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Characterization of salt affected soils in the central Rift Valley and assessing salt tolerance of different plants: A case study at the southwestern shore of Lake Ziway

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Msc thesis submitted to the University of Addis Ababa School of graduate studies in partial fulfillment of the requirements for the degree of Master of Science in Environment

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Abbreviations

ANOVA	Analysis of Variance
BGS	British Geological Survey
BPMC	Bridger Plant Material Center
CIAT	International Center for Tropical Agriculture
CSIRO	Common Wealth Scientific and Industrial Research Organization
EC	Electrical Conductivity
ESP	Exchangeable Sodium Percentage
FAO	Food and Agricultural Organization
ILEC	International Lake Environment Committee
ICBA	Independent Community Bankers of America
LSD	Least Significant Difference
MCM	Million Cubic Meter
Meq/l	Milliequivalent per Liter
MoWR	Ministry of Water Resources
NERC	Natural Environment Research Council
NRCS	Natural Resource Conservation Service
PGRC	Plant Genetic Resources Center.
RDP	Rural Development Program
SAR	Sodium Adsorption Ratio
SPSS	Statistical Package for Social Studies
TDEC	Tennessee Department of Environment and Conservation
USSLS	United States of America Salinity Laboratory Staff

Abstract

The objective of this study was to characterize salt affected soils based on their salt content & to assess growth responses of selected species and identify salt tolerant species; namely, Rhodes grass (Chloris gayana), Setaria sphacelata, Saltbush (Atriplex halimus) and Guinea grass (Panicum maximum). Soil samples were collected from three different sites of southwestern shore of Lake Ziway area. Samples were taken in replicate of 16 from each site and composited. Soil chemical analysis of the soluble salts, exchangeable salts, EC, texture, calcium carbonate, pH, organic carbon and total nitrogen were done at Addis Ababa University and National Soil Research Center. In addition, to select salt tolerant plant species experiment was conducted in a greenhouse involving the different soil types and the four different plant species as experimental treatments. The experimental design used was CRD (Complete Random Design). Throughout the experimental period, survival percentage and height of each plant species were recorded.

Based on the laboratory analysis, salt problem was observed in all the soil samples collected from the study area. According to the standard guidelines, all tested soil samples fall under the category of saline-sodic soils based on their salt content. Even though they all belong to same category, the absolute salt content of each soil type was very different. The EC, SAR, ESP value for soils collected from the first site was 9.3 dS/m, 58.7 & 34.3%, for soils from the second site, which was 19.3 dS/m, 385.9 & 78.8%, and for soils from the third site was 8.1dS/m, 95.3 & 65.5% respectively. These differences in absolute salt content were reflected in the differential responses of the plant species grown on them. There was statistically significant difference in the mean survival percentage between different species on soil types collected from the same site ($P<0.05$). This shows that there is a marked difference in salt tolerance between the selected species. In addition, the mean survival percentage & height attained by each species showed statistically significant difference between different soils collected from the three sites ($P < 0.05$). From all the planted species the survival percentage and height of only two species, namely *Atriplex halimus* & *Chloris gayana* were recorded on soils collected from the first and third sites. However, the other two species, *Setaria*

sphacelata, & *Panicum maximum* were not able to grow on all the soils collected from the three sites. The survival percentage and height attained by the two species on soils from the third site was very low.

The result suggests that the presence of high salt problem in the study area and some soils of the area could support the growth of two species. From the two species, *Chloris gayana* can be selected as a high salt tolerance grass for the salt content found in soils from the first site by observing its survival percentage. However, the survival percentage of other tolerant species, *Atriplex halimus* decrease drastically through time on both soils from the first and third sites and the survival percentage of *Chloris gayana* were very low on soils from the third site. So that it is difficult to select *Atriplex halimus* as salt tolerant plant for soils from the first and third sites and similar other soils and *Chloris gayana* for soils from the third site and similar other soils.

In combination with these salt tolerant plants, it is advisable to practice other reclamation measures especially in areas with high salt concentration. Because most of the soils of the area could not support even high salt tolerant species.

Key words: Salt affected soils, Salt tolerant plant, Soil chemical analysis, Survival Percentage and Height of species

1. INTRODUCTION

1.1. Background and Justification

All soils contain some salts but when soils contain excessive concentrations of either soluble salt that are not held on soil exchangeable sites or exchangeable sodium or both, they are called salt affected soils (Conway 2001; Denise 2003; Jim 2002). Salt affected soils are categorized into three main groups; namely saline, sodic, and saline-sodic (Gonzalez *et al.,* 2004). When soils contain excessive concentrations of water-soluble salts, they are called saline (Conway 2001; Denise, 2003). Sodic soils are low in soluble salts than saline soils but high in exchangeable sodium (Jim 2002 & Pam 2002). On the other hand, saline-sodic soils contain both large amounts of water-soluble salts and exchangeable sodium (BPMC 1996).

For plant growth, such soils are regarded as a class of problem soils that require special remedial measures and management practices (BPMC 1996). Soluble salts produce harmful effects to plants by increasing the salt content of the soil solution and by increasing the degree of saturation of the exchange materials in the soil with exchangeable sodium (Joe 2002). Excess concentration of exchangeable sodium occurs when the soluble constituents consist largely of sodium salts and is of a more permanent nature than the salt content of the soil solution, since exchangeable sodium usually persists after the soluble salts are removed (BPMC 1996; Conway 2001; Fitzpatrick *et al*., 2003).

In many areas of the world, salinity is one of the principal environmental causes of soil degradation, and consequently, a source of reduction in the biomass (André *et al*., 2004; Tejedor *et al.,* 2003; Warrick 2004). According to certain estimates, approximately 7% of soils all over the world suffer from this phenomenon (Jassogne *et al*., 2006; Ziad *et al.,* 2004). These types of soils appear mainly in arid and semi-arid areas where precipitations are insufficient to drain the soluble salts contained in the soil profile (Caitlin 2003) and most of the developing countries are located in these two areas (Ziad *et al.,* 2004).

According to Sissay (1985), salt-affected flats have increased from 6% to 16% of the total land area of Ethiopia in recent years. About 9% of the population lives in the areas affected by salinity (Sissay 1985). The semi-arid and arid lowlands and valleys in Ethiopia have major problems of salinity and alkalinity. Tamirie (1994) has revealed that 44 million ha (36% of the country's total land areas) are potentially susceptible to salinity problems. Out of the 44 million ha, 33 million ha have dominantly salinity problems, 8 million ha have combined salinity and alkalinity problems, and 3 million ha have dominantly alkalinity problems. If the increments of salt affected soils continue like this, a significant part of Ethiopian soils will degrade and then be changed to desert. One of the potential areas of risk is the Rift Valley lake areas. Therefore, this study focuses on giving some information about the salt character of soils in the Rift Valley to verify a potential salt problem and to recommend salt tolerant grass and shrub forage species for solving the environmental problem by reclaiming the salty soils.

The study was conducted on cultivated fields adjacent to the southwestern shore of Lake Ziway, which covers a total area of 50 ha. The experimental site was about 1200m^2. In this farmland, it is possible to see whitish salt incrustation on surface of soil, and irregular plant growth. This means in some parts of the farm, there are bare lands that cannot support plant growth and there are also lands that are able to support plant growth but it is possible to see some problem with these plants. Their leaves were yellow in color and the yield was low. However, except for few preliminary observations no information is available on the chemical characteristics of these soils.

Moreover, salt affected soils differ considerably in ease of reclamation method (Conway 2001; Michael & Paul 2002). Some of the reclamation methods are leaching, mulching, addition of organic matter, planting salt tolerant plants and using chemical amendment (Bonnie *et al*., 2002; Conway 2001; Jim 2002). In this study, plantation of halophyte or high forage producer plants was tried. This method is as a potential substitute of cost-intensive chemical amelioration and it has been found to be an efficient and low-cost strategy (economically viable), environmentally acceptable strategy and increase the productivity and improvement of salt-affected wastelands (Ann & Clain 2005; McCutcheon & Schnoor 2003; Qadir *et al*., 2003). Recently, halophytes have been

incorporated in pasture-improvement programs in many salt-affected regions of the world (Qadir *et al*., 2003).

Therefore, for this study four plant species were chosen, which were collected from ILRl (International Livestock Research Institute) to be planted in the green house. Selection of grass species was based on the inclusion of wide range of growth habits or the use of the plants. Out of four species two of them, Rhodes grass (*Chloris gayana), and* forage setaria (*Setaria sphacelata*) have been tested and accepted locally (in Ethiopia). They are forage grasses, which have improved productivity, palatability, and nutrient characteristics that make them desirable for inclusion in improved forage production and soil and water conservation programmes (Alemayehu 1997). In addition the other two species are, such as saltbushes (*Atriplex halimus*) shrubs have been recognized for their productivity, tolerance to saline-sodic soils, and production of forage material (Maher & EL-Sayed, 2000) and drought tolerant and most productive forage grasses *Panicum maximum* were also chosen for the study. *Chloris gayana* is also recognized for its high level of salt tolerance (Leandro *et al.,* 2006; John *et al*., 2002; Juan-Pablo 2005). These all species used as forage and have commercial value (Aganga & Tshwenyane 2004; Barrett- Lennard & Galloway 1996; Barrett-Lennard 2003; Bell *et al.*, 2001; CIAT/FAO 2006; Ferdowsian *et al.*, 2002).

1.2. Objectives of the study

1.2.1. General objective

- To asses the degree of saltiness in cultivated fields and to identify potentially suitable salt tolerant species for salt affected soils reclamation.

1.2.2. Specific objectives

- To investigate important physicochemical properties of soils that help to know the salt content of the soil.
- To determine the effects of salt content of the soil on the survival percentage and height of different plant species.

2. Literature review

2.1. Definition to describe salt affected soils

According to Gonzalez *et al.,* (2004) and Qadir and Schubert (2002) salt soil classifications currently used in all countries of the world were the one which were divided into three main groups: saline, sodic and saline sodic.

