Effect of Salinity on Performance of Four Genotypes of Sorghum (*Sorghum bicolor* L. Moench)

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Dedication

To my Father

For the uncompromising principles that guided his life

My Mother

For leading her children into intellectual pursuits

My Brothers, Sister and Friends

To My love (Abd Alal) and my kids

(Heba and Mohammed)

Rasha

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ABSTRACT

This study was conducted at the Faculty of Agriculture, University of Khartoum (latitude: 15^0-$40^/$N and 32^0-$32^/$E) in the year 2009 to investigate the performance of four genotypes of sorghum (*Sorghum bicolor* L. Monech) under five levels of salinity. The four genotypes were Wadahmed, Dabar, Kh BSL 094 and Kh BSL 095. Salinity levels were (control), EC4, EC6, EC8 and EC10. The treatments were assigned in a completely randomized design (CRD) with four replications in a factorial arrangement. The growth parameters measured were germination percentage, rate of germination, plant height, number of leaves/plant, stem diameter, leaf area index, fresh weight/plant, dry weight/plant and sodium content/plant. The results indicated that, there were no significant differences between the salinity levels in most of the studied parameters except germination percentage, rate of germination and stem diameter. When there was a significant effect, it differed with the age of the plant. The results showed that there were significant differences between the four genotypes in all characters studied, except stem diameter after 30, 40 and 50 days, leaf area index at 40 and 50 days, fresh weight at 20 and 50 days and dry weight at 20, 40 and 50 days. The genotype Kh BSL 094 exhibited the highest performance in all characters studied, except sodium content per plant, the genotype Kh BSL 095 recorded the highest sodium content. The genotype Dabar recorded the highest relative yield compared with other genotypes, while Wadahmed recorded the lowest performance in all characters studied and sodium content per plant. However, the interaction between the salinity and genotypes was not significant for most characters studied, except the germination percentage and rate of germination.

تأثير الملوحة علي أداء أربعة طرز من الذرة الرفيعة

المستخلص

أجريت تجربة خلال موسم 2009م فى كلية الزراعة جامعة الخرطوم (خط عرض $15^{0}-40^{/}$ شمال) وخط طول ($32^{0}-32^{/}$ شرق) لدراسة أداء أربع سلالات من محصول الذرة الرفيعة هى ود أحمد و دبر و Kh BSL 094وKh BSL 095 تحت اربعة مستويات من الملوحة هي EC4,EC6, EC8, EC10 بالاضافة للشاهد. تم توزيع المعاملات عشوائيا بطريق التصميم العشوائى الكامل فى اربعة مكررات، ودرست مكونات النمو الخضرى وهى نسبة الانبات ومعدل الانبات وطول النبات وعدد الاوراق بالنبات وقطر الساق ودليل مساحة الورقة اضافة للوزن الرطب والوزن الجاف للنبات الى جانب محتوى الصوديوم بالنبات . أظهرت النتائج عدم وجود فروقات معنوية بالنسبة لمستويات الملوحة في معظم المعايير المدروسة,عدا نسبة الانبات ومعدل الانبات وقطر الساق. وفي حالة وجود تاثير معنوى اختلفت قيمته حسب عمر النبات. كما اظهرت النتائج فروقا معنوية بين الطرز الوراثية الاربعة فى كل المعايير المدروسة فيما عدا قطر الساق بعد 50 ,30 ,40 يوما, دليل مساحة الورقة بعد 50,40 يوم ,الوزن الرطب بعد 20 ,50 يوما, الوزن الجاف للنبات 40 ,50 ,20 يوما. سجلت السلالة Kh BSL 094 أعلى مقاييس فى كل السلالات المدروسة , عدا محتوى الصوديوم بالنبات حيث سجلت السلالة Kh BSL 095 أعلى محتوى صوديوم بالنبات . كما سجلت السلالة دبر أعلي نسبة مئوية للوزن الجاف مقارنة مع السلالات الأخرى,بينما سجلت السلالة ودأحمد اقل المستويات في كل المعايير المدروسة وايضا محتوى الصوديوم.التفاعل بين المعاملات والطرز الوراثية لم يكن له تأثير معنوى واضح فى معظم المعايير المدروسة عدا نسبة الانبات ومعدل الانبات.

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CHAPTER ONE

INTRODUCTION

Sorghum (*Sorghum bicolor L.* Moench) is a cereal grass native to Sub-Saharan Africa and has been cultivated for centuries as a staple cereal grain (Menz *et al*., 2004). Sorghum is the fifth most important cereal grain in the world (Dogget, 1970). It ranks fourth in importance among the cereal corps in the world following rice (*Oryza sativa* L), maize (*Zea mays L.*) and wheat (*Triticum asetivum* L, em. Thell) (Janick *et al*. 1974).

About 90% of the area planted with sorghum lies in the less developed countries, mainly in Africa and Asia, where it is grown generally for food by low-income farmers. The remaining 10% is made up of large-scale commercial farms, mostly in the developed world, which produce sorghum mainly for livestock feed. These farms account for more than 40% of the global sorghum output (Datke *et al*, 2003, FAO, 2006c). The grains of sorghum are used for green chop, hay, silage and pasture (Wall and Ross, 1970). In some areas plant reaming (after head is harvested) may be used as fuel (Acland, 1973). Also grains of sorghum are boiled and eaten. In addition sorghum flour can be used mixed with corn flour to make bread (Leakey, 1970). Sorghum grains can also be used in the manufacture of starch, alcohol and glucose, According to the statistics of the FAO (2006b).

In the Sudan, sorghum ranks first both in total tonnage of grain produced and total acreage cultivated. FAO (2006a) report stated that sorghum in the Sudan was grown on 3.8, 6.4 and 6.7 million hectares in 2004, 2005 and 2006, respectively.

In the Sudan forage production, provides only 74% of the total feed requirement, but very important for livestock production due to the huge animal wealth in the country, especially that expansion of marginal agriculture; wild fire and drought also resulted in the reduction of range land.

High salt concentration is one of the main factors limiting crop production because of its effects on plant growth. Strongnov *et al*. (1973) reported that salinity causes serious loss in agricultural production attributed to decreasing the yield of various crops.

Salts may occur in the soil in various forms, soluble and/or not soluble. Salts may accumulate in arid and semiarid regions due to various factors including low rainfall and high evapotranspiration. Low rainfall reduces the leaching of salts down the soil profile, and the high evaporation causes accumulation of salts in the soil surface.

Salinity and alkalinity lower the productivity and value of large areas of agricultural lands. Saline and alkaline soils are common in arid and semi-arid regions. Poor drainage and/or poor quality irrigation water often contribute to soil salinity. As plants absorb soil water, or as water evaporates, salts from the water will remain in the soil. For this reason, soil salinity will usually be greater than the salinity of the irrigation water used (Blaylock, 1994).

Sudan is a large country dominated by arid and semi-arid tropical regions that favors the formation of salt affected soils. Salinity seems to increase with increasing aridity. High saline soils occur where the average annual rainfall is less than 200 mm. In most soils average salinity values tend to increase with depth (Mustafa, 1986).

Rapid increase in population, need for animal products, and land for fodder and forage production forced the people to shift towards the marginal lands which are affected by salt. In the Northern State, farmers used to cultivate forage close to the Nile banks, but the cultivable lands allocated for forage production were rarely enough to meet the over-increasing animals' needs. This encourages farmers to cultivate the marginal zones (terrace lands) in which soils are mostly saline.

Sorghum is well-known for its capacity to tolerate conditions of limited moisture and to be productive during periods of extended drought. . It has a number of morphological and physiological characteristics that contribute to its adaptation to dry conditions e.g. it has an extensive root system, waxy leaves and the ability to temporarily stop growing in periods of drought and recovering when moisture becomes available again. This makes it an important crop in arid areas and forage can be produced successfully on all types of soil and is more tolerant to salinity and alkalinity.

The objectives of this study were:

1. To determine the effect of salinity on germination of forage sorghum.
2. To determine the effect of salinity on growth and yield of forage sorghum.
3. To determine genotype tolerance to salinity.

CHAPTER TWO

LITERATURE REVIEW

2.1 Sorghum

Sorghum (*Sorghum bicolor* L. Moench) belongs to the Poaceae family (Romain and Raemaekers, 2001). Many annual and perennial species of sorghum are found in the wild form. It is the most important native cereal in Africa and the fifth amongst the world cereals. It is grown in the tropical and subtropical regions of the world between latitude 40° N and 40°S, but the semi-arid areas are its home. The origin of sorghum is considered to be the north-east quadrant of Africa and was first domesticated in Ethiopia (Purseglove, 1988). It is known by a variety of names in different regions and languages (guineacron, kafir corn, dura, jowar, kaoliang and mtamal) (Romain and Raemaekers, 2001).

2.1.1 Adaptation

Sorghum is adapted to a range of ecological conditions and can be grown under conditions which are unfavorable for most cereals. It is essentially a plant of hot and warm regions. Sorghum withstands extreme heat better than other corps. It can tolerate hot and dry conditions but can also grow in areas of high rainfall; however, frost will kill the crop (Onwueme and Sihna, 1991). Sorghum is well adapted and widely grown where the annual rainfall varies from 400 to 700mm. Its cultivation is limited to areas with a rainfall of about 1000mm as maximum (Onwueme and Sihna, 1991; Skerman and Riveros, 1989). Sorghum is also grown under irrigation in countries such as Sudan, Egypt, Israel and Libya. Irrigated sorghum requires 350-1010mm of water depending on soil and climate (Romain and Raemaekers, 2001).

The optimum temperature during the growing season ranges from 27-32°C. The minimum and maximum temperatures for growth are 15°C and 40°C, respectively. Extremely high temperature during seed formation period reduces seed yield (Onwueme and Sihna, 1991; Skerman and Riveros, 1989).

2.1.2 Soil

Sorghum is adapted to a wide range of soils, from the sand of the "Goz" to heavy black cracking clays (Skerman and Riveros, 1989). It can be grown at a wide range of soil pH from 5.0 to 8.5 and it is more adapted to acid soils than maize. It is generally grown on sandy loams while good fertile areas are reserved for corps such as maize. It is grown on soils too poor in fertility and tolerates salinity better than maize (Romain and Raemaeker, 2001; Onwueme and Sihna, 1991; Skerman and Riveros, 1989).

2.2 Utilization

Onwueme and Sihna (1991) reported that sorghum is used in many ways. It is used as staple food and as livestock feed. For food the white grains are preferred to the red. In Africa where sorghum is cooked as staple food, the dry grains are usually ground, either alone or with other cereals. Sorghum grains especially of the red cultivars, are used as feed, while crop residue is used as fodder, forage or silage.

Romain and Raemaekers (2001) stated that in Africa and Asia sorghum grain is processed by hand to make a variety of traditional foods such as unfermented breads and fermented bread e.g. "kisra", "injera". In some areas the straw is used as building material, and crop remains may be used for fuel. There are special sorghums, such as pop sorghum and sweet sorghum that can be parched and eaten as snacks.

2.3 Salinity

Salinity is the total concentration of water soluble salt in water and soil. Soil salinity can be measured as a concentration, but in most agricultural situation it is measured as the electrical conductivity of a saturated soil paste (ECE) or a (1:5) (ECE 1:5) water extract in units of decisi mens per meter (ds/M) at 25°C (Rogers, 1997).

Soil salinity and sodicity are becoming major problems of crop production. A number of crops were found to be seriously damaged by salinity and sodicity as a result of agricultural expansion into the so-called high terrace soils which are mostly salt affected (Ayoub, 1976).

Salt affected soils may contain excess soluble salts, exchangeable or both. Saline soils are those soils containing a concentration of natural soluble salts sufficient to seriously interfere with the growth of most plants (Brady, 1978). Such soils are generally divided into three groups, the first group is saline soils: those are soils in which the electrical conductivity (Ec) is greater than 4 ds m^{-1} at 25^0C, the exchangeable sodium percentage (ESP) is less than 15, and soil pH is below 8.5. These soils are often recognized by the appearance of white crusts of salts on the surface, or by an oily looking surface. The second group is the sodic soils with the extract of electrical conductivity less than 4 ds $m^{-1,}$ (ESP) exceeding 15, and the soil pH is generally above 8.5. These soils do not contain any natural soluble salts. Their effect on plant is due to toxicity of sodium and hydroxyl ions. The last group includes saline -sodic soils the extract of which has an electrical conductivity greater than 4 dsm^{-1}, (ESP) greater than15, and pH seldom above 8.5 (Harivandi, 1984).

2.3.1 Effect of salt on plants

Rogers (1997) demonstrated the effect of salinity on plant in three ways: initially, salts make it more difficult for plants to absorb water from the soil, (even if the soil appears quite moist), in effect, plants suffer from drought which can result in retarded growth and reduced yield. Secondly, some ions, such as Na^+ and Cl^- can be directly toxic to plants. Plants take up salts with water, and often those salts can damage the plant internally, affecting the plants physiological processes and often results in reduced growth, leaf burn and even plant death. Thirdly, high amount of ions such as Na^+ and Cl^-may affect the availability of other ions e.g. K^+, Mg^{2+}, N or P, which are extremely important for plant growth. Thus the salt effect on plant growth is by various systems, increasing the osmotic pressure of the soil solution, accumulating certain ions in toxic concentration in plant tissue and altering plants mineral nutrition.

