Effect of dilution of Red Sea water on survival and seedling growth of two geographical sources in Sudan of *Acacia tortilis* sub species *tortilis*

By

Aicha Elbagir Hamoda Elbagir

B.Sc. (Honors), Faculty of Forestry

University of Khartoum

(2004)

Supervisor

Dr. Essam Eldin Ebrahim Warrag

A dissertation Submitted to the University of Khartoum in Partial fulfillment of the Requirements for M. Sc. Degree in Desertification

Desertification and Desert Cultivation Studies Institute, Faculty of Agriculture, University of Khartoum (DADCSI)

August 2009

بسم الله الرحمن الرحيم

قال تعالي:

(وفوق كل ذي علم عليم)

صدق الله العظيم

سورة يوسف – 76

DEDICATION

To the soul of my mother,

To my father,

To my dear brothers,

To my dear friends

I dedicate this work…

With endless love,

Aicha

ACKNOWLEDGEMENT

Thanks, gratitude and praise to the almighty Allah who gave me health, strength and patience to complete this work. I would like to express my gratitude and my sincere respect to my supervisor Dr. Esaam Warrag for his advices, interest, encouragement and unlimited support at all stages of this work. Thanks to family and colleagues for their gentle support.

Dr. Eltayeb Elhag Ali, Faculty of Agriculture, University of Khartoum and Prof. Mukhtar Ahmed Mustafa and Dr. mdawi Elobied are greatly acknowledged for their encouragement. My gratitude is extended to the UNESCO Chair for desertification Study, University of Khartoum for providing the necessary facilities for my research work. My thanks and appreciations are also extended to the Institute of Desertification and Desert Study, University of Khartoum, especially to Mohammed Abd Elbagy.

Deep gratitude and appreciation are also extended to the staff of the Faculty of Forestry, University of Khartoum. Mr. Nedal Alchker and others are greatly acknowledged for their encouragement and kind helps throughout the experimental period of this study.

List of Contents

LIST OF TABLES

List of Figures

Effect of dilution of Red Sea water on survival and seeding growth of two geographical sources in Sudan of *Acacia tortilis* sub species *tortilis*

By
Aicha Elbagir Hamoda Elbagir

ABSTRACT

Acacia tortilis is an important woody species in Sudan with regard to protection and production. Its distribution is limited to the northern, north-eastern and central Sudan. It tolerates salinity and drought stresses. The objective of this study is to investigate the tolerance *of A. tortilis* seedlings from two geographical sources to saline condition with regard to survival, mineral content and vegetative growth. Two geographical sources were selected as seed sources according to soil types (Rufaa and Port Sudan). The seeds were sown in silt loam soil on polyethylene bags and irrigated every two days. The irrigation water consists of five levels of salinity EC: (0.4 as control, 4, 8, 12 and 16dSm^{-1}) and survival, plant mineral content and vegetative growth were measured. The results showed that both sources can tolerate salinity but Port Sudan source had significantly higher survival percent, potassium content and growth values than Rufaa source. It was concluded that *A. tortilis,* from Port Sudan can be included in the Red Sea refforestation program.

Effect of dilution of Red Sea water on survival and seeding growth of two geographical sources in Sudan of *Acacia tortilis* sub species *tortilis*

By

Aicha Elbagir Hamoda Elbagir

المستخلص

الهدف من هذه الدراسة هو التحقق من مقاومة ***Acacia tortilis*** (أشجار السيال) المجموعة من موقعين جغرافيين مختلفين في ملوحة التربة بإعتبار الحياة ومحتويات المعادن والنمو الخضري .

تم اختيار الجور من موقعين جغرافيين مختلفين (رفاعة وبورتسودان)، تمت زراعة البذور في تربة سلكية في أكياس البولسين وتم ريها كل يومين ، ماء الري يكون من (5) مستويات ملوحة (4. شاهد، 4 ، 8 ، 12 ، 16 dSm^{-1}).

تم قياس محتويات المعادن والنمو الخضري ، أوضحت النتائج أن كلى الموقعين الجغرافيين مقاوم للملوحة . لكن البذور المجموعة من بورتسودان سجلت أعلى نسب حياة وأعلى نسب نمو وأعلى نسب بوتاسيوم من تلك المجموعة من رفاعة .

نخلص الي أن ***Acacia tortilis*** المجموعة من بورتسودان هي أفضل في عمليات إعادة إستزراع منطقة البحر الأحمر

CHAPTER ONE

INTRODUCTION

1.1 General Background

Desertification is defined as land degradation in arid, semi-arid and dry sub-humid areas, resulting from various factors including climate variation, and human activities (UNCCD 1994).The process of deterioration that can be measured by reduced productivity of desirable and undesirable plants. The principal desertification processes are degradation of vegetative cover, water erosion and water-logging (Mustafa 2007). According to Arab Organization for Agriculture Development (AOAD 2000) and others, desertification is considered as the most important environmental problem facing Sudan. Desertification affected about 13 Sudanese states at varying degrees. About 44 thousands km^2 are desertified, these area falls within the semi-desert zone, where the mean rainfall is about 300mm\ annum. However, (Salih 1996) estimated that the desert margin areas using NDVI maps cover an area of 307.000 km^2. Another problem is drought which is naturally occurring phenomenon that exists when precipitation has been significantly below normal recorded levels, causing serious hydrological imbalances that adversely affect land resource production system (Earth Summit 1992). Drought and rainfall fluctuation are causing desertification expansion (AOAD 2000). Vegetation degradation is the quantitative and\or qualitative degradation of the vegetation cover resulting from various factors including human induced activities and severe prolonged drought under poor land resource management. Under natural conditions, and in the ecosystems prone to desertification, plant cover varies from sparse or non-existent in the desert and the arid regions. Plants are more vulnerable to degradation in the drier part of the arid region than the wetter part.

Degradation of the vegetative cover exposes the surface of the land and makes it vulnerable to soil erosion (Mustafa 2007).

Salinization causes land degradation and thereby reduces the productive capacity of agricultural lands, forestlands, and rangelands, and thus, it is considered as a desertification process (Mustafa 2007).

Salinity is defined as increase of concentration of some mineral salts. It is determining factor of nutrient and water uptake by plant (Allen *et al*. 1994). Salinization is the increase of the total soluble salt concentration in the root zone of the soil profile. If salinization is not checked, it will result in the formation of saline soils, which are more extensive in the arid and semi-arid regions, particularly, in the coastal regions where the ingress of sea water through estuaries, sea mists and rivers and through ground water causes large-scale salinization.

The Red Sea State is characterized by an arid environment where good quality water is limited. The annual recharge of the ground water is limited and its quality is deteriorating due to limited rain fall (Osman *et al*. 2004).

The total area of the Red Sea state is 212.410km². Approximately 55% of this area is a range land, 42% is salt-affected and desertified land, and 3% is agricultural land. (Ministry of Agriculture and Animal Resources and Irrigation 2000).

1.2 Justifications

Salinity is regarded as the one of the main factors that contributes to desertification process and render about half of the land in arid and semi-arid and coastal regions (Kozolowski 1997) and this creates the need for reforestation in theses sites. The proper choice of adapted forest spices remains the most viable cost effective means of utilization of drought-affected lands. Planting of multipurpose drought tolerant tree species may offer an attractive alternative for economic utilization of drought-affected areas in the arid and semi-arid lands, to increase their productivity and to meet the increasing demands for fuel wood, timber and other indispensable forest products. Indigenous trees and shrubs suitable for multiple uses should have priority over fast-growing exotics, which exclusively yield timber.

Local trees and shrub are usually well adapted to tolerate climatic extremes, pests, diseases and traditional forms of land use.

Saline soils are known to exist every where throughout the world, particularly in arid and semi-arid part of the Sudan and the area appears to have been affected by excessive soluble salts and the rainfall is not adequate where *A. tortilis* is distributed naturally.

There is little literature on the tolerance of *A. tortilis* from different sources to salinity stress.

1.3 Research problems

Acacia tortilis is multipurpose tree that might resist desertification, drought and salinity in arid and semi-arid lands. Due to its tolerance to salinity and drought stresses (Archibold 1995).

Its survival and existence in the arid and semi-arid areas of northern Africa and Arabian Peninsula is due to its ability to endure harsh conditions and, therefore, it generally forms open pure stands or mixed stands in this dry land.

It is tolerant to nearly all soil types, but favors alkaline soils and can not withstand water logging (Elhouri 1982). It is capable of fixing nitrogen and can stabilize sand dune (Alstad 1994, Munzbergova 2002). It is distribution in arid and semi-arid regions in Sudan that are drought prone with saline soils suggest its tolerance to drought and salinity. However, the variation in the drought and salinity levels in the natural range of the Sudan suggests varying degrees of tolerance to drought and salinity.

1.4 Objectives

The main objective of this study: is to investigate the tolerance of the seedlings of *A. tortilis* to saline conditions. The specific objectives are to study:

1. Seedlings survival in five levels of salinity from two sources (Port Sudan and Rufaa).
2. Seedlings shoot and root growth in five levels of salinity from two sources.
3. Concentration of K and Na on seedlings in five from two sources.

CHAPTER TWO

LITRAETURE REVIEW

2.1 Salinization as a desertification process

Desertification is defined as land degradation in arid, semi-arid and dry sub-humid areas, resulting from various factors including climate variation, and human activities (UNCCD 1994). About 70 percent of dry lands used for agriculture are already degraded. More than 110 countries have land at risk of desertification (UNCCD 2003).