2.1.1. Saline soils

All soils contain some water-soluble salts, but when these salts occur in amounts that are harmful for germination of seeds and plant growth, they are called saline (Conway 2001; Denise 2003). The soluble salts that occur in soils consist mostly of various proportions of the cations calcium (Ca^{++}), magnesium(Mg^{++}) and sodium (Na^{+}), and the anions chloride (Cl^{-}), and sulfate ($SO_4^{=}$). Constituents that ordinarily occur only in minor amounts are the cation potassium (K^{+}) and the anions bicarbonate (HCO_3^{-}), nitrate (NO_3^{-}) and carbonates (CO_3^{2}) but soluble carbonates are almost invariably absent. The salts types found in saline soils are mostly sulfates and/or chlorides of calcium and magnesium (Bonnie *et al*., 2002; BPMC 1996; Joe 2002).

Owing to the presence of excess soluble salts and the absence of significant amounts of exchangeable sodium, saline soils generally are flocculated often are in normal physical condition with good structure; and, as a consequence, the permeability is equal to or higher than that of similar nonsaline soils (BPMC 1996; Conway 2001; Jim 2002).

Saline soils are often recognized by the presence of white crusts of salts on the soil surface called “White alkali” (soluble salts) and irregular plant growth. Electrical conductivity of these soils when a solution extracted from saturated soil is greater than or equal to 4.0 mmhos/cm at 25^0C. The pH is generally less than 8.5, sodium makes up less than 15 percent of the exchangeable cations and the sodium adsorption ratio (SAR) is less than 13 (Conway 2001; Jim 2002; Michael & Paul 2002).

2.1.2. Saline-Sodic Soils

Saline Sodic soils contain large amounts of total soluble salts and exchangeable sodium

(BPMC 1996). As long as excess soluble salts are present, the good physical properties (stable soil structure), the whitish appearance, the EC which is greater than 4 mmhos/cm at 25^0C and the pH which is less than 8.5 are generally similar to those of saline soils. But they differ by the fact that more than 15 percent of the exchangeable cations are sodium and the sodium adsorption ratio is greater than 13 (Conway 2001; Jim 2002).

If the excess soluble salts are leached downward, the properties of these soils may change markedly and become similar to those of sodic soils with high pH above 8.5, the dispersion of particles and the soil becomes unfavorable for the entry and movement of water and for tillage (BPMC 1996; Denise 2003). Saline-sodic soils sometimes contain gypsum. When such soils are leached, calcium dissolves and the replacement of exchangeable sodium by calcium takes place concurrently with the removal of excess salts (Conway 2001).

2.1.3. Sodic soils

Sodic soils are low in soluble salts than saline or saline-sodic soils but high in exchangeable sodium (Jim 2002; Pam 2002). The soil solution of sodic soils, although relatively low in soluble salts, has a composition that differs considerably from that of normal and saline soils. These soils contain (HCO_3^{2-}), and CO_3^{2-}as the dominant anion (Qadir & Schubert 2002). At high pH readings and in the presence of carbonate ions, calcium (Ca^{++}) and magnesium (Mg^{++}) are precipitated and hence, the soil solutions of sodic soils usually contain only small amounts of these cations but high amount of sodium (Na^{+}) being the predominant one (BPMC 1996; Joe 2002; Qadir & Schubert 2002). In addition, when the plants extract the water from the soil; the salts remain and become concentrated. This concentration causes the calcium to precipitate as calcium carbonate, while much of the sodium remains in the soil water (Conway 2001).

These soils have exchangeable sodium percentages of more than 15. This means that sodium occupies more than 15 percent of the soil cation exchange capacity (CEC) and the sodium adsorption ratio (SAR) is greater than 13. The electrical conductivity is less than 4 mmhos/cm at 25^0C and the pH readings usually range between 8.5 and 10. In saline-sodic soil, the presence of hydrolysis of the exchangeable sodium often causes a

rise of the pH reading of the soil as high as 10 (Conway 2001; Jim 2002).

These soils frequently occur in semiarid and arid regions, which are often referred to as "slick spots." The combination of high levels of sodium, low total salts and high pH causes the soil aggregates to break down and causes swelling and dispersion of clays in the soil. This results in the destruction of the soil structure that makes sodic soils of poor tilth (Conway 2001; Denise 2003). Dispersed and dissolved organic matter present in the soil solution of highly sodic soils may be deposited on the soil surface by evaporation, thus causing darkening and giving rise to the term "black alkali" (Denise 2003). Sodic soils are sticky when wet, nearly impermeable to water (extremely low water intake rates) and have a slick look. As they dry, they become hard, cloddy and crusty (Conway 2001; Jim 2002).

2.2. Causes of salt affected soils

Salts in the soil occur as ions (electrically charged forms of atoms or compounds). These ions are released from two main sources: primary or natural sources and secondary or salinization caused by human factors (Michael & Paul 2002).

2.2.1. Primary salinity

Primary salinity is caused by naturally occurring salt deposits mostly in arid and semi-arid areas. Some salt soils are released from weathering saline parent rocks. Also when precipitation is insufficient to leach ions from the soil profile and transport the salts away from the root zone and when there is high evaporation rate salts accumulate in the soil and soil salinity can result this way too (Ashraf & Harris 2005; Salliah & Pathmarajah 2003).

Poor drainage is another factor that usually contributes to the salinization of soils, it is the most common cause, and it may involve the presence of a high ground-water table or low permeability of the soil. The high ground-water table is often related to topography. Therefore, there are drainage basins that have no outlet to permanent streams. The drainage of salt-bearing waters away from the higher lands of the basin may raise the ground-water level to the soil surface on the lower lands, may cause temporary flooding,

or may form permanent salty lakes. Under such conditions, upward movement of saline ground water or evaporation of surface water results in the formation of saline soil (Ashraf & Harris 2005). Low permeability of the soil causes poor drainage by impeding the downward movement of water. Low permeability may be the result of an unfavorable soil texture or structure or the presence of indurated layers (Ashraf & Harris 2005; Salliah & Pathmarajah 2003).

2.2.2. Secondary salinity

Natural salinity has been intensified by change in land use, which means change from more water use plant to less water use plant cause water table rise, when irrigation water quality is marginal or worse (Selliah & Pathmarajah 2003). In addition, when the drainage of the soil may not be adequate for irrigation, the ground-water table may rise from a considerable depth to a few feet of the soil surface in a few years due to irrigation. When the water table rises to 5 or 6 feet of the soil surface, ground water moves upward into the root zone and to the soil surface. Under such conditions, ground water, as well as irrigation water, contributes to the salinization of the soil. Deforestation, overgrazing, or intensive cropping, fertilizer and amendments applied to soils are another secondary salinity causes (Ashraf & Harris 2005; Selliah & Pathmarajah 2003).

2.3. Tests to quantify and qualify soil saltiness

There are several tests to quantify or qualify soil saltiness. It is important to understand the differences among these tests because each provides a specific type of information (Joe 2002).

Electrical conductivity (EC) describes the amount of electrical current conducted by extracting the solution (water containing ions) from a saturated soil sample at a fixed temperature (Joe 2002). The higher the moisture content, the easier it will be to obtain the extract. The greater the concentration of ions or soluble salts in the saturation extract, the more electricity the solution will conduct, the greater the EC reading, and the greater the toxicity to plants. This test does not distinguish between one type of salt and another; it simply provides an overall measure of water-soluble salts. The electrical conductivity

of the saturation extract is often referred to by the abbreviation ECe (Conway 2001). Units of measurement include decisiemens per meter (dS/m or dS m^{-1}) and millimhos per centimeter (mmhos/cm or mmhos cm^{-1}), which are synonymous (1dS m^{-1} = 1mmhos cm^{-1}) (BPMC 1996; Conway 2001; Joe 2002; Marx *et al.,* 1996).

Since Na toxicity to plants is severe, and the effects of Na on soil pH and structure are significant, two tests have been devised to describe the relative amounts of Na present in the soil. **The exchangeable sodium percentage (ESP**) provides a measure of the amount of exchangeable Na relative to the total cation exchange capacity of the soil expressed as a percentage. As the ESP goes up, more exchangeable Na is available, and the greater the potential to be toxic to plants and soil. Its unit is percent (BPMC 1996; Joe 2002; Marx *et al.,* 1996). **The Sodium Adsorption Ratio (SAR)** describes the ratio of the concentration of soluble sodium ion in the soil solution to the square root of the dissolved calcium and magnesium ion concentration that moderate the adverse effects of sodium (Joe 2002). It is calculated from concentration of cations (me/l) in the saturation extract. This measure is important, because magnesium and calcium provide a buffering effect on the impacts of high sodium that means where Na^{+} ions favor dispersion and Ca^{2+} and Mg^{2+} favor flocculation of soils. However, the presence of high magnesium has the same problem with sodium (Qadir & Schubert 2002). Excess exchangeable Mg^{2+} alone or in combination with excess exchangeable Na^{+} may behave like Na+ in soil degradation (Qadir & Schubert 2002). The greater the SAR, the more Na relative to Ca and Mg, the greater the toxicity to plants and indicates a sodic soil. SAR is unitless. At equivalent solution concentrations, the amounts of calcium and magnesium adsorbed are several times that of sodium (BPMC 1996; Conway 2001; Marx *et al.,* 1996; TDEC 2005).

Soil pH is another important soil measure even though it does not directly measure saltiness. It is a measure of the hydrogen ion concentration in soil solution. This is an important indication of the chemical status of the soil. Since soluble salts affect soil pH and vice versa, it is often included in evaluations and discussions of soil saltiness. A main implication of changing the soil pH is plant nutrient availability (Conway 2001; Joe 2002; Marx *et al.,* 1996).

