability to tolerate salt accumulation in soils, but if levels are high over (16 ds/m) only tolerant plants will survive. As salts accumulate in the soil, soil solution osmotic pressure increases. When this happens the amount of water available for plants uptake decreases and plants exhibit poor growth and wilting even though the soil is not dry. Forage production and consumption in Sudan is increasing over time due to the increasing rate of livestock population (140 million head) (Ministry of Animal Resources, 2007). According to the recent survey conducted by Khair and Salih (2007), the amount of forage crops produced in Sudan was estimated at 971 thousand tons of dry matter which was produced from a cultivated area of 121 thousand hectares. The main forage crops produced in the country were Abu sabein *Sorghum bicolor* L Moench cv constituting about 43% of the total annual yield occupying an area of 70 thousand hectares . No wonder if forage sorghum can be produced in all types of soils as it is tolerant to salinity and sodicity. Sorghum (*Sorghum* *bicolor* L.Moench) is a crop of world –wide importance. The tremendous increase in demand for animal products has led to great expansion in the area allocated for fodder crops. Sorghum is the most important irrigated forage crop in the Sudan. The traditional sorghum cultivar (Abu Sabein) is the most important cultivar grown for forage in the Sudan. In Khartoum State, it represents more than 60% of the total area cultivated. According to the statistics of the Ministry of Agriculture in 2009, the area cropped with fodder crops in Khartoum State was estimated at 200000 fed., in the River Nile and Northern States for the same year, 55000 and 29000 fed respectively. Research efforts aiming at developing improved forage types were very few. The seed of all forage sorghum hybrids currently in use are imported. Four hybrids were tested and released by Agricultural Research Corporation. (Mohammed , 2007). Nitrogen is the most limiting nutrient for sorghum forage production on a global basis (Foth and Ellis, 1988) and the improper cultural practices, sowing methods , irrigation intervals and nitrogen fertilization properly used by many farmers in the country. Forage sorghum has not reached its required level of production both in quality and quantity . Recent studies were focused on improving sorghum forage both quantitatively and qualitatively.

The main objective of this work is to study the performance of two fodder crop cultivars mainly "Abu 70" and "Garawia", on saline soil, under different irrigation intervals , and two types of soil preparation methods.

The specific objectives are:-

1- To determine the best irrigation interval under the treatment conditions.

2- To investigate the effect of two soil preparation methods coupled with four irrigation intervals on the performance of two sorghum forage crops in saline soil.

3- To investigate the effects of the coupling leaching requirements to different irrigation intervals on the production of sorghum cultivars**.**

4- To study the effects of the different treatments on the dry matter and different growth parameters.

CHAPTER TWO

Literature Review

2-1 Land use:

Sudan total land area amounts to some 1.861.484 km^2) with 16.630 km^2 of irrigated land. The country soils can be divided geographically into two categories. These are the sandy soils of the northern and west, central areas, and the clay soils of the central region. Less extensive and widely separated, but of major economic importance the third group consists of alluvial soils found along the lower reaches of the White Nile and Blue Nile rivers, along the main Nile to lake Nubian, in the Delta of the Qash River in Kassala area and in Baraka Delta in area of Tokar near the Red Sea. Agriculturally, the most important soils are the clay in central Sudan that extend from west Kasala through central regions to Kordofan They are used in the area of Aljazeera and Khashim Al qirba for irrigated cultivation. East of the Blue Nile large areas are used for mechanized rain fed crops. West of the White Nile soils are used by traditional cultivators to grow sorghum, sesame and peanut. The sandy soils in the semi-arid areas south of the desert in Northern Kordofan and Northern Darfur States are used for grazing in the southern part of these States and the western part of southern Darfur are the so-called qoz sands. Livestock raising in these areas is the major activity, but significant amount of crop cultivation. (en. Wikipedia. (2013). Forest and wood lands cover about 64.36 million ha., while range lands are estimated to cover 24 million ha,. Forage from range lands is estimated to provide, depending upon the region, from 55—80% of the national herd feed requirements. Fodder crops are grown primarily under irrigation to feed dairy cattle, small ruminants drought animals, and the good part of the production is channeled to the local market where it is sold as green fodder. The total area is estimated at about 126.000 ha with almost half in Khartoum State (Zaroug *et al*, 1997). This area is expanding with increased attention given to dairy production, particularly around urban centers. Normally 80—90 % of the area allocated to fodder crops is devoted to annuals, mainly forage sorghum cv. (Abu sabein), with limited area under maize and lablab, the remaining area is occupied by alfalfa, the major perennial fodder. Soils affected by salts have been given descriptive and even colorful names, these names come from the land surface appearance as soils become salt contaminated-virtually eliminating all plant growth as salt concentration increases. Salts usually affect plant growth because of osmotic effect- high salt concentration increases the suction forces holding water in the soil and makes it difficult for plant roots to extract the soil moisture. During a drying period salt in soil solutions may be so concentrated as to kill plants by pulling water from the (exosmosis). Salts in the soil solution force the plant to excrete mo re energy to absorb water.

2-2- Soil particle size distribution:

Soil particles are divided initially into two size classes with the limit normally set at 2 mm to delimit the "fine earth" from the larger separates including gravel. Larger separates- material > 2mm.The nature and properties of the coarse particles can often lead to important conclusions about the origin and formation of the parent material and about the soil itself. The soil < 2 mm is divided into sand, silt and clay, the size limits of which vary between workers but normally either the international scheme or that proposed by the United State Department of Agriculture. App,(1).

According to the relative amounts of sand, silt and clay twelve classes have been created and presented in the form of a triangular diagram by using only three size limits. (Fitzpatrick, 1978). The mineral particles of the soil are classified according to size into three principal groups, which are called sand, silt, and clay. The qualitative classification tool used in both the field and laboratory to determine classes for agricultural soils based on their physical texture. . The classes are distinguished in the field by the" textural feel" which can be further clarified by separating the relative proportions of sand, silt and clay using grading sieves.

2-3 The nature of salt affected soils:

Salt affected soils differ from normal soils in respect of soil reaction pH and soluble salt content. Visually, they are recognized by the presence of white or grayish-white efflorescence of salts on the soil surface during dry months.(Salt affected soil may have problem of salinity and sodicity). Salt affected soils are broadly classified into groups of saline soils. Soluble salts are mostly carbonates and bicarbonates of sodium. The exchangeable sodium percentage (ESP) of these soils often exceeds 15. In barren sodic soils the exchange complex maybe largely occupied by sodium ions, and the presence of large amounts of exchangeable sodium dispersed in the soil resulting in their poor physical condition. (Central Soil Research Institute, Carnel, 2001 India).

2-4 General Characterization of Saline and Sodic soils:

Salt-affected soils are directed into three groups depending on the amount and kinds of salts present. Classification depends on total soluble salts (measured by electrical conductivity, E.Ce), soil pH, and exchangeable sodium percentage. App. (2):

2-4-1 Saline Soils:

These are defined as soil containing sufficient amount of soluble salts that affect plant growth and their productivity. All soils contain some water – soluble salts, but when these salts occur in amounts that are harmful to germination and plant growth, they are called saline. Saline soils are the easiest of the salt – affected soils to reclaim if good quality water is available and the site is well drained. Saline soils often are in normal physical condition with good structure and permeability. They are characterized by irregular plant growth and salty white crusts on the soil surface. These salts are mostly sulphate and /or chlorides of calcium and magnesium and soluble sodium.

2-4-2 Sodic Soils: (High amount of exchangeable Na).

Sodic soils are low in total soluble salts but high in exchangeable sodium. The combination of high levels of sodium and low total soluble salts tends to disperse soil particles, making sodic soils of poor tilth. These soils are sticky when wet, nearly impermeable to water and have a slick look. As they dry, they become hard, cloddy and crusty. Sodic soils have exchangeable sodium percentages of more than 15. This means that sodium occupies more than 15 of the soil's cations exchange capacity (CEC). The pH is greater than 8.5, and the electrical conductivity is less than (4 ds/m. Sodic soils are detrimental to growth of most plants.

2-4-3 Saline-sodic soils:

These soils contain large amounts of total soluble salts greater than 15 percent exchangeable sodium. The pH is generally less than 8.5., with poor physical condition and low permeability. (Ray and David , 1992).

2-4-4 Salinity and sodcity in soils:

Soils are said to be saline if they contain an excess amount of soluble salts and less amount of exchangeable sodium. Two classes of saline soils are recognized, saline-non sodic and saline-sodic, according to their content of sodium. The term non saline- sodic is applied to soils with a high concentration of exchangeable sodium but not of soluble salts. The term salt-affected soil is applied to saline-non sodic, saline -sodic and non saline- sodic soils collectivity. Non saline- sodic soils are included in the group because they are usually derived from saline - sodic soils, because soluble salts are removed from soils by leaching with water. Occurrence of salts-affected soils are much more frequent in arid regions than in humid regions. Excesses of soluble salts and sodium have important influences on plant growth. Agricultural production in parts of the world is limited by detrimental effects associated with these conditions. Salinity and Sodicity usually reduce the productivity of over one - fourth of the areas under irrigation and prevent the farming of additional areas. The principal management problems are associated with the accumulation, presence, and removal of soluble salts. (Ibrahim and Gafar. 2013)

2-5 Classification of Salt-Affected Soils:

2-5-1 Saline non-sodic soils:

Saline -non sodic soils contain soluble salts in quantities great enough to interfere with growth of most crop plants. The solution extract of saline -non sodic soils has electrical conductivity (ECe) greater than 4 ds/m at 25 °C. and exchangeable sodium percentage (ESP) less than 15. The pH value is usually below 8.5. A white crust of salts often occurs on the surface in dry weather (Ibrahim and Gafar, 2013).

2-5-2 Saline-sodic soils:

Saline - sodic soils contain soluble salts and exchangeable Sodium in quantities great enough to interfere with the growth of most crop plants. The saturation extract has a specific electrical conductivity greater than 4ds/m at 25 °C. and ESP greater than 15. The appearance and properties are similar to those of saline-non sodic soils, the pH value is usually more than 8.5 (Ibrahim and Gafar, (2013).

2-5-3 Non saline – sodic soils:

Non saline--sodic soils contain enough exchangeable sodium to interfere with the growth of most crop plants, but they do not contain an excess of soluble salts. The saturation extract of non saline- sodic soils has an electric conductivity less than 4 ds/m at 25 °C. and ESP greater than 15, and the pH value is 8.5-10 (Ibrahim and Gafar, 2013).

2-6 Effect of salt concentration:

Salts are usually most damaging to young plants but not necessarily at the time of germination. Yet high salt concentrations which may be most concentrated at seed depth, can slow seed germination several days or completely inhibit it because soluble salts move readily with water evaporation will move salts to the surface where they accumulate sometimes visible as powdery white salt crust. plant species have variable tolerance to the presence of salt in soils and the specific effects on various parts of the plants are also variable (Ibrahim and Gafar , (2013).

2-7 Reclamation of saline soils:

The quantity of water required to remove salts from the soil depends on many factors such as how deep the salts are to be washed, what percentage of the salts are to be removed and how the leaching is done. The first step toward reclamation of any salt—affected soil is: soil irrigated lightly but frequently by good quality irrigation water to keep it at-a high moisture content during the salt-sensitive germination and seedling stages, plants are normally more tolerant and able to survive towards mature stage of growth. The second step, to select the suitable plant in order to tolerate the salinity. Third step, add a required amount of water calculated by using the leaching requirement equation in order to remove the soluble salt deeper out of the root zone (Ibrahim and Gafar, (2013).

2-8 Managing salt affected soils:

It is not always possible or practical to eliminate all salts from soil but to manage the soil to minimize salt damage in salted soils. In slightly saline soils, the control of water, the proper techniques of planting and the choice of tolerant crops are essential for success crop production.

2-8-1 Water control:

Maintaining a high water content in the soil near field capacity dilutes salts and lessens their toxic and osmotic effects . A light irrigation by sprinklers after planting will move salts below the planting and early rooting zone .When the salt gradually moves up -wards with water, the plant will be more mature and more salt tolerant. Sprinkler-applied water after planting increases germination by 20 percent. Periodic leaching before crop growth with available water will move some salts deeper, perhaps out of the root zone. Generally, saline soils can be amended by leaching or growing salt tolerant crops. Sodicity can be amended by the replacement of exchangeable Na by exchangeable Ca ions.

2-8-2 Choice of Crops:

The choice of crop is based upon:

1- Tolerance to salts.
2- Adaptability to the climate or soil characteristics.
3- Value of the crop in the individual farm activity.

Crops differ in the ability to tolerate salt accumulation in the soil. When levels are high enough (16 ds/m) only tolerant plants will survive. As salts accumulate in the soil, the soil solution osmotic pressure increases, when this happens the amount of water available for plant uptake decreases, and plants above crop selection can be a good management tool for moderately saline soil. Management practices, irrigation water quality, environment, and crop variety also affect tolerance. As crops differ in tolerance to high salt concentrations, they also differ in their ability to withstand high sodium concentration. Crop growth and development problems on sodic soils can be nutritional. (sodium accumulation by plants.), associated with poor soil physical conditions, or both. Plants on sodic soils usually show a burning or drying of tissue at leaf edges, progressing inwards between veins. General stunting is also common. Crops differ in their ability to tolerate sodic soil, but if sodium levels are high enough, all crops can be affected. Generally, soybeans are quite sensitive, corn and grain sorghum are intermediate and wheat and alfalfa are more tolerant. Crested and tall wheat grass and a few sorghum-Sudan hybrids are very tolerant, able to grow on soils with exchangeable sodium percentage above 50 percent. (Ray and David,1992). The purpose of farming is to make a highly profitable crop. Salted soils are unproductive unless the harmful salts are lessened or removed. Salted soils include: Saline soils (too high in salts), sodic soils(over 15 of the exchangeable Ion of sodium)-saline--sodic (high levels of both salts and exchangeable sodium).Soluble salts of soils are mostly sodium, calcium, magnesium, chloride, sulfate- and bicarbonate Ions. Many plants are relatively tolerant to salts and some have low salt tolerance. Removing salts is easy in theory: the salts are dissolved in irrigation water and washed out of the soil profile. If the salt content is not too high soils sometimes can be used for plant growth by careful management. In managing salt soils, salt tolerant plants suitable for that farm operation are selected. Frequent irrigations are used to keep salts diluted. Irrigation in non growing –season is used to leach salts partially and seeds are planted in low salt areas of seedbeds   (Ibrahim, 2012).

2-9 Management of Saline and Sodic Soils:

Saline and sodic soils can significantly reduce the value and productivity of a soil and plants. Such problems generally occur in arid and semi-arid climates where rainfall is insufficient to leach soluble salts from the soil or where surface or internal soil drainage is restricted. Salinity problems can also occur on irrigated land, particularly when irrigation water quality is marginal or worse. In humid regions salt problems are less likely to occur because rainfall is sufficient to leach soluble salts from the soil, but even in higher rainfall areas, salinity problems occur, in some areas with high water tables. Problems may occur with surface evaporation leaving salts to accumulate. Ions most commonly associated with soil salinity include the anions chloride (CL). sulphate. carbonate, and sometimes nitrate and the sodium cations (Na^{+}). calcium (Ca^{++}) magnesium (Mg^{++}), and sometimes potassium (K). Salts of these ions occur in highly variable concentrations and proportions. Salt –affected soils have been called white alkali, black alkali, gumbo, slick spots and other descriptive names. These names are associated with soil appearance caused by salt accumulation. The term alkali often refer to soils light in color and prone to surface crusting and implies that affected soils are high in exchangeable sodium. Salt - affected soils differ considerably in use stability, productivity, ease of reclamation , and management.

2-10 The Effect of Soluble Salts on Plant Growth:

Soluble salts have two types of effect on the growing plant. Specific effects due to particular harmful ions they contain. And the general effect due to the raising of osmotic pressure of the solution around the root of the crop. Specific effects fall into two classes those operative at low and those at high concentrations. Of the former only two salts are normally of importance sodium carbonate and soluble borate, the former may be harmful in itself but its harmful effect is more likely to be due to the consequence of the high pH it brings about. Thus, many nutrients such as phosphate, zinc ion and manganese become unavailable to the plant at these high pH values . On the one hand, the soil structure tends to become water unstable bringing about conditions of low water permeability, poor aeration, and almost unworkable soil. The general effect of high salt content in the soil is to give a dwarf stunted plant and yield can be reduced by over 20% without salt damage being apparent to the farmer. As the salt content becomes higher, the stunting becomes more noticeable, the leaves of the crop become dull—colored and often bluish-green and they become coated with a waxy deposit. Further, because many crops growing in very saline soils do not display the same symtomts of wilting very clearly, considerable loss of yield can occur if irrigation is applied only when the plants are obviously wilted. The effects of salt damage have been summarized as follows: (Poijakoff and Gale, 1975).

1-Physiological drought which is a direct osmotic effect.

2-Increased hydraulic resistance of roots and leaves.

3-Alteration of hormone level so influencing growth rates.

4-Direct damage, particularly to photosynthetic mechanisms.

5-Ion competition increasing energy use to maintain the K^+, Na^+ balance.