Salinization is the increase of total soluble salt concentration in the root zone of the soil profile. It can result in the formation of saline soils, which are more extensive in the arid and semi-arid regions. It can occur in the coastal regions by the ingress of sea water through estuaries, sea mists and rivers and through ground water. It causes land degradation and thereby reduces the productive capacity of agricultural lands, forestlands, and rangelands, and thus, it is considered as a desertification process (Mustafa 2007, FAO and UNEP 1984).

Large parts of the world are covered by arid and semi-arid regions. The main characteristic of the arid regions is that they have low erratic rainfall in which during the greater part of the year, precipitation is less than potential evapotranspiration (Salih 1996). This is the major reason for salinity in arid regions.

Salinization restricted about the third of the world's land and renders about half of the land in semi-arid and coastal regions barren and unsuitable for many crop yield (Kozolowski 1997).

2.2 Saline soils

Saline soils are defined as those having an electrical conductivity of the saturation extract (ECe) greater than 4dSm^{-1} and an exchangeable sodium percentage (ESP) less than 15% The pH of saturated soil paste of non-calcareous soil is usually less than 8.5. However, it may increase sometimes to reach 10. The harmful effect on plants is caused by decreasing the osmotic potential of soil water, and through toxicity of specific ions mainly Na,Cl, (Abrol *et al.* 1998). However, irrigation water having appreciable salt concentration contributes to secondary soil salinity (Doneen 1967). The total concentration of soluble salts can be adequately expressed for purposes of diagnosis and classification in term of electrical conductivity.

The soil solution of non-saline-alkali soil, although relatively low in soluble salts, has a composition that differs considerably from that of normal and saline soils. While the anions present consist mostly of chloride, sulphate and carbonate, small amounts of carbonate often occur. At the high pH reading, in presence of carbonate ions, calcium and magnesium are precipitated; hence, the soil solution of non-saline-alkali soils usually contains only small amount of these cations. Sodium being the predominant one, large quantities of exchangeable and soluble potassium may occur in some of these soils (Allen *et al*. 1994).

Sodic soils are defined as those whose ESP is greater than 15 and in which the conductivity of saturation extract is less than four dsm^{-1}. The pH of these soils usually ranges between 8.5 and 10 due to hydrolysis of adsorbed sodium in absence of electrolytes in the soil solution. These soils are dispersed, have poor aeration, and permeability of soil to water is therefore restricted (Allen *et al.* 1994).

2.3 Red Sea Environment

2.3.1 The area

The Red Sea is a narrow elongated body of water running

NNN-SSE (directions) between the landmasses of Africa and Arabia (Morocs 1970). It extends southeast northwest between 12°N, 43°and 30°N, 32°E (PERSGA 2001). It branches at its northern end into the Gulf of Suez and Agaba while, in the south, it meets Gulf of Aden and Indian Ocean (Morocs 1970). The Red Sea is approximately 2000Km long and is about 280 Km across at its widest point. It has total surface area of 440000 Km^2 (PERSGA 2003).

The coast of Red Sea extends through a vast area of desert and semi-desert land called Tohama (PERSGA 2003). Typically bounded by narrow (1-50Km) coast strip, backed by high hill which rise to 3000m in some regions (Cox 1931).

Maritime salt marches are chiefly dominated by mangrove species, the most important of which are *Avicenna marina and Rhizophora mucronara* (Chapman 1970).

2.3.2 Ecosystem

The Red Sea is a unique tropical marine system, which is characterized by highly diversified rich and varying fauna and flora. This ecosystem is exposed to extreme natural influences: intensive sun irradiation, constant hot winds, and subsequent highly evapo-transpiration with negligible inflow (Abu Gideiri 1984). (Klausewitz 1964) suggested that during its long period of isolation, the Red Sea must have dried up sufficiently for its entire previous fauna to have been lost .This time of drying may have given rise to the extensive evaporated deposits that provide potential source of exploitable mineral deposits in the region.

The vegetation cover is scattered, and the state is dominated by Acacia sps. mainly *Acacia tortilis* (Smar), *Meerua crassifalia* (Sarah), *Leptadenia pyrotechina* (Marakh), *Salvadoora persica* (Arak), *Capparis desidua* (Tundub), *Zizphus spina christi* (Sidir), *Calotropis* *procera* (Usher), *Acacia nubica* (Laot), *Hyphaena thebica* (Dom), *Blanites aegyptica* (Heglig), *Tamarix aphylla* (Tarfa) and *Prospis chilensis* (Meskeet) (Basher 1998).

2.3.3 Climate

In the northern Red Sea, the prevailing wind direction is NNW during winter and southerly winds that blow during summer. In the southern Red Sea (south of 20° N) the prevailing wind direction in the summer is northerly whilst in the winter is SSE (UNEP 1985).

The warm east zone of the Red Sea is between 20° N and 16° N. The shores of the Gulf of Aden are considered to be among the hottest regions of the world.

Rainfall throughout the Red Sea is very low and subject to great variations from year to year (UNEP 1985).

2.4 Salinity stress

Salinity which is defined as increase of concentration of some mineral nutrients is determining factor in nutrient uptake and water by plants. Saline soil is abundant in arid and semi- arid regions where rainfall is not sufficient for substantial leaching of salt.

A wide spread factor restricting growth in many temperate regions is soil salinity. Millions of acres have gone out of production. Many factors interact with salinity, and this complicates studies on the effects of salinity (Allen *et al*. 1994).

2.5 Effect of stresses on plant

All plants are subjected to a multitude of stresses throughout their live cycle. Depending on the species of the plant and the source of the stress, the plant responds in to different ways.

The one of the environmental factor that currently reduces plant productivity is salinity (Zekri 1993). Salt stress can be a major challenge to plants. It limits agriculture all over the world. As more lands become a salnized due to poor irrigation practices, the impact of salinity become more important (Wincov 1998).

2.6 Effect of salinity on woody plants

2.6.1 Injury

Salinity adversely affects plant by inducing injury, inhibiting growth, altering in plants morphology and anatomy, often being a prelude to tree mortality (Kozlowski and Pullardy 1997). Injury is more sever when salts absorbed from the soil are augmented by salts include stunted growth and reduced yields. All parts of the plant including leaves, stems, roots and fruits, maybe reduced in size. The signs and symptoms displayed by deciduous and broad-leaved trees and shrubs in dude leaf necrosis (death), marginal leaf of needle bum, leaf drop and eventual plant death. Entire leaves can be affected and drop prematurely. Buds may fail to open or grow and branches may die. Some times deciduous trees may exhibit early fall color and leaf drop. Salt damage on evergreen trees and shrubs usually first appears in late winter to early spring and becomes more extensive during the growing season. In extreme situations, trees and shrubs will die due to saline soil damage (Volkmar et al. 1998).

2.6.2 Seed germination

To both non halophytes and halophytes, salinity reduces the total number of seeds germination and postpones initiation of germination process; however, within each group the responses are variable and related to the specific species. Salinity influences seed germination primarily by lowering the osmotic potential of the soil solution sufficiently to retard water absorption by seeds, but also by toxicity to the embryo (Zekri 1993). Seeds of many halophytes accumulate less than 10% of the ionic content present in shoots, indicating that they process a mechanism for preventing excess ion accumulation in the embryo (Wamgwattana et al. 1998).

2.6.3 Vegetative growth

Salinity reduces vegetative and reproductive growth of non halophytes. Combined flooding and salinity typically decrease growth and survival more than stress alone (Noble and Rogers 1994).

2.7 Tolerance and plant Adaptation to the salinity stress

The response of plants to salt stress is based on the transcriptional action of many defense proteins, and research has not discovered the basis for them all (Serrano et al 1999).

There is a wide spectrum of salinity tolerance among higher plants (Robinson *et al*. 1997).

The plant is dividing to salinity living to the following:

1- Halophytes; can grow in sodium retch to (200-250) mM while normal plants can grow in less than, (50) mM.

2- The plants regulator of salt are keep low levels of ion in their leave, by reducing the trans location of ion to their shoot, also allowing the salt build up out side the cells to the inter cellular space or salt gland.

3- The plant accumulation of salt their have several tissue tolerance occurs when ion have already accumulated salt in the tissue compartment into the vacuoles for storage (Allen *et al.* 1994).

4- Glycophtes these are who have plants morphological features in their root. There are two mechanisms this can be done through the passive exclusion of ion by a permeable membrane, the active expelling of ions by ion pumps, or by dilution of ions in the tissue of the plant (Allen *et al*. 1994).

In other hand means of salt stress damage is found in relation to potassium within cell. Due to the similar structures of sodium and potassium, the competition for binding sites causes potassium deficiency within the cell (Maathius and Amtmann 1999).

2.7.1 Plant tolerance to salinity

Plants differ in their response to excessive salts and to specific ions. In addition, crops that are sensitive at an early growth stage may be tolerant during another stage, (Carter and Fanning 1964). Generally, established plants are usually more tolerant to salinity than at germination or early seeding stage (Bernestien 1964; AL-Jaloud and Hussain 2004). Salinization results generally delayed seed germination (Unger 1991; Zekri, M. 1993 and ELnour *et al*. 2006). These workers found that, high NaCl concentration reduced growth of plant of all species, which broadly match result obtained by (Gale *and Mayber*1970; Kelly *et al*. 1982; Glenn and Leary 1984; Gorham 1996; Harrouni *et al*. 2001; Daoud *et al*. 2001). Iranians farmers' application of brackish water resulted in decreased relative yields, which decrease with increase of water salinity (Alizadeh *et al*. 2004).