Cation-Exchange-Capacity (CEC) is the capacity of a soil to adsorb and exchange cations. It is commonly expressed in milli equivalents per 100 gm. of soil (Joe 2002; Michael & Paul 2002; Robert & Robert 2001). Cation adsorption being a surface phenomenon is identified mainly with the fine silt, clay, and organic matter fractions of soils and it occurs as a consequence of the electrical charges at the surface of the soil particles. In general, it should be noted that the soil CEC values will increase in the following order of textural classes: sand, loamy sand, loam, silty loam, silty clay loam, clay loam and clay (Mostafa *et al.,* 2001; TDEC 2005; Yormah & Egbenda 2005). Sodium, calcium, and magnesium cations are always readily exchangeable. Other cations, like potassium and ammonium, may be held at certain positions on the particles in some soils so that they are exchanged with great difficulty and, hence, are said to be fixed (Fabrice & Michael 2003; Marx *et al.,* 1996; Robert & Robert 2001). Salt affected soils having pH in alkaline range (pH>7) do not have Aluminum ion on the exchangeable site (Qadir & Schubert 2002). It is thus possible to use Effective Cation Exchange Capacity (ECEC) like CEC in soil which have pH value >7. The term ECEC refers to the sum of the four cations such as Sodium, Calcium, and Magnesium and Potassium (Robert & Robert 2001)

2.4. Impact of Salt affected soil on plant

Strong salt affected soils can affect plant growth both physically (osmotic effect) and chemically (nutrition effect and/or toxicity). Due to these plant growth and yield is reduced, and the quality or value of agricultural production is lowered (BPMC 1996; Denise 2003; Gonzalez *et al.,* 2004).

Adverse effect of high soil salt content on vegetative growth is due to three main reasons: (Conway 2001; Jim 2002). 1) Prevention of soil water uptake into the plant because of the osmotic effect; 2) specific ion toxicity, which can disrupt the nutritional processes of the plant; and 3) alteration of the soil structure and permeability.

2.4.1. Osmotic effect of salt

Water is absorbed into plants because of a gradient that exists between the soil solution and the cell sap of the interior root cells. High concentration of neutral salts in the soil

solution tends to narrow the gap between the soils (external) and plant cell (internal) water potentials (BPMC 1996). This means that salts increase the energy with which water is held in the soil. Then the soil water potential become more negative, making water movement to the root cells more difficult. If the soil solution potential becomes negative enough, water may actually migrate out of the plant cells and into soil solution (Joe 2002; Silvertooth, & Norton 2000). There may be ample available soil moisture for plant growth; it is just that the plant cannot extract it because of the strong negative potential. The effect is essentially the same as drought. The plant cannot get enough water to maintain proper growth, or it takes so much plant energy extracting the water that growth suffers. The situation is exacerbated under water stress conditions or drought, particularly on fine-textured soils where it takes more pull for the plant to remove water at a given soil moisture level (Conway 2001; Gonzalez *et al.,* 2004).

High salinity (high EC) causes plant cell dehydration, reduced plant growth and possibly death in less tolerant plants, while tolerant ones survive in a number of physiological ways (Joe 2002). All of which show similar visual symptoms. The first visual symptoms appear the same as those of moisture stress from dry conditions. Plants may be stunted, leaves may cup, and overall plant health and color are affected. The symptoms progress to brown and brittle leaf tips, leaf margins, the overall leaf and, finally, the entire plant (Denise 2003).These symptoms may occur within a few days of planting young seedlings or after several weeks. With older plants, water deficit may present as a rapid dying off or browning of leaves at the top of the plant (BGS 2001)

2.4.2. Nutrition and ion toxicity of salt

In addition to the osmotic effect, certain ions are directly toxic to plants (Joe 2002). Specific ions such as sodium, chloride and boron have toxic effects on plants: reducing plant emergence and growth or causing damage to cells and membranes. Plants sensitive to these elements may be affected at relatively low salt levels if the soil contains enough of the toxic element (BPMC 1996; Fisseha 1998; Gonzalez *et al.,* 2004).

Moreover, ions such as Na can influence soil chemistry and biology to such a degree as to limit plant nutrient availability by disrupting the uptake and utilization of other

minerals needed by the plants (Joe 2002). This can cause disorders in mineral nutrition. Because many salts are also plant nutrients, high salt levels in the soil can upset the nutrient balance in the plant or interfere with the uptake of some nutrients (Conway 2001). For example, high sodium concentrations may cause deficiencies of other elements, such as potassium and calcium, and high levels of sulfate and chloride diminish the rate of nitrate absorption (BPMC 1996). In sodic soils, higher pH generally occurs, which also can affect nutrient availability. Soils with pH above 7 can have fewer nutrients availability (Denise 2003). The nutritional deficiencies and toxicities of plants can be characterized by necrosis (tip burning or marginal scorch browning and dieback of leaves), Chlorosis (turning yellow in color), and abscission (premature dropping) (BPMC 1996).

2.4.3. Structure and permeability problem of salts in the soil

Lastly, certain ions negatively influence soil structure and permeability characteristics, there by retarding plant growth (Joe 2002). Sodic and saline–sodic soils show structural problems created by certain physical processes (slaking, swelling and dispersion of clay) and specific conditions (surface crusting and hard setting). Such problems may affect water and air movement, plant-available water holding capacity, root penetration, seedling emergence, runoff and erosion, as well as tillage and sowing operations in sodic and saline-sodic soils (Qadir *et al.,* 2003).

If a sodic clay layer occurs near the surface of sodic soils it often acts as a barrier to roots. Hence, most roots are restricted to the topsoil above the clay pan, because movement of water, nutrients is restricted (Fitzpatrick *et al*., 2003; Pam 2002). Plants on sodic soils usually show a burning or drying of tissue at leaf edges, progressing inward between veins. General stunting is also common (Fitzpatrick *et al*., 2003; Pam 2002).

Besides plant growth, salinity may also reduce seed germination, thereby affecting the ability to revegetate these sites. According to Conway (2001), a high salinity level restricts seed germination, but does not affect seed viability. Usually the plant stages that are most sensitive are germination or the early growth stages. However, some plants, known as halophytic (salt-loving) plants, are more tolerant (Denise 2003). Salt tolerance

refers to the ability of a plant to maintain growth and metabolic function (including photosynthesis) when exposed to a high concentration of salt in the soil or in irrigation water (Duncan & Carrow 2000; Marcum 2001).

2.5. Adaptations of salt tolerant plants

Plant selection is an important management tools as species have a wide variability in salt tolerance and thus may have high potential for use in reclamation of saline sites by minimizing the salinity effect (Conway 2001).

Salt tolerant species or halophytes have adopted salinity tolerance mechanisms that include salt exclusion, uptake and compartmentalization of salts, and extrusion of salts (Holly 2004). The physiological uniqueness of halophytes is often expressed in morphological features such as salt glands, salt hairs, and succulence. In many cases, plants may rely on more than one tolerance mechanism for salt resistance (Holly 2004; Naidoo & Naidoo 1999).

Salt tolerant plants are able to adjust internally to the osmotic effects of high salt concentrations or they are more able to absorb water from saline soils. Salt exclusion allows plants to regulate and minimize the amount of salt reaching meristems, developing leaves, and young fruits. Some species have developed diverse “excluder mechanisms”, such as salt filtration in the roots and interruption of salt transport through storage in roots, upper stem and stalks. Salt avoidance is usually accomplished by limiting germination, growth, and reproduction to specific seasons during the year, by growing roots into nonsaline soil layers, or by limiting salt uptake (BPMC 1996).

Some salt resistant species do not exclude the salt ion at the root, but rather excrete salt through glands, at the surface of the shoot, and by shedding parts heavily loaded with salt (Holly 2004 & Larcher 2001). Salts excreted through glands and hairs are transported via the transpiration stream (xylem) to the glands and extruded to the leaf surface (Holly 2004; Taiz & Eduardo 1998). The salt is crystallized on the surface and is no longer harmful to the plant. Hairs of some species accumulate chlorides in the cell sap, die off, and are replaced by new hairs. Additionally, shedding of older leaves that have accumulated salts allows a plant to rid itself of salinity. Young leaves replace the

older, salt-laden leaves and are eventually shed as salts again accumulate. Succulence is a widespread phenomenon among halophytes in wet, saline environments (Holly 2004; Larcher 2001). Damage to protoplasm is a result of high salt concentrations within a cell. In order to maintain survivable salt concentrations, the storage volume of the cell will increase progressively with the uptake of salt through equal greater water storage. This allows the plant to take up an adequate amount of water to keep salt concentrations reasonably constant for extended periods. Lastly, halophytes have the ability to adjust their water potential in response to salinity (osmotic stress) through uptake and compartmentalization of salts (André *et al*., 2004). Halophytic plants accumulate ions in the vacuole and synthesize organic solutes in the cytosol (Marcum 2001; Taiz & Eduardo 1998). Accumulation of ions in the vacuole allows the plant to absorb water along an osmotic gradient without damaging salt sensitive enzymes. Vascular accumulation also reduces the concentrations of salt to which the chloroplasts are exposed (Larcher 2001; Taiz & Eduardo 1998). Synthesis of organic solutes enables plants to maintain water balance between the cytoplasm and vacuoles (Holly 2004; Marcum 2001). When total water potential in the plant is lower than the water potential of salty soil, the plant is able to extract water from soil solution (Holly 2004; Taiz & Eduardo 1998).

2.6. Some salt tolerant plants

Saltbush (*Atriplex halimus*) is one example of a halophytic plant, where salts are taken up from soil moisture; eventually accumulate within the plant cells and sometimes crystallise on the leaf surfaces (Barrett-Lennard 2003; Denise 2003; Hall 2004; Semple 2001).

Atriplex halimus is a halophytic shrub, well adapted to living in soils with high concentrations of salt. Unlike many plant species that exclude salts during the uptake of soil moisture, halophytes both tolerate and utilize salts present within the soil profile. These physiological traits of saltbush make it an ideal plant for rehabilitating saline soils. This species of saltbush performs incredibly well in harsh climatic conditions, including low rainfall, severe frosts, strong winds and very shallow soils. Waterlogged sites should be drained appropriately prior to planting and mounded to ensure plants are

not established in waterlogged and anaerobic conditions. The construction of mounds in clay soils can however cause smearing and lead to poor germination. This species has grazing value; productivity; and environmental benefits (Barrett-Lennard 2003).

There are much nutritional benefits from grazing; sheep consumption of saltbush increases their level of vitamin E intake, helping to protect them from a muscle wasting disease known as nutritional myopathy. In addition to providing nutritional benefits to sheep, saltbush helps reduce farmers' costs incurred in providing synthetic vitamin supplements during the dry summer months (Stephens 2004).