2.3.2 Effect of salinity on plant growth

Salinity affects plant growth by weakening the plant's ability to absorb water from the soil. The large amount of salt found in soils affected by salinity makes it hard for the plant to absorb all the nutrients necessary for healthy growth. As a result, most of the plants become weaker, and in some cases, end up dying.

Soils affected by salinity are usually toxic because of the large amount of salt they contain. Elemental ions such as sodium, chlorine, magnesium and calcium play a big part in the toxicity level of soil plagued by salinity. Plants that are found in soil with high salinity usually absorb high concentrations of salt. As a result, the plant becomes unhealthy and grows slower. The plant may become subject to chlorosis, which makes leaves appear pale and yellowish in color. Other plants affected by salinity have been found to have a dull appearance and contain leaves with a hard wax-like feel. Vegetables and fruits that are produced by plants that have been affected by salinity are usually smaller than average (Sterling, 2004).

Brady (1978) stated that saline and saline-sodic soils influence plants because of their high soluble salts. Salts contact with plant cells will cause shrinkage of protoplasm (plasmolysis), and cells collapse.

2.3.2.1 Germination

Germination and seedling vigor of *Setaria italica* seeds produced by plants grown under various levels of salinity were not significantly different (Thimmaiah *et al.*, 1989). However, salt treatments inhibited germination and affected seedling vigor of sorghum negatively (Prisco *et al.,* 1987). The maximum germination rate of *Lipdium sativum* L seeds when germinated in Petri dishes was attained at lowest concentration of 50 mM NaCl, and decreased as salinity increased from 100-200 mM NaCl. The maximum plumule and radical length and growth rate were obtained in control and were found to decline significantly with increasing salinity (El-Drier and Yousef, 2000). Ghoulam and Fares (2001) found that germination percentage, rate of germination and relative germination percentage of sugar beet (*Beta vulgaris* L) seeds were decreased by sodium chloride treatments. Also increasing salinity from 0-8 mmhs/cm caused reduction in germination and early seedling growth of sesame (*Sesamum indicum*) seed (Ragiba, 2000). Campos and Asuneao (1990) showed a significant effect of salinity on germination, number of abnormal plants and ungerminated seeds of rice. Hosseine *et al*. (2002) found that the germination of soybean (*Glycine max* L) was 81% at NaCl concentration of 300 mmoh/cm and at 420mmoh/cm NaCl only 40% of seeds germinated, while at 500 mmoh/cm NaCl there was no germination and seedling growth rate decreased drastically with increasing salinity.

The effect of different levels of salinity on germination and growth of sorghum, alfalfa and sunflower plant was studied, using NaCl and CaCl2 (1:1 w/w) at 1000, 3000, 5000 and 7000 ppm in Hoagland solution. During germination stage sorghum tolerated salinity up to 3000ppm, Alfalfa 7000ppm, but during vegetative growth stages sorghum plant growth parameters decreased at all salinity levels (Malibari *et al*, 2008).

Bhumbla and Singh (1968) found that maize was very sensitive to salinity at later stage of growth, while sugar beet was considered to be sensitive at the germination stage. In the case of rice, 0.4% of salt markedly reduced the germination.

2.3.2.2Plant height

Plant height of wheat (treated with irrigation water with four sodium adsorption ratio “SAR” levels) decreased with increasing SAR levels, (Majumdar and Balai, 2000), whereas salinity (16 ds/m) reduced plant height of onion (*Allium cepa*) (Yadao *et al*. 1998). Also Francois, (1996) found that all hybrid cultivars of sunflower in high salt plots were about 50% shorter than the control plants. A similar reduction in height was reported by Hang and Evans (1985) and Unger (1983) for water stressed sunflower.

Azhar and McNeilly (1989) studied the response of four genotypes of sorghum to increasing NaCl concentration of 0, 100 and 150 mM at three growth stages GS1,GS2,GS3 (early stage of growth, vegetative growth stage and reproductive stage) respectively. The result showed that increasing salinity significantly reduced plant height at GS1whilest shoot and dry weight were less affected. The effect of NaCl on these characters was greater at GS2 and GS3 and accessions differed significantly in their response to salinity.

2.3.2.3 Number of leaves/plant

Generally a reduction in plant growth evident by a reduction in plant height or in the number of leaves is the plants response to salinity (Rogers, 1997). Both water stress (Oasterhusis and Cart Weight, 1983) and salinity stress (Grieve and Francois; 1992, Mass and Grieve, 1990) during the early vegetative growth stage have been shown to decrease leaf number in wheat. However, leaf primordial initiation of spring wheat was more sensitive to changes in salinity, and the final main stem leaf number was controlled by the new applied salinity rather than the original stress level salinity. Salinity level of (16 ds/m) reduced the number of leaves/plant of onion.

2.3.2.4 Fresh and dry weights

The results of a study to evaluate the effect of salinity on growth parameters (shoot fresh weight, shoot dry weight and leaf area index) in sorghum genotypes, showed that as salinity increased, the amount of the above growth parameters of the studied sorghum genotypes decreased (Almodares, *et al* 2008).

2.4 Crop salt tolerance

Plants vary in response to soil salinity. Salt tolerant plants (plants less affected by salinity) are better able to adjust internally to the osmotic effect of high salt concentration than salt sensitive plants (Blaylock, 1994). The salt tolerance of a crop may be appraised according to three criteria, (1) the ability of the crop to survive on saline soils, (2) the yield of the crop on saline soils, (3) the relative yield of the crop on saline soils as compared with its yield on a non-saline soil under similar conditions. The tolerance of crops to salinity changes with the stage of growth (Arbol *et al*., 1988). Yang *et al*. (1990) reported the greater reduction observed in sorghum was associated with higher level of CL^-, higher Na^+/K^+ ratios and greater capacity for osmotic adjustment. Seedlings are usually most sensitive to salt during the emergence and early stages and plants salt tolerance increases as the crop develops through the growing season (Soltanpour and Follett, 2001). Gabier (1986) stated that sunflower, fodder grasses like sorghum and maize were the most tolerant crops. Sing *et al*. (1991) reported that sorghum is semi-tolerant to sodic soils. Salinity tolerance is influenced by many plants, soil and environmental factors and their interrelationships (Kotuby-Amchar *et al*., 1997). Generally, fruits, vegetables and ornamentals are more salt sensitive than forage or field crops. In addition, certain varieties, cultivars or root stalks may tolerate higher salt levels than others.

Plants are more sensitive to high salinity during seedling stage, immediately after transplanting and when subjected to stresses such as diseases, insects and nutrients deficiency.

Climate and irrigation also influence salinity tolerance (Kotuby- Amchar *et al*., 1997). As soils dry up, salt becomes concentrated in the soil solution, increasing salt stress. Therefore, salt problems are more severe under hot, dry conditions than under cool, humid conditions. Increasing irrigation frequency and applying water in excess of plant demand may be required during hot, dry periods to minimize salinity stress.

2.5 Mechanisms of salinity tolerance

Despite the negative impact of salinity on several plant functions, many species persist in saline environments. These plants have adapted a variety of mechanisms to alleviate the negative impacts of salinity. Such mechanisms range from cellular level to whole plant reactions and are often an integrated response at multiple levels.

The physiological and molecular mechanisms of tolerance to osmotic and ionic components of salinity stress are reviewed at the cellular, organ, and whole-plant level. Plant growth responds to salinity in two phases: a rapid, osmotic phase that inhibits growth of young leaves, and a slower, ionic phase that accelerates senescence of mature leaves. Plant adaptations to salinity are of three distinct types: osmotic stress tolerance, Na^+ or Cl^- exclusion, and the tolerance of tissue to accumulated Na^+ or Cl^- (Rana and Mark, 2008). The mechanisms discussed are:

Salt exclusion

Salt can be excluded from entering the plant through its root system or within the plant, thus salt can be restricted from reaching sensitive organs (Larcher, 1980). Restricted uptake in the roots, while a first line of defense, is not a very efficient mechanism and is often found in conjunction with internal exclusion mechanisms. Internal exclusion mechanisms can involve such processes as sequestering salt ions in specialized tissues by removing them from the transport stream. One way plants achieve this is by exchanging K^+ ions for Na^+ions as they pass through the xylem. However, the ion accumulation capacity of the xylem is limited and reduces the efficacy of this process (Hagemeyer, 1987).

Salt excretion

Some plants simply rid their systems of salt by excreting it back into the environment. Plants can excrete salt through their roots, shoots, and leaves. Some plants transport and accumulate salt to storage areas that are shed later (Larcher, 1980). Specialized structures for excretion have evolved in the epidermis of some species. Bladder hairs are structures on leaf surfaces that consist of several stalk cells and bladder cells. The stalk cells transport ions into the vacuole of the bladder cell, which eventually dies and falls off the plant. Salt glands are used by some species to excrete salt. These specialized structures transport ions directly out of the plant through both roots and leaves (Hagemeyer, 1987).

Succulence

One defense against salt in plant tissues is to simply dilute the concentration of ions. Plants achieve this by increasing their storage volume by developing sinks, fleshy, succulent structures (Larcher, 1980; and Hagemeyer, 1987). This mechanism is common in wet saline environments, like salt marshes, where water is not a limiting resource (Larcher, 1980). Succulence is mainly a result of vacuoles of mesophyll cells filling with water and increasing in size. This mechanism is limited by the dilution capacity of plant tissues (Hagemeyer, 1987).

Osmotic adjustment

Some salt tolerant plants control the accumulation of salt ions to counterbalance low water potentials created by saline soils (Hagemeyer 1987). Salt ions are compartmentalized in vacuoles to protect proteins and membranes from ion toxicity. The active transport of ions requires energy, however, and represents a trade-off where energy is allocated to tolerance rather than to growth and reproduction (Larcher 1980). Another trade-off with this mechanism is maintaining an osmotic balance within the cell cytoplasm. Solute-rich vacuoles have a high osmotic potential that creates a gradient in which water moves from the cytoplasm into the vacuole. To counterbalance this gradient, plants produce osmotically active organic solutes called compatible solutes. They are termed compatible because they do not interfere with plant physiological processes. A variety of compounds act as compatible solutes, such as amino acids and amides (e.g., proline), ammonium compounds (e.g., betaine) and soluble carbohydrates (Hagemeyer, 1987).

Membrane composition

Several of the mechanisms discussed above require specialized properties of plasma membranes, which are responsible for regulating the transport of salt ions. Membrane composition can affect membrane fluidity, permeability, and membrane protein activity. Each of these membrane characteristics can be related to the effectiveness of the salinity tolerance mechanisms discussed above. However, an understanding of the functions of plasma membrane composition in salinity tolerance is just beginning to develop (Wu *et al*., 1998).

CHAPTER THREE

MATERIALS AND METHODS

3.1 General

A set of laboratory tests and a pot experiment were carried out on seed of four sorghum cultivars namely Wad Ahmed, Dabar, Kh BSL 094 and Kh BSL 095, to investigate the effect of salinity on seed germination and plant growth, and to find out which cultivar has best tolerance to salinity. The laboratory tests were conducted at the Seed Research Laboratory, Agronomy Department, Faculty of Agriculture, University of Khartoum. The pot experiment was carried out in the Glass House of the Faculty of Agriculture, University of Khartoum at Shambat. Shambat is located at latitude 32^0 $32^/$ and longitude 15^0 $40^/$ within semi desert region (Adam, 2002). The experiment was conducted in the rainy season of 2009 (July-September).

3.2 Materials

3.2.1 Plant material

Four genotypes of sorghum, (*Sorghum bicolor L*. Moench) Wad Ahmed, Dabar, Kh BSL 094 and Kh BSL 095.

3.2.2 Treatments

Consisted of five levels of salinity as follows:

- EC_0 Control
- EC_4 = 1.535 g NaCl per liter.
- EC_6 = 2.060 g NaCl per liter.
- EC_8 = 2.516 g NaCl per liter.
- EC_{10}= 2.925 g NaCl per liter.

3.3 Methods

3.3.1 Laboratory tests

3.3.1.1 Standard germination test

This test was conducted to study the effect of salinity on germination of sorghum. The four sorghum genotypes were germinated at the five levels of salinity. In four replications, each of 25 seeds, the four sorghum genotypes were placed in double moist filter papers in petri dishes. The seeds were watered using saline water corresponding to the different treatments i.e. EC_0, EC_4, EC_6, EC_8 and EC_{10}. The seeds were placed two centimeter apart to avoid contact of seedlings during germination. To study the effect of salinity on germination 6 readings were taken at 2, 3, 4, 5, 6 and 7 days. At the end of germination period the number of normal seedlings was recorded and the germination percent was calculated as follows:

$$\text{Germination \%} = \frac{\text{Number of normal seedling}}{\text{Number of seeds planted}} \times 100$$

3.3.1.2 Rate of germination

This test was carried out as per standard germination test described above. Daily count of normal seedlings was recorded, and the speed of germination was obtained by multiplying the number of seed germinated in a specific day by the reciprocal of the day on which the germinated seedlings were recorded using the following formula as described by Wiese and Binning (1987).

Gr =(number germination since n-1) /n

where: Gr= germination rate; n= days of incubation.