Studying climatic conditions interaction with salinity (Gale *and Mayber* 1970) found that plants were taller in humid chamber than in dry chamber. Plant in the dry chamber were, however, much leafier than those in the humid chamber, and the dry weight ratio of leaves of plant in the dry chamber was greater than that of the humid chamber. Meiru and Mayber 1970) showed that the leaf area of bean plants growing in Nacl salinized substrate decreased, but the juvenile the leaf, the less was the effect of salinity.

Adaptation mechanism to salt stress.

2.7.1.1 Salt Avoidance

2.7.1.1.1 Exclusion

In the case of plants possessing the exclusion mechanism, the root may show impermeability to salts up to a point, followed by a burst of salt causing poisoning and sometimes death. This mechanism depends on a balance between monovalant (K^+ and Na^+) and divalent (mainly Ca^{++}) captions (Levitt 1980; Fawzi and Abdullah 2006).

When this balance is disturbed by too high concentration of monovalant cations, permeability increases, leading to injury. Therefore, a plant with salt avoidance due to exclusion must possess a low permeability for Na salts even in the presence of relatively high salt concentration. This perhaps explains discovery of halophytes that remain alive after drying upon a solution of pure NaCl, yet that die in a relatively weak Ca solution. Glycophytes showed a reverse behavior. The salt excluding cell may maintain the normal balance in presence of high preferential adsorption of Ca^{++} on the plasma membrane (Levitt 1980; Fawzi and Abdulla. 2006).

Some plants of intermediate salt resistance may succeed in excluding the salt only from the shoot. A large part of the Na^+ absorbed by their roots is retained in the root cells and accumulates in the vacuoles of the root cells. In these cases, the regulatory system may occur within the roots, preventing the translocation of the salts, rather than at the root surface where absorption is prevented. Avoidance of salt injury by salt exclusion is dependent on temperature (Levitt 1980; Fawzi and Abdullah 2006).

2.7.1.1.2 Extrusion

More salt-resistant wild species of the glycophytes posses' agland- like extrusion system. Sensitive glycophyes reabsorbed salts from the xylem sap in the mature region of the root.

Salt tolerant appeared to be due to exclusion of salt from the Photosynthetic cells or organelles and to the ability of the resistant patterns to exclusion even thought reactions were dead (Levitt 1980; Fawzi and Abdullah 2006).

2.7.1.1.3 Dilution

Due to the growth, water absorption in a sufficient amount to prevent an increase in concentration. This dilution of the cells sap due to growth has also been found in some moderately salt resistant species (Hall 1976; Levitt 1980) .

Salt sensitive adjust osmotic stress as a result of a rapid growth response and consequent increase in plant water content. And in wild resistant species close their stomata which lead to dilution. Halophytes avoid the increase in concentration by an increase in succulence. The cells (especially the parenchyma) enlarge due to an increase in water content, which prevents an excessive concentration of salts in the cell sap.

2.7.1.2 Tolerance

2.7.1.2.1 Osmoregulation

This is a process of maintaining cell turgor by a sufficient increase in cell solutes to compensate for external osmotic stress since the cell membrane is freely permeable to water, it is not possible for a plant growing in aqueous medium to avoid the osmotic stress of their urrounding (Gorham 1995). The first response to salinity is, therefore, a less of turgor and it less is reverse enough, less the ability, and tolerance can be of two types:

a- Dehydration avoidance:

Permit dehydration of the cell, return of the cell turgor and recommencement of cell growth (Chaves 1991).

b- Dehydration tolerance:

Some plants survive by the loss of turgor but maintain cells in a non growing state (Francois and Clark 1978; Dobson 1991; Matheny and Clark 1999).

2.7.1.2.2 Tolerance of indirect strain

Toxic, growth and enzyme tolerance if the indirect strain that-injuries the salt sensitive plant is due to a toxic product, salt tolerance could be to an ability to metabolize those toxics, this substances do not appear to toxic non halophytes.

Salt stress inhibits the activities of some enzymes and stimulates others, particularly hydrolass.

Tolerance due to avoidance of metabolic disturbance has been explained by an enzyme tolerance or even requirement of high salt concentration in obligate halophytes.

There is quite some literature available classifying tree\ shrub species according to their sensitivity to salt (Francois and Clark 1978; Dobson 1991; Matheny and Clark 1999).

2.8 *Acacia tortilis*

Acacia tortilis is a drought-resistant species. Its survival and existence in the arid and semi-arid areas of northern Africa and Arabian peninsula is due to its ability to endure the harsh condition and, therefore, it generally forms open pure stands or mixed stands in these dry lands. Wherever it grows its plays an important role in human, animal and other plant species lives (Archibold 1995).

Acacia tortilis is one of the most important Sudanese woody species; both regarding production and protection (i.e. shade for men and animals). It is a major source of fodder for livestock (goats and camels), fuel wood, charcoal and construction material for the local inhabitants. It is also used as shelter belt around villages and crops, and for sand stabilization and dune fixation in many countries including Libya and the Sudan (Jackson *and* Shawki 1950; Turi 1982; Ahlcrona 1988; Armborg 1988). *Acacia tortilis* is an African (Sahelo-Sudanian) element (Ross 1981). The species occurs abundantly in all northern and eastern African countries and extends eastward to the Arabian Peninsula and southward to southern Africa (Sahni 1968; El Amin 1972; Brenan 1983). In the Sudan the species is ripersented by three subspecies, *A. tortilis* ssp. *tortilis* (Forsk.) Hayne; *A. tortilis* gradual transitions are regularly found, it is difficult to collect data on the sub - specific level. Hence, we will deal here with *A. tortilis* on the species level only. In the Sudan the distribution of *A. tortilis* is limited to the central, northern and north-eastern regions. It occurs mostly in the first two, northern zones of the bio-climatic zonation distinguished in the Sudan (Harrison *and* Jackson 1958; Sahni 1968). This zonation is mainly determined by the pattern of rainfall, both total amount and seasonal distribution, and the pattern of soil types. It includes from north to south: Desert (rainfall < 75 mm / yr), Semi-desert (75 - 300 mm / yr), Woodland savanna (300 - 800 mm / yr). Montane vegetation and Riverine vegetation. The boundary between the Desert and Semi-desert, here established at 75 mm / yr, has been taken as 100 mm / yr for northern Africa (Le Houerou 1986), though more generally as 120 mm / yr (Shmida 1986). *A. tortilis* occurs in a variety of habitats. In the Desert and Semi-desert zones it is usually restricted to wadis (seasonal water courses) and sites receiving run-off (El Amin 1976; Ayyad *and* Ghabbour 1986). However, in areas receiving > 150 mm / yr it is also found outside the wadis. Generally, ssp. *tortilis* and ssp. *spirocarpa* dominate runnels and small wadis, while ssp. *raddiana* predominates in the larger wadis. *A. tortilis* is generally indifferent to soil type when growing in wadis.

It is tolerant to nearly all soil type but favors alkaline soils and can not withstand water logging (Elhori 1982). It is capable of fixing nitrogen and can stabilize sand dunes ((Alstad et al. 1994 and Munzbergova 2002), powered by hydraulic lift, controlled by its deep-rooting system, it can extract water from deep resources and thrives where other co-existing plants failed to perform (Ludwig et al. 2003).

CHAPTER THREE

MATERIALS AND METHODS

3.1 Seed Source

Seeds of *A. tortilis* were collected from two sites that differ in soil type: Rufaa site (Umjalfa forest), Geizera state and Red sea site (Hoshery shrub land), Red Sea State. The soil of each site was analyzed where soil samples were collected from 0-30 cm soil depth. Soil samples were taken from three different positions in the forest: A, B and C. The first position was the nearest side of the forest to the village (A). Position B was the central part of the forest and C was the distant part of the forest.

The soil samples were air-dried and sieved through a 2 mm sieve and thoroughly mixed then analyzed. A soil paste was made by adding distilled water to 250 g air-dry soil. The paste was left overnight and then extracted by a suction unit using Buchner funnel equipped with filter paper (Whatman No. 42). The soil pH was determined by a pH meter and electrical conductivity (EC) of the soil paste extract was measured using EC- meter, model no. (c851)

3.2 Nursery arrangement

Seedlings were raised on soil that contains a mixture of equal ratio of silt and sand media filled in polyethylene bags (20 ×10 cm). The soil was analyzed before irrigation for ECe, pH, and the content of Ca, Mg, Na and K. Tables (3.2) below shows the pH and ECe in the saturated soil paste and soil paste extract which were performed according to (Richard *et al*. 1969).

Table 3.1: Soil properties of the two selected sites

Site	ECe (dSm^{-1})	PH	Percentage of Ca + Mg(mq/L)
Rufaa (A)	0.81	7.1	1.5
Rufaa (B)	0.69	6.63	2.3
Rufaa (C)	0.741	6.43	1.3
Port Sudan (A)	3.43	7.56	4.2
Port Sudan (B)	3. 81	8.90	3.5
Port Sudan (C)	4.4	7.80	2.9

Table 3.2: The main chemical properties of the soil media used for growing *A. tortilis* seedlings

PH	ECe dSm^{-1}	Ca Meq/l	Mg (Meq/l)	Na (Meq/l)	K (Meq/l)
7.36	0.0453	1	1.2	0.4	0.092

3.3Irrigation treatments

Water treatments were applied to the seeds in the polythene bags starting from the first day of sowing. The treatment consisted of 5 levels of dilutions of Red Sea water with fresh water having the five values of EC. Tap water was used as control (the first level). Water from the Red sea was adjusted to four levels of EC. Sea water was analyzed for determination of cations, anions, and EC before adjustments. Table 3.3 shows analysis of cations of both soil and Sea water. Analysis of Ca and Mg was done by Versenate methods according to (Chen and Bray 1951 and Diehl *et al*. 1950). Na and K were determined by flame photometer and soil soluble anions.