There are many environmental benefits to be gained from the successful establishment of saltbush in saline environments. Saltbush has the potential to utilize salts present within the soil profile, lower shallow water tables and prevent the development of perched aquifers. Ultimately, this facilitates the rehabilitation of saline areas, allowing other grasses and vegetation to establish beneath the saltbush and may prevent degradation of areas at risk of salinisation (Barrett-Lennard & Galloway 1996; Barrett-Lennard 2003; Ferdowsian *et al.,* 2002).

Biodiversity and habitat values have also been found to increase in mainland trials. A range of mixed native plant species have regenerated naturally within saltbush stands, along with increased insect populations. An important feature to note is that the establishment of saltbush and the associated benefits need not be dependant on a site being saline. Saltbush will still perform well on non-saline sites, providing many environmental benefits such as windbreaks, soil stabilization and fodder reserves for stock, both sheep and cattle. *Atriplex halimus* is well adapted to drought and saline conditions, occurring in areas with rainfall between 150 and 500mm per annum, but it can also persist in areas with much less. It will grow on a variety of soils including those that are shallow and infertile or highly alkaline, but does not like waterlogged conditions (Barrett-Lennard 2003; Millsom 2002).

Another salt tolerant grass species is *Chloris gayana*. *Chloris gayana* is perennial species, found in summer moist saline sites, but can be difficult to establish from seed in saline sites. This species is widely used as forage grass, and recognized for its high level

of salt tolerance (Leandro *et al.,* 2006). It can tolerate up to 8 dS/m of soil salt level (Rogers *et al.,* 2003). Rhodes grass (*Chloris gayana*) pasture leys were able to dramatically improve soil organic matter contents in the upper 30cm and infiltration rates into the soil profile (Bell *et al.,* 2001).

Panicum maximum (guinea grass) is native to Africa but this grass was introduced to almost all tropical countries as a source of animal forage. It is annual forage grass, it grows well on a wide variety of well-drained soils of good fertility, and it is suitable to stop soil erosion. It can survive quick moving fires that do not harm the underground roots and drought because of the deep, dense and fibrous root system. Guinea grass is a clump-forming perennial which grows best in warm frost free areas receiving more than 900 mm rainfall and it is more drought tolerant than Rhodes grass. It will tolerate soil pH to 8.0 (Aganga & Tshwenyane 2004; CIAT/FAO 2006; Jank *et al.*, 2002).

2.7. Other reclamation methods of salt affected soils

Salt affected soils differ considerably in use suitability, productivity, ease of reclamation, and management (Conway 2001; Michael & Paul 2002).

Saline Soils are usually the easiest to reclaim if sufficient moisture is available and the soil has good permeability or adequate drainage to allow the excessive soluble salts to be leached below the root zone (Jim 2002; Michael & Paul 2002). Washing salts off the soil surface is not sufficient to prevent damage to plant roots. Internal and adequate drainage (either natural or man-made) is usually necessary to allow leaching of salts below the root system of the plant. Sometimes a layer of clay or compaction in the soil will prevent proper drainage (Michael & Paul 2002). To improve the permeability, the incorporation of large amounts of organic matter is recommended. The organic matter improves soil structure, infiltration and percolation of moisture, thereby enhancing the salt leaching. This is particularly important where excessive soil loss has occurred (Conway 2001). Mulching is also good to prevent evaporation and subsequent build-up of salt in the soil (Bonnie *et al*., 2002).There is no chemical amendments that will reclaim saline areas. The addition of soil amendments such as sulfur, gypsum, or other calcium salt materials will not reclaim saline soils (BPMC 1996; Conway 2001).

Sodic soils are detrimental to growth of most plants. They can be reclaimed, but it may be slow and most expensive soil type to reclaim due to the lack of a stable soil structure, which slows water drainage (Jim 2002).

The addition of chemical amendments, organic matter, or deep tillage followed by sufficient leaching is required to reclaim these soils (Conway 2001). The purpose of applying chemical amendments is to supply calcium in the soil water for the replacement of the absorbed sodium on the clay particles. The major chemical amendments are gypsum ($CaSO_4$), lime ($CaCO_3$), calcium chloride dihydrate (Ca CI,-2H, O), elemental sulfur, and sulfuric acid (H_2S0_4). Gypsum is the most common amendment and adds sulfur to the soil (BPMC 1996; Conway 2001; Jim 2002;).

Gypsum tends to increase the levels of Ca^{2+} in the soil that can then exchange with the Na^+ creating Na^+ sulfate (Na_2SO_4), which is mobile and can be leached from the soil. The addition of Ca^{2+} lowers the sodium adsorption ratio (SAR) and contributes to the exchange and removal of Na^+ (Silvertooth & Norton 2000).

Lime is only beneficial if the pH is below 7.5. The elemental sulfur or sulfuric acid will be beneficial for sodic soils that are calcareous (high in calcium carbonate). The sulfur will react with the calcium carbonate to form gypsum (BPMC 1996; Michael & Paul 2002). Elemental S, when oxidized by soil microbes and combined with water, reacts to form sulfuric acid (H_2SO_4), which reacts with naturally occurring Ca^{2+} carbonate ($CaCO_3$), releasing “free” Ca^{2+}. This Ca^{2+} in the soil solution can then exchange for Na^+ in the form of Na_2SO_4, which can be leached from the soil.

The finer textured soils (clay soils) require more amendments and a longer time to reclaim than coarse textured soils (sandy soils). Application of elemental sulfur is a slower process, as microbial activity is required to oxidize the sulfur (BPMC 1996; Michael & Paul 2002). Applications of amendments may be largely ineffective unless the soil is periodically leached so the sodium can be moved deeper in the soil profile (Conway 2001).

Adding organic matter is always beneficial when working with sodic soils. It can help to

open up the sodic soil, improving soil structure, drainage and moisture holding capacity along with planting salt tolerant species will enhance the reclamation process (Bonnie *et al*., 2002). Decomposing organic matter helps stabilize calcium as well as providing channels in the soil to conduct water, and to help reduce evaporative losses. The organic matter also helps to lower the soil pH, which decreases the exchangeable sodium near the surface and it stimulates microbial activity, which promotes aggregate stability of the soil particles (BPMC 1996; Jim 2002).

Over the recent years, several commercially available Ca bearing products have become available for a potential treatment of sodic soil conditions. These products include CAN-17 (17-0-0-24Ca), N-Cal™ (18-0-0- 6Ca), and CN-9 (9-0-0-11Ca) just to name a few (Silvertooth & Norton 2000).

In reclamation of saline-sodic soils, the leaching of excess soluble salts must be accompanied (or preceded) by the replacement of exchangeable sodium by calcium. In saline sodic soils leaching of the soluble salts without the addition of a calcium product, such as gypsum, will result in a sodic soil (Conway 2001; Jim 2002). The amelioration procedure for saline–sodic and sodic soils needs a source of calcium (Ca^{2+}) to replace sodium (Na^{+}) from the cation exchange sites. The displaced Na^{+} is leached from the root zone through excess irrigation, a process that requires adequate flow of water through the soil (Qadir *et al.,* 2003).

As a potential substitute of cost-intensive chemical amelioration, phytoremediation (a plant-assisted reclamation approach) of saline–sodic soils has been found to be an efficient and low-cost strategy. This plant-assisted approach relies on enhanced dissolution of native calcite within the root zone to provide Ca^{2+} for Na^{+}–Ca^{2+} exchange at the cation exchange sites. The salinity–sodicity combination in soil solution during phytoremediation remains suitable, which helps in maintaining adequate soil structure and aggregate stability that prevent reduction in soil permeability to air and water (Qadir *et al.,* 2003). In recent years, phytoremediation has shown promise for the amelioration of calcareous sodic and saline-sodic soils. It also provides financial or other benefits to the farmer from the plant grown during the amelioration process. Phytoremediation of

sodic and saline-sodic soils is achieved by the ability of plant roots to increase the dissolution rate of calcite, resulting in enhanced levels of Ca^{2+} in soil solution to replace Na^{+} from the cation exchange complex. Research has shown that this process is driven by the partial pressure of CO_2 within the root zone, the generation of protons (H^{+}) released by roots of certain plant species, and to a much smaller extent the enhanced Na^{+} uptake by plants and its subsequent removal from the field at harvest (Qadir *et al.*, 2005). Aqueous CO_2 produces protons (H^{+}) and bicarbonate (HCO_3^{1}). In a subsequent reaction, H^{+} reacts with native soil calcite ($CaCO_3$) to provide Ca^{2+} for Na^{+}-Ca^{2+} exchange at the cation exchange sites (Qadir *et al*., 2003).

Along with the conventional methods of treating sodic and saline conditions, there has been an increasing emergence of numerous synthetic water-soluble polymers (WSP's). The WSP's include polyacrylamide (PAM), polyvinyl alcohol (PVA), polymaleic anhydride (PMA), and polysaccharides. Research studies have shown that these synthetic polymers have reduced soil surface crusting, improved water holding capacity, improved aggregation and reduced clay dispersion, enhanced nutrient uptake by crops and enhanced ability for reclamation of saline and sodic soils. However, they do not impart an exchange for Na on the soil adsorption complex (Silvertooth & Norton 2000).

2.8. Salt Affected soils in Ethiopia

Ethiopia is reported to posses over 11 million hectares of unproductive naturally salt affected wastelands (Tadelle 1993). The naturally salt affected areas are normally found in the arid and semi arid lowlands and in Rift valley and other areas that are characterized by higher evapotranspiration rates in relation to precipitation (PGRC 1996). The Great Rift Valley runs from northeast to southwest of the country and separates the western and southeastern highlands and contains twelve Ethiopian lake basins. The high lands on each side of the rift valley give way to extensive semi-arid lowlands to the east, south and west of the country. Pastoral agriculture is practiced here mainly at an elevation below 1,500 m.a.s.l. and with annual rainfall of below 450-mm. Soil salinity and low moisture are potential environmental problem and production constraints particularly in the arid zone. In general, this zone is liable to be converted

into a desert if the current human activities continue unabated, and the drought conditions continue (PGRC 1996).