As the osmotic pressure in the soil solution increase (The osmotic potential becomes more negative) so does the osmotic pressure in the cell sap. The difference between these may remain the same, with the cell sap having a pressure of about 1.0 Mp_a higher, (Slatyer, *et al* 1961) or the osmotic pressure of the cell sap may increase more rapidly than the osmotic pressure of the soil solution.(Boyer, 1965) As the osmotic pressure in the external solution increases, the transpiration rate and stomatal resistance in the leaves may remain constant,(Eaton, 1942), it usually reduces the growth rate of the plant and its rate of photosynthesis, though it sometimes reduce and sometimes increase the dark respiration rate (Maas,1983).However, in the field, salts are usually unevenly distributed in the soil, so that those roots growing in volumes of soil containing less salt than average will take up relatively more water than those roots growing in volumes containing more than average (Gardner, 1967). Plants differ in their ability to withstand the harmful effects of salinity in the field. Early work (Briggs, and Shantz 1913), showed that plants have different abilities to extract water from soils in the wilting range, and plants better adapted to saline soils tend to have a greater ability to extract water at the drier end of this range. However, salt tolerance and drought tolerance are not necessarily related, Coconut, for example, is salt tolerant but drought sensitive. The greater the salinity of the soil , the less water crop can remove before it begins to suffer from water shortage, so that irrigated soils with an appreciable salt content need more frequent irrigations than non-saline soils (Shalhevet,1984). Crop yields can easily be reduced unnecessarily by allowing too long an interval between irrigations and this is liable to happen because the crop may not show signs of wilting as clearly as if it were growing in a low – salt soil. With more frequent irrigations, aeration may become limiting (Wesseling, 1974), There is also some field evidence that loss of yield due to moderate salinity can be more serious on soils of low than of high fertility, and that moderate level of salinity sometimes increases the response of a crop to fertilizer, particularly to phosphate and perhaps also to nitrogen (Ravikovitch, *et al* 1967). Phosphate fertilizers have advantage that they do not increase the osmotic pressure of the soil solution because phosphate is usually strongly adsorbed by the soil. Salt tolerance is complex for other reasons. The tolerance of a plant may be low when it is young but high when established, Lucerne is an example. The plant may survive at high salt contents, but will make very little growth. It only grows slowly at moderate salt content, and hence will be of little commercial value. Though the plant may grow in fairly saline soil, the quality of the part harvested may be affected.

. 2-11 **Irrigation definition:**

Irrigation is defined as the artificial application of water to soil for the purpose of supplying the moisture essential to plant growth. Irrigation may be accomplished in different ways: by flooding; by means of furrows, large or small; by applying water underneath the land surface by sub-irrigation and thus causing the ground water to rise; or by sprinkling. (Olsen, 1953) .

2-12 Soils and irrigation:

The influences of soil properties on irrigation practice are of very great importance. As a rule, the importance of soil influences on irrigation practice is underestimated. Some soils consist of coarse particles loosely compacted, and these are highly permeable to water. Others consist of fine particles tightly compacted and these are almost impermeable to water. The permeability of a soil greatly influences irrigation practice. Highly permeable soils tend to cause excessive water losses through deep percolation, whereas impermeable soils are difficult to moisten adequately. Soils are also storage reservoirs in which irrigation water is held between the periods of irrigation for the use of plants. The size of soil particles, their compactness, the depth of the soil, the organic matter it contains, and the position of the water table- all these soil properties influence the depth of available water that the irrigator can store in his root-zone soil in a single irrigation and hence influence the required frequency of irrigation. The depth of the soil greatly influences its capacity as a storage reservoir for water and the necessary frequency of irrigation. Variation in size of soil particles, compactness, permeability, and the depth from place to place is the rule and not the exception. There is no such thing as uniformity in natural soils. (Olsen, 1953).

2-13 Some Irrigation methods:

Irrigation is the controlled application of water for agricultural purposes through manmade systems to supply water requirements not satisfied by rain fall. Crop irrigation is vital throughout the world in order to provide the worlds ever—growing populations with enough food. Many different irrigation methods are used worldwide including:-

2-13-1 **Sprinkler or spray irrigation:**

A sprinkler system consists of four basic components: pumping unit, main lines, lateral lines, and sprinkler. The system sprays water over the land surface. The advantage of the system over surface irrigation is that it avoids uneven penetration of water and its subsequent waste. The system is suited to a wide range of slopes, soil and crops. However, because of high capital cost, the method is generally confined to crops that offer a high return.

A wide range of sprinkler systems is available, they can be classified into three types:

- Portable: refers to the technique where all equipment (pumping unit, main, submain and laterals) is portable and can be moved from one place to another.
- Semiportable or semipermanent: means that the pumping unit is fixed, the main and submains are underground and only the lateral are portable.
- Permanent: means that all components (pumping unit, mains, submains, laterals) are permanently located.

Center pivot: Automated sprinkler irrigation achieved by automatically rotating the sprinkler pipe or boom, supplying water to the sprinkler heads or nozzles , as a radius from the center of the field to be irrigated . Water is delivered to the center or pivot point of the system. The pipe is supported above the crop by towers at fixed spacing and propelled by pneumatic, mechanical, hydraulic, or electric power on wheels or skids in circular paths at uniform angular speeds. Water is applied at a uniform rate by progressive increase of nozzle size from the pivot to the end of the line. The depth of water applied is determined by the rate travel of the system. Single units are ordinary about 1250 feet to 1300 feet long and irrigate about a 130 acre circular area.

.**Drip:** A planned irrigation system in which water is applied directly to the root zoon of plants by means of applicators (orifices/emitters/porous tubing, perforated pipe/etc.) operated under low pressure with the applicators being placed either on or below the surface of the ground.

Flood: The application of irrigation water where the entire surface of the soil is covered by pond water.

Furrow: A partial surface flooding method of irrigation normally used with clean –tilled crops where water is applied in furrows or rows of sufficient capacity to contain the designed irrigation system.

Gravity: Irrigation in which the water distribution is not pumped but flows and by gravity.

Rotation: A system by which irrigators receive an allotted quantity of water not a continuous rate, but at stated intervals.

Sprinkler : A planned irrigation system in which water is applied by means of perforated pipes or nozzles operated under pressure so as to form a spray pattern .

Sub--irrigation : Applying irrigation water below the ground surface either by raising the water table within or near the root zone or by using a buried perforated or porous pipe system that discharges directly into the root zone .

Travelling gun : Sprinkler irrigation system consisting of a single large nozzle that rotates and is self-propelled . The name refers to the fact that the base is on wheels and can be moved by the irrigator or affixed to a guide wire .

.**Surface :** irrigation when the soil surface is used as a conduit , as in furrow and border irrigation as opposed to sprinkler irrigation or sub irrigation . http: // water. usages. gov, (2014).

2-14 **Soil type influencing irrigation strategy:**

Soil characteristics play an important role in application of soil amendments, pesticides, fertilizers and water. Irrigation strategy for clay-based soils is much different than the strategy for sand-based soil. Many growers question how much, how long, how fast, and how often they need to irrigate. The answers usually involve a combination of soil characteristics, plant growth stage and weather, how fast to supply water is based solely on soil type. Clay-based soils have small, flat, compact particles with large surface to volume ratios. These soils are often difficult to prepare for planting since they are slippery when wet and hard when dry, making timing for field operations critical to avoid damaging soil structure and getting proper soil tilth for planting . Sand-based soils are at the other end of the spectrum having comparatively large particles with small surface to volume ratios, they are generally easier to prepare for planting and can be worked shortly after significant rainfall. For irrigation purposes, it is important to remember water is absorbed and moves slowly through clay soils, but once wet, they retain significant amounts of moisture. Water is absorbed and moved quickly through sandy soils, but they retain very little moisture. This means water applied quickly to clay soils has a tendency to run off rather than move into the soil. When irrigating clay soils water should be applied slowly over a long period, but then the site may not need irrigation for several days. Irrigation on sandy soils should be applied quickly but for short periods. Irrigation times on sandy sites should be shorter otherwise water moves beyond the root zone, becoming unavailable to the plant and contributing to soil leaching. For efficient water use under certain weather conditions, sandy site may need daily irrigation for short periods. Clay soils have greater capillary (side ways and upward), movement than do sand soils . Quick water application on sandy soils will contribute to a broader wetting area providing more soil volume for roots to exploit (Ron, 2012).

2-15 Required depth of irrigation application:

When the irrigation schedule has been determined, it is known how much water (in mm) has to be given per irrigation application. It must be checked that this amount can indeed be given with the irrigation method under consideration. Field experience has shown that most water can be applied per irrigation application when using border irrigation less with basin irrigation, using basin irrigation 30-60 mm in border irrigation, and least with furrow irrigation. In practice in small-scale irrigation projects, usually 40-70 mm of water is applied in basin irrigation, 30-60 mm in border irrigation and 20-50 mm in furrow irrigation. (In large scale irrigation projects, the a mounts of water applied may be much higher). This means that if only little water is to be applied per application, on sandy soils and shallow rooting crops furrow irrigation would be most appropriate (However, none of the surface irrigation methods can be used if the sand is very coarse, if the infiltration rate is more than 30mm / h). If on the other hand, a large amount of irrigation water is to be applied per application, on a clay soil with a deep rooting crop, border or basin irrigation would be more appropriate. The net irrigation application values used are only a rough guide (App.(3) they result from a combination of soil type and rooting depth.

2-16 Level of technology:

Furrow irrigation with the possible exception of short, level furrows-requires accurate field grading. This is often done by machines. The maintenance, ploughing and furrowing, is also often done by machines. This required skill, organization, foreign currency for fuel, equipment and spare parts.

2-17 Environmental Impact of Irrigation:

While surface irrigation can be practiced effectively using the right management under the right conditions, it is often associated with a number of issues:

Water logging – can cause the plant to shut down delaying further growth until sufficient water drain, from the root zone, water-logging may be counteracted by drainage, tile drainage or water table control by another form of sub surface drainage.

Deep drainage—over irrigation may cause water to move below the root zone resulting in rising water table, in regions with naturally occurring saline soil layers.

Stalinization—depending on water quality, irrigation water may add significant volume of salt to the soil profile, while this is a lesser issue for surface irrigation compared to other irrigation methods (due to the comparatively high leaching fraction). Lack of surface drainage may restrict the leaching of salts from the soil . This can be remedied by drainage and soil salinity control through flushing. (Wikipedia. Org. 2015).

2-18 Soil moisture retention:

The amount of water held by a soil in the root zone between field capacity (F.C) and permanent wilting point (P.W.P) , and which can be used by plants is described as available water (F.C - P.W.P = available water) for sand , loam , and clay the values are 6—20—17 by volume percent, respectively .

2-19 Soil water holding capacity:

One of the main functions of soil is to store moisture and supply it to plants between rainfall or irrigations. Evaporation from soil, transpiration by plants and deep percolation combine to reduce soil moisture status between water applications. If the water content becomes too low, plants become stressed. The plant available moisture storage capacity of a soil provides a buffer which determines a plant capacity to withstand dry spells. (Blasko 2008).

2-20 Irrigation efficiency:

The field application efficiency mainly depends on irrigation method and the level of farmer discipline. Some indicative values of the average field application efficiency, are shown on appendix (4).

2.21 Field water use efficiency (FWUE) :

FWUE was obtained according to (Hillel, 2000) by dividing yield of dry matter (DM) by the total amount of water applied to the field during that period.

2.22 **Basic soil and water retention**

2-22-1 Soil moisture function and content:

The functions of soil moisture in plant growth are very important. Excessive volume of water in soils retard or inhibit plant growth and make drainage essential. Sterility of arid – region soils is usually caused by deficient amounts of water. Irrigation is an artificial means of preventing deficiencies in the moisture content. .

2-22-2 **Infiltration**:

Downward water flow from the soil surface into surface soil is designated infiltration. Usually, the infiltration rate is much higher at the beginning of a rain or irrigation than it is several hours later. It is influenced by the soil properties and also by the hydraulic slope. (Olsen 1953). A convenient means of expressing infiltration is in terms of depth lowering of water surface per hour.

2-22-3 **Permeability:**

One of the most important properties of soils is the velocity of water flow through the pore-spaces caused by a given force.

The permeability of soil is defined as the velocity of flow under a hydraulic gradient or slope of unity, in which the driving force is I 1b per 1b of water.

Permeability is not influenced by the hydraulic slope, and this is an important point of difference between permeability and infiltration. Also the term permeability is used for designating flow through, or in, saturated soils in any direction. It is most influenced by the physical properties of the soil. Changes in water temperature influence permeability slightly.

2-23 **Sources of irrigation water:**

The sources of water for irrigation can include: surface water sources , ground water sources , municipal water supplies , and other agricultural and industrial process waste water .

-Surface water: sources include flowing water supplies (creeks, streams, canals,) and standing or stored water supplies (ponds, reservoirs, lakes…etc).

--Ground water supplies: may come from springs and wells, and although the quality is usually good, the available quantity that can be pumped at any time may again limit the irrigation method.

--Grey-water: Is domestic waste water, other than that containing human excrete, such as sink drainage, washing machine discharge or bath water.

The quality of agricultural or industrial process of waste waters often limits their use to surface or sprinkler irrigation methods, and in their suitability for fruits and vegetable crop irrigation. (http/ nrcca Cornel 2010)

2-24 **Time of irrigation:**

Two major considerations influence the time of irrigator, namely;

a) The water needs of the crops, and b) The availability of water with which to irrigate.

Both crop needs and available water supply must be considered; in a discussion of the proper time to irrigate.

2-24-1 Crop Needs:

Growing crops use water continuously, but the rate of use varies with the kind of crop grown, age of the crop. The temperature, and the atmospheric condition - all variable factors. It is essential, in irrigation farming, to use the root-zone soils as storage reservoirs for available water. At each irrigation, a volume of water sufficient to supply the needs of the crop for a period varying from a few days to several weeks is stored in the unsaturated soil in the form of available soil water. How frequently the water should be applied to soils of different properties in order to best supply the crop needs is a question of real practical significance. The factor of major importance in arriving at the desirable frequency and time of irrigator is the water need of the crop (Olsen, 1953).

2-25 **Reaction of soils of Arid Regions:**

Arid region zonal soils occur in areas where the rainfall is seldom more than 20 inches per year. Lack of extensive leaching leaves the base status of these soils high. A fully and normally developed profile usually carries at some point in its profile (usually in the C-horizon) a calcium carbonate accumulation greater than that of its parent maternal. As a result, these soils may have alkaline subsoils and alkaline or neutral surface layers. When enough leaching has occurred to free the soluable of calcium carbonate, a mild acidity may develop in the surface horizon (Nyle , 1974).

2-26 **Reaction of Saline and Sodic Soils:**

When the drainage of irrigation soils is impeded and the surface evaporation becomes excursive, soluble salts accumulate in the surface horizon. Such intra zonal soils are designated " A Halamorphic" and have been classified under three headings: Saline, Saline - sodic, and sodic (Nyle 1974).

2-26-1 Saline Soils:

These soils contain a concentration of neutral soluble salts sufficient to seriously interfere with the growth of most plants. The electrical conductivity of a saturated extract (Ece) is greater than 4mmhos/cm. Less than 15 % of the cation exchange capacity of these soils is occupied by sodium ions and the pH usually is below 8.5. This is because the soluble salts present are mostly neutral, and because of their domination, only small amount of exchangeable sodium is present. Such soils are sometimes called white alkali soils because a surface incrustation, if present, is light in color. The excess soluble salts, which are mostly chlorides and sulfates of sodium, calcium, and magnesium, can readily be leached out of these soils with no appreciable rise in pH. This is a very important practical consideration in the management of these soils. Care must be taken to assure that the leaching water is low in sodium.

2-26-2 Saline - Sodic Soils:

The saline - sodic soils contain appreciable quantifies of neutral soluble salts and enough adsorbed sodium ions to seriously affect most plants. Although more than 15 percent of the total exchange capacity of these soils is occupied by sodium, their pH is likely to be below 8.5. This is because of the repressive influence of the neutral soluble salts as in the saline soils. The electrical conductivity of a saturated extract is more than 4 mm ds/cm. But unlike the saline soils, leaching will markedly raise the pH of saline-sodic soils unless calcium or magnesium salts concentrations are high in the soils or in the irrigation water. This is because the exchangeable sodium, once the neutral soluble salts are removed, readily hydrolyzes and thereby sharply increases the hydroxyl ion concentration of the soil solution. In practice, this is detrimental since the sodium ions disperse the mineral colloids, which then develop a tight, imperious soil structure. At the same time, sodium toxicity to plants is increased.

2-26-3 Sodic soils:

These soils do not contain any great amount of neutral soluble salts, the detrimental effects on plants being largely due to the toxicity of the sodium as well as of the hydroxyl ions. The high pH is largely due to the hydrolysis of sodium carbonate, which occurs as follows

$$2Na^{+} + Co_3^{-} + 2H_2o = 2\ Na^{+} + 2OH^{-} + H_2CO_3, \qquad (1)$$

The resulting hydroxyl ions gives pH values of 10 and above. Also the sodium complex undergoes hydrolysis as follows:

$$Na\ \boxed{\text{Micelle}} + H\,O\,H \quad H\ \boxed{\text{Micelle}}\ a^{+} + O\,H \qquad (2)$$

The exchangeable sodium, which occupies decidedly more than 15 percent of the total exchange capacity of these soils, is free to hydrolyze because the concentration of neutral soluble salts is rather low. The electrical conductivity of a saturated extract is less than 4 mm hos / cm. Consequently, the pH is above 8.5, after rising as high as 10.0. Owing to the deflocculating influence of the sodium, such soils usually are in an unsatisfactory physical condition. The leaching of a saline-sodic soil will readily change it to a characteristic sodic soil. Because of the extreme alkalinity resulting from the $Na_2\ Co_3$ present, the surface of sodic soils usually is discolored by the dispersed humus carried upward by the capillary water- hence the name black alkali is frequently used these soils are often located in small areas called slick spots surrounded by soils that are relatively productive (Nyle , 1974).