Red Sea water was mixed with freshwater (EC 0.4 dsm^{-1}) to get four levels of salinity for irrigation (4, 8, 12 and 16dsm^{-1}). The EC of mixed Red Sea with fresh water was measured by EC-meter and also according to formula given by (Richard et al. 1969) as follows:

$$EC_M = \frac{(EC.V)_S + (EC.V)_F}{V_S + V_F}$$

Where:

EC_M = EC of mixed sea water with fresh water

V_s & EC_s= Volume and electrical conductivity of sea water

V_F & EC_F = Volume and electrical conductivity of fresh water

The treatments were applied by mixing tap water with sea water with the ratios of 1: 14.7, 1: 6.5, 1: 3.9 and 1: 2.6 sea: tap water to give the corresponding EC of 4, 8, 12 and 16 dSm^{-1}, respectively.

Table 3.3 Main chemical properties of the Red Sea water

Cations (mg/l)					Anions (meq/l)				EC dSm^{-1}
Na	**Ca**	**Mg**	**K**	**T.D.S**	**Cl**	**CO_3**	**HCO_3**	**SO_4**	
653	28	121	138.1	922.1	835	-	14.7	72.4	57

3.4 Seedling establishment

The experiment was carried out in the nursery with 50% shade from June – October 2008. Five levels of water were applied to *Acacia tortills* seeds from two sources (Rufaa and Port Sudan) in a completely randomized design with ten seedlings per treatment and site giving a total of 100 experimental units. The seeds were treated to break seed coat dormancy by H_2SO_4 98% then washed with water and planted. Seedlings were irrigated daily during the first week and thereafter irrigation was performed every two days.

3.5 Data collection

The growth performance of the Seedlings was monitored by taking regular measurements every week of plant shoot height using a ruler, stem diameter using verneyer at the middle of the stem and the number of leaves. The growth parameters were determined using three selected seedlings per treatment and site. Growth measurements started one month after sowing and continued for three months. Assessment of survival was recorded every week by counting the number of living plants.

At harvest, each plant was separated into shoot and root. The shoot of each plant was further separated into leaves and stem. The fresh mass of each plant fraction was determined. For determination of the dry mass, all plant fractions were oven-dried at 60 -70°C for 72

h. A third soil analysis was performed following harvest.

The five levels of saline water applied to Rufaa seedling (R1, R2, R3, R4 and R5) and those applied to Port Sudan seedlings (P1, P2, P3, P4 and P5) were indicated with pH, ECe and the mineral content.

Table 3.4: Soil chemical properties after harvesting of seedlings of *A. tortilis* from Rufaa (R) and Port Sudan (P) sites

Sample	pH	ECe dSm^{-1}	Ca Meq\l	Ca + Mg Meq\l	Mineral%		
					Mg	Na	K
R0.4 dSm^{-1}	7.47	0.104	2.4	4.2	1.8	1.80	0.095
R 4 dSm^{-1}	6.96	0.210	34.4	50.6	16.2	70.43	0.49
R 8 dSm^{-1}	6.80	0.443	55.2	87.2	32	120.00	0.85
R 12 dSm^{-1}	6.95	0.280	25	47.4	22.4	95.86	0.67
R 16 dSm^{-1}	7.00	0.640	29.6	70.4	40.8	265.65	1.64
P 0.4dSm^{-1}	7.40	0.144	2.8	6.8	4	3.26	0.12
P 4dSm^{-1}	6.95	0.213	36.7	55.8	19.6	71.74	0.44
P 8 dSm^{-1}	6.90	0.441	33.2	60.0	26.8	321.25	2.08
P 12 dSm^{-1}	6.93	0.605	18.4	32.8	14.4	123.91	0.83
P16 dSm^{-1}	7.02	0.487	24.6	50.4	25.8	168.69	1.026

3.6 Plants chemical analysis

The whole plant was used for the determination of plant chemical analysis including K and Na content by the dry ashing procedure after (Chapman and Pratt 1961) with minor modifications. A portion of plant material was weighed (200 g) in 50 ml pyrex glass beaker, and then placed into a cool muffle furnace and was increased the temperature gradually to 550°C, then the muffle furnace was shut off and the door was carefully opened for cooling.

After cooling the beaker was taken out and the cool ash was dissolved in 5 ml portions 2 N HCl and mixed with a plastic rod. After 20 minutes, the volume was adjusted to 50 ml using distilled water, and mixed thoroughly. The mixture was allowed to stand for 30 minutes. K and Na contents were measured by the flame photometry.

3.7 Statistical analysis

Data were analyzed by the statistical programme SAS (SAS institute Inc., Cary, North Carolina, USA). Differences between means were considered significant at ($P \leq 0.05$).

CHAPTER FOUR

RESULTS AND DISCUSSION

The present study aimed to investigate the tolerance of *A. tortilis* seedlings from two sites in Sudan (Port Sudan and Rufaa) to salt stress. To this end, survival and the plant growth performance were evaluated. In addition, the mineral content was analyzed in the soil and plant tissues.

4.1 Germination

4.2 Survival

Survival percentage was 100% for Port Sudan seedlings during the first two months for all dilution treatments. However, survival dropped during the last two months for the seedlings that received the highest salt concentrations (Figure 4.1).

On the other hand, the survival of Rufaa seedlings was not affected for the control EC 0.4dSm^{-1} and those treated with EC 4 dSm^{-1}. In contrast, survival of the seedlings was observed to be decreasing with increasing the salt concentration. The most remarkable effects were evident in the seedlings which were treated with the highest salt concentration, (16dSm$^{-1)}$ where survival was reduced 80% and 40% during the first month and the 4th month, respectively Figure (4.2). These results indicated that Ruffaa seedlings were more sensitive to salt stress than those from Port Sudan (Figure 4.3).

The analysis of survival showed that *A. tortilis* seedlings from Port Sudan were more tolerant than Rufaa seedlings to saline conditions. Due to the fact that Port Sudan soil is more saline than that of Rufaa (Table 3.1), it could be speculated that Port Sudan seedlings had better adaptation to salinity. This adaptation could be via various salt tolerance or salt avoidance or both.

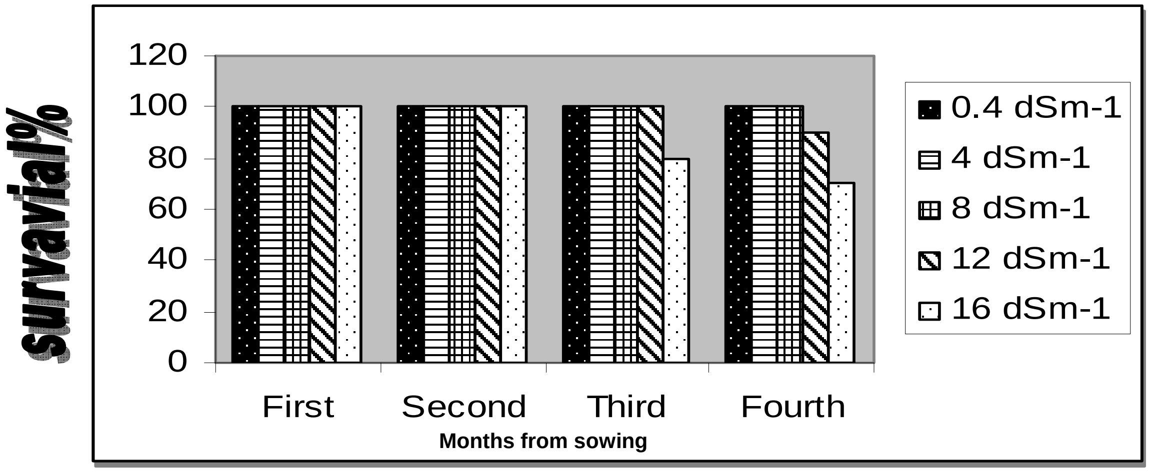
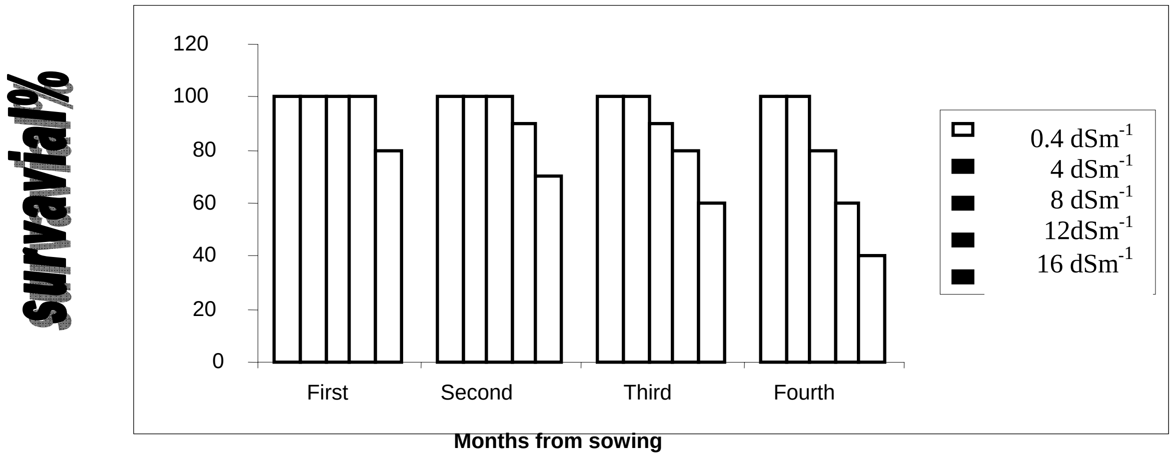


Fig. 4.1: Survival of *A. tortilis* seedlings planted by seeds collected from Port Sudan and exposed to five salinity levels**.**



Fig, 4.2: Survival of *A. tortilis* seedlings planted by seeds collected foRufaa seedlings treated with five salinity levels.