With the development and expansion of irrigated agriculture, however, man's activities are greatly contributing to the build up and spread of salinity problems. Close to 3 million ha of potentially irrigable land in the different river basins and in the rift valley areas where existence of salinity problems are well documented (Tadelle 1993).Where as the freshest lake (Ziway) which falls with in the main rift valley area has been targeted in particular for substantial irrigation development by the government since the 1970's, by taking water directly from lake Ziway and its two feeder rivers Katar and Meki. This lake is suitable for irrigation (Tenalem 1998). However, around the riverbank in Ziway horticultural state farm, one is able to see the Solonchack with white salt incrustation on surface (Fisseha 1998). The arid like climate in the irrigated area allow limited leaching by favoring concentration and accumulation of soluble salts in the soil. Poor water management practices(excess application of irrigation water contribute to recharge of ground water) and lack of adequate drainage facilities have greatly contributed to the conversion of large productive lands in to an unproductive waste land in a short period of time. Rising ground water leads to water logging of the root zone area and ultimately to salinization. Salinization processes continue to affect production and productivity since drainage facilities are absent and water management practices remain inefficient and quite wasteful (Tadelle 1993).

High salinity in the Ethiopian ground waters is apparent in some parts of the Rift because of the influence of saline geothermal waters. In the southern parts of the Rift, sodium and bicarbonate (high alkalinity) are the dominant dissolved constituents. High concentrations of dissolved salts in the ground waters from the sedimentary formations are also common, as a result of reaction of the often-abundant evaporite minerals. In these, high salinity may be manifested by high concentrations of sodium, chloride and/or sulphate in particular. Observed increased salinity in many ground waters from sediments in the south, southeast and northeastern parts of the country arises from the dissolution of evaporite minerals (the products of evaporation) in certain horizons of the sediments (BGS 2001). Areas of the Rift affected by geothermal waters, as well as saline

ground waters from the evaporite bearing sediments of eastern and northern Ethiopia may have increased concentrations of boron, although no data are available (BGS 2001).

According to Sissay (1985) salt-affected flats have increased from 6% to 16% of the total land area of Ethiopia in recent years. About 9% of the population lives in the areas affected by salinity. Tamirie (1994) has revealed that 44 million ha (36% of the country's total land areas) are potentially susceptible to salinity problems. Out of the 44 million ha, 33 million ha have dominantly salinity problems, 8 million ha have combined salinity and alkalinity problems, and 3 million ha have dominantly alkalinity problems.

3. Materials and Methods

3.1. Study area description

The study was conducted on cultivated fields located on the southwestern shore of Lake Ziway (Figure 1), the Rift Valley zone of Ethiopia. The study area is situated in East Shewa Zone of Oromia Region at about 160 km from Addis Ababa. The average elevation is 1640 m.a.s.l. the study site is about 50ha of land. The area is characterized by shallow to relatively deep groundwater with thick aquifer and relatively good permeability (Lemlem 2003; MoWR 2006).

Population

Before the dwellers on the islands and land surrounding the Lake Ziway were Gurages. However, today the inhabitants of the western shore of Lake Ziway are Oromos (Abdurhman 2002 & James 1977). Orthodox Christians and Muslims form the largest proportion of the religious groups in the area; Catholics and Protestants form minority group (Abdurhman 2002).

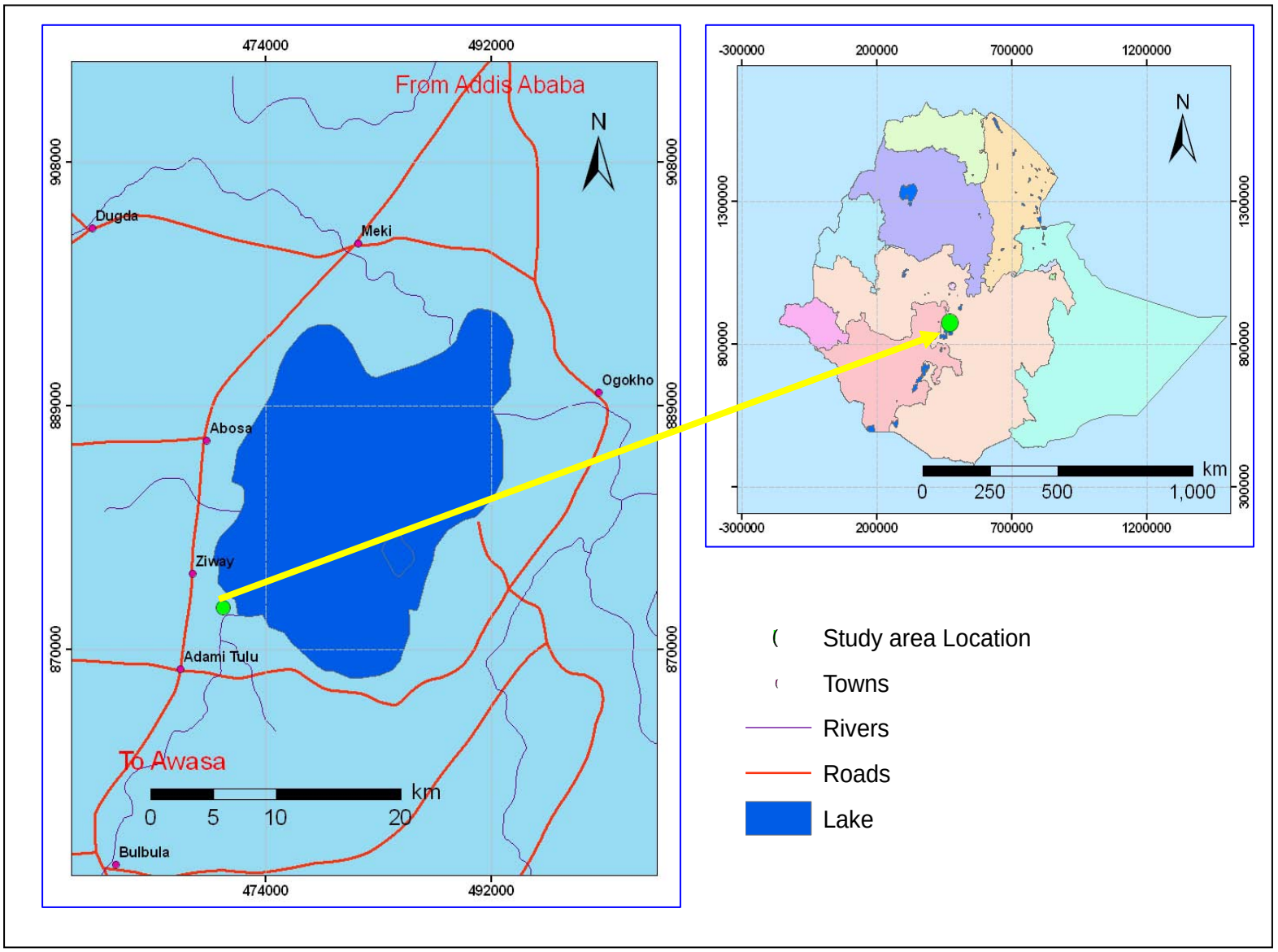
Climate

The climate of the area around Lake Ziway has arid characteristics for most of the year and monthly average rainfall never exceeds evaporation. The mean annual rainfall is 760mm (MoWR 2006). The mean daily temperature at Ziway is 19.3°C. The highest temperatures occur between March and June prior to the start of the main rains, though seasonal variation in daily temperature is relatively slight. The mean annual temperature of the area is with in the range of 16-25^{0}c (MoWR 2006).

Wind

Strong and persistent daytime winds are significant feature of the Lake Ziway area. During the afternoon in the dry season, the prevailing northeasterly winds are reinforced to the west and south of the lake by local on-shore airflow (MoWR 2006).

Figure 1. Location map of the study area



Sunshine Hours

The lowest sunshine hours are recorded during the rainy season while the highest values are generally observed in November through February (MoWR 2006).

Soil type

The areas around Lake Ziway are composed of volcanic rocks, with alkaline lavas, ashes and ignimbrites, mainly of Tertiary and younger age. The sediments covering the volcanic rocks in the area are, generally mixed deposits of sandstone, limestone and silts, with frequent occurrences of evaporite minerals (BGS 2001). In Ziway, area gentle levees are formed of sandy clay loams. The appearance of the soil and plant in the study area were shown in Figure 2:

Figure 2. The appearance of soil and plant in the study area



Lake Ziway

Lake Ziway is the freshest lake of the Rift Valley lakes and has an electrical conductivity value of 0.357 dS/m (Huib & Herco 2006). The concentrations of the major elements in the Lake Ziway and the major incoming rivers do not impose major limitations to use the water for irrigated agriculture and human consumption (Huib & Herco 2006). The concentration of soluble salts: Ca, Mg, Na, K, Cl, SO_4 in the lake are with in the range of 0.55-1.15meq/l, 0.5-0.83meq/l, 2.3-3.4meq/l, 0.21-0.35meq/l, 0.26-0.46meq/l and 0.04-0.32meq/l respectively. The sum of CO_3 and HCO_3 concentration is 4me/l (Gashaw 2006). The government has focused on development of irrigation in the basin since the 1970's. The dominant cation is sodium followed by potassium and calcium, amongst the anoins, the main one is bicarbonate with minor chloride and sulfate ions and pH range of 6 to 8. Lake Ziway has lower EC than the other lakes in the Rift Valley due to the large inflow of fresh water from rivers and the existence of outlets. The annual direct precipitation over the lake is 323MCM. The main inflow is from the rivers Katar and Meki are 392MCM and 265MCM respectively (Tenalem 1998). The predominant ions in the Meki and Ketar River are calcium and bicarbonate. Lake Ziway has a relative abundance of sodium and bicarbonate. The different water composition can be explained by the geology of the area. The main source for sodium is the dissolution of sodium containing rock minerals. As there is relatively much interaction between water in the (shallow) lake and the rocks, the sodium concentration rises in the lake (Huib & Herco 2006). The studied field is irrigated with water from Lake Ziway.

3.2. Methods

3. 2. 1. Site selection and soil sample collection

Soil samples were collected from cultivated field. Three sampling sites were chosen across the cultivated field from which representative soil samples were collected. The size of each site was 400m^2, totally 1200m^2. From each site, 16 samples were randomly collected using auger at 0-20 cm depth and composited to homogenize it. About 70kg of composited soil samples were collected from each sites and labeled as soil type A, B, and C. Sampling was done in October 2006. The collected soil samples were used for

soil chemical analysis to determine the level of saltiness and the type of ions involved and for growing the different forage plants in a green house.