2-27- Management of saline and sodic soils

There are three general ways in which saline and alkali lands may be handled in order to avoid injurious effects to plants.

The first is eradication, the second is a conversion of some of the salts to less injurious form; the third may be designated control. In the first two methods, an attempt is made actually to eliminate by various means some of the salts or to render them less toxic. In the third, Soil management procedures are utilized which keep the salts so well distributed throughout the soil solum that there is no toxic concentration within the root zone.

2-27-1 Eradication of excess salts:

The most common method used to free the soil of excess salts are; a) Under drainage. b) Leaching or flushing. A combination of the two, flooding after tile drains have been installed, is the most thorough and satisfactory. When this method is used in irrigated regions, heavy and repeated applications of water can be made. The salts that become soluble are leached from the solum and drained off through the tile. The irrigation water used must be relatively free of silt and salts, especially those containing sodium.

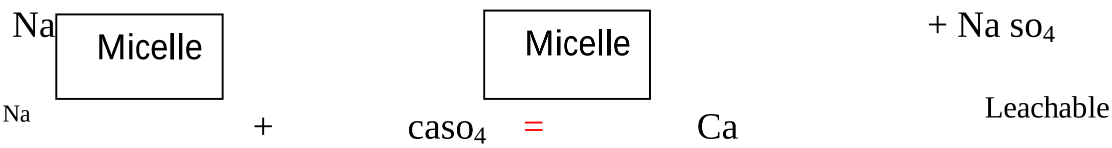
The leaching method works especially well with pervious saline soils, whose soluble salts are largely neutral and high in calcium and magnesium. Of course, little exchangeable sodium should be present. Leaching saline, Sodic soils (and even sodic soils if the water will percolate) with waters very high in salt but low in sodium may be effective. Conversely, treating sodic and saline - sodic soils with water low in salt may intensify their alkalinity because of the removal of the neutral soluble salts. This allows an increase in the percent sodium saturation there by increasing the concentration of hydroxyl ions in the soil solution. This may be avoided by converting the toxic sodium carbonate and bicarbonate to sodium sulfate by first treating the soil with heavy applications of gypsum or sulfur. Leaching will there render the soil more satisfactory for crops.

2-27-2 Conversion of the caustic alkali carbonates into sulfates:

The use of gypsum on sodic soils is often recommended for the purpose of changing part of the caustic alkali carbonates into sulfates. Several tons of gypsum per acre are usually necessary. The soil must be kept moist to hasten the reaction, and the gypsum should be cultivated into the surface, not plowed under. The treatment may be supplemented later by a thorough leaching of the soil with irrigation water to free it of some of its sodium sulfate. The gypsum reacts with both the Na Co_3 and the adsorbed sodium as follows:

$$Na_2\,Co_3 + Ca\,So_4 \quad = \quad CaCo_3 + Na_2So_4 \quad \downarrow \qquad (3)$$

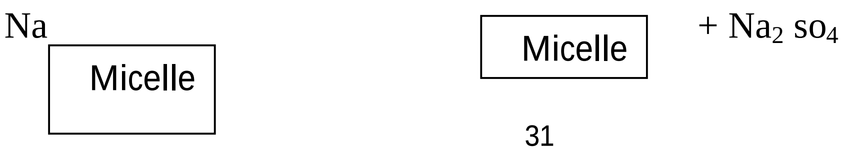
Leachable



It is also recognized that sulfur can be used to advantage on salty lands, especially where sodium carbonate is abundant. The sulfur upon oxidation yields sulfuric acid, which not only changes the sodium carbonate to the less harmful sulfate but also tends to reduce the intense alkalinity. The reactions of the sulfuric acid with the compounds containing sodium may be shown as follows:

$$Na_2\,Co_3 + H_2\,So_4 \quad = \quad Co_2 + N_2o + Na_2\,So_4 \quad \downarrow \qquad (4)$$

Leachable



Na + $H_2 So_4$ = H Leachable

Not only is the sodium carbonate changed to sodium sulfate, a mild neutral salt, but the carbonate radical is entirely eliminated. When gypsum is used, however, the carbonate remains as a calcium salt.

2-27-3 Control of salty soils:

The retardation of evaporation is an important feature of the control of salty soils. This will not only save moisture but will also retard the translocation upward of soluble salts into the root zone, there are no inexpensive methods of reducing evaporation from large acreages. Consequently, other control practices must be explored. Where irrigation is practiced, an excess of water should be avoided unless it is needed to free the soil of soluble salts. Frequent light irrigations are often necessary, however, to keep the salts sufficiently dilute to allow normal plant growth

The timing of irrigation is extremely important on salt soils, particularly during the spring planting season - since young seedlings are especially sensitive to salts, irrigation often precedes or follows planting to move the salts downward. After the plants are well established, their salt tolerance is somewhat greater. The use of salt-resistant crops is another important feature of the successful management of saline and alkali lands. Sugar beets, cotton, sorghum, barley, rye, sweet clover, and alfalfa are particularly advisable. More over, a temporary alleviation of alkali will allow less - resistant crops to be established. Farm manure is very useful in such an attempt. A crop, such as alfalfa, once it is growing vigorously, may maintain itself in spite of the salt concentrations that may develop later. The root action of tolerant plants is exceptionally helpful in improving sodic soils which have a poor physical condition.

2-28 Crop and irrigation aspects for crop salt tolerance:

The salt tolerance of a plant can be defined as the plant's capacity to induce the effects of excess salt in the medium of root growth (Maas, 1990). The salt tolerance of a plant is not an exact value. It depends on many factors, conditions and limits including environmental factors (Soil fertility, physical condition of the soil, salt distribution in the profile, irrigation method and climate) and biological factors (Stage of growth, varieties and root stocks). The tolerance of a plant with respect to soil salinity can be described by the yield response function which is a plot of the relative yield as a function of soil salinity. The yield response function can be represented by two linear lines; one a tolerance plateau (threshold) and the other a concentration- dependent line whose slope indicates the yield reduction per unit increase in salinity (Maas, 1990).

For soil salinities exceeding the threshold of any given crop, the crop yield can be given by the following linear equation (Van Genuchten and Hoffman, 1984):

$$Y = Y_m - Y_m s(C-C_t) \qquad (5)$$

Where:

Y = crop yield

Y_m = the crop yield under non - saline condition.

S = The slope of the line determining the yield decline per unit increase in salinity, beyond the threshold

C = The average root zone salinity

C_t - The salinity threshold.

Maas (1990) provided salt tolerance data for a wide range of herbaceous crops (fiber, grain, fruit, vegetable, grass, forage crops and special crops) and woody crops (trees) and gave the limits of salt tolerance for 49 species of ornamental shrubs, tress and ground cover grown in Riverside California.

2-29 Crop water requirements:

Plants consume water essentially for the two processes of photosynthesis and transpiration. They absorb water through the roots and primarily through the root hairs. Water transported through the plants and then removed from the leaf surface via transpiration. Transpiration is controlled by the stomata aperture and by the vapor pressure gradient from the leaf to the air (Blad, 1983). The crop transpires during its growth. At the same time evaporation takes place at the soil surface. The combined quantify of water used under conditions of optimum availability is known as consumptive use or evapotranspiration. The amount of water required by plants for their growth depends on a number of factors including the type of plant, its stage of development, soil properties and meteorological conditions (temperature, radiation, humidity and wind).The demand for water is not evenly spread over the growing season. At the beginning of the season, consumptive use is low. It increases as the plant foliage develops and the days become warmer, peaks during flowering and fruit formation and rapidly decreases towards the end of the growing season. The amount of water in the soil useable by plants lies between field capacity and wilting point. This portion is called the useable capacity. The field capacity is the maximum amount of water capable of being held by the soil in opposition to gravity. The wilting point corresponds to that amount of water that oppose the absorptive strength of the plant (Seemann, 1979). The amount of useable capacity depends on the soil type. It is low in sandy soil and high in loam and loess. Optimum plant growth occurs when soil moisture is near field capacity. Wilting of plants occurs when the suction exerted by the roots on the moisture in the soil fails to maintains an adequate flow of water to the leaves. If the level of soil water is approaching wilting point, rainwater or irrigation is required to maintain plant growth. At the other limit, when saturation is reached, air is cut off from the roots and the plant growth stops. Excess water on farm lands may be caused by rain, excessive irrigation of by poor land grading. Excess water should be drained to maintain healthy soil moisture for crop production.

The evaluation of water requirement of crops to achieve full production at a particular location is based on the estimation of evapotranspiration. A simple method consists of converting the class A pan evaporation to evapotranspiration by multiplying by a crop coefficient. The coefficient depends on the specific crop and the growth stage of the crop (Rural Water Commission of Victoria, 1988). It is important to note that because the amount of salt removed by crops is negligible, salt will accumulate in the root zone and will cause a loss in production. Consequently, salt must be leached by supplying more water than is required by the crops. The amount of leaching water needed depends mainly on the salt content of the irrigation water, soil and ground water; and the salt tolerance of the crops. The ratio of the depth of drainage water to the depth of the applied water (Irrigation plus rainfall) is called the leaching fraction. (Hoffman,1990).

2-29-1 **Surface irrigation:**

Surface irrigation is widely used and consists of the following types:

* Boarder irrigation; this is so called because of the type of preparation of the land surface required for distribution of water. In this method the land is divided in to long, narrow parallel strips separated by earth banks. These are arranged lengthwise in the direction of the maximum gradient of the land. The water consigned to each irrigation unit from a watering conduit situated at the highest point flows down the gradient to the bottom, moistening the soil.

* Basin irrigation: The layout of basin irrigation is similar to that of border irrigation, the main differences being cross banks constructed on the contour at regular intervals down the slope and a pipeline or channel to supply water to each basin. The spacing of the cross banks is determined by the amount of the longitudinal slope. Once a basin is filled with water the flow is turned into another basin and the ponded water is allowed to soak into the soil.

* Furrow irrigation: Furrow irrigation has been practiced in many parts of the world since ancient times and remains a very important method of irrigation today. The principles of the method are similar to those of border irrigation but land preparation differs because numerous furrows are used instead of the smooth surface of bays .As with other surface method of irrigation, water is released from a supply point to head channel or pipeline located on the highest land. If an open head channel is used water is released in to the furrow by siphon tubes, outlet pipes or shovel cuts. The furrow may be V- shaped or U-shaped.

2-29-2 Localized irrigation:

Localized irrigation covers trickle (drip), micro jet (micro spray) and mini sprinkler systems. Common to these three types of irrigation system is the frequent application of water at low rates, keeping the soil around the roots near field capacity. The advantages include: Crops are watered with increased uniformity; soil structure is preserved; water is saved because of reduced evaporation; and the correct control of water quantities reaching plants. The disadvantages include: Obstruction of small drippers because of water impurities, biological or chemical formations; creation of an area of permanently saturated or near-saturated soil favoring the development of plant or animal pests; and saline accumulation at the edges of moisture areas (Romita and Galbiati, 1978). Localized irrigation is almost exclusively used for orchards, Vineyards. Some vegetable crops, and occasionally sugarcane.

2-29-3 Localized irrigations systems:

* Trickle (Drip) irrigation: Trickle or drip irrigation is the method applying water directly to the soil around the plant root at low rates of flow rates of flow but frequently enough to keep the soil around the roots at or near field capacity. The components of the system include: Pump, filter, main, sub mains, laterals, and drippers. With drip irrigation, water should be free of physical impurities and organic matter and should be filtered to avoid the deposition of material in the lines and drippers. Fertilizer and pesticides can also be applied in the water.

The interval between irrigation varies according to the soil texture and the evaporative demand. For very coarse soil with a small water-holding capacity, irrigation may be for a short period each day when plants are using the most water. For light sandy soil, the interval may vary from one to four days. For heavier loam and clay loam, the interval between watering may vary from two to eight days. The duration of application also varies with the type of soil-. Heavy soil might be watered for 10 to 16 hours. Light soils for 6 to 10 hours.

2-29-4 Micro jet irrigation:

Micro jet irrigation is essentially an under-tree method of irrigation. It differs from mini-sprinkler in as much as it has no moving spinner to distribute the water droplets. Instead a fine jet of water is directed on to a fixed surface to produce a spray.

* Mini-sprinkler irrigation: Mini-sprinkler irrigation is another method of under- tree irrigation. The condition that govern the adoption of micro jet irrigation also apply to this method. However, because mini-sprinklers deliver more water and over a greater area than micro jets and because some sprinkles have a pressure compensation valve, they are often used on mature plantings in place of micro jets. Micro jets tend to be used on new plantings and young trees.

2-30 Selection of irrigation method:

The suitability of the various irrigation methods Surface, Sprinkler, or drip irrigation depends mainly on the following factors:

1) Natural conditions: soil type, slope, climate, water availability, water quality.

2) Type of crop: Surface irrigation can be used for all types of crops . Sprinkler and drip irrigation because of their high capital investment per hectare, mostly used for high value cash crops . Drip irrigation is suited to irrigating individual plants or trees. It is not suitable for close growing crops

3) Type of technology: in general, drip and sprinkler irrigation are technically more complicated methods (purchasing equipment-maintaining , regular supply of fuel and spare parts

4) Surface irrigation system usually require less sophisticated equipments for both construction and maintenance (unless pumps are used).

5) Previous experience with irrigation: Irrigation method depends on the irrigation tradition within the region or country. It is not certain that the farmers will accept the new method.

6) Required labor inputs: Surface irrigation often requires a much higher labor input – for construction, operation and maintenance than drip irrigation and sprinkler irrigation.

7) Cost and benefits: Before choosing an irrigation methods an estimation must be made of the cost and benefits of the available options. Cost should be compared with the expected benefits (yields). Surface irrigation the most wide spread irrigation methods. It is normally used when condition are favorable. In case of steep or irregular slopes, soils with a very high infiltrations rate or scarcity of water, sprinkler or drip irrigation may be more appropriate.

2-31 Irrigation intervals:

The increase in irrigation interval from 5 to 20 days the weight of the dry leaf, stem ears and total fresh weight (sum of two cuttings).The comparison of mentioned traits average in this experiment showed that with the increase of irrigation intervals, the leaf to stem ratio increased, but protein yield decreased, significantly. The result of this research showed that water stress had negative effect on forage production, and qualitative traits but planting pattern had no significant effect on these traits.

2-32 Frequency of irrigation:

Irrigation frequency refers to the number of days between irrigation during periods without rainfall. It depends on consumption use of rate of a crop and on the amount of available moisture in the crop root zone. It is a function of crop, soil, and climate. Sandy soils must be irrigated more often than fine texture deep soils. A moisture use ratio varies with the kind of crop and climate conditions and increases as crop grows larges and days becomes longer and hotter .

In general irrigation should start when about 50 percent and not over 60 percent of the available moisture has been used from root zone in which most of the roots are concentrated. The stage of crop growth with reference to critical periods of growth as also kept in view while designing irrigation frequency. The intervals that can be safely allowed between two successive irrigations is known as frequency of irrigation:

$$\text{Irrigation intervals} = \frac{\text{allowable soil moisture depletion}}{\text{Daily water use}} \qquad (6)$$

A allowable soil water depletion s equal to 25 % of available soil water

(Agri Info. in 2011).

2-33 Forage sorghum yield and water use efficiency under variable irrigations:

The response of forage sorghum (*Sorghum bicolor* (L) Moench) to three irrigation treatments in a semi arid environment was studied in the field for two seasons. Irrigation frequency –plant heights and leaf area of forage sorghum where higher in the frequent watered plots than in plots where irrigation water was delivered less frequently. Average over the two seasons, maximum dry matter (DM) yields were 16.3, 11.8 and 10.5 tones/ ha for frequent, intermediate, and infrequent irrigation regimes, respectively. Light, frequent irrigation resulted in a significantly higher water use efficiency (WUE) compared to the other two regimes. These results suggest that in such semiarid environments DM yields and WUE of forage sorghum could be with a short intervals. (Saeed and EL.Nadi. 1998).

2-34 Monthly crop factor (kc)

Monthly crop factor (Kc) calculated as ratios of actually measured (Ec crop) to reference evapo transpiration ((Eto) for 2010-2011-2012 . Values of Kc are shown to vary with the age of the crop, season and the prevailing weather conditions. Presented data indicated that ratios of crop factor (Kc) were found to increase with the crop age from initial stage , through the development stage to maturity stage. The Kc values were higher during development to maturity stage than the initial stage. Ratios ranged between 0.3 during initial stage and (0.62) during the development stage, at the maturity stage Sorghum Kc value reached (1.0-1.02).

2-35 Growth of plants on Halamorphic soils:

Saline and saline-sodic soils with their relatively low pH (usually less than 8.5) detrimentally influence plants largely because of their high soluble -salt concentration. It is common knowledge that when a water solution containing a relatively large amount of dissolved salts is brought into contact with plant cells will cause shrinkage of the protoplasmic lining. This action called, plasmolyzis, increases with the concentration of the salt solution. The phenomenon is due to the osmotic movement of the water, which passes from the cell toward the more concentrated soil solution. The cell then collapses. The nature of the salt, the species, and even the individuality of the plant, as well as other factors, determine the concentration at which the individual succumbs. The adverse physical condition of the soils, especially the saline-sodic may also be a factor. Sodic soils, dominated by active Sodium , exert a detrimental effect on plants in three ways: a) Caustic influence of the high alkalinity induced by the sodium carbonate and bicarbonate, b) Toxicity of the bicarbonate and other ions, and c) The adverse effects of the active sodium ions on plant metabolism and nutrition . (Nyle , 1974)

2-36 Tolerance of higher plants to Halamorphic soils:

The capacity of higher plants to grow satisfactorily on salty soils depends on a number of interrelated factors. The physiological constitution of the plant, its stage of growth, and its rooting habits certainly are among them. It is interesting to note that old alfalfa is more tolerant than young alfalfa and that deep-rooted legumes show a greater resistance than those with shallow root age.