3.3.2 Pot experiment

3.3.2.1Cultural practices

The pots were filled with 20 kg of 1:1 sand and clay. The pots were irrigated before sowing to ensure a fine seed bed. The seeds were sown in holes 2.5cm deep, ten seeds in each pot at the rate of two seeds per hole. The pot experiment received equal quantities of normal water for three weeks for establishment and salinity treatments were applied after 21 days. The pots were irrigated regularly at 80% field capacity by applying 943 ml H_2O according to the treatments. Furdan granules were added at the rate of 2g per pot against fungal diseases one week after sowing. The seedlings were thinned to three plants per pot two weeks after sowing. Nitrogen as urea was applied at the rate of 50kg/fedan added as 2g urea in each pot two weeks after sowing.

3.3.2.2 Experimental design

The experiment was carried out in a factorial arrangement in a completely randomized design with four replications.

3.4 Data collection and analysis

3.4.1 Data collection

The parameters studied were plant height, number of leaves per plant, stem diameter, leaf area index, plant fresh weight, plant dry weight and sodium concentration in plant tissue, to study the effect of salinity on plant development. Five readings were taken at 10,20,30,40 and 50 days after starting the treatments.

3.4.1.2 Plant height (cm)

Plant height was measured from the base of the plant above the soil surface to the tip of the youngest leaf using a meter tape.

3.4.1.3 Number of leaves per plant

This parameter was obtained by counting all the leaves in the plants from each pot and mean number of leaves per plant was recorded.

3.4.1.4 Leaf area index

Leaf area was determined using the following formula:

Leaf area (cm^2) = maximum leaf length x the maximum leaf width x 0.75 (Sticler *et al.*, 1961).

Leaf area index was calculated as the ratio of leaf area to unit ground area using the following formula:

$$\frac{\text{Area of individual leaf x average number of leaves/plant x number of plant/area}}{\text{Ground area}}$$

3.4.1.5 Stem diameter (cm)

Measured at the 3rd internodes of the plants from each pot using verniea calipers.

3.4.1.6 Plant fresh weight (g)

Samples of three plants each were removed from each genotype in each replication for determination of plants fresh weight. Plants were cut at soil surface and laid in bundles. The fresh weight was recorded in the laboratory using a sensitive balance (METTLER P3). The fresh plants were weighed to obtain the average plant fresh weight as follows:

$$\text{Average plant fresh weight} = \frac{\text{Total weight of plants}}{\text{Number of plants}}$$

3.4.1.7 Plant dry weight (g)

Plants from the same sample used for fresh weight determination were dried in an oven set at 80C for 48 hours. Plants were then weighed to determine the dry weight. And the average plant dry weight was computed.

3.4.1.8 Sodium content in the plants (meq/l)

This included determination of Na content by dry aching. The procedure was that of by Miller and Reeney (1982). Samples of plant material weighing (2g) were placed in a 50 ml Pyrex glass beaker, then put into a cool muffle furnace until the temperature was increased gradually up to 550^0C, and the door of the muffle Furnace was opened cautiously for rapid cooling. After cooling, the beakers were taken out and the cool ash was dissolved in 5ml portion 2N hydrochloric acid (HCl) and mixed with a plastic rod. After 20 minutes, the volume was made up to 50ml using distilled water and mixed thoroughly and allowed to stand for 30 minutes. Using the filter paper Whatman, the first portion of the filter was discarded and the aliquot was measured, using the yellow color method and Na was determined by flame photometry. The Na concentration was calculated in the equation below:

$$\text{Na milliequvalent/liter} = \frac{\text{Flame Reading X Dilute Factor X 10}}{\text{Equivalent weight (23) X 100}}$$

$$\text{* Dilute Factor} = \frac{\text{Total volume}}{\text{Taken volume}}$$

3.4.1 Statistical analysis

Data generated were subjected to statistical analysis system (SAS) Version 09, using Two-Factors Analysis of Variance (CRD); where factor A= level of salt, factor (B)= varieties. Means were tested and separated using Duncan's Multiple Range Test (DMRT) (Gomez and Gomez, 1984).

CHAPTER FOUR

RESULTS

[I]Experiment-1

4.1 Germination test

Analysis of variance showed that there were highly significant differences between the salinity levels, and between the four sorghum genotypes, as well as the salinity X genotypes interaction (Appendix 1). The highest germination percentage (66.3) was recorded at EC4, which was significantly greater than that at all other salinity levels. The lowest germination percentage (42.50) was recorded at EC0. The genotype Dabar showed the highest germination percentage (76.10), which was significantly greater than all other genotypes. The lowest germination percentage (43.8) was recorded for Wadahmed. The highest value (80.00) was recorded for Kh BSL 094 at EC4 and Kh BSL 095 at EC10. The lowest value (26.00) was recorded for Kh BSL 094 and EC0. (Table 1), Appendix (4)

After three days from germination, analysis of variance showed that there were highly significant differences among the salinity levels, and between the four genotypes, as well as the salinity X genotypes interaction (Appendix 1). The highest germination percentage (87.75) was recorded at EC0, it was not significantly different from that obtained at EC8 and EC4, but significantly different from that at EC6 and EC10. The lowest germination percentage (73.00) was recorded at EC0. The genotype Kh BSL 094 recorded the highest germination percentage 87.60%, it was not significantly different from that obtained for Dabar. The lowest germination percentage (75.20) was recorded for Wadahmed. The highest value (98.00) was recorded for Kh BSL 095 at EC10. The lowest value (54.00) was recorded for Kh BSL 095 at EC6 (Table 1), Appendix (4).

After four days from germination, analysis of variance showed that there were highly significant differences between the salinity levels, and between the four sorghum genotypes, as well as the salinity X genotypes interaction (Appendix 1). The highest germination percentage (92.3) was recorded at EC8, it was not significantly different from that obtained at EC10 and EC4, but significantly different from that obtained at EC6 and EC0. The lowest germination percentage

(80.8) was recorded at EC0. The genotype Kh BSL 094 recorded the highest germination percentage (93.8), it was not significantly different from that obtained for Dabar, but significantly different from that of Kh BSL 095 and Wadahmed. The lowest germination percentage (81.00) was recorded for Wadahmed. The highest value (99.00) was recorded for Kh BSL 094 at EC6. The lowest value (59.5) was recorded for Kh BSL 095 at EC6 (Table1), Appendix (4).

After five days from germination, analysis of variance showed that there were no significant differences between the salinity levels. On the other hand, there were highly significant differences between the four sorghum genotypes, but the salinity X genotypes interaction was not significant (Appendix 1). The overall mean germination percentage was (90.1). The genotype Kh BSL 094 recorded the highest germination percentage (94.80), which was not significantly different from that obtained for Dabar and Kh BSL 095. The lowest germination percentage (82.2) was recorded for Wadahmed. (Table 1), Appendix (4).

After six days from germination, analysis of variance showed that there were no significant differences between the salinity levels, but there were highly significant differences between the four sorghum genotypes, and the salinity X genotypes interaction (Appendix 1).The genotype Kh BSL 094 recorded the highest germination percentage (95.2), it was not significantly different from that obtained for Dabar and Kh BSL 095. The lowest germination percentage (85.4) was recorded for Wadahmed. The highest value (99.0) was recorded for Kh BSL 094 at EC6. The lowest value (73.5) was recorded for Kh BSL 095 at EC0 (Table 1), Appendix (4).

Table (1): Performance of four sorghum genotypes under five salinity levels (EC0, EC4, EC6.EC8 and EC10) for germination percentage, during 2009/2010 season at Shambat.

Salinity levels	2 days after germination					3 days after germination					4 days after germination				
	Wadahmed	**Dabar**	**Kh BSL 094**	**Kh BSL 095**	**Mean**	**Wadahmed**	**Dabar**	**Kh BSL 094**	**Kh BSL 095**	**Mean**	**Wadahmed**	**Dabar**	**Kh BSL 094**	**Kh BSL 095**	**Mean**
EC0	31.00^{fg}	79.00^{a}	34.00^{fg}	26.00^{g}	42.50^{d}	65.00^{efg}	84.00^{abcd}	83.00^{abcd}	60.00^{fg}	73.00^{c}	69.00^{ef}	92.00^{ab}	90.00^{ab}	72.00^{def}	80.75^{c}
EC4	37.00^{efg}	78.00^{a}	80.00^{a}	70.00^{ab}	66.25^{a}	69.00^{defg}	90.00^{abc}	80.00^{abcde}	90.00^{abc}	82.25^{ab}	80.00^{bcde}	93.00^{ab}	93.00^{ab}	91.00^{ab}	89.25^{ab}
EC6	50.00^{de}	67.00^{abc}	67.00^{abc}	50.00^{de}	58.50^{bc}	79.00^{bcde}	82.00^{abcde}	95.00^{ab}	54.00^{g}	77.50^{bc}	87.00^{abcd}	89.00^{abc}	99.00^{a}	59.50^{f}	83.63^{bc}
EC8	57.00^{bcd}	77.00^{a}	45.00^{def}	44.00^{def}	55.75^{c}	89.00^{abc}	87.00^{abc}	87.00^{abc}	88.00^{abc}	87.75^{a}	95.00^{ab}	89.00^{abc}	91.00^{ab}	94.00^{ab}	92.25^{a}
EC10	44.00^{def}	79.50^{a}	55.00^{cd}	80.00^{a}	64.63^{ab}	74.00^{cdef}	85.00^{abcd}	93.00^{ab}	98.00^{a}	87.50^{a}	74.00^{cdef}	93.00^{ab}	96.00^{ab}	98.00^{a}	90.25^{ab}
Mean	43.80^{c}	76.10^{a}	56.20^{b}	54.00^{b}		75.20^{b}	85.60^{a}	87.60^{a}	78.00^{b}		81.00^{b}	91.20^{a}	93.80^{a}	82.90^{b}	
C.V%	16.26					13.14					11.33				

Means bearing different superscript letters are significantly different ($P \leq 0.05$).

Table (1) continued: Performance of four sorghum genotypes under five salinity levels (EC0, EC4, EC6.EC8 and EC10) for germination percentage, during 2009/2010 season at Shambat.

Salinity levels	5 days after germination					6 days after germination					7 days after germination				
	Wadahmed	Dabar	Kh BSL 094	Kh BSL 095	Mean	Wadahmed	Dabar	Kh BSL 094	Kh BSL 095	Mean	Wadahmed	Dabar	Kh BSL 094	Kh BSL 095	Mean
EC0	78.00^{bc}	95.00^{a}	95.00^{a}	74.00^{c}	85.50^{b}	80.00^{bc}	98.00^{a}	97.00^{a}	73.50^{c}	87.13^{a}	80.00^{bc}	98.00^{a}	97.00^{a}	73.50^{c}	87.13^{a}
EC4	85.00^{abc}	96.00^{a}	93.00^{ab}	98.00^{a}	93.00^{a}	89.00^{ab}	96.00^{a}	93.00^{ab}	98.00^{a}	94.00^{a}	90.00^{ab}	96.00^{a}	93.00^{ab}	98.00^{a}	94.25^{a}
EC6	87.00^{abc}	93.00^{ab}	99.00^{a}	78.00^{bc}	89.25^{ab}	87.00^{abc}	93.00^{ab}	99.00^{a}	85.00^{abc}	91.00^{a}	87.00^{abc}	93.00^{ab}	99.00^{a}	85.00^{abc}	91.00^{a}
EC8	87.00^{abc}	91.00^{ab}	91.00^{ab}	97.00^{a}	91.50^{ab}	97.00^{a}	91.00^{ab}	91.00^{ab}	97.00^{a}	94.00^{a}	97.00^{a}	91.00^{ab}	91.00^{ab}	97.00^{a}	94.00^{a}
EC10	74.00^{c}	97.00^{a}	96.00^{a}	98.00^{a}	91.25^{ab}	74.00^{c}	97.00^{a}	96.00^{a}	98.00^{a}	91.25^{a}	74.00^{c}	97.00^{a}	96.00^{a}	98.00^{a}	91.25^{a}
Mean	82.20^{b}	94.40^{a}	94.80^{a}	89.00^{a}		85.40^{b}	95.00^{a}	95.20^{a}	90.30^{ab}		85.60^{b}	95.00^{a}	95.20^{a}	90.30^{ab}	
CV%	10.58					10.28					10.28				

Means bearing different superscript letters are significantly different ($P \leq 0.05$).

After seven days from germination, analysis of variance showed that there were no significant differences between the salinity levels, but there were highly significant differences between the four sorghum genotypes, as well as the salinity X genotypes interaction (Appendix 1). The genotype Kh BSL 094 (Table 1) (95.2) was recorded the highest germination percentage; but it was not significant from that obtained for Dabar and Kh BSL 095. The lowest germination percentage (85.6) was recorded for Wadahmed. The highest value (99.00) was recorded for Kh BSL 094 at EC6. The lowest value (73.5) was recorded for Kh BSL 095 at EC0 (Table 1), Appendix (4).

4.2 Rate of germination

For the rate of germination, analysis of variance showed that there were highly significant differences between the salinity levels, the four sorghum genotypes, as well as the salinity X genotypes interaction (Appendix 2). The highest rate of germination (2.79) was recorded at EC0 which was greater than all other salinity levels, and the lowest speed of germination (2.43) recorded at EC10. The genotype Kh BSL 095 (2.71) was recorded the highest speed of germination. It was not significantly different from that obtained for Wadahmed and Kh BSL 094 but significantly different from Dabar. The lowest speed of germination (2.35) was recorded for Dabar. The highest value (3.23) was recorded for Kh BSL 095 at EC6, while the lowest value (2.21) was recorded for Dabar at EC8 (Table 2).