3.2.2. Plant sample collection

Seeds of four different plants, three grasses (*Setaria sphacelata*, *Chloris gayana* and *Panicum maximum*) and one shrub (*Atriplex halimus*) species were collected from ILRI (International Livestock Research Institute).

3. 2. 3. Laboratory analysis of soil samples

The selected soils were subjected to various soil chemical analyses (pH, electrical conductivity, cation exchange capacity, exchangeable cations, soluble cations and anoins, calcium carbonate, texture, organic carbon and total nitrogen) in the National Soil Laboratory and Addis Ababa University. Important chemical properties of the soil were determined using the following standard methods and procedures. EC and pH of the soil samples were determined from saturated paste extract with conductivity meter and pH meter with glass calomel combination electrode respectively. Electrical conductivity (ECse), soluble cations, and soluble anions were measured in the saturation extracts (USDA-NRCS 1996).Soluble cations and anions in saturated paste extract were determined as follows: soluble Ca, and Mg by Atomic Absorption Spectrophotometer (RDP 1986), Na and K by Flame Photometer, (FAO 1984), SO_4 by calorimeter and chloride (Cl) by titration. CO_3 and HCO_3 were determined by potentiometer titration of saturated extract with HCl or H_2SO_4 to pH 8.4 and 4.4 respectively (USSLS 1954). The CEC and exchangeable base were extracted using 1:1 alcohol and Ammonium acetate extraction method after (Bower *et al*., 1952). Exchangeable Base (Ca, Mg) were determined using Atomic Absorption Spectrophotometer, K and Na using Flame Photometer. Calcium Carbonate content was determined by volumetric calcimeter according to Allison and Moodie (1965). Organic carbon and total nitrogen were analyzed using Walkely Black and Micro Kjeldahl Method respectively. Particle size analysis was determined after samples were dispersed in sodium hexametaphosphate solution and shaken on a horizontal reciprocating shaker for 12 hrs using hydrometer method (Day 1965).

Derived calculation for SAR and ESP estimates were made using appropriate formula

$$SAR = \frac{[Na+]}{[Ca^{2+} + Mg+2]}$$ (Gapon 1933)

$$ESP = \frac{Na}{CEC} * 100$$

Where the concentration of each component is in meq/100g of soil or meq or mmol/l of soil.

The soils were classified into different salt affected soils according to the standard guidelines by Abrol *et al.,* (1988); Gonzalez *et al*., (2004); Qadir & Schubert (2002), which is summarized in the Table 1.

Table 1. Guidelines for classification of salt affected soil.

Soil classification	EC (dS/m)	SAR	ESP	pH
Saline	>4	<13	<15	<8.5
Saline-sodic	>4	>13	>15	<8.5
Sodic	<4	>13	>15	>8.5

3. 2. 4. Greenhouse experiment

3.2.4.1. Experimental design

The experimental design used for the greenhouse experiment was CRD (Complete Random Design). For the design 36 pots, three grass and one shrub species and three different soil types collected from three different sites were used. By taking the three types of soils and the four different plants as a treatment. The soils were sieved and passed through 2mm mesh sieve before use to discard the roots of unwanted species, where individual pots were filled with a 2kg of soil. From 36 pots, twelve pots were filled with the same type of soils. The seeds of four plants sowen on the three types of soils by taking their seeding rate with three replication. In the design, there were 12 treatments out of these four treatments replicated three times and randomized on the

same type of soil. The treatments were 1A, 2A, 3A, 4A, 1B, 2B, 3B, 4B, 1C, 2C, 3C, and 4C. The serial number indicates the type of species (1= indicate *Atriplex halimus*, 2=*Chloris gayana*, 3= *Setaria sphacelata*, 4= *Panicum maximum*) and the letter next to it indicate the type of soils. The plants were watered twice a day and the room temperature was 38^0c. The design used for the greenhouse experiment was as shown below:

Soil from site A

1A	2A	3A	4A

Soil from site B

1B	2B	3B	4B

Soil from site C

1C	2C	3C	4C

3. 2. 4. 2. Greenhouse data collection

The data collected include survival count (no. of survived(grown species)/no. of sown plants multiplied by hundred) of each plant species, which was conducted every week and height growth of each seedling in each pot, which was measured and the average height was taken for three months from the green house. The experiment was conducted for three months.

3.3. Data analysis

The data collected from the greenhouse experiment were analyzed using analysis of variance (ANOVA) to determine if there were differences between treatment means at ($P<0.01$) significant level. Analysis of variance (ANOVA) was performed by statistical package for social studies (SPSS) software version 11.0 (SPSS Inc., 1999). ANOVA test was used to know the presence of significant difference between species survival percentage on soils with the same salt content. In addition, it is used to know the

presence of significant difference on survival percentage and height of same species between soils with different salt content. Where significant differences were found among the variables, multiple comparisons among the means were made using the least significant difference (LSD) test.

4. Result and Discussion

4.1. Categorizations of soils based on their salt content

The result of this study reveals the existence of the salt problem in the study area from the laboratory analysis of three-soil samples. The extent of salinity in the study area was categorized based on four main parameters of salt affected soils such as EC (electrical conductivity), pH, ESP (exchangeable sodium percentage), SAR (sodium adsorption ratio) because these values are used in the guidelines for classification of salt affected soil (Gonzalez *et al.,* 2004; Qadir & Schubert 2002). From the parameters, the three values namely EC, ESP and SAR show the total soluble salts and the amount of sodium salts in the exchangeable sites of the soil (BPMC 1996; Jim 2002 & Michael; Paul 2002). The other parameter, which is soil pH, does not directly measure saltiness. Since soluble salts affect soil pH and vice versa, it is often included in evaluations and discussions of soil saltiness (Akhter *et al.,* 2003; Joe 2002).

Table 2. The EC, SAR, ESP and pH values for soils from the three sites

Sites	EC	SAR	ESP	pH
A	9.3	58.7	34.3	8.8
B	19.3	385.9	78.8	10.1
C	8.1	95.3	65.5	9.4

4.1.1. Soils from site A

The EC value of the soils collected from site A was generally greater than 4dS/m (Table 2), which indicates the presence of much soluble salt in the soil solution, which is a threshold used to define saline soils see Table 1. The SAR value of this soil type was greater than 13 that indicates the concentration of sodium in the soil solution is much higher than the concentration of calcium and magnesium, this value is a threshold to define sodic and saline-sodic soils see Table 1. The value of ESP was higher than 15, which shows that the presence of more exchangeable sodium percentage relative to the total exchangeable cations; which is a threshold to define sodic and saline-sodic soils see Table 1. According to Joe (2002) even though there are occasional deviations, generally

low SAR value of the saturated extract are associated with low ESP values in the soil and high SAR value donate high ESP values. This indicates the presence of more sodium in the soil solution leads to have significant amount of sodium in the exchangeable sites. The same thing happened in soil collected from site A. In this soil type, there was more sodium in the soil solution to give significant amount of sodium on the exchangeable site. This was presented in Tables 2, 3 and 4.

Table 3. Soil solution properties of soils from the three sites.

Sites	Water soluble ions meq/l							
	Ca	Mg	K	Na	HCO_3	Cl	SO_4	CO_3
A	3.29	0.75	3.18	83.30	11.7	29.23	37.45	18.2
B	1.08	0.139	1.25	301.05	24.7	38.78	34.53	163.8
C	1.5	0.30	3.2	90.5	5.72	29.7	22.05	39

According to Gonzalez *et al*., (2004) the three parameters namely EC, ESP and SAR indicate soil from site A was neither saline nor sodic. However, it has the characteristics of both saline and sodic, so from the guideline of salt affected soil categories this soil falls under saline-sodic soil class see Table 1. Saline-sodic soil has a pH value less than 8.5. However, pH value of soils collected from site A was 8.8 that is slightly greater than 8.5, generally this value indicates the characteristics of sodic soils rather than saline-sodic soils (Conway 2001; Gonzalez *et al.,* 2004; Qadir & Schubert 2002). According to Ann & Clain (2005) the pH value of saline-sodic soil are seldom higher than 8.5 due to high exchangeable Sodium and carbonate (CO_3^{2-}) ions. When an exchangeable sodium or carbonate ion reacts with water, they produce hydroxide ions (OH^-) via the following reactions:

$$\text{Na-clay} + H_2O \longrightarrow \text{H-clay} + Na^+ + OH^-$$

$$CO_3^{2-} + H_2O \longrightarrow HCO_3^- + OH^-$$

The resulting increase in OH^- ions causes pH to increase. Soils collected from site A, has high exchangeable sodium and there was considerable carbonate ion see Table 3 and 4. This could be the reason for the slight increase of pH in this soil type. Generally, based on the four parameters and the above reason and explanation, soil from site A falls under

the classification of salt affected soil categories of saline-sodic soils. In saline-sodic soils, high pH values may be related to the accumulation of sodium bicarbonates and carbonates, which are soluble salts capable of undergoing alkaline hydrolysis. Which can increase the pH over 8.5 (Guerrero-Alves, 1998).

Table 4. Exchangeable base and cation exchange capacity of soils from the three sites

Soil type	Exchangeable bases meq/100g soil				
	Ca	Mg	K	Na	Effective CEC
A	14.78	2.57	13.93	16.31	47.59
B	6.51	0.36	18.65	94.98	120.50
C	9.07	0.63	6.54	30.76	46.99

Texture

Having high sodium than calcium & magnesium and high magnesium alone or with high sodium leads to dispersion of soil particles. This results in destruction of soil structure and problem in water penetration (permeability problem) due to sodium adsorption to the soil particles. Fine textured soils, especially those high in clay, are most subjected to this action (Jim 2000; Qadir & Schubert 2002; Wendroth *et al.,* 1999). As it is listed in Table 5, the textural class of soil collected from site A is loam, which indicates the presence of appropriate balances of sand, silt and clay in the soil (Larry *et al*., 2002). However, from the percentage of each particle, clay has the lowest percentage when compared to silt and sand particles see Table 5. This indicates the above-mentioned problems due to high sodium adsorption to the soil particles would be severe if clay percentage dominates from the other particles.