Concerning the soil the nature of the various salts, their proportionate amounts, their total concentration and their distribution in the slum , must be considered. The structure of the soil and its drainage and aeration are also important .As a result, it is difficult to forecast accurately the tolerance of crops. Only carefully controlled trials will answer this question and even then with no great degree of certainty (Nyle ,1974).

2-37 Importance of pasture and forage:

Pasture and forages are considered first, among all the feeds, because of their importance in livestock production. For all classes of stock good forage including abundant pasture, is the foundation of efficient production. High -quality forage is very important as a source of vitamins, minerals and protein.

During recent years there has been a striking trend to-ward "grassland farming". This is the result of our farmers appreciating more fully the economy of good pasture and hay crops for stocks, and also their importance in maintaining soil fertility and preventing water and wind erosion. This great change in our agriculture has resulted because of the extensive research on forage production. (Frank 1972).

2-38 Crops Description and Climate

2-38-1 ***Sorghum bicolor*** Abu 70

Sorghum species have been utilized worldwide for the production of grain, forage, sugar, and more recently bio fuel, (Roony *et al*, 2007). It is utilized primarily for human consumption throughout Asia, Africa, and Central America and for animal feed in the US, Australia, and South America.(ICRISAT, 2004).Sorghum spp. have more recently been evaluated as bio energy feed stocks, including a grain starch substitute for corn-derived bioethanol, a stem sugar substitute for sugarcane-derived bioethanol, and a dedicated lignocelluloses energy crop (Roony *et al*,20007, Wu *et al*., 2008). All reports to date concerning sorghum bio energy feeds stocks have utilized *Sorghum bicolor*, which has an annual growth cycle in temperate climates and exhibits only weak perenniality in tropical and subtropical climates. Sorghum is widely adopted and utilized across 588 million acres of forage and pasture land and 61.5 million acres of hay land in the US (USDA/ RMA, 2011), it could also serve as a dual-use forage : bio fuel feedstock in the near-term while bio fuel refineries are under construction and market development (Jessup, *et al*.2012).

Abu sabein is the Arabic name of *Sorghum bicolor* L Moench cv, which comes from the period the crop takes to reach the cutting stage at (70 days). (Kambal, 2003). Kambal (2003) also reported that the name Abu sabein is used for sorghum grain in the Rubatab and Alyab area of northern Sudan .In recent years the identification and use of forage plants from the semi -arid saline areas of the Northern region of Sudan has become increasingly important economically and particularly ecologically.

Sorghum is the fifth most important cereal crop in the world and is the dietary staple for more than 500 million people in more than 30 countries. Sorghum is a water efficient crop which makes it an important cereal in semi-arid and arid environments where water is the main limiting factor of production. However, it must compete economically with other cereal crops, and to meet this challenge, the yield of sorghum must increase significantly. (Alikhani, *et al* 2012).

2-38-2 Growth Stages:

Grain sorghum has five distinct growth stages

1 Seedling stage: Germination takes place in 4—5 days. Emergence of coleoptiles indicates seedling stage

2 Flag leaf stage: 3---4 leaves with fully expanded leaf area. Stage reached in 40—50 days.

3 2 Boot stage: Ear head covered within sheath: i.e under flag leaf stage reached in -50-- days.

4 Soft dough-endosperm filled with watery fluid, it is called milky stage, reached in 70—days

5 Physiological Maturity: Grain with maximum of dry matter. Stage reached in 85-90 days .

For the purpose of this study the fodder sorghum plant life cycle is considered to be 70 days, sub- divided into three stages:

1) Initial stage , 20 days

2) Development stage, 30 days

3) Fodder maturity stage, 20 days.

2-39- Climate:

Sorghum is becoming an increasingly important forage crop in many regions of the world. Its high resistance to drought makes it a suitable crop for semi- arid areas. Sorghum can respond to additional irrigation by stem elongation and increase of yield, it was reported that water deficit reduced quantitative and qualitative yield including total fresh weight, total dry weight, leaf dry weight, stem dry weight, protein yield and leaf/stem ratio of forage millet (nutria feed) were reported that significant differences between irrigation intervals of 8-12-16 and 20 days for fresh-feed yield and dry-feed yield were obtained in forage sorghum. In this study, highest fresh and dry-feed yield (52.4and15.5ton/ha respectively). Obtained when 8 days irrigation interval was applied, adverse effects on L.A of sorghum were reported as soil water deficit developed. Yield decrease due to soil salinity under irrigation is : 0% at ECe 4 mm ds/cm, 10% at 5.1, 25% at 7.2, 50% at 11 and 100% at ECe 18 mm ds/cm. During drought the cyanide content remains high. Minimum temperature required for germination is 7—10 ^{o}C, optimum temperature for growth is 25—30 ^{o}C.

2-40 Soil Requirement :

The crop does well on most soils but better so in light to medium textured soils. The soil should preferably be well-aerated and well-drained. Sorghum is relatively tolerant to short periods of water logging. It grows best in deep alluvial soils with irrigation. It can withstand moderate salinity. Salinity is a continuing problem in the arid and semi-arid tracts of the world. It could be alleviated using irrigation management and/or crop management. However, the former approach is outdated and very expensive. Nevertheless, the latter is economical as well as efficient and it enables to produce salt tolerant crop line (Asfaw, 2010). Salt-affected soils are distributed throughout the world and no continent is free from the problem (Brady and Weil, 2002). Salt-affected soils are serious threat to crop production in the arid and semi-arid tracts of the world (Verma and Yadova, 1986). Globally, a total land area of 831 million ha is salt-affected. African countries like Kenya (8.2 m ha), Nigeria (5.6 m ha), Sudan (4.8 m ha), Tunisia (1.8 m ha), Tanzania (1.7 m ha) and Ghana (0.79 m ha), are salt-affected to various degree (F.A.O, 2005). In Ethiopia, salt- affected soils are prevalent in the Rift Valley and the low lands. The physical practice (irrigation management is not economically feasible (EL-Khashab *et al*, 1997). There is a need to concentrate on biological approach or crop management. (Ashraf and McNeilly, 1988).The combination of drought-tolerance and salt-tolerance makes sorghum a very interesting feed source under arid and semi-arid conditions in saline lands., (AL-Khalasi *et al*, 2010., Fahmy *et al* 2010., Khanum, *et al.*, 2010).

2-41 Water efficiency and salt- tolerance:

Sorghum has high water efficiency and requires less total water to reach its production potential. In environments where water is limited due to drought or declining aquifers and where it is necessary to conserve or reallocated available water, forage sorghums are promoted as a substitute for more water-consuming crops, particularly forage maize. Sorghum will be an extremely valuable forage wherever water becomes a scarce and precious resource due to global climate change.(Brouk and Bean, 2011, Emile *et al*, 2006. Conreras *et al* 2010).

2-42 Forage sorghum yield:

Forage sorghum yield is about 20 Tons green matter/ ha (Balole and Legwaila 2006). But may reach 75T/ ha under optimal growth conditions. (F.A.O. 2010). Ibrahim, (1999), obtained 54.0--65-3 t/ha as green fodder and 32.7—32.6 dry fodder respectively.

2-43 (Sudan grass) ***Sorghum sudanense:*** :

2-43-1 Characteristics:

Annual (or biennial), widely distributed in northern and central Sudan,it is, however, suitable only for areas with warmer hot dry summer. Sudan grass is valued for its reasonably high seed yield, ease of establishment, the ability to recover after grazing or cutting, better than most of the annual grasses, high herbage yield and good quality of herbage. Tufted with above ground runners with fine stems growing to a height of 3 m. It gives good quality hay which, like maize and grain sorghum, should be cut late, grain in dough stage. Can be grazed when 50 cm high, but some danger of prussic acid poisoning exists. Not as good for silage as maize and grain sorghum. Sudan grass has a fine stemmed and leafy plant with very quick regrowth. It is best used for pasture or in multiple cut systems, yield will be less than that of sorghum. Forage quality will be high due to low fiber content if cut frequently. (www. omafra. gov. on .ca/ 2013).

2-43-2 Environment:

Sorghum Sudan grass offers a solution to producing forage dry matter when an emergency occurs. They are warm season grasses, they are more efficient in water absorption because they have twice as many secondary roots, they have the ability to go dormant during extended drought periods, they have the advantages that they can be cut 2-3 times during the season and can be also stored as either chopped or silage, green chopped or pastured.(www. omafra.gov.on. ca/2013). The seed rate is 15 kg /ha and should be planted at a depth of 2-3.5 cm. Fertilizer: 100-125 kg/ha nitrogen applied at planting. After each cut, 50Kg/ha more nitrogen should be applied to encourage growth. Sorghum Sudan grass can grow in a wide pH range with 5.5-7.5 as the optimum .The first cut will be ready for harvesting 60 days from planting , a second cut should be ready 30-35 days later.(www.omafra. gov.on.ca /2013).

Chapter Three

Materials and Methods:

3-1 : Site description and climate:

The study was conducted at the Demonstration Farm: College of Animal Production Science and Technology. Sudan University of Science and Technology Sudan - Kuku - for two consecutive seasons. (2010 Nov - 2011-Oct 2012). The study area lies in Khartoum North. latitude 15.40 N longitude 32.32 E and altitude 380 meters above sea level a (sl). (Oliver 1965). The soil of the experimental site is clay (fine montmorillonite, hyper thermidentic chromusterts. Initial chemical and physical characteristics of the soil (0-60 cm) were collected from the experimental site . The soil recorded Ec_e above 4.4 ds / m slightly saline soil. (Table 3-1).

The climate of the locality is tropical semi-arid with low relative humidity, maximum temperature is about 40 ^{0}C in summer and 20 ^{0}c in cool season but night temperatures are lower (Oliver, 1965). The mean annual rainfall is about 160 mm. However, there is considerable fluctuation in annual rain fall from year to year (Adam, 2005).

3-2. The experimental field layout:

The experimental field used had a total surface area of 1280 m^2 divided into 64 plots each 20 m^2 (4*5 m). These were divided into two sub-plots each having 32 plots, for two soil preparation methods (ridged and flat) each (32 plots) divided into two sub-sub plots each having 16 plots, sub-sub-plots were divided into four irrigation intervals (7-10-14-21 days), each replicated four times . Fig (3-1) .

Experimental field layout

Ridged	G	ABU 70	G	ABU 70	G	G	ABU 70	ABU 70	7 days
	ABU 70	70AB U	G	G	G	ABU 70	ABU 70	G	10 days
	G	70 ABU	70AB U	G	70AB U	G	G	ABU 70	14 days
	ABU 70	G	ABU 70	ABU 70	G	70AB U	G	G	21 days
Flat	70AB U	G	G	70AB U	ABU 70	ABU 70	G	G	7 days
	ABU 70	ABU 70	G	G	ABU 70	G	G	ABU 70	10 days
	G	G	70AB U	ABU 70	G	G	ABU 70	ABU 70	14 days
	G	ABU 70	ABU 70	G	G	ABU 70	ABU 70	G	21 days

KEY:

G	green
ABU 70	orange

Fig (3.1) The experimental field layout.

3.3. Experimental farm soil analysis

Soil mechanical analysis was carried out at Khartoum University, the Faculty of Agriculture, soil laboratories. Chemical, physical analysis for site samples were carried out at the same laboratories using appropriate laboratory methods. Samples were collected in plastic bags, first dried at room temperature and then grinded. A mesh sieve 2 mm size was used. Table (3-1) shows results of chemical analysis.

Table (3-3-1) physical and chemical analysis of the soil.

Sample depth/cm	**PH /paste**	**EC_e ds/m**	**S.P %**	**Soluble Ca+Mg (mg/L)**	**Soluble Na(mg/L)**	**SAR**	**Soluble K (mg/L)**
0.10	7.8	4.6	63.0	35.0	21.0	4.8	1.08
10-20	8.0	4.4	61.0	32.0	20.3	4.0	1.13
20-30	8.02	4.1	60.0	30.0	20.0	4.6	1..15
Sample depth /cm	**Total Na %**	**Pppm**	**CEC mg/100G)**	**Exch. Na**	**Clay %**	**Silt %**	**Sand %**
0-10	0.05	6.2	40.0	3.06	3.60	32.0	32.0
10-20	0.03	6.0	41.0	3.02	38.0	33.0	29.0
20-30	0.01	5.8	42.5	3.5	40.0	32.0	28.0
Sample depth/cm	**PH /paste**	**EC_e ds/m**	**S.P %**	**Soluble Ca+mg (meg/L)**	**Soluble Na (meg/L)**	**SAR**	**K (meg/L)**
30-40	8.03	3.92	61.26	23.5	19.913	5.809	0.152
40-50	8.11	5.41	64.63	25.5	31.17	8.728	0.158
50-60	8.21	3.25	73.47	25.5	57.28	16.040	0.182
Sample depth /cm	**Total N%**	**Ppmm**	**CEC(meg/100g)**	**Exch. Na**	**Clay %**	**Silt %**	**Sand %**
30-40	0.028	0.2948	43.1525	4.4787	47.06	24.37	28.57
40-50	0.056	0.3802	44.020	8.5086	47.06	24.37	28.57
50-60	0.028	0.2665	46.0875	18.2240	54.56	21.87	23.57

.3-3-1 Soil sampling

A screw auger was used to take samples at (0-10),(10-20),(20-30), (30-40)-(40-50-) -(50-60) cm.

3-4. Land preparation:

The experimental area was first ploughed to a depth of 30cm-followed by disc harrowing and adequate leveling, and ridging (furrow width 70cm) for only 32 plots, the other 32 plots were leveled to flat, a buffer zone of 150 cm separated the ridged and flat plots, and a buffer zone of 70 cm between different irrigation interval plots.

3-5. Source of irrigation water:

The source of the irrigation water was from a domestic water tank. plate (3-1). Chemical and physical analysis of water was carried out at the National Rural Water Development Corporation (NRWDC) Khartoum, Sudan. The irrigation water EC_w recorded 0.285 ds/m. The applied amount of water was controlled by a flow meter, plate (3.2), attached at the end of the pipe. The irrigation pipes were $2^{//}$ diameter. Attached to the two inches flow meter was a flexible two inch (PE) pipe used to distribute water among plots controlled by a ball valve, plate (3.3).

The water tank

Plate (3-1) The water tank used as source of irrigation water: The dimensions 3*3*2.4 meter

The flow meter

Plate (3-2) The two inch flow meter.

The ball valve.

Plate (3.3) The ball valve

3.6 Field practices:

3-6-1 Fodder varieties used:

Two cultivars of sorghum forage seeds were used ; *Sorghum bicolor* . *L. Moench* cv. Local breed Alyab. Abu sabein and *Sorghum sudanense* C F S H 30. Garawia.

3-6-2 **Seed rate:**

The seed rate used for Abu sabein was local breed Alyab. 20 kg per fadden and 4 kg per fadden for garawia CFSH 30.

3-6-3 Sowing methods:

Two different Sorghum varieties (Abu sabein and garawia), four plots each , were broadcasted on ridges (0.7m between ridges) and all over the flat plots. A hand fork was used to cover the seeds. The effective sowing date is at the first irrigation which was given immediately after sowing. Subsequent irrigations followed.

3-6-4 Fertilizer application:

Urea (46% N) was applied as source of Nitrogen at 77 kg per fadden in two equal doses, applied over the plots at the second and fourth waterings, at 200 g / plot per dose.

3-6-5 Determination of reference evapotranspiration in mm /day

The computer software (CROPWAT), designed by FAO-Penman-Monteith approach (Smith *et al* (1991), was chosen to compute the reference evapotranspiration (ETo) in mm/day for each month of the growing season .Meteorological data taken from Shambat Meteorological Observatory station were entered as input data. The first season started at November , through December to early January, for (70 days) using the following ETo data (6.15 , 5.30, 5.91 mm/day) respectively . The second season started on November through December, to early January for (70 days) using the same ETo data (6.15, 5.30 5.91 mm/ day) , respectively .Table (3.6.5.1).Monthly mean minimum and maximum temperatures, relative humidity (%), wind speed (kg/ day), sun shine hours and solar radiation (Mj / m^2 / day) .

Table (3-6+5-1): The evapotranspiration (ET_o) mm / day throughout the year.

Country:	Sudan		Station	SHAMBAT			
Altitude :	380 m.		Latitude:	15.40 N	Longitude:	32.32 E	
Month	Min Tem	Max Tem	Humidity	Wind	Sun	Rad	ET_o
	C^o	C^o	%	km/day	Hours	MJ/m/day	mm/day
January	14.5	30.6	35	242	10.4	21	5.91
February	14.8	32	30	242	10.7	23.2	6.59
March	18	36	25	242	10.4	24.6	7.71
April	20.7	39	22	242	10.6	25.8	8.58
May	24.2	41	24	216	9.9	24.7	8.41
June	25.8	41	33	242	9.8	24.2	8.63
July	25	37.5	46	268	8.6	22.5	7.69
August	24.3	35.5	59	242	8.6	22.6	6.51
September	24.3	37.5	47	216	9.2	22.9	6.98
October	23.2	38.5	36	190	10.1	22.7	4.94
November	19.7	34.6	34	190	10.6	21.6	6.15
December	15.6	31.3	38	190	10.4	20.3	5.30

3-7 Crop coefficient (Kc) :

The crop coefficient kC was taken for both crops Abu 70 and Garawia from (CROP WAT) data for the two crops growth stages .Table (3.7.1).