[II] Pot experiment-2

4.3 Plant height (cm)

After 10 days from start of treatments, analysis of variance showed that there were highly significant differences between the salinity levels, and between the four sorghum genotypes, but the salinity X genotypes interaction was not significant (Appendix 3). The highest plant height (52.2) was recorded at EC0 (Table 3). It was not significantly different from that obtained at EC4 and EC10. The lowest plant height (34.2) was recorded at EC8. The genotype Kh BSL 094 recorded the highest plant height (55.1), which was significantly

Table (2): Performance of four sorghum genotypes under five salinity levels (EC0, EC4, EC6.EC8 and EC10) for rate of germination, during 2009/2010 season at Shambat.

Salinity levels	Varieties				Mean
	Wadahmed	Dabar	Kh BSL094	Kh BSL095	
Ec_0	2.88^{bc}	2.41^{fghij}	2.91^{bc}	2.98^{b}	2.79^{a}
Ec_4	2.99^{b}	2.25^{hij}	2.80^{bcd}	2.40^{fghij}	2.61^{b}
Ec_6	2.55^{efg}	2.43^{fghij}	2.36^{ghij}	3.23^{a}	2.64^{b}
Ec_8	2.50^{efg}	2.21^{j}	2.53^{efg}	2.70^{cde}	2.48^{c}
Ec_{10}	2.60^{def}	2.45^{fghi}	2.46^{fgh}	2.23^{ij}	2.43^{c}
Mean	2.70^{a}	2.35^{b}	2.61^{a}	2.71^{a}	
CV% = 6.36					

Means bearing different superscript letters are significantly different ($P \leq 0.05$).

greater than all other genotypes, whereas the lowest plant height was recorded for Wadahmed (33.4), Appendix 5.

After 20 days from starting the treatments, analysis of variance showed that there were no significant differences between the salinity levels. On the other hand, there were highly significant differences between the four sorghum genotypes; while the salinity X genotypes interaction was not significant (Appendix 3). Over the salinity levels the overall mean plant height was (52.3 cm). The genotype Kh BSL 094 recorded the highest plant height (58.8) which was not significantly different from that obtained for Dabar and Kh BSL 095. However, the lowest plant height was recorded for Wadahmed (42.5). (Table 3), Appendix (5).

After 30 days from start of treatments, analysis of variance (Appendix 3) showed that there were no significant differences among the salinity levels. On the other hand, there were highly significant differences among the four sorghum genotypes. However, the salinity X genotypes interaction was not significant. The genotype Kh BSL 094 (61.1) recorded the highest plant height it was not significantly different from that obtained for Dabar and Kh BSL 095, the lowest plant height was recorded for Wadahmed (46.6). (Table 3), Appendix (5).

After 40 days from starting the treatment, analysis of variance showed that there were no significant differences between the salinity levels. On the other hand, there were highly significant differences between the four sorghum genotypes, but the salinity X genotypes interaction was not significant (Appendix 3).The genotype Kh BSL 095 recorded the highest plant height (66.99). However; it was not significantly different from that obtained for Dabar and Kh BSL 094. The lowest plant height (49.6) was recorded for Wadahmed (Table 3), Appendix (5).

After 50 days from starting the treatments, analysis of variance showed that there were no significant differences between the salinity levels. On the

Table (3): Performance of four sorghum genotypes under five salinity levels (EC0, EC4, EC6.EC8 and EC10) for plant height (cm), during 2009/2010 season at Shambat.

Salinity levels	**10 days after starting treatments**					**20 days after starting treatments**					**30 days after starting treatments**				
	Wadahmed	**Dabar**	**Kh BSL 094**	**Kh BSL 095**	**Mean**	**Wadahmed**	**Dabar**	**Kh SL 094**	**Kh BSL 095**	**Mean**	**Wadahmed**	**Dabar**	**KhBSL 094**	**Kh SL 095**	**Mean**
EC0	41.38^{bcdef}	56.70^{abc}	62.58^{a}	49.38^{abcd}	52.51^{a}	46.08^{bcd}	59.10^{ab}	59.24^{ab}	54.76^{abc}	54.79^{a}	50.42^{abc}	60.08^{ab}	60.88^{ab}	59.76^{ab}	57.78^{a}
EC4	34.80^{def}	48.90^{abcd}	53.98^{abc}	40.58^{bcdef}	44.57^{ab}	48.53^{abcd}	54.61^{abc}	57.34^{ab}	51.78^{abcd}	53.06^{a}	60.08^{ab}	58.99^{abc}	60.34^{ab}	55.57^{abc}	56.97^{a}
EC6	34.17^{def}	45.40^{abcde}	54.97^{abc}	34.71^{def}	42.31^{b}	38.32^{d}	46.33^{bcd}	63.12^{a}	51.80^{abcd}	49.89^{a}	58.99^{abc}	53.53^{abc}	66.01^{a}	58.08^{abc}	55.00^{a}
EC8	23.33^{f}	38.42^{cdef}	46.28^{abcde}	28.68^{ef}	34.18^{c}	39.68^{cd}	53.83^{abc}	54.67^{abc}	49.85^{abcd}	49.51^{a}	53.53^{abc}	58.88^{abc}	56.58^{abc}	66.76^{a}	56.14^{a}
EC10	33.13^{def}	46.83^{abcde}	57.43^{ab}	46.25^{abcde}	45.91^{ab}	39.92^{cd}	60.45^{ab}	59.51^{ab}	56.26^{ab}	54.03^{a}	58.88^{abc}	62.31^{ab}	61.53^{ab}	61.50^{ab}	57.51^{a}
Mean	33.36^{c}	47.25^{b}	55.05^{a}	39.92^{c}		42.51^{b}	54.87^{a}	58.77^{a}	52.89^{a}		62.31^{ab}	58.76^{a}	61.07^{a}	60.33^{a}	
C.V%	25.37					17.45					18.22				

Means bearing different superscript letters are significantly different ($P \leq 0.05$).

Table (3) continued: Performance of four sorghum genotypes under five salinity levels (EC0, EC4, EC6.EC8 and EC10) for plant height (cm), during 2009/2010 season at Shambat.

Salinity levels	40 days after starting treatments					50 days after starting treatments				
	Wadahmed	**Dabar**	**Kh BSL 094**	**Kh BSL 095**	**Mean**	**Wadahmed**	**Dabar**	**Kh BSL 094**	**Kh BSL 095**	**Mean**
EC0	53.23^{abc}	61.80^{abc}	61.76^{abc}	61.41^{abc}	59.55^{a}	55.25^{bcd}	65.59^{abcd}	68.41^{abc}	65.68^{abcd}	63.73^{a}
EC4	50.83^{bc}	59.92^{abc}	61.83^{abc}	63.74^{abc}	59.08^{a}	55.43^{bcd}	66.42^{abcd}	68.54^{abc}	64.18^{abcd}	63.64^{a}
EC6	49.06^{c}	63.26^{abc}	69.05^{abc}	68.79^{abc}	62.54^{a}	55.88^{bcd}	69.13^{abc}	73.78^{ab}	65.60^{abcd}	66.10^{a}
EC8	47.29^{c}	66.18^{abc}	58.29^{abc}	71.35^{ab}	60.78^{a}	50.90^{cd}	72.93^{ab}	61.70^{abcd}	74.93^{ab}	65.12^{a}
EC10	47.51^{c}	74.76^{a}	65.76^{abc}	69.65^{abc}	64.42^{a}	47.20^{d}	81.38^{a}	71.70^{ab}	73.40^{ab}	68.42^{a}
Mean	49.58^{b}	65.18^{a}	63.34^{a}	66.99^{a}		52.93^{b}	71.09^{a}	68.83^{a}	68.76^{a}	
C.V% = 21.16						C.V% = 17.96				

Means bearing different superscript letters are significantly different (P≤0.05).

other hand, there were highly significant differences between the four sorghum genotypes, but the salinity X genotypes interaction was not significant (Appendix 3). The highest plant height (71.09) was recorded for Dabar. It was not significantly different from that obtained for Kh BSL 094 and Kh BSL 095. The lowest plant height (52.93) was recorded for Wadahmed. (Table 3), Appendix (5).

4.4 Number of leaves per plant

After 10,20 and 30 days from starting the treatments no significant differences between the salinity levels or between the four sorghum genotypes or salinity X genotypes interaction was found (Appendix 3). The overall mean number of leaves was (5.7) (Table 4).

After 40 days from starting the treatments, analysis of variance showed that there were highly significant differences between the salinity levels, but no significant differences between the four sorghum genotypes, or the salinity X genotypes interaction (Appendix 3). The highest number of leaves (9.6) was recorded at EC10 which was not significantly different from that obtained for EC0, but was significantly different that found at EC4 and EC6. The lowest number of leaves was 8.1 recorded at EC8 (Table 4).

After 50 days from starting the treatment, analysis of variance showed that there were highly significant differences between the salinity levels, as well as between the four sorghum genotypes. On the other hand, the salinity X genotypes interaction was not significant (Appendix 3). The highest number of leaves was recorded at EC10. It was not significantly different from that obtained at EC0, but significantly different from that found at EC4, EC6 and EC8. The lowest number of leaves was (9.13) recorded at EC4. The genotype Kh BSL 094 recorded the highest number of leaves (10.25). The lowest number of leaves was (9.44) recorded at EC10. (Table 4).

4.5 Stem diameter (cm)

After 10 days from starting the treatment, analysis of variance, showed that there were highly significant differences between the salinity levels, and between the

Table (4): Performance of four sorghum genotypes under five salinity levels (EC0, EC4, EC6.EC8 and EC10) for number of leaves per plant, during 2009/2010 season at Shambat.

Salinity levels	10 days after starting treatments					20 days after starting treatments					30 days after starting treatments				
	Wadahmed	Dabar	Kh BSL 094	Kh BSL 095	Mean	Wadahmed	Dabar	Kh BSL 094	Kh BSL 095	Mean	Wadahmed	Dabar	Kh BSL 094	Kh BSL 095	Mean
EC0	5.70^{a}	5.73^{a}	5.90^{a}	5.78^{a}	5.78^{a}	6.10^{a}	6.20^{a}	5.90^{a}	6.28^{a}	6.12^{a}	7.48^{a}	7.63^{a}	7.83^{a}	7.70^{a}	7.70^{a}
EC4	6.00^{a}	5.48^{a}	5.60^{a}	5.85^{a}	5.73^{a}	6.15^{a}	6.25^{a}	6.20^{a}	5.85^{a}	6.11^{a}	7.50^{a}	7.30^{a}	7.88^{a}	7.55^{a}	7.55^{a}
EC6	6.10^{a}	5.63^{a}	5.70^{a}	5.95^{a}	5.84^{a}	6.10^{a}	6.35^{a}	6.08^{a}	5.95^{a}	6.12^{a}	7.35^{a}	7.83^{a}	7.83^{a}	7.63^{a}	7.63^{a}
EC8	5.85^{a}	5.55^{a}	5.85^{a}	5.43^{a}	5.67^{a}	6.30^{a}	6.18^{a}	6.38^{a}	5.93^{a}	6.19^{a}	7.55^{a}	7.15^{a}	7.55^{a}	7.38^{a}	7.38^{a}
EC10	5.65^{a}	5.60^{a}	5.55^{a}	5.53^{a}	5.58^{a}	6.35^{a}	6.10^{a}	6.13^{a}	6.03^{a}	6.15^{a}	7.33^{a}	7.73^{a}	7.88^{a}	7.70^{a}	7.70^{a}
Mean	5.86^{a}	5.60^{a}	5.72^{a}	5.71^{a}		6.20^{a}	6.22^{a}	6.14^{a}	6.01^{a}		7.44^{b}	7.53^{ab}	7.79^{a}	7.59^{ab}	
C.V%	6.42					6.64					6.42				

Means bearing different superscript letters are significantly different ($P \leq 0.05$).

Table (4) continued: Performance of four sorghum genotypes under five salinity levels (EC0, EC4, EC6.EC8 and EC10) for number of leave per plant, during 2009/2010 season at Shambat.

Salinity levels	**40 days after starting treatments**					**50 days after starting treatments**				
	Wadahmed	**Dabar**	**Kh BSL 094**	**Kh BSL 095**	**Mean**	**Wadahmed**	**Dabar**	**Kh BSL 094**	**Kh BSL 095**	**Mean**
EC0	8.88^{abc}	8.85^{abc}	8.88^{abc}	9.70^{ab}	9.08^{ab}	10.18^{ab}	10.25^{ab}	10.32^{ab}	9.88^{bc}	10.16^{a}
EC4	8.80^{abc}	8.58^{bc}	8.43^{bc}	7.95^{bc}	8.44^{bc}	9.75^{bcd}	8.75^{cd}	9.58^{bcd}	8.43^{d}	9.13^{b}
EC6	7.60^{c}	8.53^{bc}	8.65^{abc}	8.33^{bc}	8.28^{bc}	9.10^{bcd}	9.25^{bcd}	10.4^{ab}	9.43^{bcd}	9.55^{b}
EC8	7.85^{bc}	8.25^{bc}	8.10^{bc}	8.38^{bc}	8.14^{c}	9.18^{bcd}	9.40^{bcd}	9.68^{bc}d	9.48^{bcd}	9.43^{b}
EC10	9.55^{ab}	9.18^{abc}	10.40^{a}	9.08^{abc}	9.55^{a}	9.65^{bcd}	10.18^{ab}	11.25^{a}	10.00^{abc}	10.27^{a}
Mean	8.54^{a}	8.68^{a}	8.89^{a}	8.69^{a}		9.57^{b}	9.57^{b}	10.25^{a}	9.44^{b}	
C.V% = 12.40						C.V% = 8.37				

Means bearing different superscript letters are significantly different ($P \leq 0.05$).

four sorghum genotypes. On the other hand, the salinity X genotypes interaction was not significant (Appendix 3). The highest stem diameter was recorded at EC0. It was not significantly different from that obtained at EC4, EC6, EC8 and EC10. The genotypes Kh BSL 094 Kh BSL 094 recorded the highest stem diameter (3.6 cm), it was not significantly different from that obtained for Dabar, but significantly different for Wadahmed and Kh BSL 095 (Table 5).