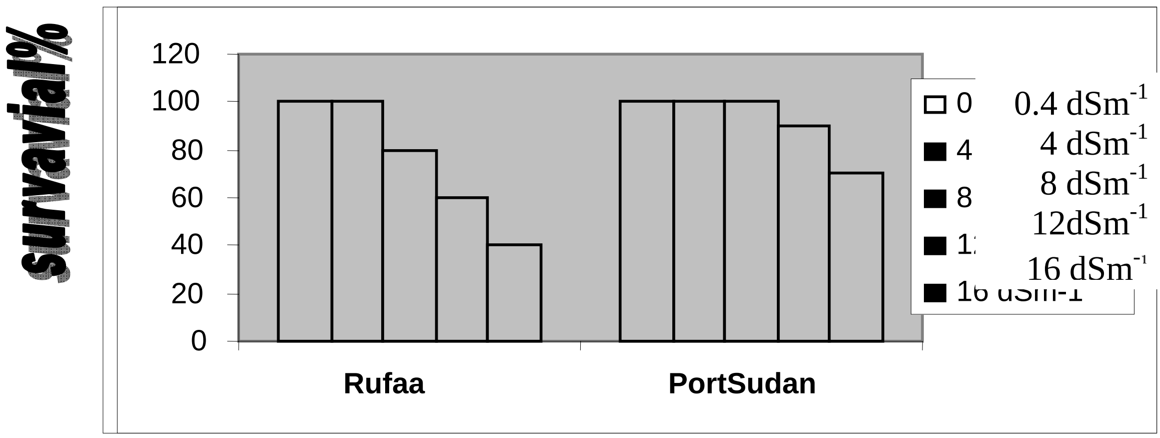


Fig. 4.3: Comparison of survival between Rufaa and Port Sudan's *A. tortilis* seedlings during the last month of the experiment.

4.2 Growth

4.2.1 Diameter

The diameter of *A. tortilis seedlings* growth was significantly reduced at the age of 3 months for Port Sudan seedlings. The diameter decreased with increasing salinity (Table 4.1). Although no effect of salt treatment was detected in Rufaa seedlings at the beginning of the treatment, after 3 months seedlings attained greater increment in diameter growth than those of Port Sudan. The comparison of the EC of the two source soil revealed no effect of salinity on seedling diameter growth (Table 4.2).

4.2.2 Height

Exposure to salt treatment caused early (6week after sowing) reduction in height growth in Port Sudan seedlings. However, Rufaa seedlings exhibited late response (8 weeks). These observations indicated that Rufaa seedlings were less sensitive to salt treatment. The data showed further that increasing the salt concentration was associated with decreasing in plant shoot height (Table 4.3).

Salt stress treatment caused reduction in height growth of the seedling for Rufaa site which was observed two months after sowing. The same response was also observed for Port Sudan seedlings. It was also observed that the height growth was decreasing with increasing of water EC (Table 4.4).

Table 4.1: Effect of salinity levels on diameter of *A. tortilis seedlings* for Rufaa and Port Sudan seedlings exposed to 5 salinity levels.

Electrical Conductivity (dSm$^{-1)}$	**Diameter (cm)**	
	Rufaa	**Port Sudan**
0.4	0.13	0.13 A
4.0	0.13	0.13 A B
8.0	0.13	0.12AB
12.0	0.12	0.12 B
16.0	0.12	0.12 B
P value	0.87	0.028*

Means with the same letters in the same columns were not significantly different at 0.05 level

Table 4.2 Effect of salinity levels on the diameter of *A. tortilis seedlings* from Rufaa and Port Sudan**.**

Electrical conductivity (dSm^{-1})	**Diameter (cm)**		***P value***
	Port Sudan	**Rufaa**	
0.4	0.13	0.12	0.37
4	0.13	0.13	1.00
8	0.13	0.12	0.12
12	0.12	0.12	0.37
16	0.12	0.12	1.00

Table 4.3

Table 4.4

During the 4th week of the last month of dilution treatment Rufaa seedlings showed reduction in their height growth compared to Port Sudan (Table 4.5).

4.2.3Comparison between the two sites

The comparison between the two sites at the first level of dilution treatment (EC 0.4) showed significant variation in the height growth at the second week of measurements. This variation was also observed during the 8th week and persisted till the end of the experiment.

Table 4.6 shows the effect of the first salinity level (0.4dSm^{-1}) on seedling shoot height from Rufaa and Port Sudan sites during the measurements period which lasted three between the sources. The numbers (1 to 12) indicate weeks of measurements. Data are presented as means. A Significant differences between the means is indicated by ($P<0.05$).

The comparison of shoot height showed variations between the two sites at the second level (EC 4dSm^{-1}) of dilution treatment. These variations were observed during the last two months of measurements (Table 4.7).

The comparison of shoot height showed variations between the two sites at the third level (EC 8dSm^{-1}) of saline treatment. These variations were observed during the last month of measurements (Table 4.8).

The comparison of shoot height showed variations between the two sites at the fourth level (EC 12dSm^{-1}) of saline treatment. These variations were observed during the last months of measurements (Table 4.9).

Table 6

Table 7

Table 8

Table 9

The comparison of shoot height showed variations between the two sites at the last level (EC 16dSm^{-1}) of salt treatment. These variations were observed during the last two months of measurements Table (4.10)

Survival and growth data showed that Port Sudan seedlings were more tolerant to salinity conditions than Rufaa seedlings. The inhibitory effect of high dilution treatment on seedlings growth could be attributed to perturbations in metabolic functions in the plant including decreased photosynthetic rate and alterations in enzymatic activity. High ionic content on photosynthetic efficiency can lead to reducing stomatal conductance and diversion of resources to osmotica.

The present study showed that the growth of *A. tortilis* seedlings from both sources was affected by increasing salinity stress. However, *A. tortilis* seedlings from Port Sudan showed better tolerance to salinity than those from Rufaa. Thus, Port Sudan seedlings are likely more suitable to saline conditions.

The present results are in accordance with (Maynard *et al*. 1997) who studied the growth of spruce (*Picea glauca*) under saline water (EC of 0, 0.5, 1.0, 1.7 and 3.1 dSm^{-1}) condition. Their results indicated that the growth decreased to 50% in the 0.5dSm^{-1} treatment compared with control. (El-Settawy and El-Gamal 2003) studies the effect of salinity at 0, 1.5 and 10 mg Nacl/g soil on *Casuarina glauce* seedlings and found that plant height, stem diameter, total dry mater were decreased by increasing salinity stress. These findings support the present results.

Table 10

4.3 Biomass

4.3.1 Fresh mass

No variation was observed in all biomass elements (total fresh mass, shoot fresh mass, and root fresh mass) of the seedlings from the two sites. However, salt treatment caused significant reduction in leaf fresh mass for the two sites and the highest salinity was associated with the lowest fresh mass.

Although Rufaa source attained higher mean of weight parameters on the three first EC (0.4, 4, 8 dsm^{-1},), but in EC (12, 16 dsm^{-1}) Port Sudan attained the highest mean (Table 4.11, 4.12). That proves *A. tortilis*, in general, is suitable to use in arid regions, but the seeds that collected from saline sites is more adapted and tolerated to high concentration levels of salinity EC (12, 16) dSm^{-1}.

The effect of salt stress was significant on leaf fresh mass. Salinity inhibited the vegetative growth with a consequent reduction in shoot growth.

4.3.2 Total dry mass

Salt stress treatment caused significant reduction in the total dry mass for Port Sudan seedlings. The lowest total dry mass was found in seedlings that received the highest level of salinity. It was observed that Port Sudan seedlings exhibited greater total plant dry mass under the highest salt treatments (12 and 16 dSm^{-1}) compared to Rufaa seedlings (Table 4.13).

Reduction in dry mass is due to increasing accumulation of salts in the plant tissues.

Table 4.11: Effect of salinity levels on *A. tortilis* seedling weight parameters from Rufaa and Port Sudan sources.