Table (3.7.1) Crop coefficient :

Crop growth stages	Initial stage (20days)	Development stage (30 days)	Maturity stage (20 days)
Crop coefficient /Kc	` 0.3	0.38 , 0.62 , 1.01	1.02

crop wat 8

3-8 The crop growth stages :

The phonological cycle was divided into three stages since the crop is harvested before grain maturity . i.e :

A : Initial stage (20 days)

B : Development stage (30 days)

C : maturity stage (20 days)

The total duration of the cycle was 70 days.

3-9 Irrigation intervals:

Four levels of irrigation intervals were adopted (7 -10 -14 -21 days) .The amount of irrigation water (ET_C), was calculated according to kc and ETo data (Crop -Wat 8 windows ver 4.3). The short irrigation intervals (7-10-14 days) , were adopted to test their effects on the concentration of soil soluble salts on crop performance .

3.10 Yield parameters determination

3-10-1 Plant height determination in (cm):

One square meter from different plots was taken for the different measurements required. Four plants were randomly selected and measured.

3-10-2 Stem thickness determination in (cm) :

Four plant stems were randomly taken for stem perimeter determination in (cm), which was calculated by multiplying the stem diameter by 3.14. .

3-10-3 Number of leaves:

The number of leaves was counted along the stem for four plant.

3-10-4 The leaf Area determination:

Four leaves were taken randomly, the leaf area was determined by multiplying the maximum width by its length and a factor of 0.75.

3-10-5 Root sampling and root depth:

Many methods have been devised for examining, sampling and measuring root systems (Bohm, 1979). A simple hand auger method is described for taking known volume of soil from which roots can be extracted. A common method is as follows: place the core in the water, after several hours stir the soil-water mixture by hand to give a smooth suspension. Few minutes later the roots will tend to float. Pour the suspension and the roots onto a 0-5 mm sieve and wash with spray of water, repeat the process until no further roots are decanted. Place the roots in water ready for separating from organic debris. It is essential to clean the root sample before measurement, this is a tedious process, place the root, in a flat dish of water. Using tweezers pick out the organic debris and dead roots, If measurements are not made immediately after washing, store roots in 5 per cent (v/v) formaldehyde or 20 per cent (v/v) ethanol . For very small root samples or single roots direct measurement can be made by placing the roots on graph paper, straightening then with tweezers so that they do not overlap, and estimating their length.

3-11 Water use efficiency (WUE) :

The water use efficiency was calculated to each crop sampling according to (Micheal , 1978) , by dividing crop dry matter (DM) weights (ton / ha) by monthly evapotranspiration ET_c crop, in the period between successive cuts .Water management in arid areas is the most important factor that determines productivity. With the increase of the irrigated area and the onset of the drought cycle, water resources become limiting and endangered by salinity. Rainfall is very scanty and erratic in arid areas with annual total ranges between less than 100 and 400 mm. Water use efficiency (WUE) is a useful relative term in drought selection. Under stress conditions, the main concern is the production per unit of applied water rather than absolute production. (Stewart *et al* 1983).

3-12 Field water use efficiency (FWUE):

FWUE was obtained by dividing yield of dry matter (DM) by the amount of water applied to the field during that period .

Water Use Efficiency (WUE) can be calculated using the total amount of applied water for grain and dry matter as follows:

$$WUE = \frac{Y_{DM}}{Wt} \qquad (7)$$

Where:

WUE = Water use efficiency (kg / ha. cm)

Y_{DM} = Dry matter yield (kg/ha)

W_T = total water applied (cm) (Ibrahim 1997).

3-13 Fodder crop yields determination:

By the end of the growing season and at maturity stage 70-days from sowing, one square meter area was harvested from soil surface in a randomized manner from the middle of each plots, for different irrigation intervals, the harvested plants were immediately weighed in Kg / m^2, for

The total fresh yields, and then left to dry till a fixed weight was obtained for dry matter in (kg / m^2).

3-14 Statistical Analysis:

The data were analyzed by the analysis of variance (ANOVA), then the means comparison was made by the LSD. The analysis were conducted using the MSTAT program .

Table (3-7-2) Kc used for water requirements for different intervals during sorghum crop cycle . 0.3-------------1.03

Intervals	**Initial**	**Development**	**Maturity**
7 days	0.3		
7 days	0.3		
7 days	0.3		
7 days		0.38	
7 gays		0.46	
7 days		0.54	
7 days		0.62	
7 days			0.75
7 days			0.88
7 days			1.01
10 days	0.3		
10 days	0.3		
10 days		0.4	
10 days		0.5	
10 days		0.6	
10 days			0.82
10 days			1.03
14 days	0.3		
14 days	0.3		
14 days		0.61	
14 days			0.82
14 days			1.03
21 days	0.3		
21 days		0.46	
21 days		0.62	
21 days			1.0

Table (3-7-3-) Crop water requirements in mm depth for sorghum

Interval	Initial	Initial	Development	Develpopment	Maturity	Maturity	Net Etc
	Kc	Et_o	Kc	Et_o	kc	Et_o	Mm
7 days	0.3	6.15					1.85
7 days	0.3	6.15					1.85
7 days	0.3	5.30					1.59
7 days			0.38	5.30			2.01
7 days			0.46	5.30			2.44
7 days			0.54	5.30			2.86
7 days			0.62	5.91			3.66
7 days					5.91	0.75	4.43
7 days					5.91	0.88	5.20
7 days					5.91	1.01	5.97
10 days	0.3	6.15					1.85
10 days	0.3	6.15					1.85
10 days			0.40	5.30			2.12
10 days			0.50	5.30			2.65
10 days			0.60	5.30			3.18
10 days					0.82	5.91	4.85
10 days					**1.03**	**5.91**	**6.09**
14 days	0.3	6.15					1.85
14 days	0.3	5.30					1.59
14 days			0.61	5.30	5.3		3.23
14 days					0.82	5.91	4.85
14 days					1.03	5.91	6.09
21 days	0.3	6.15					1.85
21 days			0.46	5.30			2.44
21 days			0.62	5.30			3.29
21 days					1.0	5.91	5.91

3-15 Leaching requirement :

The portion of water applied which is required to pass through the root zone to control salts at a specific level is called the Leaching Requirement. The Leaching requirement (LR) can be estimated from the crop salinity tolerance, as defined by the electrical conductivity of a saturated paste extract of the soil at which no yield loss can occur , Ec_e, and the salinity of the irrigation water , as defined by the electrical conductivity of the applied water Ec_w. Although several methods exist for estimating the leaching requirement each with its own limitation and benefit. The most widely used equation is provided below.

$$LR = \frac{Ec_w}{5\,Ec_e - Ec_w} \qquad (8)$$

Ec_w= electrical conductivity of the irrigationn water

Ec_e= electrical conductivity of soil

Frequently, the number obtained for the LR from the above equation is incorrectly multiplied by the crop seasonal consumptive use to obtain an estimate of the amount of water required on a seasonal basis for salinity control, this leaching amount is then added to the consumptive use to obtain an estimate of the total amount of irrigation water required to be applied (assuming a 100% irrigation efficiency). Such an approach is totally incorrect. (arizona.edu/pubs/water/az).

Thus L.R is estimated as follows:

Ec_w = 0.285

Ec_e = 4.4

0.285

--------------------- (9)

5*4.4—0.285

0.285

22—0.285 = 21.715

LR 0.285 ÷ 21.715 = 0.013

The leaching amount is then used to calculate the actual irrigation water to be applied, as shown by Ayers *and West cot* (1985).

Applied Water = Consumptive use

--------------------------- (10)

1----LR = 1 – 0.013= 0.987 mm

Table (3-7-4) Leaching requirement in mm depth for sorghum _ Et_{c+} LR

Interval	Initial	Initial	Deve	Development	Maturity	Maturity	Total
	Etc	LR	Etc	LR	Etc	LR	
7 days	1.85	0.987					2.84
7 days	1.85	0.987					2.84
7 days	1.59	0.987					2.58
7 days			2.01	0.987			3.00
7 days			2.44	0.987			3.43
7 days			2.86	0.987			3.85
7 days			3.66	0.987			4.65
7 days					4.43	0.987	5.42
7 days					5.20	0.987	6.19
7 days					5.97	0.987	6.96
10 days	1.85	0.987					2.84
10 days	1.85	0.987					2.84
10 days			2.12	0.987			3.11
10 days			2.65	0.987			3.64
10 days			3.18	0.987			4.17
10 days					4.85	0.987	5.84
10 days					6.09	0.987	7.08
14 days	1.85	0.987					2.84
14 days	1.59	0.987					2.58
14 days			3.23	0.987			4.22
14 days					4.85	0.987	5.84
14 days					6.09	0.987	7.08
21 days	1.85	0.987					2.84
21 days			2.44	0.987			3.43
21 days			3.29	0.987			4.28
21 days					5.91	0.987	6.90

3-16 Irrigation efficiency:

Gross applications was calculated as the net irrigation including leaching requirements divided by an assumed application efficiency of 70 % . The value for furrow irrigation,(67.5%) was considered an achievable value for producers, as from (Solomon 1988). The overall irrigation efficiency for surface irrigation in literature between (50-70 %). 70 % which is the higher range was taken in this respect as water was distributed to the plots in pipes. Table (2.4) .

Table (3-7-5) Gross irrigation requirement in mm depth/ day at 70 % overall irrigation efficiency .

Interval	Initial		Develop		Maturity		Total
	App. Water	Eto70%	App.water	Eto70%	App. Water	Eto70%	App water.
7 days	2.84						4.06
7 days	2.84				.		4.06
7 days	2.58						3.69
7 days			3.00				4.29
7 days			3.43				4.90
7 days			3.85				5.50
7 days			4.65				6.64
7 days					5.42		7.74
7 days					6.19		8.84
7 days					6.96		9.94
10 days	2.84						4.06
10 days	2.84						4.06
10 days			3.11				4.44
10 days			3.64				5.20
10 days			4.17				5.96
10 days					5.84		8.34
10 days					7.08		10.11
14 days	2.84						4.06
14 days	2.58						3.69
14 days			4.22				6.03
14 days					5.84		8.34
14 days					7.08		10.11
21 days	2.84						4.06
21 dats			3.43				4.90
21 days			4.28				6.11
21 days					6.90		9.86

Table (3-7-6) Gross irrigation requirements for all irrigation intervals in mm depth per watering. Net*Interval

Interval	Initial	Initial	Deve	Develo	Maturity	Maturity	Total
	Net	Int	Net	Int	Net	Int	mm
7 days	4.06	7					28.42
7 days	4.06	7					28.42
7 days	3.69	7					25.83
7 days			4.29	7			30.03
7 days			4.90	7			34.30
7 days			5.50	7			38.50
7 days			6.64	7			46.48
7 days					7.74	7	54.18
7 days					8.84	7	61.88
7 days					9.94	7	69.58
10 days	4.06	10					40.60
10 days	4.06	10					40.60
10days			4.44	10			44.40
10days			5.20	10			52.00
10days			5.96	10			59.60
10days					8.34	10	83.40
10days					10.11	10	101.10
14days	4.06	14					56.84
14days	3.69	14					51.66
14days			6.03	14			84.42
14days					8.34	14	116.76
14days					10.11	14	141.54
21days	4.06	21					85.26
21days			4.90	21			102.90
21days			6.11	21			128.31
21days					9.86	21	207.06

Table (3-7-7) Watering in m^3/ plot for all irrigation intervals

Intervals	Initial	Initial	Develo	Develo	Maturity	Mat	Total $m^{3/}$plot
	Net/Int	m^3m^2	Net/Int	m^3m^2	Net/Int	m3m^2	
7 days	28.42	0.028					0.56
7 days	28.42	0.028					0.56
7 days	25.83	0.026					0.52
7 days			30.03	0.030			0.60
7 days			34.30	0.034			0.68
7 days			38.50	0.039			0.78
7 days			46.48	0.046			0.92
7 days					54.18	0.054	1.08
7 days					61.88	0.062	1.24
7days					69.58	0.070	1.40
10 days	40.60	0.041					0.82
10 days	40.60	0.041					0.82
10 days			44.40	0.044			0.88
10 days			52.00	0.052			1.04
10 days			59.60	0.060			1.20
10 days					83.40	0.083	1.66
10 days					101.10	0.101	2.02
14 days	56.84	0.057					1.14
14 days	51.66	0.052					1.04
14 days			84.42	0.084			1.68
14 days					116.76	0.117	2.34
14 days					141.54	0.142	2.84
21 days	85.26	0.085					1.70
21 days			102.90	0.103			2.06
21 days			128.31	0.128			2.56
21 days					207.06	0.207	4.14

Table (3-7-8) Total water used in all crop growth stages / plot in m^3 for sorghum.

Intervals	Initial	Development	Maturity	Total m^3/ plot
7 days	1.64	2.98	3.82	8.44
10 days	1.64	3.12	3.68	8.44
14 days	2.18	1.68	5.18	9.04
21 days	1.70	4.62	4.14	10.46

Chapter four

Results and Discussion

In the present study, the performance of two fodder Sorghum cultivars Abu 70 and Garawia was evaluated under four watering intervals 7,10,14,21 days on two soil preparation methods (ridged, flat). Generally prolonging the irrigation interval decreased the values of the attributes measured. Comparatively higher yield in short intervals can be attributed to the relatively lower salt concentration in soil water at the end of the interval. As the interval becomes longer the effect of salt concentration at the end of the interval becomes more profound on yields. As a result the longer intervals tend to give lower dry and fresh yields specially in the second season. This trend applies to most yield parameters except the leaves number. Not all of the parameters showed significant differences .The insignificant effects of watering treatments on some of the measured parameters.

4-1 Cultivars dry yield (t /ha):

4.1.1 Abu 70 dry matter yield:

Abu 70 on ridged and flat plots scored the following dry matter yields in kg per ha under different irrigation intervals, as seen on Table (4.1). On the first season, it can be seen that at 10 days intervals scored higher yield on ridge plots. In the second season Abu 70 yield on ridged plots under 7 days interval gave higher dry matter yield as shown on Table (4.1),. Ridging seem to reduce the salt concentration at plant root level, and salt concentration tend to accumulate at the top of the ridge.

Table (4.1) Yield (DM) in kg per hectare of Abu 70 on ridge and flat plots for all intervals in the first and second season.

Intervals	7 days	10 days	14 days	21 days
Ridge (first season) (t/ha)	9300	10600	9300	8800
Flat (first season) (t/ha)	7300	8500	7500	1300
Ridge (second season) (t/ha)	14500	13000	11500	10000
Flat (second season) (t/ha)	11000	9000	7500	2100

.4.1.2 Garawia dry matter yield.

Garawia on ridge and flat plots scored the following dry matter yield in kg per ha under different irrigation intervals , on two seasons as shown on Table (4.2),on the first season it can be seen that at 7 days intervals gave higher yield on ridge plots. In the second season Garawia yield on ridge is shown on Table (4.2). it can be seen that under 7 days interval gave higher yield on ridge plots, as shown on Table (4.2) .Ridging seem to reduce the salt concentration at plant root level, and salt concentration tend to accumulate at the top of the ridge.

Table (4.2) Yield (DM) in kg per hectare of Garawia on ridge and flat plots for all intervals in the first and second season.

Intervals	7 days	10 days	14 days	21 days
Ridge (first season) (t/ha)	**10000**	**9100**	**7300**	**3200**
Flat (first season) (t/ha)	**8500**	**8400**	**6500**	**5300**
Ridge (second season) (t/ha)	**10500**	**8000**	**7500**	**4000**
Flat (second season) (t/ha)	**7000**	**6000**	**3500**	**7000**

4.2 The effects of different treatments on fresh and dry matter yields for the two cultivars:

Table (4.3) shows the results of the irrigation intervals on dry yield in two seasons, the 7. 10, 14 days intervals gave a significant differences in the first seasons compared to 21 days, In the second season the 7, days interval revealed a significant difference at (0.5% level), compared to 10, 14, 21 days intervals. Table (4.4) Shows the dry matter yield for the interaction of crop varieties *irrigation intervals. No significant differences were observed in the first season. Abu70 under 7 days intervals in the second season scored a significant difference over Garawia under the different intervals. Abu 70 gave a higher yield over Garawia in the two seasons under different irrigation intervals.

Table (4.3): The effects of irrigation intervals on Fresh and dry matter yields in two seasons, (2011-2012) seasons.

Treatment	Fresh weight (t/ ha		Dry weight (t / ha	
	2011	2012	2011	2012
7 days	11.22 a	19.69 a	8.75 a	10.65a
10days	12.03 a	16.31 b	9.25a	8.88 b
14days	9.94a	13.50 c	7.62 a	7.34 c
21days	6.08 b	10.49 d	4.82 b	7.84d
F. V	4.75*	0.006*	4.72*	43.36*
C.V%	49.28	10.12	47.96	10.24
L.S.D	1.722	0.568	1.299	0.317
S.E	1.209	0.399	0.912	0.222

Means having the same subscripts within a column for e ach season shows no significant different at 5% level.

Table 4.4: The effect of crop varieties× irrigation intervals for fresh and dry matter yield for (2011-2012) seasons.