After 20 days from starting the treatments, analysis of variance showed that there were no significant differences between the salinity levels, but there were highly significant differences between the four sorghum genotypes. However, the salinity X genotypes interaction was not significant (Appendix 3). The genotype Kh BSL 094 recorded the highest stem diameter (4.5 cm). It was not significantly different from that obtained for Kh BSL 095 and Dabar. The lowest stem diameter (3.39 cm) was recorded for Wadahmed. The overall mean stem diameter was 3.98 cm (Table 5).

After 30 days from starting the treatments, analysis of variances showed that there were highly significant differences between the salinity levels, but no significant differences between the four sorghum genotypes, or the salinity x genotypes interaction (Appendix 3). The highest stem diameter (7.5 cm) was recorded at EC0, which was significantly greater than all other salinity levels. The lowest stem diameter (5.6 cm) was recorded atEC4. (Table 5).

After 40 days from starting the treatments, analysis of variance showed that there were highly significant differences between the salinity levels. On the other hand, there were no significant differences between the four sorghum genotypes, or the salinity X genotypes interaction (Appendix 3). The highest stem diameter was recorded at EC0 (10.04 cm), which was significantly greater than all other salinity levels. However, the lowest stem diameter (8.28) was recorded at EC8. The overall mean stem diameter was 8.4 cm (Table5).

After 50 days from starting the treatments, analysis of variance showed that there were highly significant differences between the salinity levels. On the other hand, there were no significant differences between the four sorghum genotypes, or

Table (5): Performance of four sorghum genotypes under five salinity levels (EC0, EC4, EC6.EC8 and EC10) for stem diameter (cm), during 2009/2010 season at Shambat.

Salinity levels	10 days after starting treatments					20 days after starting treatments					30 days after starting treatments				
	Wadahmed	**Dabar**	**Kh BSL 094**	**Kh BSL 095**	**Mean**	**Wadahmed**	**Dabar**	**Kh BSL 094**	**Kh BSL 095**	**Mean**	**Wadahmed**	**Dabar**	**Kh BSL 094**	**Kh BSL 095**	**Mean**
EC0	3.13^{bc}	3.75^{ab}	4.43^{a}	3.73^{ab}	3.76^{a}	3.48^{bcd}	4.43^{abcd}	4.80^{ab}	5.25^{a}	4.49^{a}	6.78^{bcd}	6.78^{bcd}	8.96^{a}	7.58^{abc}	7.52^{a}
EC4	3.43^{abc}	3.51^{abc}	3.48^{abc}	2.51^{c}	3.23^{b}	3.75^{abcd}	4.75^{abc}	3.93^{abcd}	3.20^{cd}	3.91^{ab}	6.51^{bcd}	5.63^{cd}	5.53^{cd}	4.85^{d}	5.63^{c}
EC6	2.44^{c}	2.79^{bc}	3.28^{abc}	2.60^{bc}	2.78^{b}	3.43^{bcd}	3.75^{abcd}	4.15^{abcd}	3.20^{cd}	3.63^{b}	6.21^{bcd}	6.48^{bcd}	7.45^{abc}	5.58^{cd}	6.43^{bc}
EC8	2.48^{c}	3.35^{abc}	3.23^{bc}	2.83^{bc}	2.97^{b}	3.18^{cd}	3.88^{abcd}	4.51^{abcd}	4.33^{abcd}	3.97^{ab}	6.03^{cd}	6.10^{bcd}	6.58^{bcd}	8.30^{ab}	6.75^{ab}
EC10	2.58^{bc}	2.95^{bc}	3.58^{abc}	3.01^{bc}	3.03^{b}	3.13^{d}	3.13^{d}	5.13^{a}	4.08^{abcd}	3.86^{ab}	5.58^{cd}	6.10^{bcd}	6.18^{bcd}	6.50^{bcd}	6.09^{bc}
Mean	2.81^{b}	3.27^{ab}	3.60^{a}	2.93^{b}		3.39^{b}	3.99^{a}	4.50^{a}	4.01^{a}		6.22^{a}	6.22^{a}	6.94^{a}	6.56^{a}	
C.V%	22.42					23.39					20.55				

Means bearing different superscript letters are significantly different (P≤0.05).

Table (5) continued: Performance of four sorghum genotypes under five salinity levels (EC0, EC4, EC6.EC8 and EC10) for stem diameter (cm), during . 2009/2010 season at Shambat.

Salinity levels	40 days after starting treatments					50 days after starting treatments				
	Wadahmed	**Dabar**	**Kh BSL 094**	**Kh BSL 095**	**Mean**	**Wadahmed**	**Dabar**	**Kh BSL 094**	**Kh BSL 095**	**Mean**
EC0	9.45^{ab}	9.33^{ab}	11.63^{a}	9.78^{ab}	10.04^{a}	10.91^{bc}	10.45^{bcd}	13.66^{a}	11.27^{ab}	11.57^{a}
EC4	7.98^{b}	8.43^{b}	7.88^{b}	7.60^{b}	7.97^{b}	9.73^{bcd}	10.86^{bc}	9.78^{bcd}	8.06^{d}	9.61^{b}
EC6	7.70^{b}	8.80^{ab}	7.55^{b}	7.13^{b}	7.80^{b}	9.00^{bcd}	9.88^{bcd}	10.20^{bcd}	9.00^{bcd}	9.52^{b}
EC8	7.95^{b}	8.88^{ab}	7.18^{b}	9.10^{ab}	8.28^{b}	8.88^{bcd}	9.28^{bcd}	9.70^{bcd}	11.65^{ab}	9.88^{b}
EC10	7.10^{b}	8.23^{b}	8.55^{ab}	8.03^{b}	7.98^{b}	8.36^{cd}	9.13^{bcd}	9.63^{bcd}	10.38^{bcd}	9.37^{b}
Mean	8.04^{a}	8.73^{a}	8.56^{a}	8.33^{a}		9.38^{b}	9.92^{ab}	10.59^{a}	10.07^{ab}	
C.V% = 22.93						C.V% = 16.25				

Means bearing different superscript letters are significantly different (P≤0.05).

the salinity X genotypes interaction (Appendix 3).The highest stem diameter (11.57) was recorded at EC0, which was significantly greater than all salinity levels. The lowest stem diameter was recorded atEC10 (9.4 cm). The overall mean stem diameter was 10.1 cm (Table 5).

4.6 Leaf area index per plant

After 10, 20 and 30 days from starting the treatments, analysis of variance showed that there were no significant differences between the salinity levels. On the other hand there were highly significant differences between the four sorghum genotypes, whereas, the salinity X genotypes was not significant (Appendix 3). The highest leaf area index was recorded for Kh BSL 094. It was not significant from that obtained for Dabar and Kh BSL 095. The lowest leaf area index (0.9) was recorded for Wadahmed (Table 6).

After 40 days from starting the treatments, analysis of variance showed that there were significant differences between the salinity levels, as well as between the four sorghum genotypes. On the other hand, the salinity X genotypes interaction was not significant (Appendix 3). The highest leaf area index was recorded at EC0 (4.5), which was significantly greater than all other salinity levels. The lowest leaf area index was recorded at EC4 (2.7). The genotype Kh BSL 094 recorded highest leaf area index (3.99). It was no significantly different from that obtained for Dabar and Kh BSL 095. The lowest leaf area index (2.4) was recorded for Wadahmed. (Table 6).

After 50 days from starting the treatments, analysis of variance revealed that there were no significant differences between the salinity levels, or between the four sorghum genotypes and the salinity X genotypes interaction (Appendix 3). The overall mean leaf area index was (3.6) (Table 6).

4.7 Plant fresh weight (g)

After 10 days from starting the treatments, analysis of variance showed that there were significant differences between the salinity levels. Also there were highly significant differences between the four sorghum genotypes. However, the salinity X genotypes interaction was not significant (Appendix 3). The highest fresh weight

Table (6): Performance of four sorghum genotypes under five salinity levels (EC0, EC4, EC6.EC8 and EC10) for leaf area index, during 2009/2010 season at Shambat.

Salinity levels	10 days after starting treatments					20 days after starting treatments					30 days after starting treatments				
	Wadahmed	**Dabar**	**Kh BSL 094**	**Kh BSL 095**	**Mean**	**Wadahmed**	**Dabar**	**Kh BSL 094**	**Kh BSL 095**	**Mean**	**Wadahmed**	**Dabar**	**Kh BSL 094**	**Kh BSL 095**	**Mean**
EC0	0.97^{bc}	1.09^{bc}	0.91^{bc}	1.39^{ab}	1.09^{ab}	1.49^{abcd}	1.87^{abcd}	2.17^{abcd}	1.55^{abcd}	1.77^{ab}	2.37^{bcd}	3.08^{abcd}	3.53^{ab}	2.86^{abcd}	2.96^{a}
EC4	1.13^{b}	1.15^{b}	1.06^{bc}	1.11^{bc}	1.11^{ab}	1.33^{abcd}	1.81^{abcd}	1.79^{abcd}	1.30^{bcd}	1.56^{ab}	1.84^{cd}	2.42^{bcd}	2.85^{abcd}	2.15^{bcd}	2.32^{a}
EC6	0.81^{bc}	1.03^{bc}	1.17^{b}	0.67^{bc}	0.92^{b}	0.89^{cd}	1.75^{abcd}	2.20^{abcd}	0.86^{cd}	1.43^{b}	1.83^{cd}	2.65^{abcd}	3.42^{ab}	2.22^{bcd}	2.53^{a}
EC8	0.37^{c}	0.98^{bc}	1.97^{a}	1.03^{bc}	1.09^{ab}	0.77^{d}	1.99^{abcd}	2.78^{ab}	2.28^{abc}	1.96^{ab}	1.85^{cd}	2.71^{abcd}	3.30^{abc}	3.14^{abcd}	2.75^{a}
EC10	1.07^{bc}	1.19^{b}	1.98^{a}	1.32^{ab}	1.34^{a}	1.24^{cd}	2.30^{abc}	2.81^{a}	2.14^{abcd}	2.13^{a}	1.66^{d}	3.26^{abc}	4.09^{a}	2.58^{abcd}	2.90^{a}
Mean	0.87^{b}	1.09^{b}	1.42^{a}	1.10^{b}		1.15^{c}	1.95^{ab}	2.35^{a}	1.63^{bc}		1.91^{c}	2.82^{b}	3.44^{a}	2.59^{b}	
58.76^{a}	C.V% 39.53					C.V% 49.08					C.V% 34.12				

Means bearing different superscript letters are significantly different (P≤0.05).

Table (6) continued: Performance of four sorghum genotypes under five salinity levels (EC0, EC4, EC6.EC8 and EC10) for leaf area index, during 2009/2010 season at Shambat.

Salinity levels	40 days after starting treatments					50 days after starting treatments				
	Wadahmed	**Dabar**	**Kh BSL 094**	**Kh BSL 095**	**Mean**	**Wadahmed**	**Dabar**	**Kh BSL 094**	**Kh BSL 095**	**Mean**
EC0	3.48^{ab}	4.43^{ab}	5.01^{a}	5.00^{a}	4.48^{a}	3.54^{a}	4.17^{a}	5.13^{a}	4.54^{a}	4.35^{a}
EC4	1.99^{b}	2.91^{ab}	3.20^{ab}	2.78^{ab}	2.72^{b}	2.41^{a}	3.27^{a}	2.96^{a}	2.43^{a}	2.77^{a}
EC6	2.54^{ab}	3.67^{ab}	3.47^{ab}	2.86^{ab}	3.14^{b}	2.74^{a}	3.86^{a}	4.26^{a}	2.99^{a}	3.46^{a}
EC8	1.88^{b}	3.39^{ab}	3.37^{ab}	2.93^{ab}	2.89^{b}	1.98^{a}	3.89^{a}	3.62^{a}	3.45^{a}	3.24^{a}
EC10	2.24^{b}	3.91^{ab}	4.89^{a}	3.78^{ab}	3.70^{ab}	2.16^{a}	4.06^{a}	4.99^{a}	4.14^{a}	3.84^{a}
Mean	2.42^{b}	3.66^{a}	3.99^{a}	3.47^{a}		2.57^{b}	3.85^{ab}	4.19^{a}	3.51^{ab}	
C.V% = 45.0						C.V% = 62.07				

Means bearing different superscript letters are significantly different (P≤0.05).

(3.8g) was recorded at EC0. It was not significant from that obtained at EC4, EC6 and EC10. The lowest plant fresh weight (1.5g) was recorded at EC8. The genotype Kh BSL 094 recorded the highest plant fresh weight (3.81), which was significantly greater than all other genotypes. The lowest plant fresh weight (1.48g) was recorded for Kh BSL 095. (Table 7).