Electrical conductivity (dSm^{-1})	Total fresh weight		Leave fresh weight		Shoot fresh weight		Root fresh weight	
	Rufaa	Port Sudan	Rufaa	Port Sudan	Rufaa	Port Sudan	Rufaa	Port Sudan
0.4	0.67	0.61	0.16^{A}	0.14^{A}	0.27	0.30	0.23	0.16
4	0.56	0.55	0.16^{B}	0.14^{A}	0.23	0.25	0.19	0.15
8	0.56	0.54	0.12^{B}	0.13^{A}	0.18	0.23	0.18	0.15
12	0.42	0.52	0.06^{B}	0.12^{b}	0.17	0.23	0.17	0.14
16	0.41	0.46	0.00^{A}	0.04^{C}	0.12	0.17	0.16	0.13
P value	0.49	0.12	0.037^{*}	0.02^{*}	0.23	0.07	0.70	0.0

Means with the same letters in the same column were not significantly different at 0.05 level

Table 4.12: Effect of salinity levels on *A. tortilis* seedling means of mass parameters (g)/plant from Rufaa and Port Sudan sources.

level	Geographical sources	Fresh weight(g)			
		Total	**Leave**	**Shoot**	**Root**
0.4 dSm^{-1}	Port Sudan	0.64	0.14	0.3	0.13
	Rufaa	0.66	0.56	0.27	0.18
	***P** value*	0.91	0.17	0.61	0.31
4 dSm^{-1}2	Port Sudan	0.52	0.13	0.25	0.15
	Rufaa	0.69	0.16	0.23	0.23
	***P** value*	0.09	0.51	0.38	0.11
8 dSm^{-1}3	Port Sudan	0.54	0.12	0.23	0.15
	Rufaa	0.41	0.12	0.18	0.16
	***P** value*	0.14	0.91	0.54	0.39
12 dSm^{-1}4	Port Sudan	0.55	A0.14	0.24	0.19
	Rufaa	0.59	A0.11	0.17	0.16
	***P** value*	0.88	0.05*	0.19	0.63
16 dSm^{-1}5	Port Sudan	0.74	0.04	0.17	0.15
	Rufaa m	0.42	0	0.12	0.17
	***P** value*	0.78	0.17	0.31	0.7

Means with the same letters in the same column and salinity level were not significantly different at 0.05 level

Table 4.13: Effect of salinity on *A. tortilis* seedlings dry mass from Rufaa and Port Sudan sites.

Electrical Conductivity (dSm^{-1})	**Dry mass (g)**	
	Rufaa	**Port Sudan**
0.4	0.42	0.35A
4.0	0.37	0.30A
8.0	0.37	0.29A
12.0	0.19	0.28B
16.0	0.18	0.19B
P value	0.08	0.01**

Means with the same letters in the same column were not significantly different at 0.05 level

4.4 Minerals concentration in plant tissue

In Port Sudan seedlings significant variations were observed between the control seedlings compared to any of the other dilution treatments. The same results were found in Rufaa for Na. The highest salinity associated with lowest Na%

The comparisons between the two sites revealed that there was no variation in the minerals content in the control relative to any of the other levels per site.

Trends in the distribution of ions were similar for several salts halophytes and mangroves (Jefferies *et al*. 1979; Nadioo 1985; Slim *et al*. 1996). In general, salinity reduces plant growth by limiting water and nutrient uptake and salt ion toxicity. Salinity stress was found to reduce cell elongation by diverting energy to sustain osmotic adjustment (Volkmar *et al*. 1998). In another study, it was found that the main ions in Red Sea water were Na and Cl, which are known to be toxic for some fruit trees (Ahmed 2007).

Table 4.14 Effect of salinity levels on *A. tortilis* seedling dry mass from Rufaa and Port Sudan sites.

Level	Site	Total Dry mass (g/plant)
0.4 dSm^{-1}	Port Sudan	0.34
	Rufaa	0.37
	P value	0.73
4 dSm^{-1}2	Port Sudan	B0.29
	Rufaa	A0.42
	P value	0.005**
8 dSm^{-1}3	Port Sudan	0.3
	Rufaa	0.22
	P value	0.16
12 dSm^{-1}4	Port Sudan	0.28
	Rufaa	0.24
	P value	0.61
16 dSm^{-1}5	Port Sudan	0.19
	Rufaa	0.19
	P value	0.9

Means with the same letters in the same column and salinity level were not significantly different at 0.05 level

Table 4.15: Effect of salinity levels on *A. tortilis* seedling K% and Na% from Rufaa and Port Sudan sites.

Electrical conductivity (dSm^{-1})	K %		Na %	
	Rufaa	Port Sudan	Rufaa	Port Sudan
0.4	0.96	1.2^{A}	1.36^{A}	0.72
4	0.91	0.7^{B}	1.20^{AB}	0.72
8	0.74	0.7^{B}	0.39^{B}	0.59
12	0.71	0.7^{B}	0.11^{BC}	0.39
16	0.65	0.4^{B}	0.04^{C}	0.21
P value	0.28	0.05^{*}	0.023^{*}	0.08

Means with the same letters in the same column were not significantly different at 0.05 level

Table 4.16: Effect of salinity levels on *A. tortilis* seedling K % and Na % from Rufaa and Port Sudan sites.

Level	Site	K %	Na %
0.4 dSm^{-1}	Port Sudan	0.74	0.21
	Rufaa	0.96	0.11
	P value	0.33	0.08
4 dSm^{-1}2	Port Sudan	0.74	0.4
	Rufaa	0.91	0.24
	P value	0.68	0.41
8 dSm^{-1}3	Port Sudan	1.1	0.65
	Rufaa	0.7	0.4
	P value	0.17	0.63
12 dSm^{-1}4	Port Sudan	0.64	0.72
	Rufaa	0.74	1.3
	P value	0.43	0.29
16 dSm^{-1}5	Port Sudan	0.12	1.6
	Rufaa	0.07	1.20
	P value	0.14	0.53

Means with the same letters in the same column and salinity level were not significantly different at 0.05 level

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1. Conclusions

The present study evaluated the response of *A. tortilis* seedlings from two sites to a wide range of salt stress treatments. The results showed that Port Sudan seedlings were more adapted than those from Rufaa as indicated by higher percentage of survival. In addition, growth performance of Port Sudan seedlings and biomass production were higher relative to Rufaa seedlings. It can be concluded that *A. tortilis*, *A. tortilis* from Port Sudan was more tolerant to saline conditions than *A. tortilis* from Rufaa.

5.2. Recommendations

1. *A. tortilis* seedlings from Port Sudan exhibited high salt tolerance. Thus, it can be used as a candidate species in afforestation programme of in the Red Sea as well as for arid and semi-arid regions.

2. The Red Sea water could be a useful natural resource, and mixed with rain water harvesting it can be helpful in re-forestation. In turn, this will lead to combating desertification and poverty alleviation in eastern Sudan.

3. Seedlings produced from areas other than the origin (Port Sudan) should be irrigated with mixed water to give an EC close to that of their origin.

4. More research on the growth of plants under saline conditions is needed. Moreover, the mechanisms and plant strategies for adaptation to such stress conditions need to be explored.

REFERENCES

Abrol, I.P., Yadav, J.S.P., and Masoud, F.I. **(1988).** Salt-affected soils and their management. FAO, Soils Bulletin 39, 6-7.

Abu Gideiri, Y.B. **(1984).** Implication of sea mining of the Red Sea environment, environmental programme, Saudi-Sudanese Red Sea joint commission, Jeddah, Kingdom of Saudi Arbia, 15-19.

Ahmed, N. G. and Abo-Elnaga, H. I. G. **(2007).** Pathogenicity, toxicity and Gibberellic Acid content of Fusaruim moniliforme causing root rot and damping off pepper, plant pathology J., 6: 318-323.

Ahlcrona, E. **(1988).** The impact of climate and man on land transformation in central Sudan. *PhD dissertation*, Department of Geography, University of Lund, Sweden.

Alizadeh, A., Malak-Mohammedi, I. and Kamaili, A.G. **(2004)** Sustainable utilization of saline water in agriculture based on indigenous knowledge *in* Taha FK, Ismail S, Jaradat, Pensula, 483-490.

Al-Jaloud, A.A. and Hussain, G. **(2004).** Saline irrigation management for sustainable agriculture. Natural Resource and Environment Research Institute. King Abdulaziz City for Science and Technology, Saudi Arabia. In Taha, F. K., Ismail, S., Jaradat, A. Prospects of saline agriculture in the Arbian Pensula, 2004. P. 341-450.

Allen, J.A., Chamers, J.L. and Stine, M. **(1994).** Prospects for increasing salt tolerance of forest trees: A review. Tree physiology 14: 843-853.

Alstad G. and Vetaas, O.R. **(1994).** The Influence of Acacia tortilis Stands on Soil Properties in Arid north Eastern Sudan. Acta Oecologica 15 (4): 449-460.

Arnborg, T. **(1988)**. Where Savanna turns into desert. Experiences from the Sudan Savanna Zone in Sokoto State, Nigeria. Rural Development Studies 24, Uppsala.

AOAD (Arab Organization for Agricultural Development) **(2003)**. Arab Report for food security. AOAD, Khartoum -Sudan.

Archibold, O.W. **(1995).** Ecology of world vegetation. London: Chapman and Hall, 1995.Australian, J. Biol. Sci. 23: 937-945.

Ayyad, M.A. and Ghabbour, S.I. **(1985).** Hot desert of Egypt and Sudan. In: Evenari, M., Noy-Meri, Land Goodall, D. W. (Eds.), Hot desert and arid shrub lands. 1st ed. Elsevier Science and Technology Book Division.

Ayyad, M.A. and Ghabbour, S.I. **(1986).** Hot deserts of Egypt and the Sudan. In: Evenari, M., Noy-Meir, I. & Goodall, D. W. (eds.), Ecosystems of the World, Vol. 12B, Hot Deserts and Arid Shrub lands, B, pp. 149 - 202. Elsevier, Amsterdam.

Basher, L. R., Webb, T. H., **(1997).** Wind ersion rates on terraces in the Mackenize Basin Journal of the Royal Society of Newzland, 27, 499-521.

Brenan, J.P.M. **(1983).** Manual on taxonomy of Acacia species. FAO, Rome.

Carters, D.L. and Fanning, C.D. **(1964)**. Combining surface mulches and periodic water application for reclaiming saline soils. Soil Sci. Soc. Amer. Proc. 28: 564.