Treatment	Fresh weight(t/ha)		Dry weight(t / ha)	
	2011	2012	2011	2012
Abu70 ×7 days	10.38	23.94 a	8.25	12.69 a
Abu70 ×10days	12.19	19.81 b	9.53	10.94ab
Abu70×14days	10.75	17.31 b	8.36	9.44ab
Abu70 ×21days	6.66	16.88 c	5.40.	10.13cde
Garawia ×7 days	12.06	15.44 b	9.25	8.63 bc
Garawia×10days	11.88	12.81 b	8.96	6.81b cd
Garawia×14days	9.13	9.69 c	6.89	5.25 e
Garawia×21days	5.50	10.13 d	4.23	5.56 de
F .V	0.37 ns	0.96 ns	0.36 n.s	0.255 ns
C.V%	49.28	10.12	47.96	10.24
L.S.D	1.72	0.57	1.29	0.32
S.E	1.710	0.564	1.290	0.314

Means having the same subscripts within a column for each season shows no significant different at 5% level.

Table (4.5): The interaction of crop varieties × soil preparations methods for fresh and dry matter yields (2011-2012) seasons. .

Treatment	Fresh weight(t / ha)		Dry weight(t / ha)	
	2011	2012	2011	2012
Abu 70×F	7.83	17.88 a	6.31 a	9.41a
Abu70×R	12.16	21.09 a	9.46 a	12.19 a
Garawia×F	9.41	10.44 b	7.21 a	5.72 b
Garawia×R	9.88	13.59 b	7.45 b	7.40 b
F. V	2.545ns	0.006 ns	2.535 ns	6.052*
C.V%	49.28	10.12	47.96	10.24
L.S.D	1.72	0.57	1.29	0.32
S .E	1.209	0.399	0.912	0.222

Means having the same subscripts within a column for each season shows no significant different at 5% level.

Table (4.5) demonstrates the interaction of methods of soil preparation and cultivars, no differences were observed on ridged and flat plots for Abu 70 and Garawia in the first season. The results recorded that Abu 70 scored a significantly different yield on the two methods of soil preparation in the second season. Garawia gave a higher yield in the second season on the ridged method. The two cultivars showed a higher yield on ridged method than flat method in the second season.

Table (4.6): The interaction of soil preparation methods*irrigation intervals for fresh and dry matter yields (2011-2012) seasons.

Treatment	Freshweight(t/ha)		Dry weight(t / ha)	
	2011	2012	2011	2012
F ×7 days	12.19	16.69 cd	9.50	8.88 abcd
F ×10days	13.19	15.13 de	10.10	7.44 bcd
F ×14days	10.81	10.50 f	8.27	5.38 d
F ×21days	7.88	14.13 ef	5.94	8.56 bcd
R ×7 days	10.25	22.69 a	7.99	12.44 a
R ×1 0days	10.88	17.50b	8.39	10.31ab
R ×14days	9.06	16.50bc	6.97	9.31 abc
R ×21days	4.29	12.69 f	3.70	7.13 cd
F. V	0.12^{ns}	20.80^{*}	0.05^{ns}	31.29^{*}
C.V%	49.28	10.12	47.96	10.24
L.S.D	1.722	0.568	1.299	0.317
S.E	1.710	0.564	1.290	0.314

Means having the same subscripts within a column for each season shows no significant different at 5% level.

Table (4.6) displays the interaction of methods of soil preparation with irrigation intervals. The results revealed no differences for the two methods within different intervals in the first season. The second season showed a significant difference at (0.5% level) for 7, 10 days intervals on ridged, compared to flat. The results of interaction of cultivars on both ridged and flat methods under different irrigation intervals for dry yields in the two seasons, showed no significant differences in the first season, the second season show significant differences. Table (4.7),for Abu 70 on ridge under 7days 10days 14days 21days than Garawia. The two cultivars in the two seasons are shown on table (4.8). Abu 70 cultivar gave a higher yield in the two seasons, than Garawia. Table (4.9) shows soil preparation methods in the two seasons. Ridged method scored a significant different at (0.5% level) in the second season for flat. The two methods gave a higher yield in the second than the first season.

Table (4.7): The effect of crops varieties ×soil preparations methods ×irrigation intervals for fresh and dry matter yields (2011-2012) seasons.

Treatment	Fresh weight (t/ ha)		Dry weight (t / ha)	
	2011	2012	2011	2012
Abu70 ×F ×7 days	9.13	20.88 abc	7.26	10.88 abc
Abu70 ×F ×10days	10.88	18.50bcde	8.50	9.13 abcd
Abu70 ×F ×14days	9.50	15.25dcde	7.44	7.50 bcde
Abu70 ×F ×21days	1.82	16.88 cde	1.09	10.13 cde
Abu70 ×R ×7 days	11.63	27.00 a	9.24	14.50 a
Abu70 ×R ×10days	13.50	21.13ab	10.60	12.75 ab
Abu70 ×R ×14days	12.00	19.38abc	9.27	11.38 ab
Abu70 ×R ×21days	11.50	16.88bcde	8.72	10.13abcd
Garawia×F×7 days	11.38	12.50bcde	8.73	6.88 bcde
Garawia×F×10days	10.88	11.75bcde	8.32	5.75 bcde
Garawia×F×14days	8.63	5.75 de	6.50	3.25 e
Garawia×F×21days	6.75	11.75bcde	5.31	7.00 bcde
Garawia×R×7 days	12.75	18.38 ab	9.77	10.38 abc
Garawia×R×10days	12.88	13.88 abc	9.61	7.88 abcd
Garawia×R×14days	9.63	13.63 bcd	7.28	7.25 abcd
Garawia×R×21days	4.25	8.50 e	3.16	4.13 de
F .V	$1.322^{n.s}$	3.269^{*}	$1.54^{n.s}$	2.429^{*}
C.V%	49.28	10.12	47.96	10.24
L.S.D	1.722	0.568	1.299	0.317
S.E	2.419	0.797	1.824	0.445

Means having the same subscripts within a column for each season shows no significant different at 5% level.

Table (4.8): The effects of crop varieties on fresh and dry matter yield in two seasons.

Treatment	Fresh weight(t / ha)		Dry weight(t / ha)	
	First season	Second season	First season	Second season
Ab 70	9.99 a	19.48 a	7.88 a	10.80 a
Garawia	9.64 b	12.02 b	7.33 b	6.56 b
F .V	0.08 *	351.25*	0.37*	362.81*
C.V%	49.28	10.12	47.96	10.24
L.S.D	1.722	0.568	1.299	0.317
S.E	0.855	0.282	0.645	0.157

Means having the same subscripts within a column for each season shows no significant different at 5% level.

Table (4.9): The effects of soil preparations methods on fresh and dry matter yields in two seasons. .

Treatment	Fresh in Ton / ha		Dry in Ton / ha	
	First season	Second season	First season	Second season
Flat	11.02	14.16 b	8.45	7.56 b
Ridged	8.62	17.34 a	6.76	9.80 a
F .V	3.93ns	63.977*	3.441ns	101.022*
C.V%	49.28	10.12	47.96	10.24
L.S.D	1.722	0.568	1.299	0.317
S.E	0.855	0.282	0.645	0.157

Means having the same subscripts within a column for each season shows no significant different at 5% level.

4-3- Cultivars fresh yield (t/ ha) in the two seasons:

Table (4.3) shows the results of the irrigation intervals in the two seasons, at 7. 10,14days. No significant differences except at 21 days which showed a significant difference in the first season. In the second season, 7 days intervals revealed a significant different at (0.5% level) as compared to the other intervals.

Table (4.4) revealed the interaction of cultivars with irrigation intervals. The results showed no differences in season one for Abu 70 or Garawia . The second season showed a significantly different yield at (0.5% level) throughout the different irrigation intervals for Abu 70 over Garawia.

Table (4.5) demonstrates the interaction of methods of soil preparation and cultivars. No significant differences on flat and ridged plots for Garawia and Abu 70 in the first season. Abu 70 in the second season, recorded a significantly different yield on ridged and flat methods. A higher yield in the second season was on the ridged method. The two cultivars showed a higher yield on ridged method in the second season than flat method. Table (4.6) displays the interaction of methods of soil preparation with irrigation intervals. The results revealed no significant differences for the two methods within different intervals in the first season. The second season showed a significantly different yield at (0.5% level) for 7 and 10 days intervals on ridged than flat. Table (4.7) revealed the results of crop varieties, soil preparation methods and irrigation intervals for the two seasons, the first season showed no differences. In the second season Abu 70 on ridged treatment scored higher yields than Garawia on flat. The two cultivars in the two seasons are presented on Table (4.7). A significantly different yield at (0.5% level) for Abu 70 was observed in the two seasons. However, the two cultivars in the second season gave a higher yield than in the first season.

Table (4.8) shows the soil preparation methods for the two seasons. Ridged method scored a significant difference at (0.5% level) in second season. The two cultivars gave a higher yield in the second season than the first one.

The fresh weight was observed to be influenced by irrigation intervals in both seasons. The maximum fresh yield was obtained by shorter intervals 7-10 days. These findings are similar to several research workers for example Mustafa and Abdel Magid 1982) . Izzeldeen (2000), Babiker (1995) and Ghsemi *et al* (2012) . Fresh fodder at harvest increased with decreased watering intervals. These results were observed by Saeed (1984) for Abu sabein and lucern. He found that higher yields of fresh fodder in all sampling occasions were associated with frequent irrigations and the yield decreased as the irrigation intervals were prolonged. The trend for dry weight was similar to that reported for fresh weight, since dry weight represented between 20-25 percent of the fresh weight. (Hassan 1987) for soya beans, (Buck *et al* 1983) and Ishag (1982) .There were significant differences between ridged and flat soil preparation methods for Abu 70 and Garawia The ridged method showed differences throughout the irrigation intervals, and different soil preparation methods in the two seasons. Many research workers found a reduction in dry matter due to water stress, e.g. Hassan (1987) for, Soya bean. Recently, Saeed *et al* (2008) reported that the dry matter yield of lucerne irrigated every 7 and 10 days intervals was higher than yield of lucerne under 13 days, intervals. The slight differences in the two seasons for the cultivars was because the harvest ended at early January when both temperature and relative humidity were low, a trend which is known in semi-arid regions (El Amin 1976) .

4-4 The growth parameters for the fodder crops during the two seasons.

4-4-1 Plant height:

Table (4.10) Shows the growth parameters for fodder crops Garawia and Abu 70. The statistical analysis showed no significant differences within the findings, in the first and second season for plant height. The plant height is not significantly different at (5.0% level) for the cultivars during the first seasons.(Table (4.10), but both Abu 70 and Garawia were taller in the second season than in the first season.

Table (4.10) The effects of two fodder crops varieties on The growth parameters for. (2011-2012) seasons.

Treat.	**Plant height (cm)**		**Stem thickness (cm)**		**Leaf No.**		**L.A (cm^2)**		**Root depth (cm)**	
	2011	**2012**	**2011**	**2012**	**2011**	**2012**	**2011**	**2012**	**2011**	**2012**
Garawia	147.16	171.09	1.63	1.93 a	7.13	6.16	4.17.	7.75 a	15.16 b	29.72 a
Abu 70	142.44	175.94	2.36	2.15 b	7.97	6.85	7.89	17.33 b	27.63 a	23.22 b
F .V	0.68ns	0.68ns	76.87	7.13*	5.79*	8.18ns	126.7	130.38*	114.21*	124.01*
C.V%	15.82	13.53	16.50	16.84	18.58	14.80	22.03	26.75	21.82	8.82
L.S.D	8.16	8.36	0.12	0.12	0.49	0.34	0.47	0.18	1.66	0.83
S.E	4.051	4.151	0.058	0.061	0.248	0.170	0.235	0.593	0.825	0.413

Means having the same subscripts within a column for each season shows no significant different at 5% level.

The results of soil preparation methods for the two seasons, showed taller plants on flat in season one, and a significant difference for ridged treatment in the second season, (Table 4.11). However, season two showed taller plants than the first season for both ridge and flat treatments.

Table (4.11) The effects of two soil preparation methods, on the growth parameters for the two cultivars. (2011-2012) seasons.

Treat.	Plant height (cm)		Stem thickness (cm)		Leaves No.		Leaf area (cm^2)		Root depth (cm)	
	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012
Flat	149.22	166.25 b	1.82 b	1.74 b	7.59 a	6.31 b	5.63 b	9.10 b	22.41 a	25.28 b
Ridged	140.38	180.78 a	2.16 a	2.34 a	7.50 a	6.69 a	6.45 a	15.99 a	20.38 a	27.66 a
F. V	2.38 n.s	6.13*	17.57 *	48.98 *	0.07n .s	2.43*	6.09*	67.42*	3.03*	16.56*
C.V %	15.82	13.53	16.50	16.84	18.58	14.80	22.03	26.75	21.82	8.82
L.S.D	8.16	8.36	0.12	0.12	0.49	0.34	0.47	0.18	1.66	0.83
S.E	4.050	4.151	0.058	0.061	0.248	0.170	0.235	0.593	0.825	0.413

Means having the same subscripts within a column for each season shows no significant different at 5% level.

The results of interaction of soil preparation and cultivars for the two seasons are shown on Table (4.12). The taller plants for the two methods were observed in the secon**d** season than the first one for both cultivars. The plants within second season were taller than the first season for Abu 70. No significant different for Garawia within the two seasons.

Table (4.12) The interaction of two soil preparation methods and two fodder crops on the growth parameters for (2011-2012) seasons.

Treatment	Plant height (cm)		Stem thickness (cm)		Leaf No.		Leaf area (cm^2)		Root depth (cm)	
	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012
Gr * R	146.94	167.81	2.09 a	1.70 a	7.13	6.25	4.73 b	7.33b	28.94 b	22..75
Gr * F	147.38	164.69	1.56 b	1.79 b	7.13	6.06	3.60 b	8.43b	15.88 b	28.75
Abu70*R	133.81	184.06	2.63 a	2.61a	7.88	7.13	8.16 a	24.64 a	26.31a	24.06
Abu70 * F	151.06	177.50	1.70 b	2.07 b	8.06	6.56	7.65 a	10.03 a	14.44 a	31.25
F .V	2.15ns	0.09ns	5.99 *	12.41 *	0.07ns	0.61 ns	0.87 *	84.93 *	0.26*	1.39ns
C.V%	15.82	13.53	16.5	16.84	18.58	14.8	22.0	26.75	21.82	8.82
L.S.D	8.16	8.36	0.12	0.122	0.49	0.34	0.74	0.18	1.66	0.83
S.E	5.73	5.87	0.08	0.09	0.35	0.24	0.33	0.84	1.17	0.58

Means having the same subscripts within a column for each season shows no significant different at 5% level.

Irrigation intervals results are presented on Table (4.13) which revealed that taller plants were obtained in the second season under 7 and 10 days intervals.

Table (4.13) The effects of different irrigation intervals, on the growth parameters, for the two cultivars. (2011-2012) seasons.

Treatment	Plant height (cm)		Stem thickness (cm)		Leaf No,		L.A (cm^2)		Root depth (cm)	
	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012
7 day	138.63 b	186.56 b	2.19 a	2.55 a	7.75	7.19 a	7.54 a	13.09 a	22.5 a	18.63 d
10 day	172.19 a	188.44 a	2.28 a	2.24 b	7.56	7.25 b	5.70 b	12.12 a	16.0 b	24.75 c
14 day	137.25 b	165.0 b	1.83 a	1.88 c	7.31	5.75 c	5.56 b	14.15 a	22.94 a	28.75 b
21 day	131.13 b	154.06 b	1.68 b	1.49 d	7.56	5.81 c	5.34 b	11.08 b	24.13 a	33.75 a
F .V	10.49*	8.16*	11.8*	28.9*	0.26 ns	11.94*	9.38*	2.14*	9.83*	120.04*
C.V%	15.82	13.5	16.5	16.8	18.6	14.8	22.0	26.8	21.82	8.82
L.S.D	8.16	8.36	0.18	0.12	0.50	0.34	0.47	0.18	1.66	0.83
S.E	5.73	5.87	0.08	0.09	0.35	0.24	0.33	0.84	1.17	0.58

Means having the same subscripts within a column for each season shows no significant different at 5% level.

The highlight of the interaction of soil preparation with irrigation intervals in two seasons.

The results on Table (4.14) showed taller plants for ridged method at 10 days interval in the first season than on the other preparation method and intervals. Ridged method at 7 and 10 days intervals in second season showed taller plants in season two than in the first season.

Table (4.14) the interaction of soil preparation methods and irrigation intervals, on the growth parameters for the two cultivars. (2011-2012) seasons.

Treatment	Plant height (cm)		Stem thickness (cm)		Leaves No,		Leaf area (cm^2)		Root depth (cm)	
	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012
Ridged*7 Day	137.75	191.25	2.38	2.88	7.88	6.50	8.82a	15.38 b	15.88b	18.38 a
Flat * 7 day	139.50	181.88	1.98	2.23	7.63	7.88	6.25b	10.80 b	29.13b	18.88 a
Ridged*10 day	167.38	200.63	2.50	2.64	7.63	8.00	6.01a	14.50 a	19.50a	25.38 a
Flat * 10 day	177.00	176.25	2.04	1.83	7.50	6.50	5.39b	9.73b c	12.50a	24.13 a
Ridged * 14 day	129.25	174.38	1.92	2.12	7.25	6.00	5.90a	20.25 cd	23.13a	29.13 a
Flat* 14 day	145.25	155.63	1.74	1.64	7.38	5.50	5.12b	7.54d	22.75c	28.38 a
Ridged*21 day	127.03	156.88	1.84	1.72	7.25	6.25	5.05b	13.81 d	23.00a	37.75 a
Flat * 21 day	135.13	151.25	1.52	1.25	7.88	5.38	5.64a	8.32d	25.25a	29.75 b
F .V	0.26 ns	0.53 ns	0.55 ns	0.85 ns	0.30 ns	6.62 *	3.90*	5.41*	13.04*	10.72 *
C.V%	15.82	13.53	16.5	16.84	18.58	14.8	22.03	26.75	21.82	8.82
L.S.D	8.16	8.36	0.12	0.12	0.49	0.34	1.47	0.18	1.66	0.83
S.E	8.1010	8.302	0.12	0.12	0.50	0.34	0.47	1.19	1.65	0.83

Means having the same subscripts within a column for each season shows no significant different at 5% level.