After 20 days from starting the treatments, analysis of variance showed that there were no significant differences between the salinity levels (Appendix 3). Also there were no significant differences between the four sorghum genotypes and also the salinity X genotypes interaction was not significantly different. The overall mean plant fresh weight was 10.4g (Table 7).

After 30 days from starting the treatments, analysis of variance revealed that there were highly significant differences between the salinity levels, as well as between the four sorghum genotype (Appendix 3). On the other hand, the salinity X genotypes interaction was no significant. The highest plant fresh weight (26.5g) was recorded at EC0. It was not significantly different from that obtained at EC10, but significantly different from that obtained at EC4, EC6 and EC8. The lowest plant fresh weight (12.83g) was recorded at EC8. The genotype Kh BSL 094 recorded the highest plant fresh weight (23.43g), which was significantly greater than all other genotypes; the lowest plant fresh weight (13.5g) was recorded for Wadahmed. (Table 7).

After 40 days from starting the treatments, analysis of variance showed that there were highly significant differences between the salinity levels, and the four genotypes. On the other hand, the salinity X genotypes interactions was not significant (Appendix 3). The highest plant fresh weight (26.9g) was recorded at EC10, and was not significantly different from that obtained at EC4 and EC6. The lowest plant fresh weight (15.95g) was recorded at EC8. The genotype Kh BSL 094 recorded the highest plant fresh weight (26.93g) which was not significantly different from that obtained for Dabar. The lowest plant fresh weight (16.1g) was recorded for Wadahmed (Table 7).

Table (7): Performance of four sorghum genotypes under five salinity levels (EC0, EC4, EC6.EC8 and EC10) for plant fresh weight (g), during 2009/2010 season at Shambat.

Salinity levels	10 days after starting treatments					20 days after starting treatments					30 days after starting treatments				
	Wadahmed	Dabar	Kh BSL 094	Kh BSL 095	Mean	Wadahmed	Dabar	Kh BSL 094	Kh BSL 095	Mean	Wadahmed	Dabar	Kh BSL 094	Kh BSL 095	Mean
EC0	3.34^{abc}	4.42^{ab}	5.53^{a}	1.85^{bc}	3.78^{a}	5.30^{a}	10.30^{a}	11.65^{a}	13.22^{a}	10.12^{a}	20.43^{abc}	32.09^{a}	30.43^{ab}	22.92^{abc}	26.47^{a}
EC4	2.18^{abc}	2.31^{abc}	4.08^{abc}	1.52^{bc}	2.52^{ab}	14.58^{a}	10.66^{a}	11.60^{a}	5.85^{a}	10.67^{a}	16.67^{abc}	20.86^{abc}	20.01^{abc}	13.74^{bc}	17.82^{bc}
EC6	1.83^{bc}	2.67^{abc}	3.76^{abc}	0.84^{c}	2.27^{ab}	5.08^{a}	8.08^{a}	13.58^{a}	5.65^{a}	8.097^{a}	8.32^{c}	14.58^{bc}	16.26^{abc}	13.36^{c}	13.13^{c}
EC8	0.93^{bc}	1.58^{bc}	2.10^{abc}	1.25^{bc}	1.47^{b}	3.91^{a}	10.25^{a}	18.33^{a}	7.90^{a}	10.10^{a}	8.76^{c}	14.18^{bc}	17.53^{abc}	10.84^{c}	12.83^{c}
EC10	1.34^{bc}	2.43^{abc}	3.59^{abc}	1.77^{bc}	2.28^{ab}	6.33^{a}	10.10^{a}	18.98^{a}	15.85^{a}	12.82^{a}	13.36^{c}	24.18^{abc}	32.93^{a}	21.68^{abc}	23.04^{ab}
Mean	1.92^{b}	2.68^{ab}	3.81^{a}	1.44^{b}		7.04^{b}	9.88^{ab}	14.83^{a}	9.70^{ab}		13.51^{c}	21.18^{ab}	23.43^{a}	16.51^{bc}	
58.76^{a}	C.V% 83.51					C.V% 9.45					C.V% 52.97				

Means bearing different superscript letters are significantly different ($P \leq 0.05$).

Table (7) continued: Performance of four sorghum genotypes under five salinity levels (EC0, EC4, EC6.EC8 and EC10) for plant fresh weight (g), during 2009/2010 season at Shambat.

Salinity levels	40 days after starting treatments					50 days after starting treatments				
	Wadahmed	Dabar	Kh BSL 094	Kh BSL 095	Mean	Wadahmed	Dabar	Kh BSL 094	Kh BSL 095	Mean
EC0	17.09^{cde}	25.84^{abcde}	34.18^{ab}	24.18^{abcde}	25.32^{ab}	28.34^{a}	44.35^{a}	52.01^{a}	42.67^{a}	41.84^{a}
EC4	17.51^{cde}	25.86^{abcde}	23.35^{bcde}	17.93^{cde}	21.16^{abc}	19.18^{a}	27.26^{a}	27.09^{a}	22.08^{a}	23.90^{b}
EC6	16.68^{cde}	22.11^{bcde}	22.11^{bcde}	18.76^{cde}	19.92^{bc}	18.34^{a}	30.42^{a}	29.60^{a}	22.33^{a}	25.17^{ab}
EC8	15.01^{cde}	19.18^{cde}	17.51^{cde}	12.10_{e}	15.95^{c}	18.25^{a}	35.76^{a}	27.84^{a}	37.73^{a}	29.90^{ab}
EC10	14.18^{de}	29.18^{abc}	37.53^{a}	26.68^{abcd}	26.89^{a}	18.50^{a}	55.35^{a}	39.76^{a}	39.17^{a}	38.19^{ab}
Mean	16.09^{c}	24.43^{ab}	26.93^{a}	19.93^{bc}		20.52^{b}	38.63^{a}	35.26^{a}	32.80^{ab}	
C.V% = 38.74						C.V% = 69.64				

Means bearing different superscript letters are significantly different (P≤0.05).

After 50 days from starting the treatments, analysis of variance showed that there were no significant differences between the salinity levels, or between the four sorghum genotypes, as well as the salinity X genotypes interaction (Appendix 3). (Table 7).

4.8 Plant dry weight (g)

After 10 days from starting the treatments, analysis of variance showed that there were no significant differences between the salinity levels (Appendix 3). However, there were highly significant differences between the four sorghum genotypes. On the other hand, the salinity X genotypes interaction was not significant (Table 8). The genotype Kh BSL 094 recorded the highest plant dry weight (0.98 g), which was significantly greater than all other genotypes, whereas the lowest plant dry weight (0.37 g) was recorded for Kh BSL 095, Appendix (6).

After 20 days from starting the treatments, analysis of variance revealed that there were no significant differences between the salinity levels (Appendix 3). On the other hand, there were significant differences between the four sorghum genotypes. However, the salinity X genotypes interaction was not significant. The genotype Kh BSL 094 recorded the highest plant dry weight (3.07) which was significantly greater than all other genotypes. The lowest plant dry weight was recorded for Wadahmed (1.4g) (Table 8), Appendix (6).

After 30 days from starting the treatments, analysis of variance showed that there were highly significant differences between the salinity levels (Appendix 3). Also there were highly significant differences between the four sorghum genotypes. However the salinity X genotypes interaction was not significant. The highest plant dry weight (5.7g) was recorded at EC0, it was not significantly different from that obtained at EC4 and EC10, but was significantly different from EC6 and EC8. The lowest plant dry weight (2.83g) was recorded at EC6. The genotype Kh BSL 094 recorded the highest plant dry weight (5.39g) which was not significantly different from that obtained for Dabar but was significantly different from Wadahmed and Kh BSL 095. The lowest plant dry weight was recorded for Wadahmed (3,1g) (Table 8), Appendix (6).

After 40 days from starting the treatments, analysis of variance showed that there were no significant differences between the salinity levels (Appendix 3). Also there were no

Table (8): Performance of four sorghum genotypes under five salinity levels (EC0, EC4, EC6.EC8 and EC10) for plant dry weight (g), during . 2009/2010 season at Shambat.

Salinity levels	10 days after starting treatments					20 days after starting treatments					30 days after starting treatments				
	Wadahmed	**Dabar**	**Kh BSL 094**	**Kh BSL 095**	**Mean**	**Wadahmed**	**Dabar**	**Kh BSL 094**	**Kh BSL 095**	**Mean**	**Wadahmed**	**Dabar**	**Kh BSL 094**	**Kh BSL 095**	**Mean**
EC0	0.73^{abc}	1.17^{ab}	1.43^{a}	0.50^{bc}	0.96^{a}	1.75^{ab}	3.03^{ab}	2.18^{ab}	1.32^{b}	2.07^{a}	4.68^{abcde}	6.73^{a}	7.03^{a}	4.43^{abcde}	5.71^{a}
EC4	0.47^{bc}	0.57^{bc}	1.01^{abc}	0.38^{bc}	0.61^{ab}	1.47^{b}	1.90^{ab}	2.50^{ab}	1.30^{b}	1.79^{a}	3.84^{abcde}	5.18^{abcd}	4.85^{abcde}	3.08^{cde}	4.24^{bc}
EC6	0.38^{bc}	0.54^{bc}	0.91^{abc}	0.23^{c}	0.51^{b}	1.88^{ab}	1.68^{ab}	2.60^{ab}	1.10^{b}	1.81^{a}	1.63^{e}	3.46^{bcde}	4.01^{abcde}	2.22^{de}	2.83^{c}
EC8	0.29^{c}	0.46^{bc}	0.52^{bc}	0.33^{bc}	0.40^{b}	0.70^{b}	2.16^{ab}	3.60^{ab}	2.71^{ab}	2.29^{a}	2.02^{de}	3.43^{bcde}	4.75^{abcde}	2.08^{de}	3.07^{c}
EC10	0.45^{bc}	0.55^{bc}	1.03^{abc}	0.42^{bc}	0.61^{ab}	1.18^{b}	1.78^{ab}	4.48^{a}	1.87^{ab}	2.32^{a}	3.25^{bcde}	5.61^{abc}	6.33^{ab}	4.42^{abcde}	4.90^{ab}
Mean	0.46^{b}	0.66^{b}	0.98^{a}	0.37^{b}		1.39^{b}	2.11^{ab}	3.07^{a}	1.66^{b}		3.08^{b}	4.88^{a}	5.39^{a}	3.24^{b}	
58.76^{a}	C.V% 79.06					C.V% 87.37					C.V% 45.86				

Means bearing different superscript letters are significantly different ($P \leq 0.05$).

Table (8) continued: Performance of four sorghum genotypes under five salinity levels (EC0, EC4, EC6.EC8 and EC10) for plant dry weight (g), during . 2009/2010 season at Shambat.

Salinity levels	40 days after starting treatments					50 days after starting treatments				
	Wadahmed	Dabar	Kh BSL 094	Kh BSL 095	Mean	Wadahmed	Dabar	Kh BSL 094	Kh BSL 095	Mean
EC0	12.35^{a}	9.36^{ab}	10.42^{ab}	7.53^{ab}	9.91^{a}	8.28^{ab}	11.68^{ab}	12.10^{ab}	9.95^{ab}	10.50^{a}
EC4	5.18^{ab}	9.01^{ab}	9.60^{ab}	5.76^{ab}	7.39^{ab}	5.84^{ab}(71.1)	7.48^{ab} (64.1)	7.60^{ab}(62.8)	5.02^{b}(50.5)	6.484^{a}
EC6	4.93^{ab}	7.18^{ab}	6.75^{ab}	5.68^{ab}	6.13^{ab}	7.50^{ab} (90.4)	8.36^{ab}(71.8)	7.43^{ab}(61.4)	7.00^{ab}(70.4)	7.571^{a}
EC8	3.93^{ab}	5.76^{ab}	4.99^{ab}	3.25^{b}	4.48^{b}	6.25^{ab}(75.9)	11.25^{ab}(96.6)	7.01^{ab}(57.9)	12.10^{ab}(120.6)	9.151^{a}
EC10	4.17^{ab}	12.02^{a}	11.70^{ab}	7.50^{ab}	8.85^{a}	4.26^{b} (51.8)	15.68^{a}(134.2)	10.41^{ab}(86.3)	12.11^{ab}(121.7)	10.62^{a}
Mean	6.11^{a}	8.67^{a}	8.69^{a}	5.94^{a}		6.42^{b}	10.89^{a}	8.91^{ab}	9.23^{ab}	
C.V% = 68.73						C.V% = 66.18				

Means bearing different superscript letters are significantly different ($P \leq 0.05$).

Value between braces is relative dry weight, expressed as per cent over EC10.

significant differences between the four sorghum genotypes, as well as the salinity X genotypes interaction (Table 8), Appendix (6).

After 50 days from starting the treatments, analysis of variance (Appendix 3) showed that there were no significant differences between the salinity levels. Also there were no significant differences between the four sorghum genotypes, as well as the salinity X genotypes interaction (Table 8), Appendix (6).

4.9 Sodium content per plant (meq)

Analysis of variance (Appendix 3) showed that there were highly significant differences between the salinity levels. Also there were highly significant differences between the four sorghum genotypes. On the other hand, the salinity X genotypes interaction was not significant. The highest Na content (30.7) was recorded for EC10; it was not significantly different from that obtained for EC4, EC6 and EC8. The lowest Na content (27.07) was recorded for EC0. The genotype Kh BSL 095 had the highest Na content (32.35), which was significantly greater than all other genotypes, whereas, the lowest Na content (12.69) was recorded for Wadahmed. The overall mean Na content was (25.06) (Table 9), Appendix (7).