Carbon/Nitrogen ratio

According to Kirsten (2005), the two extremely important chemical elements in organic matter, proportional relationship is the carbon-nitrogen ratio. When the ratio was between than 10:1-15:1, it is optimum for plant growth, even though the proportions of C/N ratio differ for different type of organic matter (Kirsten 2005). The carbon nitrogen ratio of soil collected from site A was 12.3:1(Table 5); which is good for plant growth.

In salt-affected degraded areas, SOC (soil organic carbon) levels are likely to be affected by declining vegetation health and hence, decreasing biomass inputs and concomitant lower levels of organic matter accumulation. Moreover, potential SOC losses can be higher from dispersed aggregates due to sodicity (Vanessa *et al.,* 2006).

In this soil type, there was calcium carbonate see Table 5. Calcium carbonate was less soluble so that the presence of calcium carbonate indicates the precipitation of calcium in the form of carbonate (Tayim & Al-Yazouri 2005). The reason for the precipitation of calcium as calcium carbonate is due to high pH of 7.5 or above, resulting in the formation of calcium carbonate precipitates (Tayim and Al-Yazouri 2005). However, in this soil type the amount of calcium was very low to form more precipitated calcium carbonate see Table 3.

Table 5. Selected physicochemical properties of soils from the three sites

Sites	$CaCO_3$ %	Clay %	Silt %	Sand %	Texture class	Total N %	Organic C %	C/N ratio
A	6.2	27	42	31	Loam	0.3	3.7	12.3:1
B	3.7	17	30	53	Sandy loam	0.1	0.8	8:1
C	6.2	21	30	49	Loam	0.2	1.8	9:1

4.1.2. Soils from site B

Like soil from site A the three parameters, such as EC, SAR and ESP value makes the salt affected soil categories of soil from site B to fall in saline-sodic soil class see Table 1 & 2. However, the concentration of soluble salt and exchangeable base is not the same as soil of site A, this can be seen from the values of four parameters in Table 2. The pH value of this soil type was 10.1, which is more than 8.5. By the same reason mentioned above these values does not hinder soil of site B to be categorized in salt affected class of saline-sodic soils. The pH value of this soil type was higher than the other two soil types; the reason could be due to the presence of high carbonate and high exchangeable sodium in this soil type than the other two soil types see Table 3 and 4 (Ann & Clain

2005).

Texture

The textural class of this soil type was sandy loam, which indicates the presence of high sand percentage than the other soil particles. The presence of sand particles let the salt react in the soil mixture and then leaching (Ziad *et a*l., 2004; Qadir *et al*., 2003). Clay has the lowest percentage from the soil particles in this soil types. Due to the presence of low clay percentage and high sand percentage, it was expected that the destruction of soil structure and permeability problem would be lower than soil of site A. However, there was very high sodium ion in this soil types to be adsorbed on available fine texture soil particles (silt) than soil of site A. This made the problem of this soil type to be higher. The presence of high permeability problem was observed in this soil type than the other two soil types during the greenhouse experiment.

Carbon/Nitrogen ratio

The carbon nitrogen ratio of soil of site B was 8:1 this indicates the presence of high proportion of nitrogen than carbon (Kirsten 2005). This could be due to the usage of nitrogen fertilizer (urea) in the study area. Carbon nitrogen ratio less than 10:1 indicates the presence of nitrogen store than carbon in the soil (Kirsten 2005). In addition, microorganisms are main factor for the mineralization of organic matter in the soil, as salt increases in the soil the microbial activity decreases due to the toxicity of specific ions, elevation of osmotic pressure or the increase in alkalinity which may restrict the microbial activity (Sardinha *et al.,* 2003).

In this soil type, there was calcium carbonate indicating the precipitations of calcium as calcium carbonate because high pH of 7.5 or above, resulting in the formation of calcium carbonate precipitates (Tayim & Al-Yazouri 2005).

4.1.3. Soils from site C

Even though the concentration of each ion differs, the categories of salt affected class of soil collected from site C was the same with that of soil from site A and B based on the four parameters i.e. EC, SAR, ESP and pH. The pH value was greater than 8.5 just like

the above soil types, by the same reason mentioned above this soil type falls under saline-sodic soil of salt affected class. The electrical conductivity of 8.1 indicates the presence of high soluble salt and the other two parameters such as SAR and ESP showed the presence of high sodium in the soil solution and the exchangeable sites respectively (Table 2, 3 and 4).

Texture

The textural class of soil collected from site C was loam, which indicated the presence of proportional balances of sand, silt and clay in the soil (Larry *et al*., 2002). However, from the percentage of each particle, clay had the lowest percentage when compared to silt and sand particles (Table 5). This indicated the above-mentioned problems due to high sodium adsorption to the soil particles would be sever if clay percentage dominates (Jim 2000; Qadir & Schubert 2002; Wendroth *et al.,* 1999).

Carbon/Nitrogen ratio

The carbon nitrogen ratio of soil of site C was 9:1 see Table 5 this indicated the presence of high nitrogen than carbon. This could be due to the usage of nitrogen fertilizer (urea) in the study area. Carbon nitrogen ratio less than 10:1 indicates the presence of nitrogen store than carbon in the soil (Kirsten 2005).

In this soil type, there is calcium carbonate this indicates the precipitations of calcium as calcium carbonate because high pH of 7.5 or above, resulting in the formation of calcium carbonate precipitates (Tayim & Al-Yazouri 2005). Soil from site A and C have high calcium carbonate than soil from site B. it was almost two times higher. This indicates more calcium was precipitated as carbonate in the two types of soils than soil from site B. However, the calcium amount in the three types of soils was low so that the precipitation of calcium in the form of carbonate was limited.

4.2. The type of salt formed in the three sites

Salts found in soil collected from site A, B and C were of four types: sulfates (SO_4^{2-}); chlorides (Cl^{1-}); carbonates (CO_3^{2-}); and bicarbonate (HCO_3^{1-}) (Table 3). From these salt types, there was more sulfates salts in soil from site A, followed by chloride, carbonate

and bicarbonate in decreasing order. Mostly sulfates and/or chlorides salts are found in saline soil (BPMC 1996; Bonnie *et al*., 2002; Joe 2002), which indicates that this soil type had more saline character than sodic. However, there is more carbonate salt in soil from site B and C followed by chloride, sulfate and bicarbonate in decreasing order (Table 3), mostly the presence of carbonate salt is a character of sodic soils (Qadir & Schubert 2002) which indicated that these two soil types had more sodic character than saline.

The dominant salt type in the three types of soils was different because the concentration of ions (cations and anions) which was involved in salt formation was different in each type of soils. The dominant anion in soil from site A was SO_4 followed by Cl, CO_3 and HCO_3 in decreasing order and from the cation (Table 3), there was more concentration of Na followed by K, Ca, and Mg in decreasing order (Table 3). By taking both the anion and cation concentration, it was possible to say there were more Na_2SO_4 (sodium sulfate) salt concentration which is mobile and can be leached from the soil according to Silvertooth & Norton (2000) and least Mg $(HCO_3)_2$ (magnesium bicarbonate) salts concentration in soil type A. In soil from site B and C from the cation, the most abundant one was Na followed by K, Ca and Mg and from the anion CO_3 was the dominant one followed by Cl, SO_4 and HCO_3 in decreasing order see Table 3. Based on this, the dominant salt type found in soil from site B and C was Na_2CO_3, which is soluble salt capable of undergoing alkaline hydrolysis during Na_2CO_3 hydrolysis it form NaOH (a stronger base) and this results in pH over 8.5 (Guerrero-Alves, 1998). The least expected salt type in soil from site B & C was Mg $(HCO_3)_2$. Nevertheless, this does not mean the exact concentration of salts was same between soil from site B and C.

4.3. Similarity and difference among soils from the three sites

All soil samples, which were collected from the three sites, were saline-sodic soils. However, from all soils samples, the salt problem was high in soils collected from site B based on the four parameters like EC, SAR, ESP & pH see Table 2. Soil from site C has the higher value of SAR, ESP & pH than soil form site A see Table 2. SAR & ESP values are a measurement of sodicity character (Marx *et al.*, 1996), which indicates soils from site C has high sodicity character than soils from site A. On the other hand, the EC

value is higher in soil from site A than soil from site C see Table 2. EC is the character salinity (Joe 2002), which indicates soils from site A have high salinity character than soils from site C.

The lowest part in the exchangeable sites was occupied by magnesium in all type of soils because the amount of exchangeable magnesium was the least from the other cations found in all soil collected from the three sites see Table 4. The presence of low magnesium is good because high magnesium has the same problem with sodium (Qadir & Schubert 2002). Excess exchangeable Mg^{2+} alone or in combination with excess exchangeable Na^{+} may behave like Na^{+} in soil degradation. Mixed Na^{+}–Mg^{2+} soils developed lower hydraulic conductivity than did Na^{+}–Ca^{2+} soils under similar conditions. The reasons are that the size of hydrated Mg^{2+} is larger than hydrated Ca^{2+}. Thus, the soil surface tends to absorb more water than where exchangeable Ca^{2+} is present, resulting in weakening of the forces that keep soil particles together (Qadir & Schubert 2002).

Generally, from the above it is possible to say all soil samples were much more similar in their salt character. The only difference was the severity of salt problem.

4.4. Response of plants to gradient of salts in the soils from the three sites

From the four species in the greenhouse experiment the survival percentage and height of only two species namely *Chloris gayana* and *Atriplex halimus* was recorded on soil from site A and C. However, the other two species, *Setaria sphacelata* and *Panicum maximum* did not show any growth and even germination in all the three types of soils (Figure 3, 4, 5 and 6). Of the two species, which showed growth, more survival percentage on both soil from site A and C was attained by *Chloris gayana* than *Atriplex halimus.* The reason could be high salt tolerance capacity of *Chloris gayana* than *Atriplex halimus* or the presence of permeability problem in all soil samples, which affect *Atriplex halimus* than *Chloris gayana* (Barrett-Lennard 2003). In all the growing months, survival percentage of *Atriplex halimus* was from (4) % up to 21% and *Chloris gayana* from (5) % to 63% and the maximum height attained by the two species ranged

from approximately 8cm for *Atriplex halimus* and to 65 cm for *Chloris gayana* on soil type A. Both maximum survival percentage and maximum height of two species attained on soil from site A, on soil from site C the growth and height of the two species was not satisfactory. The maximum height attained by the two species in soil from site C was 2.5cm.