The interaction of cultivars with irrigation intervals showed no significantly differences in the two seasons, except the two cultivars in the two seasons under 7, 10 days intervals scored taller plant, Table (4.15).showed that the longer intervals 14--21 days within the two seasons for the two cultivars revealed a shorter plants. The results of interaction between crop varieties, soil preparation methods and different irrigation intervals revealed no significant differences in the two seasons, (Table 4.16).

The results of growth parameters for sorghum cultivars in the two seasons indicated that no significant differences between cultivars: Abu 70 and Garawia, except under shorter intervals and the ridged method. These results were in line with the findings of Ghasemi et al (2012), for field performance of different varieties of sorghum grown in an arid region. This is also consistent with the finding of Osama (2001), for the effects of irrigation intervals and some tillage systems on salt redistribution and yield of hybrid forage sorghum. The cultivars in the second season were taller than in first season, under 10 days intervals. The ridged method showed taller stems than on flat method, this may be contradicting with the fact that ridged treatments resulted in the lowest plant height and that could be due to the relative high surface bulk density, low porosity, retarded infiltration rate and low water holding capacity. These results agreed with the finding of Abdalla (1995).

During both seasons plant height of frequently irrigated treatments, showed a significant increase. This result is similar to the finding of Saeed (1984) and Mansour (1981) for lucerne and fodder sorghum, respectively. The plant height was significantly increased with decreased irrigation intervals. Similarly Mohamed Ahmed (1988) working on wheat and El Nadi, (1980) on broad beans, indicated that irrigation at short days increased plant height as compared with longer intervals, the shorter plants were observed in plots irrigated every 14-21 days while the tallest plants were under 7-10 days. This may be to the fact that as the irrigation intervals increased the crop was subjected to high water and osmotic stress and reduced nutrient uptake, where these stress would be expected to decrease N-uptake and its utilization by the crop and inhibit cell elongation and depress photosynthesis. In general, the infrequent irrigation reduced stem height, leaf area index and total biomass production, (Saeed & El Nadi. 1997).

4-4-2 Stem thickness:

Table (4.10) Shows the growth parameters for the fodder crops Garawia and Abu 70. Analysis of variance showed significant differences between the two cultivars during the two seasons. The stem thickness of the two cultivars showed a significantly different value at (0.5% level). Table (4.10) clearly showed a significantly different stem thickness for Abu 70 for the two seasons than Garawia. The results also showed significantly thicker stems on ridged method than on flat method, in both seasons (Table 4.11). A significantly different of stem thickness at (0.5% level) (Table 4.12) appeared for Abu 70 on both ridged and flat methods in the first season and on ridged and flat in second season. Garawia gave thicker stems on ridged and flat methods for both seasons. The irrigation intervals within the two seasons revealed a significantly different stem thickness in the first season (Table 4.13) the shorter intervals 7-10 days resulted in thicker stems than 14-21 days in the first season (Table 4.13). The second season showed a thicker stems during the shorter period 7, 10 than at 14, 21 days. The results revealed a significantly different stem thickness in the first season (Table 4.13) at 14 days than 21 days, At 7 and 10 days no differences were observed. The second season showed a significantly different stem thickness for 7, 14 days intervals than 10, 21 days.

The interaction of soil preparation methods with irrigation intervals in two seasons revealed a significant differences between the different treatments. Ridged method and 10 days interval in the first season gave thicker stems than on the flat method under different irrigation intervals in the first season. The second season showed a sicker stems at 7, 10, days above 10, 21 days. The ridged method recorded a thicker stems than in flat method at different irrigation interval, Table (4.14).

The interaction of two crops varieties and irrigation intervals in the two seasons showed a significantly different stem thickness for Abu70 within different irrigation intervals in the first season, (Table 4.15), in The second season Abu70 gave thicker stems than Garawia at 10, 14days intervals.

Table (4.16) Showed a significant differences at the interaction of crop varieties, soil preparation method and irrigation intervals, where Abu 70 in two seasons, on ridged plots at different intervals was better, than Garawia.

Table (4.15) The interaction of two crops varieties and irrigation intervals on, the growth parameters for (2011-2012) seasons.

Treatment	Plant height (cm)		Stem thickness (cm)		Leaf No .		L.A (cm^2)		Root depth (cm)	
	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012
Gr*7days	142.63	184.38	1.72 a	2.50 a	7.25	7.13	4.36b	8.33b	13.0 e	17.50 f
Gr * 10 day	176.38	191.25	1.60 b	1.90 b	7.25	7.25	4.05b	8.55b	8.88 e	33.5 b
Gr * 14 day	137.38	160.00	1.65 b	1.77 a	6.75	6.50	4.22 b	8.13b	20.13 d	19.75 f
Gr * 21 day	132.25	148.75	1.56 b	1.52 a	7.25	6.50	4.00 b	6.53b	18.63 d	24.00 de
Abu70*7 day	134.63	188.75	2.65 b	2.61 a	8.25	7.25	10.73 a	17.86 a	32.0a	26.63c
Abu70*10 day	168.00	185.63	2.95a	2.57a	7.88	7.25	7.33a	15.69 a	23.31cd	41.25a
Abu70 * 14 day	137.13	170.00	2.01 a	1.99 a	7.88	5.00	6.89 a	20.18 a	25.75 bc	22.88 e
Abu70 * 21 day	130.00	159.38	1.80 b	1.44 a	7.88	5.13	6.66a	15.63 a	29.63 ab	26.25 cd
F .V	0.13 ns	0.41 ns	9.95 *	3.49 *	0.14 ns	3.27 n*	7.08 *	1.78 *	5.81*	40.45*
C.V%	15.82	13.53	16.50	16.84	18.58	14.8	22.03	26.75	21.82	8.82
L.S.D	8.158	23.64	0.117	0.122	0.499	0.34	0.473	0.181	1.662	0.831
S.E	8.1010	8.3018	0.1161	0.121	0.496	0.34	0.469	1.186	1.650	0.8255

Means having the same subscripts within a column for each season shows no significant different at 5% level.

In this study during both seasons, cultivars showed differences in stem thickness, Abu 70 showed a thicker stem under shorter intervals (2.66-1.81cm) and Garawia showed (1.71-1.55 cm) in the first season , the second season recorded (2.60-1.45cm) (2.50-1.54cm). Ghasemi *et al* (2012) obtained an average of 1.6 cm. the highest stem diameter values were obtained from Abu 70 crop and the differences between cultivars with respect to stem diameter were found to be significant.

Table (4.16) The interaction of crop varieties, soil preparation and irrigation intervals on the growth parameters for (2011-2012) seasons.

Treatment	**Plant height (cm)**		**Stem thickness (cm)**		**Leaf No.**		**L.A (cm^2)**		**Root depth (cm)**	
	2011	**2012**	**2011**	**2012**	**2011**	**2012**	**2011**	**2012**	**2011**	**2012**
Gr×R×7 days	146.00	195.00	1.93e	2.60a	7.50	7.00	4.88 g	6.50k	7.75g	17.75ij
Gr×R×10days	175.75	202.50	1.60gh	2.23b	7.00	8.00	3.75 i	7.50i	10.25g	27.25de
Gr×R×14days	135.00	165.00	1.65g	1.68a	7.00	5.00	5.95 ef	9.10h	20.25def	37.50b
Gr×R×21days	131.00	147.50	1.63g	1.78a	7.00	5.00	4.35 h	6.23j	19.50ef	42.50a
Abu70×R×7 days	129.50	187.50	2.85b	3.13b	8.25	7.50	12.78 a	24.28b	24.00cdef	19.00hij
Abu70×R×10days	159.00	198.75	3.40a	3.03b	8.25	6.50	8.28 bc	21.50c	28.75bc	23.50fg
Abu70×R×14days	123.50	183.75	2.18d	2.58b	7.50	5.00	5.85 f	31.40a	26.00cde	20.75ghi
Abu70×R×21days	123.25	166..25	2.08 e	1.70b	7.50	5.25	5.75 f	21.40c	26.50bcd	33.00c
Gr×F×7 days	139.25	173.75	1.50 h	2.40a	7.00	8.25	3.85 i	10.15e	18.25f	17.25j
Gr×F×10days	177.00	180.00	1.60 g h	1.58a	7.50	6.50	4.38 h	9.60g	7.50g	26.00ef
Gr×F×14days	139.75	155.00	1.65 g	1.88a	6.50	6.00	2.50 j	7.15l	20.00def	29.50d
Gr×F×21days	133.50	150.00	1.48 h	1.30a	7.50	5.50	3.68i	6.83j	17.75f	40.00ab
Abu70×F×7 days	139.75	190.00	2.48 c	2.08a	8.25	8.25	8.68b	11.45d	40.00a	20.50ghij
Abu 70×F×10days	177.00	172.50	2.50 c	2.13a	7.50	6.50	6.40 e	9.88f	17.50f	22.25gh
Abu70*F*14days	150.75	156.25	1.83 f	1.40a	8.25	6.00	7.93cd	8.95h	25.50cde	27.25de
Abu70×F×21days	136.75	152.50	1.55 g h	1.20a	8.25	5.50	7.60d	9.85f	32.75b	19.50hij
F. V	0.04 ns	0.67 ns	1.27 *	3.06*	0.56 ns	3.09 ns	9.74*	0.93 *	2.46*	20.04*
C.V%	15.82	10.10	16.5	16.84	18.58	14.80	22.03	26.75	21.82	8.82
L.S.D	8.16	1.13	0.12	0.122	0.49	0.3424	0.4726	0.1808	1.662	0.8313
S.E	11.4566	1.5909	0.16	0.1716	0.7010	0.4809	0.6637	1.6777	2.3334	1.1674

Means having the same subscripts within a column for each season shows no significant different at 5% level.

4-4-3 leaf number:

Table (4.10) shows the growth parameters for the fodder crops. Analysis showed no significant differences within different treatments throughout the two seasons, except between the two varieties.

Leaf number of the two cultivars (Table 4.10), showed a significant difference at (0.5% level) for Abu 70 in the first seasons. The leaf number in the first season was greater than in the second season. No differences in the second season between the two cultivars.

Table (4.11) shows the sowing methods for the two seasons. The results showed no significant difference in the first season. The second season resulted in a significantly different leaf number on ridged method. However, the first season gave more leaves than the second season.

Table (4.12) demonstrates the results of interaction of methods of soil preparation and cultivars for the two seasons. The results revealed no significant difference at (0.5% level) in the two seasons under the two methods of soil preparation.

Table (4.13) displays the irrigation intervals in the two seasons. The results revealed no significant differences in the first season under the different irrigation intervals .No differences in season one for Abu 70, or Garawia. Season two scored significant differences for 7 days intervals.

Table (4.14) highlights the interaction of methods of soil preparation with irrigation intervals in the two seasons. The ridged and flat methods showed no differences in both seasons, The interaction of cultivars with irrigation intervals in the two seasons showed no significant differences between the two cultivars under the different irrigation intervals (Table 4.15).

Table (4.16) revealed no significant differences for the interaction of crop varieties, soil preparation methods and the irrigation intervals for the two seasons in all treatments.

Number of leaves per plant wasn't significantly affected during both seasons under different irrigation intervals and sowing methods. Salter *et al.* (1984) found an increase in stem weight due to increase in stem fiber under conditions of irregular irrigation which results in higher leaf/stem ratio.

4-4-4 Leaf Area

Table (4.10) shows the growth parameters for the two fodder crops. There were significant differences throughout the two seasons under different treatments. The leaf area for both crops in the two seasons showed significant differences at (0.5% level) for Abu 70 for the two seasons than Garawia. Table (4.11) revealed a significant difference on ridged method than flat method. Table (4.12) demonstrates the interaction of methods of soil preparation and cultivars. The results showed significantly different leaf area for Abu 70 under the two methods of preparation in the first season. The second season revealed that Abu 70 gave a significantly different leaf area on the two methods of sowing. Table (4.13) displays the irrigation intervals for the two seasons. The results revealed a significant difference at (0.5% level) for 7 days intervals in the first season and no differences at 14, 21days. The second season showed a significantly different leaf area for 7, 14, days than at

10, 21, days. Table (4.14) highlights the interaction of methods of soil preparation methods with irrigation intervals in the two seasons. The results showed a significantly different leaf area for ridged method at 7, 14, days intervals, as compared to flat method. In the second season the ridge under 7 and14, days gave a significantly different leaf area than on flat method. Table (4.15) revealed the interaction of irrigation intervals and cultivars for two seasons. The results clearly showed that Abu70 gave a significantly different leaf area in the two seasons under different irrigation intervals. Table (4.16) showed significant differences in the interaction between crop varieties, soil preparation methods and irrigation intervals for Abu 70 throughout the different treatments.

Abu 70 leaf area was higher than Garawia which is characterized with a thinner leaf width. In this study the ridged method recorded a larger leaf area than the flat method for both seasons. A previous work by Mansour (1981) Ishag (1982) found that the leaf area index was increased under more frequent irrigation. The reduction in leaf area with prolonging water intervals may be due to leaf rolling.. Similar results were also reported by many workers. Hussein, *et al* (1978), Mustafa, (1982), Kabbashi, (1991),. However it disagrees with the results reported by Nimer (1983) and Ibrahim (2004) .

4-4-5 Root depth:

Table (4.10) Shows the growth parameters for the two fodder crops. Results showed significant differences through all treatments. Abu 70 gave a deeper-roots in the first season, which was significantly different at (0.5% level), than Garawia, (Table 4.10). In season two, Garawia gave deeper roots than Abu70. The soil preparation methods in two seasons results revealed no significant difference in the first season. The ridged method gave a significant differences in the second season. (Table 4.11).Table (4.12) shows the results of interaction of soil preparation methods and cultivars for two seasons. The results recorded a significantly different root depth on ridged method in first season for Garawia than Abu70, In season two Abu70 scored longer roots within the two methods of sowing. The irrigation intervals within the two seasons, (Table 4.13) revealed a significantly different root depth in season one, at 7. 14, 21 days resulted in a deeper root than at 10 days. No differences at 14, 21 days intervals. In the second season a 21 days interval showed a significantly different root depth than at 7, 10, 14 days. The results on (Table 4.14), revealed a significantly different root depth in the first season, on ridged at 10 days than 7 days. No differences at 14, 21 days, the flat method scored deeper roots at 7 and 21 days than ridged at 10 days. The ridged method scored longer roots than on flat. The second season showed a significantly different root depth at 10, 21days on ridged method than 7, 14 days, the longer intervals gave the deepest roots than shorter intervals on different sowing method in the two seasons. The results of Table (4.15) showed significantly different root depth for Abu 70 all over the first season under different irrigation intervals, compared to Garawia. The second season at 7 days Abu 70 scored deeper roots, than Garawia. Garawia gave a significantly different in root depth than Abu 70 within 10 days intervals than under others irrigation intervals. Table (4.16) showed significant differences within the interaction between the two crops, two soil preparation methods and the different irrigation intervals. In the first season on flat soil at 7 days Abu 70 scored longer roots than

Garawia. In the second season, Garawia gave deeper roots on ridged and flat soil than Abu 70.

In this study the amount of irrigation water applied per day for the irrigation intervals 7-10-14-21 days caused the differences in soil moisture content within depth showed the following differences: Irrigation every 7 days resulted in relatively higher moisture contents in the top layer (0-15--30 cm) than irrigation under longer intervals. This resulted in relatively more moist soil surface under 7 days than 14 days consequently much water was lost by direct evaporation and by evapo transpiration. The root activity at the top layer of the soil was depleted more than at the lower depth. A similar finding was reported by Saeed (1984) for lucerne and fodder sorghum. Moreover, Saxena and Stewart (1983) considered that moisture at the upper 30 cm of the soil surface is about 67 % of the water available for the active root zone . As would be expected, the average water content of different soil layers under 7-10 days was higher than that under 14-21 days irrigation intervals, since shorter intervals resulted in more frequent wetting of the soil surface and therefore , water loss by evapotranspiration was always higher than under longer intervals (Michael, 1978).

4-5 The interaction of cultivars, soil preparation methods and irrigation intervals, in the two seasons.

The results of the cultivars height under different irrigation intervals on both ridged and flat methods in first season are shown on Table (4.16). The greater heights for Abu 70 and Garawia crops were obtained under 10 days intervals on flat method and the lowest height at 21 days on ridged method for Abu 70 and for Garawia. Garawia showed taller stem under 7, 10, 14 days intervals than Abu 70.The second season shows

Abu 70 obtained a higher height under 10 days on ridged and 7 days on flat, for Garawia under both 10 and 7 days intervals on ridged methods. The shorter height for Abu 70 and Garawia in two seasons on ridge under 14 and 21 days and on ridged and flat under 21 days intervals respectively.