Table (9): Performance of four sorghum genotypes under five salinity levels (EC0, EC4, EC6.EC8 and EC10) for sodium content (meq), during 2009/2010 season at Shambat.

Salinity levels	Varieties				Mean
	Wadahmed	Dabar	Kh BSL094	Kh BSL095	
Ec_0	5.60^{d}	23.75^{abc}	31.83^{ab}	26.90^{ab}	22.02^{b}
Ec_4	23.27^{abcd}	18.88^{bcd}	33.95^{ab}	28.13^{ab}	26.06^{ab}
Ec_6	8.25^{cd}	28.88^{ab}	26.25^{ab}	31.95^{ab}	23.83^{ab}
Ec_8	6.80^{cd}	21.63^{abcd}	26.40^{ab}	$35,92^{ab}$	22.69^{ab}
Ec_{10}	19.52^{bcd}	30.75^{ab}	33.67^{a}	38.88^{a}	30.71^{a}
Mean	12.69^{c}	24.77^{b}	30.42^{ab}	32.35a	
CV% = 43.52					

Means bearing different superscript letters are significantly different (P≤0.05).

CHAPTER FIVE
DISCUSSION

Soil salinity and sodicity are becoming major problems of crop production. A number of crops are found to be seriously damaged by salinity and sodicity as a result of agricultural expansion into the so-called high terrace soils which are mostly salt affected (Ayoub, 1976).

Plants vary in response to soil salinity. Salt tolerant plants (plant less affected by salinity) are better able to adjust internally to the osmotic affect of high salt concentration than salt sensitive plants (Blaylock, 1994).

In this study effect of salt stress on seed germination, growth and yield of forage sorghum was studied using five levels of NaCl and four sorghum genotypes. Different patterns of response were observed between the tested sorghum genotypes in sodium uptake and most of the studied parameters.

In this study the germination percentage was significantly increased by increasing salinity levels. These findings were in agreement with(Malibari *et al*, 2008) who found that during germination stage Sorghum tolerate salinity up to 3000ppm, and not in agreement with the result obtained by Prisco *et al*., 1987 who reported that salt treatments inhibited germination and affected seedling vigor of sorghum negatively.

The rate of germination was significantly reduced by increasing salinity levels. This result were in agreement with the result obtained by Ghoulam and Fares (2001) who found that germination percentage, rate of germination and relative germination percentage of sugar beet (*Beata vulgaris* L) seeds were decreased by NaCl treatment.

The result obtained showed that salinity levels on plant height was non significant as plant height increased with increasing the salinity. These results were in disagreement with Majumdar,and Balai,(2000) who reported that plant height of wheat decreased with increasing SAR levels, whereas salinity reduced plant height of onion(Yadao *et al*., 1998).

The results obtained cleared that effect of salinity on mean number of leaves per plant was not significant during the early stage of growth, but during last stage of growth it was highly significant. Arbol *et al*. (1988) reported that the tolerance of crops to salinity change with the stage of growth.

The results showed that mean stem diameter was significantly reduced by increasing salinity levels. These results may be due to thst saline and saline-sodic soils influence plants because of their high soluble salt contact with plant cells which will cause shrinkage of protoplasm, and collapse of cells Brady(1978).

The salt tolerance of a crop may be appraised according to the relative yield of the crop on saline soils as compared with non-saline soil under similar conditions (Arbol *et al*., 1988). In this study the relative dry weight, is used as a measure of tolerance of the sorghum genotypes to salt stress.

The ability of sorghum to tolerate salt stress, showed variation between the evaluated four sorghum genotypes. All the genotypes showed reduction in relative dry weight at EC4. After this reduction relative dry weight slightly increased in all sorghum genotypes except the genotype Kh BSL094, which showed no change in its value at EC6 and EC8. The genotype Wadahmed proved to have the least relative dry weight with increasing salinity levels, as compared to other genotypes. This result is in agreement with the result obtained by (Almodares, *et al* 2008) who reported that as salinity increased, the amount of the shoot fresh weight, shoot dry weight and leaf area index of sorghum decreased. The relative dry weight of Wadahmed was 48.2% at EC10, as a result of a drastic reduction in the measured growth parameters including: plant height (Table 3), stem diameter (Table 6), fresh weight (Table 7) and dry weight (Table 8), whilst number of leaves (Table 4) and leaf area index (Table 5) was not affected. It is worth mentioning that this genotype had the lowest sodium content per plant even at EC10 (19.5). This may indicate that the genotype Wadahmed had reduced Na uptake, or salt had made it more difficult for plants to absorb water from the soil. In effect, the plants suffered from drought which can result in retarded growth and reduced yield (Rogers, 1997). It means that the genotype Wadahmed had no mechanism to tolerate the salinity.

The genotype Kh BSL 094 had better growth parameters as compared to other genotypes, and a high sodium content. This genotype might be different from the genotype Wadahmed in being more salt tolerant. The mechanism for salt tolerance might be, osmotic stress tolerance, or the tolerance of tissue to accumulated Na^+ (Rana and Mark,2008).

Both genotypes Dabar and Kh BSL 095 showed an increase in relative dry weight even at the highest levels of salinity, EC10. Variation was observed between these genotypes in the final relative dry weight, though both of them had a high level of sodium content. This indicates that genotypes Dabar and Kh BSL 095 had tolerance for high sodium content and could grow and yield well.

The high relative dry weight (134%) at EC10 was recorded for genotype Dabar which also had high sodium content (24.8). The data showed that there were no significant differences between absolute yields at the different salinity levels, and the extreme increase in relative yield might be due to sampling or measurement errors. Also no significant differences in yield were found between the salinity levels at last stages of growth, whilst the early stages of growth showed significant differences in yield between the salinity levels (Table 8). This is in agreement with the result obtained by (Soltanpour and Follett, 2001) who reported that seedlings are usually most sensitive to salt during the emergence and early stages of growth and plant salt tolerance increases as the crop develops during the growing season. This may indicate that genotype Dabar had the ability to survive on saline soils, since the yield of the crop on saline soils or the relative yield of the crop on saline soils as compared with its yield on non-saline soil under similar conditions was not affected (Arbol *et al*, 1988). Or else these genotypes were able to continue their physiological activities and growth without reducing sodium uptake, through some mechanism for salt to tolerance.

Accordingly this genotype might be utilized for production of forage sorghum in salt affected soil. Generally, genotypes Dabar, Kh BSL 094 and Kh BSL 095 had the ability to tolerate the salinity.

SUMMARY AND CONCLUSIONS

1- Laboratory tests and pot experiment test were conducted at the Faculty of Agriculture, University of Khartoum in the year 2009 to investigate the effect of salinity on germination, growth and yield of four sorghum genotypes.

2- The salinity levels used were EC0(control), EC4, EC6, EC8 and EC10, and the four sorghum genotypes were Wadahmed, Dabar, Kh BSL 094 and Kh BSL 095.

3- The results of this study showed that, in most of the occasions, the different salinity treatments had no significant effect on all parameters except the germination percentage and rate of germination, stem diameter, as well as the sodium content per plant. When there were significant differences between the salinity levels, the effect on the parameters differed with the age of the plant.

4- The genotypes exhibited significant differences in all characters studied. The genotypes, Dabar, Kh BSL 094 and Kh BSL 095 had a high relative dry weight, as well as sodium content per plant.

5- The interaction between salinity X genotypes was not significant for all characters studied except the germination percentage and rate of germination.

6- It could be concluded that genotypes Dabar, Kh BSL 094 and Kh BSL 095had the ability to tolerate the salinity and may survive in salt affected soil.

7- Further in depth studies are needed to investigate the exact mechanisms employed by these genotypes for salt tolerance.

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APPENDICES

Appendix **(1): Mean squares from the analysis of variance of the effect of salinity levels (EC), Genotype (V), and their interaction (EC x V) on germination percentage of sorghum, at 2,3,4,5,6 and 7 days after starting the germination, during season 2009/2010**

Source	**d.f**	**Mean square**					
		After2 days	**3days**	**4days**	**5days**	**6days**	**7days**
EC	4	1425.550^{**}	655.300^{**}	373.550^{**}	134.300^{ns}	127.800^{ns}	133.050^{ns}
Varieties	3	3650.583^{**}	706.133^{**}	776.583^{**}	694.667^{**}	430.583^{**}	414.583^{**}
ExV	12	746.417^{**}	479.300^{**}	402.417^{**}	212.167^{ns}	243.333^{**}	244.250^{**}

Ns = no significant differences

*, ** = significant differences at (0.05 and 0.01) respectively.

Appendix **(2): Mean squares from the analysis of variance of the effect of salinity levels (EC), Genotype (V), and their interaction (EC x V) on rate of germination of sorghum, at 2,3,4,5,6 and 7 days after starting the germination, during season 2009/2010**

Source	d.f	Mean square
EC	**4**	0.317^{**}
Varieties	**3**	0.317^{**}
ExV	**12**	0.268^{**}

Ns = no significant differences

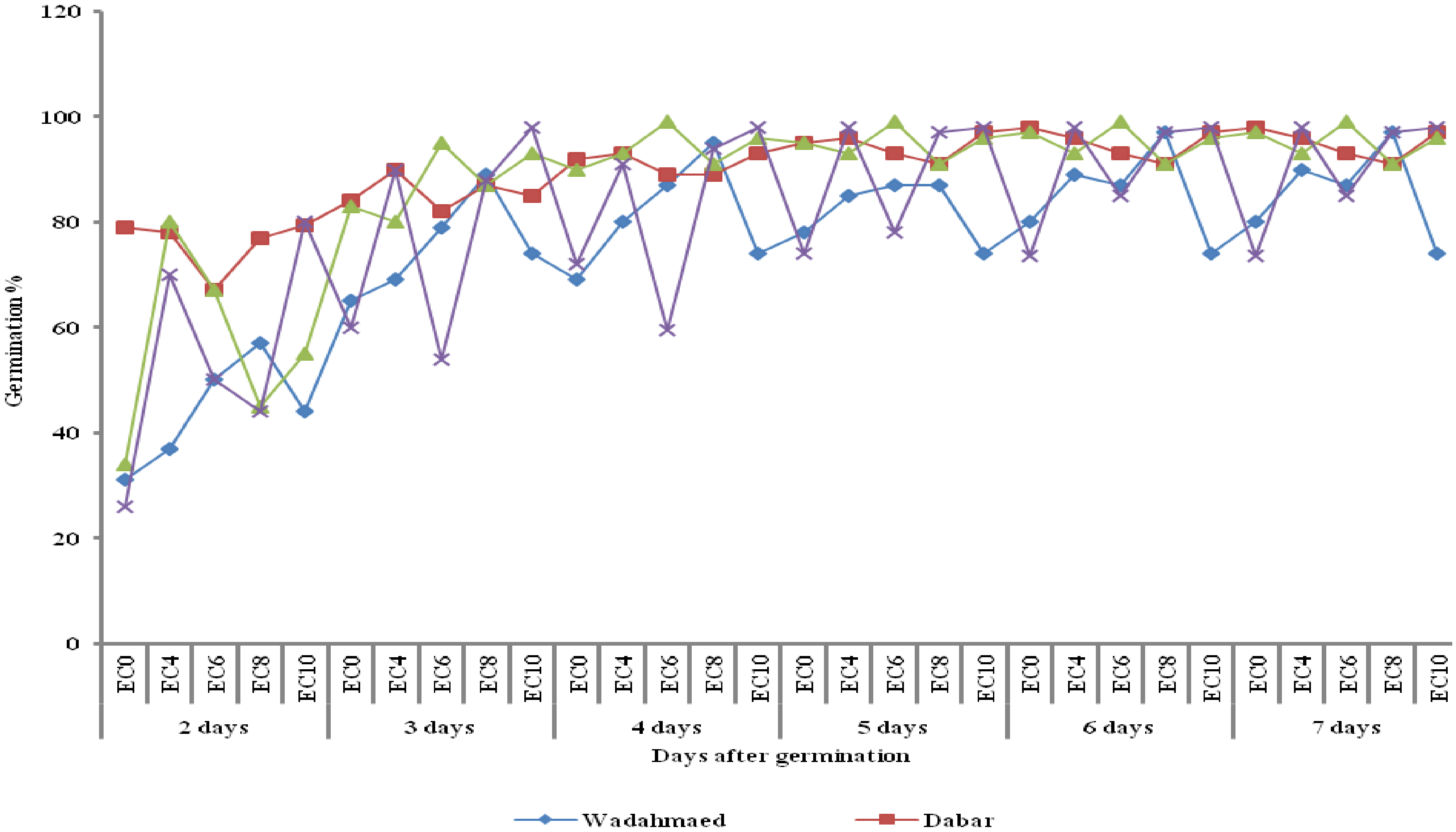
*, ** = significant differences at (0.05 and 0.01) respectively.