Chapman,H. D. and Pratt, P. F. **(1961).** Soil, water and plant analysis.

University of California, Agri.Div. publication.

Chapman, V.J. **(1970).** Mangrove phytososiology. Trop. Ecol. 11(1), 1-19.

Chaves, A. **(1991)**. Effect of water deficits on carbon assimilation. Journal Experimental Botany, 42, 1-16.

Chen, K. L. and Bary, R. H. **(1951.** Determination of calcium and magnesium in soil and plant material. Soil Sci. 72: 449-458.

Cox, L.R. **(1931).** The geology of the Farsan Islands,Gian and Kamaran Islands, Red Sea. Part 2: mollucan (Paleontology). Geol. Magazine 68, 1-13.

Dobson, M.C. **(1991).** Tolerance of trees and shrubs to de-icing salt damge to trees. Arboricultural Research Note 99\91 PATH, www. Tree devices service. Org. UK..

Doneen, L.D. **(1967).** Water quality requirement for agriculture. The National Symposium on Quality Stander for national waters. Education series No. 61. Univ. Mich. Ann Arbor, p. 213-218.

Earth Summit **(1992).** Convention of desertification. United Nations Conference on Environment and Devolvement, Rio de Janeiro Brazil 3-14, June, 1992.

El Amin, H.M. **(1972).** Taxonomic studies on the Sudan Acacias. M.Sc. Thesis, University of Edinburgh.

El Amin, H.M. **(1976).** Geographical distribution of the Sudan Acacias. Forest Research Institute Bull. 2, Khartoum.

El.Houri, A. **(1982).** The autecology of *Acacia tortils* (Forsk) Hayne, PhD thesis. Khartoum: University of Khartoum; 1982.

El.Settaway, A.A and El. Gamal, A.A. **(2003).** Effect of salinity stress on the growth of *Casuarina glauca* Sieber Ex Spreng and nadulation by endobiont frankia. Alex. J. Agric. Res., 48:149-156.

Fawzi, M.K. and Abdullah J.D. **(2006).** Salt-Tolerant Plants of the United Arab Emirates. International Center for Biosaline Agriculture.

Francois, L.E. and Clark, R.A. **(1978).** Salt tolerance of ornamental shrubs, trees, and ice plant. J. Amer. Soc. Hort. Sci. 103: 280-283

Gale, J. Poliaaff. Mayber, A. **(1970).** Interrelations between growth and photosynthesis of saltbush (Atriplex Shalimus L.) grown in saline media.

Hall, M.A. **(1976).** Plant Structure, function and adaptation. The Macmillan Press, London.

Gorham, J. **(1995).** Mechanism of salt tolerance of halophytes. In: Choukr-Allah, R. Malcolm, C.V. and Hamdy, A. (Eds). Halophytes and biosaline agriculture. Marcel Dekker, Inc. New York, pp. 31-52.

Goodin,J. R., E. Epstein, C. M. Mckelly, J. W, Oleeary (eds) **1990.** Saline Agriculture: Salt Tolerant Plants for Devoloping Countries (Planed on Saline Agriculture in Devoloping Countries). National Academy press, Washington, Dc.

Harrison, M.N. and Jackson, J.K. **(1958).** Ecological classification of the vegetation of the Sudan. For. Bull. 2.

Harrouni, M. C., Daouds. and Koyrolt. W. **(2001).** Effect of sea water irrigation on biomass production and ion composition of 7 halophytic species in Morocco. (to appearing :H. Lieth, Ed. “cash crop halophytes” potential, pilot projects, Basic and Applied

Research on Halophytes and Saline irrigation. Ten Years after Al Ain meeting. T: VS Series, Kluwer academic publishers groub, the Netherlands).

Jackson, J.K. and Shawki, M.K. **(1950).** Shifting cultivation in the Sudan. Mem. Forestry Division, No. 2. Khartoum.

Jefferies, R. L., A. J. Davy, and T. Rudmik. **(1979) .** The growth strategies of coastal halophytes in R. L. J. Davy, ediitors. Ecological Process in coastal environments. Blackwell, Oxford, England.

Klausewitz, W. **(1964).** Die Erforschung der khthyofauna des Rotan Meeres. Einleitung Sur 2. Auflage von C.B Klunzingers synopsis der fiche de Roten Meeres. J. Gramer, Weinheim.

Kelly, C. A**. (1984).** Effects of lake acidification on rates of organic matter decomposition in sediments . Deprtment of Biology, University of Winnipeg, Manitoba R3T2N6.

Kozolowski, T.T. **(1997).** Response of woody plants to flooding and salinity. Trees physiology Monograph No. 1: Heron publishing, Shelbourne, Victoria, Canada.

Le Houerou, H.N. **(1986).** The desert and arid zones of Northern Africa. In: Evenari, M., Noy-Meir, I. & Goodall, D. W. (eds.), Ecosystems of the World, Vol. 12B, Hot Deserts and Arid Shrublands, B, pp. 101 - 147. Elsevier, Amsterdam.

Levitt, J. **(1980).** Stress. Responses of Plants to Environmental Vol ll: Water, Radiation, Salt and other Stresses. Academic Press. New York.

Ludwig, F., Dawson, T.E., Kroon, H., Berendse, F., Prins, H.H.T. **(2003).**

Hydraulic left in *Acacia tortilis* trees on an East Africa Savanna. Oecologica, 134 (3): 293-300.

Maathius, F.J.M. and Amtmann, A. **(1999).** K^+ nutrition and Na^+ toxicity: the basis of cellular K+ \ Na+ ratios. Annals of Botany 84, 123-133.

Matheny, N. and Clark, J.R**. (1999).** Managing landscape using Recycled Water. Arborist News, December issue: 37-43.

Maynard, D.G., Mallett, K.I., and Myrholn, V.L. **(1997).** Sodium carbonate inhibits emergence and growth of greenhouse-grown white spruce. Cand. Jour. Soil. Sci., 77: 99-105.

Ministry of Agriculture, Animal Resources and Irrigation (2000). Investment atlas for natural, agricultural and animal resources of Red Sea state. Report 58 p.

Morcos, S.A. **(1970).** Physical and chemical oceanography of the Red Sea. Oceanography and Marine Biology Annual Review 8, 73-202.

Munzbergova, Z. and Ward, D**.(2002)**. Acacia trees as keystone species in Negev desert ecosystems. Journal of Vegetation Science, 13 (2): 227-236.

Mustafa, M.A. **(2007).** Desertification processes Pub. UNESCO Chair of Desertification University of Khartoum press.

Naidoo, G. **(1985).** Effects of water logging and salinty on plant water relations and on the accumulation of solutes in three mangrove species. Aquatic Botany, 22, 133-143.

Noble, C.L. and Rogers, M.E. **(1994).** Response of temperate forest legumes to water logging and salinity. In handbook of plant and crop stress. Ed. M. Pessarki-Marcel Dekker, New York, pp:

473-496.

Osman, H.M.A.M., Dabloube, S.M.A. and Osman, M. **(2004).** Proposed plan of action for research on desertification in the Sudan: Kassala and Red Sea states. In: Pressings of the National forum of Scientific Research on Desertification in the Sudan", by M. A. Mustafa and A. A. Mahdi. (eds), UNESCO CHAIR of desertification studies. University of Khartoum, Sudan. P 228-234.

PERSGA (Regional Organization for the Conservation of the Environment of the Red Sea and Gulf of Aden) (2003). Status of Living Marine Resources in the Red Sea and Gulf of Aden and their Management. GEF, UNEP, UNDP. Technical series, No. 4. (Arabic). pp 13-16.

PERSGA (Regional Organization for the Conservation of the Environment of the Red Sea and Gulf of Aden) (2001). Strategic Action program for the Red Sea and Gulf of Aden, Country Reports. Recycled paper 24.

Richards, L.A., Allison, L.E., Bernstein, L., Bower, C.A., Brown, J.W., Fireman M. Hatcher, J.T., Hayward, H.E., Pearson, G.A., Reeve, R.C. and Wilcox, L.V. **(1969).** Diagnosis and Improve-ment of Saline and Alkali Soils.

Robinson, M., A., Sanders., D., and Mansfield, T. A**.(1997).** How can stomata contribute to salt tolerance? Annals of Botany 80, 387-393.

Ross, J.H. **(1981).** An analysis of the African Acacia species: their distribution, possible origin and relationships. Bothalia 13: 389-413.

Sahni. K. C. **1968.** Important trees of the northern Sudan 1968 by United Nations Devolpment Programme

Salih, E.M. **(1996).** The geographic extent of desertification in Sudan, NDDU, Khartoum, Sudan.

Serrano, R., Culianz, Macia, F. and Moreno, V. **(1999).** Genetic engineering of salt and drought tolerance with yeast regulatory genes. Scientia Horticulture 78, 261-296.

Shmida, A**. (1986).** Biogeography of the desert flora. In: Evenari, M., Noy-Meir, I. & Goodall, D. W. (eds.), Ecosystems of the World, Vol. 12A, Hot Deserts and Arid Shrublands, A, pp. 23-77. Elsevier, Amsterdam.

Slim, F. S., Hemminga, M. A., Cocheret de la moriniere, E. and Vandervelde, G. **(1996).** Tidal exchange of macrolitter between mangerov forest and adjacent seagrass beds. (Gazi. Bay. Kenya). Netherland Journal of Aquatic Ecology 30: 119-128.

Turi, H. **(1982).** Reforestation and community development in the Sudan. Rep. Social Sciences and Development, University of Bergen.

UNCCD (United Nations Convention to Combat Desertification), 2003.