The cultivars stem thickness: the thicker stem for Abu 70 in the first season at 10 days on ridge and for Garawia at 7 days intervals on ridged. Table (4.16). The thinner stem for Abu 70 at 21 days on ridge, and for Garawia, at 21 days intervals on flat method. In second season Abu 70 and Garawia scored under 21 days on flat.

The cultivars leaf number, table (4.16) for Abu 70 and Garawia showed no significant differences in the two seasons. In the first season, The higher leaf number obtained by the two cultivars, under 7 and 10 days on ridged and flat. The second season showed the leaf number for Abu 70 and Garawia obtained on flat method under 7 days.

The Leaf Area revealed a significant difference for Abu 70 on the two seasons under different irrigation intervals on the two soil preparation methods over Garawia. In the first season Abu 70 gave the larger leaf area under 7 days on ridged method, the lowest leaf area under 14, 21 days, on ridged method, Garawia obtained a higher leaf area on ridged and flat method under 7 and 21 days. The lowest leaves area on ridged and flat methos at 10 and 14 days intervals. Table (4.16). In the second season Abu 70 showed a higher leaf area at 7 and 14 days on ridge method. The lowest leaf area obtained at 14 and 21 days on flat methods. Garawia scored a higher leaf area at 7 and 10 days intervals on flat, the lowest leaf area under 7, 21 days on ridge and 21 days intervals on flat methods.

The cultivars root depth, table (4.16). In the first season Abu70 gave a deepest root on flat method at 7, 21 days. The shorter root on flat method at 10 days interval. For Garawia the deepest root on ridged and flat method at 14 days. The shorter root on ridge and flat at 7 and 10 days intervals. The second season showed a deepest root on ridge at 21 days twice the depth under 7 days for Abu 70. Garawia under 21 days at ridge and flat gave the deepest root. Abu 70 and Garawia under 7 days on ridged and flat method obtained the shorter root depth.

4.6 Crop water use efficiency

Sorghum water use efficiency expressed as tons of dry matter produced by cubic meter of water, was obtained by dividing the yield of dry matter (DM) per cut by the total crop evapotranspiration (ET_C). Irrigation under shorter intervals resulted in higher WUE than under longer intervals .The average WUE for all intervals on ridged and flat for Abu 70 and Garawia in two seasons. Table (4.17a, 4.18a) fig(4.1) (4.2) on ridge in the first season. Table (4.17b), 4.18b) fig (4.1) (4.2) on flat in the first season. Table (4.19a, 4.20a) fig (4.3) (4.4) on ridge. Table (4.19b, 4.20b) fig (4.3) (4.4) on flat for Abu 70 and Garawia in the second season.

(4.6.1) Water use efficiency for Abu 70 and Garawia on two soil preparation methods at four intervals in two seasons.

Table (4.17a) Water Use Efficiency for Abu 70 on ridge plots (dry matter yield): at the first season.

Intervals	Water used (m^3/ha)	DM yield (kg/ha)	WUE(kg/ha^{-}/m)
7 days	4220	9300	220
10 days	4220	10600	251
14 days	4520	9300	208
21 days	5230	8800	168

Table (4.17b) Water Use Efficiency for Abu 70 on flat plots (dry matter yield): at the first season .

Intervals	Water used(m^3/ ha)	DM yield (kg/ha)	WUE(kg/ha/m)
7 days	4220	7300	173
10 days	4220	8500	201
14 days	4520	7500	166
21 days	5230	1300	25

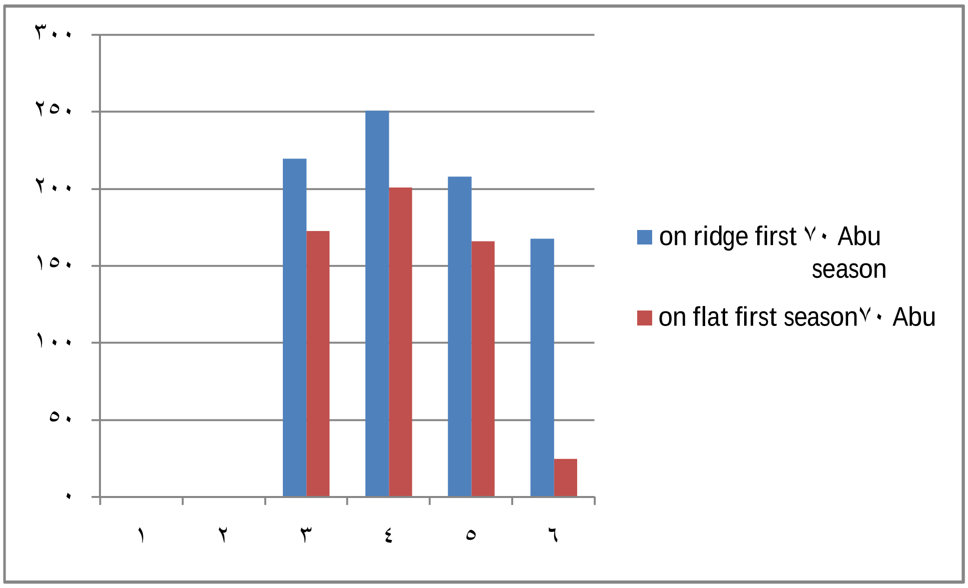


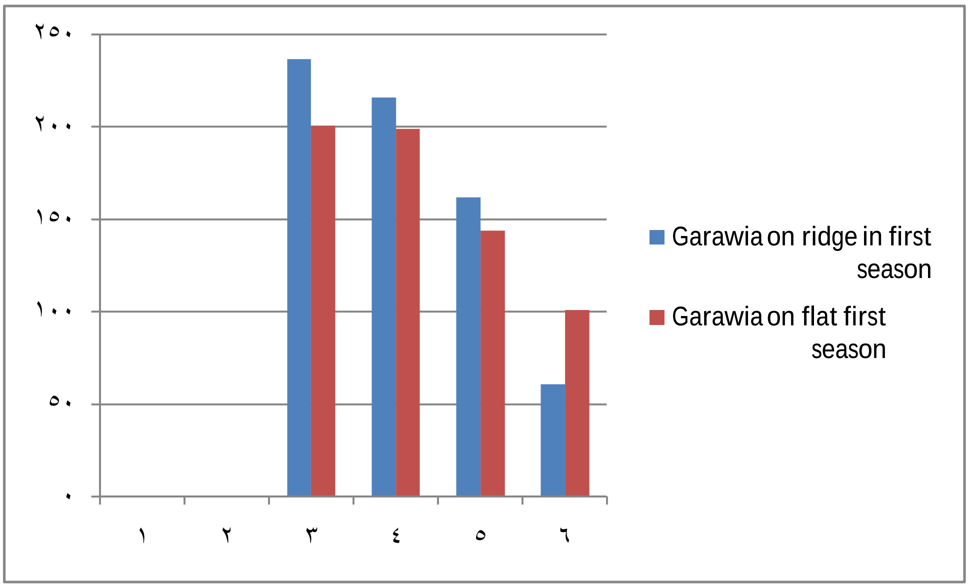
Fig (4.1) The water use efficiency for Abu70 in kg/ ha on ridge and flat in the first season

Table (4.18a) Water Use Efficiency for Garawia on ridge plots (dry matter yield): at the first season.

Intervals	Water used (m^3/ha)	DM yield (kg/ha)	WUE(kg/ha/m)
7 days	4220	10000	237
10 days	4220	9100	216
14 days	4520	7300	162
21 days	5230	3200	061

Table (4.18b) Water Use Efficiency for Garawia on flat plots (dry mater yield): at the first season.

Intervals	Water used(m^3/ha)	DM yield (kg/ha)	WUE(kg/ha/m)
7 days	4220	8500	201
10 days	4220	8400	199
14 days	4520	6500	144
21 days	5230	5300	101



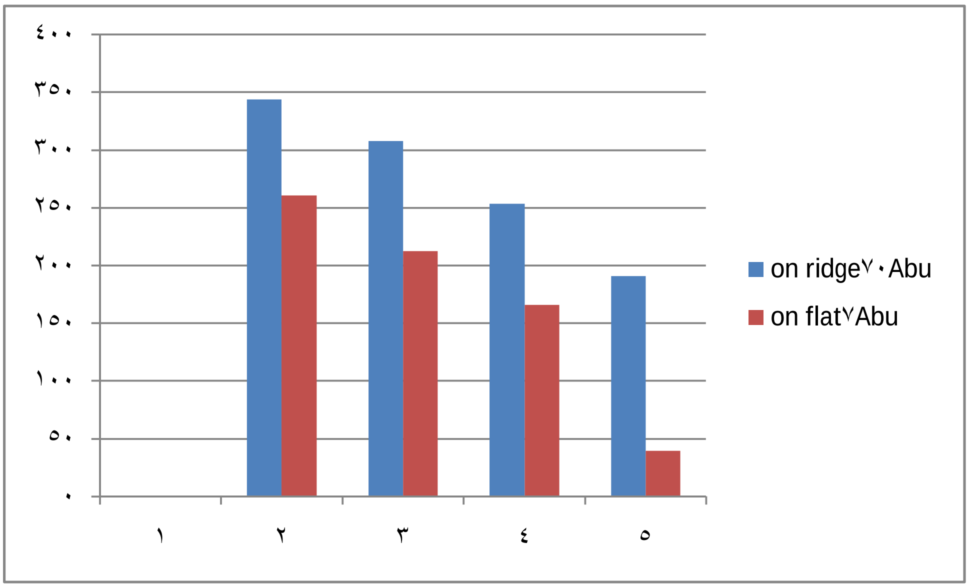
Fig(4.2) The water use efficiency for Garawia in kg /ha on ridged and flat plots in the first season.

Table (4.19a) Water Use Efficiency for Abu70 on ridge plots (dry matter yield): at the second season .

Intervals	Water used(m^3/ha)	DM yield (kg/ha)	WUE(kg/ha/cm)
7 days	4220	14500	344
10 days	4220	13000	308
14 days	4520	11500	254
21 days	5230	10000	191

Table (4.19b) Water Use Efficiency for Abu70 on flat plots (dry matter yield): at the second season .

Intervals	Water used(m^3/ha)	DM yield (kg/ha)	WUE(kg/ha/cm)
7 days	4220	11000	261
10 days	4220	9000	213
14 days	4520	7500	166
21 days	5230	2100	040



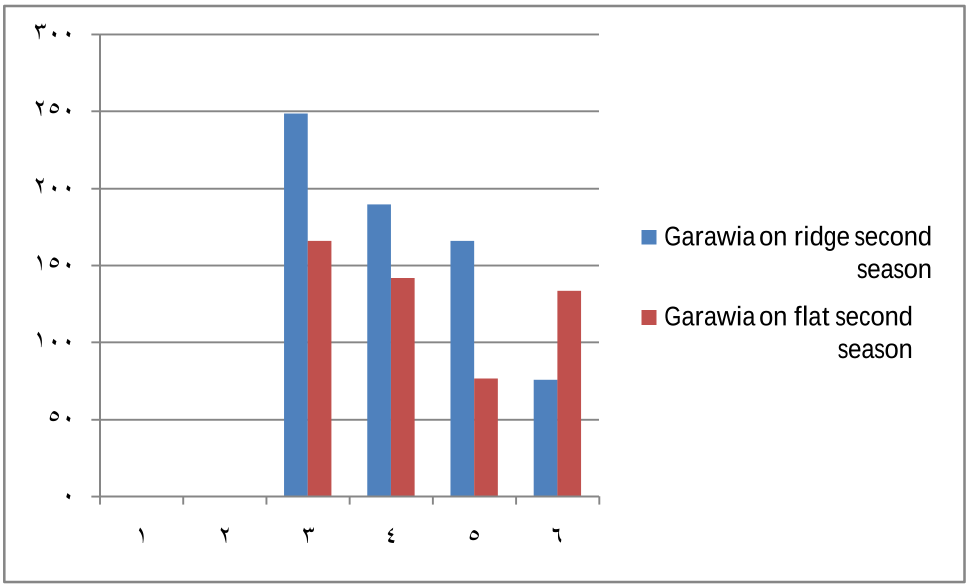
Fig(4.3) The water use efficiency for Abu 70 in Kg/ha on ridge and flat plots in second season,

Table (4.20a) Water Use Efficiency for Garawia on flat plots (dry matter yield): at the second season .

Intervals	Water used(m^3/ha)	DM yield (kg/ha)	WUE(kg/ha/cm)
7 days	4220	10500	249
10 days	4220	8000	190
14 days	4520	7500	166
21 days	5230	4000	076

Table (4.20b) Water Use Efficiency for Garawia on flat plots (dry matter yield): at the second season .

Intervals	Water used(m^3/ha)	DM yield (kg/ha)	WUE(kg/ha/cm)
7 days	4220	7000	166
10 days	4220	6000	142
14 days	4520	3500	077
21 days	5230	7000	134



Fig(4.4) **The water use efficiency for Garawia in kg /ha on ridged and flat plots in the second.**

Previous studies showed that infrequent irrigation reduced WUE of sorghum plants. These results agreed with that of Saeed (1984), in that the variability in water use efficiency with season (for Lucerne and fodder sorghum) can be mainly accounted for the different climatic conditions for the different crops and for temperature and relative humidity values in different season practices. Table (3.2) showed the differences in climatic conditions during the experimental period. However, Hatfield *et al* (2001) found that the efficiency of water use decreased as the evaporative power of the atmosphere increased. Shorter irrigation intervals resulted in higher values of WUE (382) compared to longer irrigation intervals (208), for Abu 70 at 7 days on ridged plots. AL-Jamal, *et al*, (2001) reported that irrigation practice that maintains moist soil for longer periods, allows transpiration rates approaching the potential, prevents the occurrence of water deficits and consequently results in higher WUE, the decrease in dry matter agreed with Chaudhuri and Kanemasu (1982), who found that increasing the watering level increased WUE for total dry matter. This has also been observed in the investigations conducted in Mexican high lands endowed with 93% dry land agriculture where barley showed the higher values of WUE in terms of both grain and biological yields. Fernandez *et al* (1993).

CHAPTER FIVE

Conclusions and Recommendations

5.1 Conclusions:

From the results of this study, the following conclusions are drawn:

(1) The regular shorter irrigation intervals (7 and 10 days) resulted in higher crop production than under longer irrigation intervals.

(2) The crop stem height on flat method was always higher than that obtained from ridged soil surface due to lower infiltration rate.

(3) The highest crop factor (kc) and crop water requirements (cwr) were attained at developing stage, kc values for this study ranged between 0.3—1.02 .

(4) This highest value for calculated Et_o was recorded during developing and maturity stages. Values decreased with increasing relative humidity.

(5) The Et_o values increased from the early growing season (initial stage), towards the developing stage, (elongation). The Et_o values increased during the mid growing season. This indicated that plants used much water to meet the demand for period of different physiological activities

(6) Sorghum bicolor Abu 70 showed a thicker stem and larger leaf area, than Sorghum Sudanense Garawia due to some physiological and botanical factors.

(7) The two cultivars Abu 70 and Garawia showed no differences in leaf number.

(8) The root depth affected by the different irrigation intervals, within different land preparation methods for Abu 70 in first season. In the second season at interaction between soil preparation and irrigation intervals for Abu 70.

(9) Shorter irrigation intervals (7, 10 days) resulted in higher yields, plant height, stem thickness fresh and dry matter production than longer irrigation intervals (14, 21 days).

(10) The highest value for calculated ETo was recorded during developing and maturity stages, (6.99, 6.08, 5.29). Values decreased with increasing relative humidity. The increase indicated that plants used more water to meet the demand for period of different physiological activities.

5.2 Recommendations:

1- Irrigation every seven to ten days was the best for forage sorghum and should be applied at Kuku Farm.

2- Garawia forage sorghum on ridge was better and should be used at the moderately Saline Kuku soils.

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Appendices

App. (1) Soil particles classification.

Name of soil separates	Diameter limits(mm) ,USDA classification
Clay	Less than 0.002
Silt	0.002—0.05
Very fine sand	0.05—0.10
Fine sand	0.10—0.25
Medium sand	0.25—0.50
Coarse sand	0.50—1.00
Very coarse sand	1.00- 2.00

Source: Soil Survey Division Staff (1993)

App. (2) Soil salinity classes and crop growth:

	Conductivity of the saturated Extract ds / m	Effect on crop plants
Non saline	0----2	Salinity effect negligible.
Slightly saline	2-----4	Yields of sensitive crop may be restricted.
Moderately saline	4------8	Yields of many crops are restricted.
Strongly saline	8-------16	Only tolerate crops yield satisfactory .
Very strongly saline	> 16	Only a few very tolerant crops yield satisfactory.

Source: http/www.org.docrep/.

App. (3) Selection of an irrigation method based on the Depth of the Net irrigation Application:

Soil type	**Rooting depth of the crop**	**Net irrigation depth/application(mm)**	**Irrigation method**
Sand	Shallow	20-30	Short furrow
	Medium	30-40	Medium furrow, short border
	Deep	40-50	Long furrow, medium border, small basin
Loam	Shallow	30-40	Medium furrow, short border
	Medium	40-50	Long furrow, medium border, small basin
	Deep	50-60	Long border, medium basin
Clay	Shallow	40-50	Long furrow, medium border, small basin
	Medium	50-60	Long border, medium basin
	Deep	60-70	Large basin

APP. (4): values of average field application efficiency:

Irrigation method	Field application efficiency
Surface irrigation	60 %
Sprinkler irrigation	75 %
Drip irrigation	90 %

Source (http:/ fao . org/decrep/