Appendix **(3): Mean squares from the analysis of variance of the effect of salinity levels (EC), Genotype (V), and their interaction (EC x V) on different characters of sorghum, at 10, 20, 30,40and50 days after starting treatments, during season 2009/2010**

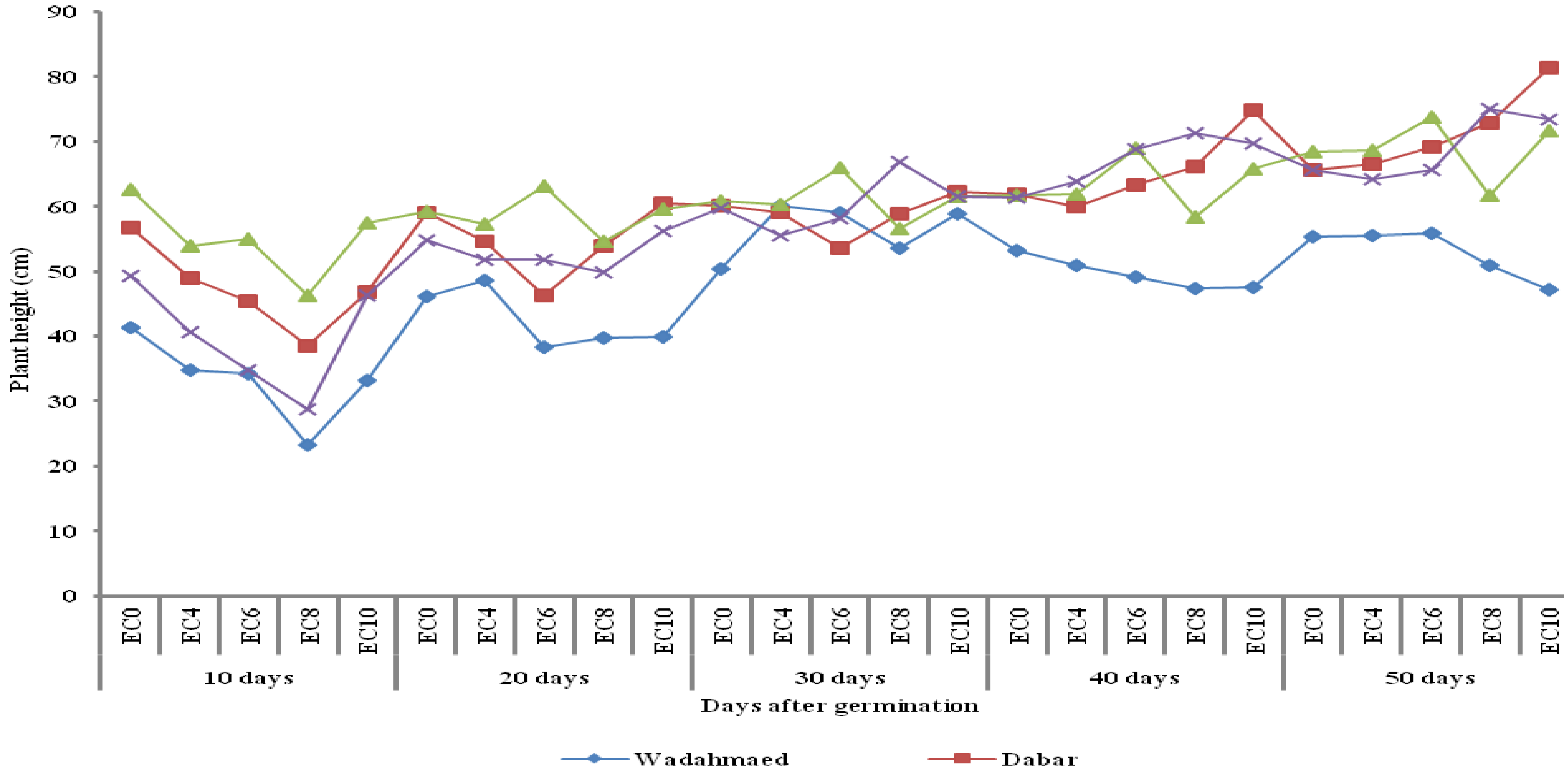
Days	10 days after starting Treatments			20 days after starting treatments			30 days after starting treatments			40 days after starting Reatments			50 days after starting Treatments		
Degree of freedom	**EC salinity**	**V genotypes**	**ECxV**	**EC salinity**	**V genotypes**	**ECxV**	**EC salinity**	**V genotypes**	**ECxV**	**EC salinity**	**V genotypes**	**ECxV**	**EC salinity**	**V genotypes**	**ECxV**
Characters	d.f=4	d.f=3	d.f= 12	d.f=4	d.f=3	d.f= 12	d.f=4	d.f=3	d.f= 12	d.f=4	d.f=3	d.f= 12	d.f=4	d.f=3	d.f= 12
Plant height	702.243**	1749.798**	20891^{ns}	93.600^{ns}	964.977**	58.584^{ns}	20.453^{ns}	929.662**	77.410^{ns}	87.076^{ns}	1258.897^{ns}	74.000^{ns}	62.207^{ns}	1405.430**	114.708^{ns}
No. of leaves	0.161^{ns}	0.227^{ns}	0.101^{ns}	0.019^{ns}	0.183^{ns}	0.099^{ns}	0.192^{ns}	0.444^{ns}	0.108^{ns}	4.890**	4.890^{ns}	0.831^{ns}	3.827**	2.700**	0.648^{ns}
Stem diameter	2.244**	2.522**	0.346^{ns}	1.593^{ns}	4.138**	1.378^{ns}	8.168**	2.361^{n}s	2.806^{ns}	13.786**	1.814^{ns}	2.494^{ns}	13.062**	5.011^{ns}	4.735^{ns}
Leaf area index	0.452^{ns}	1.023**	0.444^{ns}	1.287^{ns}	5.172**	0.747^{ns}	1.136^{ns}	7.981**	0.373^{ns}	8.158^{ns}	9.143^{ns}	0.483^{ns}	5.747^{ns}	9.769^{ns}	0.841^{ns}
Fresh weight	11.234^{ns}	21.291**	1.084^{ns}	45.507^{ns}	211.121^{ns}	56.368^{ns}	582.107**	402.015**	33.659^{ns}	306.131**	462.250**	60.542^{ns}	1006.476^{ns}	1245.236^{ns}	142.995^{ns}
Dry weight	0.702^{ns}	1.435**	0.071^{ns}	1.026^{ns}	10.875^{ns}	2.128^{ns}	23.731**	26.938**	0.730^{ns}	74.098^{ns}	46.995^{ns}	13.606^{ns}	52.651^{ns}	67.971^{ns}	19.498^{ns}
Na content	--	--	--	--	--	--	--	--	--	--	--	--	197.042*	1566.965**	108.778^{ns}

Ns = no significant differences

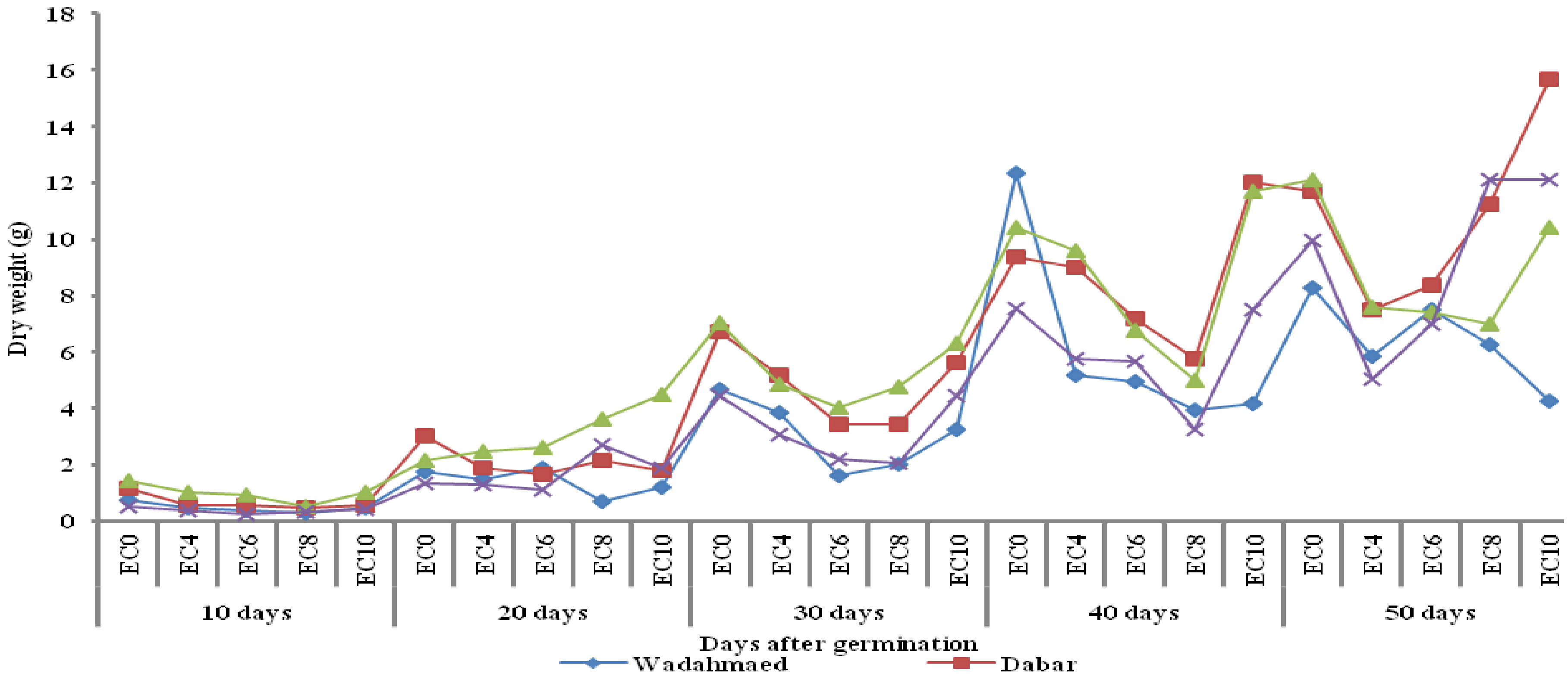
*, ** = significant differences at (0.05 and 0.01) respectively.



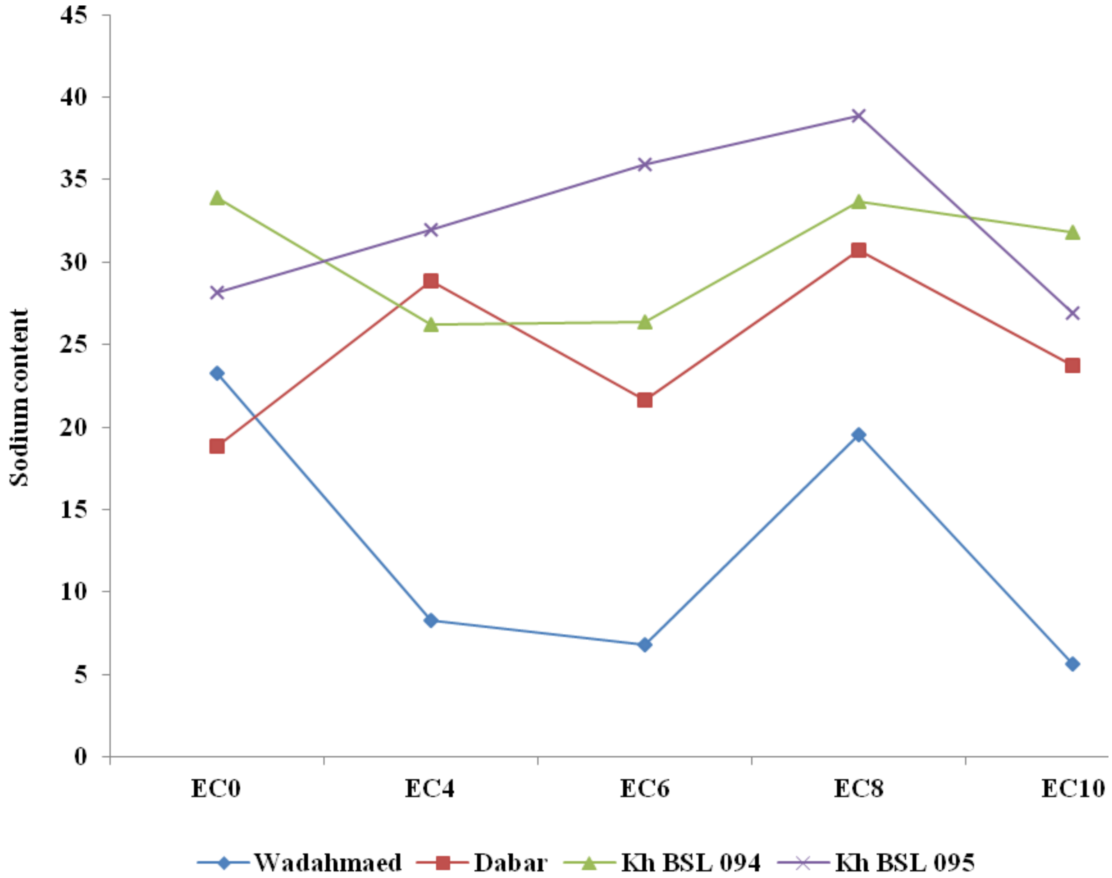
Appendix **(4): Performance of four sorghum genotypes under five salinity levels for germination percentage during season 2009/10 at Shambat.**



Appendix (5): Performance of four sorghum genotypes under five salinity levels for plant height during season 2009/10 at Shambat.



Appendix (6): **Performance of four sorghum genotypes under five salinity levels for plant dry weight during season 2009/10 at Shambat.**



Appendix (7): **Performance of four sorghum genotypes under five salinity levels for rate of sodium content during season 2009/10 at Shambat.**