UNCCD (United Nations Convention to Combat Desertification), (1994).

UNEP (United Nations Environment Program) (1985). Management and Conservation of renewable marine resources in the Red Sea and the Gulf Aden region. UNEP Regional Seas Reports and studies, reported in co-Operation with IUCN. No. 64.1-6.

Unger, I.A. **(1991).** Ecophsiology of Vacuolar Halophytes. CRC press, Boca Raton, Florida, U.S.A.

Volkmar, K.M., Hu, Y. and Steppun, H. **(1998).** Physiological response of plants to salinity: a review. CAN. J. Plant Sci 78, 19-27.

Wamgwttana, C. and M. Nanakom, S. Surawattanon and K. Kobayashi. **(1998).** Effect of sodium chloride on growth and root nodulation in some leguminous plants. J. Weed Sci. Snd Tech., 43: 129.

Wincov, I. **(1998).** New Molecular approaches to improving salt tolerance in crop plants of Botany 82, 703-710.

Zekri, M. **(1993).** Salinity and calcium effect on emergence, growth and marginal composition of seedlings of eight citrus rootstocks. J. Hort. Sci. 68, 53-62.

Table 4.3: Effect of salinity on *A. tortilis* seedling height from Rufaa and Port Sudan sites during the second month after sowing.

Height (cm) Week 4 Port Sudan	Electrical conductivity (dSm^{-1})							
	Week 1		Week 2		Week 3		Week 4	
	Rufaa	Port Sudan	Rufaa	Port Sudan	Rufaa	Port Sudan	Rufaa	Port Sudan
0.4	14.00	17.33	18.33	22.67^{A}	22.00	2383^{A}	23.67^{A}	26.17^{A}
4	11.33	16.33	17.67	20.17^{AB}	18.83	21.33^{AB}	19.68^{A}	22.17^{B}
8	10.33	12.67	17.00	16.50^{B}	17.00	17.33^{B}	19.00^{B}	20.17^{B}
12	9.67	12.00	15.33	16.17^{B}	16.17	17.00^{B}	17.83^{B}	19.00^{B}
16	9.33	12.00	15.16	15.83^{B}	16.00	16.67^{B}	17.17^{B}	18.67^{B}
P value	0.11	0.08	0.43	0.024	0.079	0.03^{*}	0.03^{*}	0.007^{**}

Means with the same letters in the same columns were not significantly different at 0.05 level

Table 4.4 Effect of salinity on *A. tortilis* seedling height from Rufaa and Port Sudan sites during the third month after sowing

Electrical conductivity (dSm^{-1})	Plant shoot height (cm)							
	Week 5		Week 6		Week 7		Week 8	
	Rufaa	Port Sudan	Rufaa	Port Sudan	Rufaa	Port Sudan	Rufaa	Port Sudan
0.4	24.0^{A}	26.67^{A}	24.00	27.50^{A}	24.50	28.33^{A}	25.67^{A}	29.67^{A}
4	20.2^{B}	23.00^{AB}	20.67	25.00^{AB}	22.33	26.00^{AB}	23.33^{AB}	27.33^{AB}
8	19.7^{AB}	21.33^{B}	20.50	23.00^{B}	21.33	23.83^{B}	23.00^{B}	25.33^{B}
12	19.0^{B}	20.67^{B}	20.00	22.67^{B}	21.33	23.83^{B}	22.17^{B}	25.00^{B}
16	18.7^{B}	20.00^{B}	18.67	21.^{BC}	19.67	22.67^{B}	20.50^{B}	24.17^{B}
P value	0.034*	0.02*	0.13	0.01**	0.13	0.01**	0.052*	0.02*

Means with the same letters in the same columns were not significantly different at 0.05 level

Table 4.5: Effect of salinity on *A. tortilis* seedling height from Rufaa and Port Sudan sites during the fourth month after sowing

Electrical conductivity (dSm^{-1})	Shoot height (cm)							
	Week 9		Week 10		Week 11		Week 12	
	Rufaa	Port Sudan	Rufaa	Port Sudan	Rufaa	Port Sudan	Rufaa	Port Sudan
0.4	25.67	31.33	26.33	29.17	27.17	33.00	28.67[a]	34.67
4	23.67	28.33	24.00	28.00	25.33	29.33	25.33[ab]	30.67
8	23.00	26.67	2.83	27.67	214.00	27.33	2517[ab]	29.00
12	22.50	26.50	22.83	26.67	23.17	26.00	23.33[b]	28.00
16	20.83	25.15	21.50	26.50	22.17	25.67	22.33[b]	27.33
P value	0.07	0.07	0.10	0.09	0.07	0.19	0.01**	0.23

Means with the same letters in the same columns were not significantly different at 0.05 level

Table 4.6: Effect of salinity level ($0.4 dSm^{-1}$) on *A. tortilis* seedling shoot Height from Rufaa and Port Sudan sites during the measurements period which lasted three between the sources. The numbers (1 to 12) indicate weeks of measurements. Data are presented as means. Significant differences between the means are indicated by P≤0.05.

Level		Shoot height											
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
0.4 dSm^{-1}	Port Sudan	17.33	22.67^{A}	23.83	26.17	26.67	27.5	28.33	29.67^{A}	31.33^{A}	32.17^{A}	33.00^{A}	34.67^{A}
	Rufaa	14.00	17.67^{B}	22.00	23.67	24.00	24.00	24.5	25.67^{B}	25.67	26.33^{B}	27.17^{B}	28.67^{B}
	P value	0.15	0.03*	0.40	0.23	0.26	0.14	0.09	0.05*	0.04*	0.04*	0.01**	0.001*

Means with the same letters in the same columns and salinity level were not significantly different at 0.05 level

Table 4.7 Effect of salinity level ($4dSm^{-1}$) on *A. tortilis* seedling shoot height on seedling shoot Height from Rufaa and Port Sudan sites during the measurements period which lasted three between the sources. The numbers (1 to 12) indicate weeks of measurements. Data are presented as means. Significant differences between the means are indicated by P≤0.05.

Level		**Shoot height**											
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
4 dSm^{-1}	**Port Sudan**	16.33^{A}	20.17	21.33	22.17	23.00	25.00^{A}	26.00^{A}	27.33^{A}	28.33	29.17	29.33^{A}	30.67^{A}
	Rufaa	11.33^{B}	18.33	18.83	17.67	20.17	20.50^{B}	21.33^{B}	22.33^{B}	23.00	23.83	24.33^{B}	25.33^{A}
	P value	0.03*	0.43	0.29	0.35	0.31	0.05*	0.054*	0.053*	0.11	0.09	0.05*	0.05*

Means with the same letters in the same columns and salinity level were not significantly different at 0.05 level

Table 4.8: Effect of salinity level ($8dSm^{-1}$) on *A. tortilis* seedling shoot Height from Rufaa and Port Sudan sites during the measurements period which lasted three between the sources. The numbers (1 to 12) indicate weeks of measurements. Data are presented as means. Significant differences between the means are indicated by $P \leq 0.05$.

Level		Shoot height											
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
$8dSm^{-1}$	**Port Sudan**	12.67	16.17	17.33	18.67	20.00	21.00	22.67	24.17	25.17^{A}	26.17^{A}	27.33^{A}	29.00^{A}
	Rufaa	9.33	15.17	16.00	17.17	17.67	18.67	19.67	20.50	20.83^{B}	21.50^{B}	22.17^{B}	22.38^{B}
	P value	0.15	0.49	0.47	0.43	0.26	0.26	0.19	0.09	0.05*	0.052*	0.05*	0.04*

Means with the same letters in the same columns and salinity level were not significantly different at 0.05 level

Table 4.9: Effect of salinity level (12dSm^{-1}) on *A. tortilis* seedling shoot Height from Rufaa and Port Sudan sites during the measurements period which lasted three between the sources. The numbers (1 to 12) indicate weeks of measurements. Data are presented as means. Significant differences between the means are indicated by P≤0.05.

Level		**Shoot height**											
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
12 dSm^{-1}	**Port Sudan**	12.00	15.83	16.67	20.17	21.33	23.00	23.83	25.33	26.67^{A}	28.00^{A}	26.00	28.00
	Rufaa	10.33	15.33	16.17	19.00	19.33	20.67	22.33	23.33	23.67^{B}	24.00^{B}	24.50	25.17
	P value	0.32	0.88	0.87	0.46	0.14	0.16	0.09	0.10	0.04*	0.03*	0.67	0.48

Means with the same letters in the same columns and salinity level were not significantly different at 0.05 level

Table 4.10: Effect of salinity level (16dSm^{-1}) on *A. tortilis* seedling shoot Height from Rufaa and Port Sudan sites during the measurements period which lasted three between the sources. The numbers (1 to 12) indicate weeks of measurements. Data are presented as means. Significant differences between the means are indicated by $P \leq 0.05$.

Level		Shoot height											
		1	2	3	4	5	6	7	8	9	10	11	12
16 dSm^{-1}	**Port Sudan**	12.00	16.5	17.33	19.00	20.67	22.67^{A}	23.83^{A}	25.67^{A}	26.50^{A}	27.67^{A}	25.67	27.33
	Rufaa	9.67	17.00	17.00	17.83	18.67	20.00^{B}	21.33^{A}	22.17^{B}	22.50^{B}	22.83^{B}	23.17	23.33
	P value	0.42	0.75	0.84	0.42	0.15	0.04*	0.05*	0.02*	0.01**	0.002**	0.43	0.22

Means with the same letters in the same columns and salinity level were not significantly different at 0.05 level