No species growth or even germination was recorded in soil from site B because the salt content of this soil type was highest than the other two soil types. As it was shown in Table 2 large amount of SAR and ESP value was recorded in soil from site B followed by soil from site C, the lowest salt content was recorded in soil from site A. That was the reason why there was more survival percentage in soil from site A and then in soil from site C. The growth response of species on all soil types showed, the presence of inverse relationship between survival percentage and soil salt level. This means high soil salt level gives less survival percentage and the reverse is true. According to Silva & Uchida (2000), the growth response of plant has inverse relationship with soil electrical conductivity and exchangeable sodium percentage see Table 6 & 7.

The response of plants for different type of electrical conductivity (salinity) was mentioned in Table 6. The electrical conductivity of soils from site A and C was 9.3dS/m and 8.1dS/m respectively, this EC value affect germination and growth of salt tolerant plants see Table 6. The electrical conductivity of soil type B was 19.3 dS/m which affects even very tolerant plants see Table 6.

Table 6. Different value of electrical conductivity with its corresponding plant Response

EC (dS/m at 25^0c	Plant response
< 2	Little, no effect on the growth and yield of plants
2-4	Affects only very sensitive plants
4-8	Affect many plants
8-16	Affect tolerant plants
>16	Affects even very tolerant plants

According to Silva and Uchida (2000), the acceptable level of ESP for plant growth was listed in Table 7. The ESP value of soil type A is 34.3 which falls in the intermediate level which is between 10- 35 but the other two soil types B and C are 78.8 and 65.5 respectively which is excessive level for plant growth or survival see Table 7.

Table 7. The ESP value and their acceptance level for plant growth

ESP value	
< 10	Acceptable
10-35	Intermediate
>35	Excessive

From the two tolerant species, *Chloris gayana* can be used to improve the saline-sodic soil type found in soil type A by observing its salt tolerance mechanism (uptake) (Peyrano 1997) and its survival percentage. However, the survival percentage of *Atriplex halimus* decrease drastically through time both on soil type A and C and the survival percentage of *Chloris gayana* was not satisfactory on soil type C. so that it was difficult to recommend this species for the improvement of salt affected soils found in the study area and other similar soil types.

Soil type B and C could not support halophyte plants satisfactorily so for the improvement of these soil types, there is a need of using other reclamation methods, which help to support halophyte and other plants. In addition to planting halophyte

plants, other reclamation methods must be used in the study area to help the reclamation ability of halophyte plants. The best reclamation method for these types of soils is first to improve the permeability of a soil by addition of large amounts of organic matter followed by leaching and then addition of chemical to replace sodium (Jim 2002 & Conway 2001). The organic matter improves soil structure, infiltration and percolation of moisture, thereby enhancing the salt leaching (Conway 2001). In reclamation of saline-sodic soils, the leaching of excess soluble salts must be accompanied (or preceded) by the replacement of exchangeable sodium by calcium. If the excess salts are leached without the addition of a calcium product, such as gypsum, calcium chloride dihydrate (Ca CI,-2H, O), elemental sulfur, and sulfuric acid (H_2S0_4) will result in a sodic soil (Jim 2002). For pH value greater than 7.5 amendments with calcium carbonate is not recommended (Jim 2000) because high pH of 7.5 or above, resulting in the formation of calcium carbonate precipitates (Tayim & Al-Yazouri 2005).

Figure 3. The survival response of *Chloris gayana* at the end of the third month on the three types of soil on the left soil type C then B and to the right A.

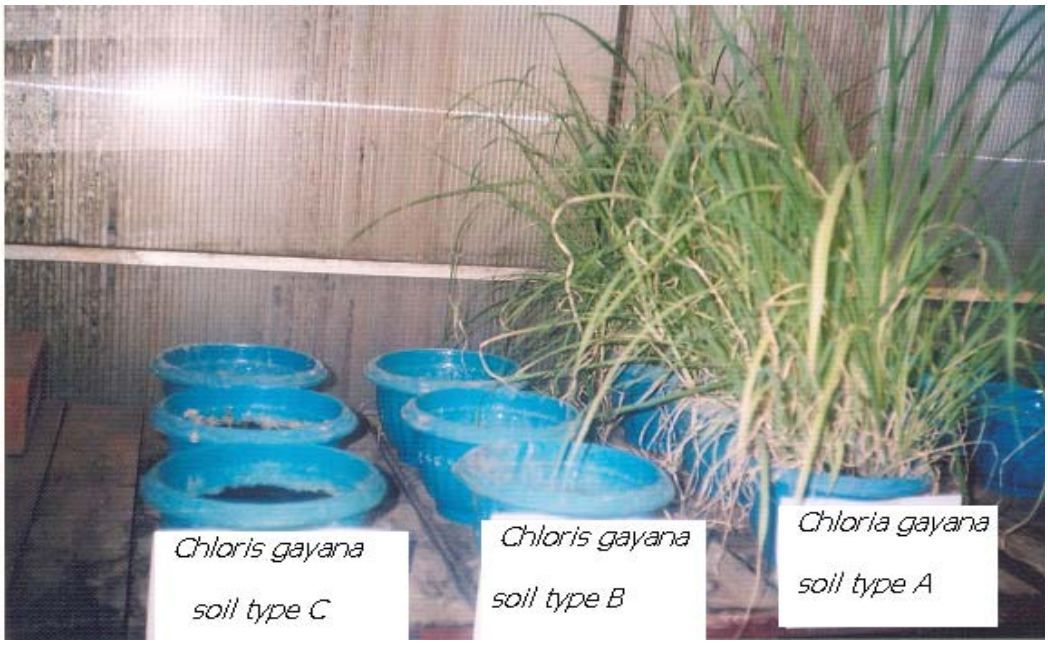


Figure 4. The survival response of *Atriplex halimus* at the end of the third month on the three types of soils on the left soil type C then B and to the right A.

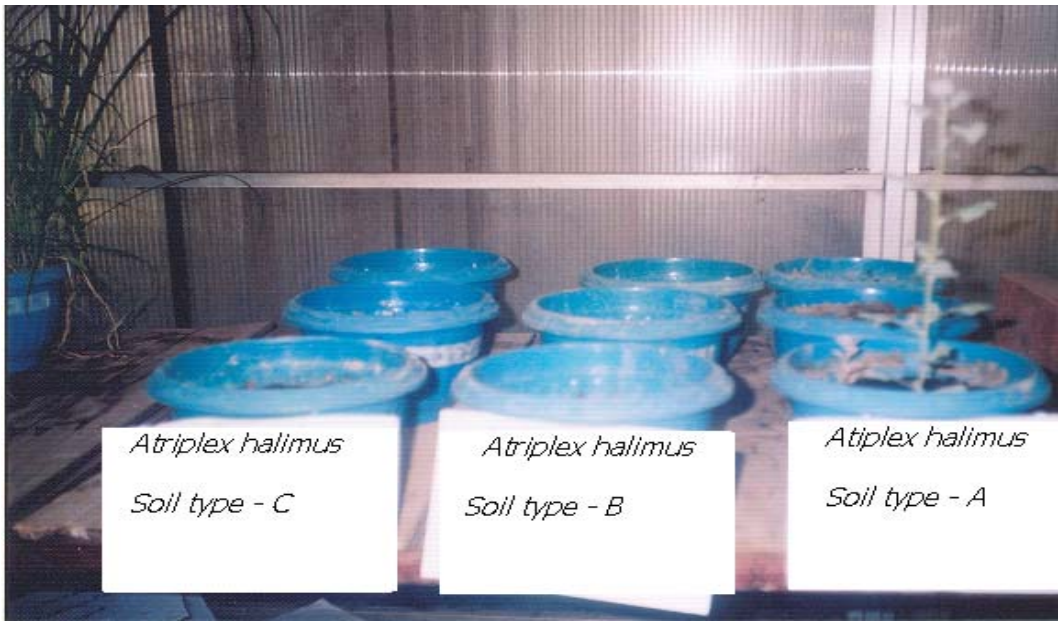


Figure 5. The survival response of *Setaria sphacelata* at the end of the third month on the three types of soil on the left soil type C then B and to the right A.



Figure 6. The survival response of *Panicum maximum* at the end of the third month on the three types of soil on the left soil type A then B and to the right C.



4.4.1. The response of each plant on all soils from the three sites

Analysis of variance Table 8 indicates the presence of significant difference of mean survival percentage and height attained by each species between the three different types of soils with different salt content.

The response of *Atriplex halimus* between soils from the three sites

The average survival percentage and height of *Atriplex halimus* showed significant difference between soils from the three sites ($P < 0.01$) which have different salt level, see Table 8. The P- value of mean survival percentage and height attained by *Atriplex halimus* between soils from the three sites was less than 0.01, which is 0.00. This indicates that the different salt content between soils from the three sites showed highly significant effects on survival percentage and height of *Atriplex halimus*.

Table 8. ANOVA result for response of *Atriplex halimus* between soils from the three sites.

Source of variation		Sum of Squares	Df	Mean Square	F	Sig.
S.P.	Between Groups	285.567	2	142.783	43.318	.000
	Within Groups	118.662	36	3.296		
	Total	404.228	38			
Hg.	Between Groups	6.344	2	3.172	13.947	.000
	Within Groups	8.188	36	0.227		
	Total	14.533	38			

S.P. – Survival percentage
Hg. - height

In the above ANOVA table, it is possible to see the presence of significant mean difference of survival percentage and height attained by *Atriplex halimus* between soils from the three sites but ANOVA table did not tell which of the two means of survival percentage and height of *Atriplex halimus* made significant difference. To know this LSD (least significant difference) test was performed see Table 9).

In Table 9, Pair comparisons using LSD mean values indicates that the most significant

difference in mean survival percentage of *Atriplex halimus* was occurred between soil from site A and B, A and C and B and C at (P<0.01). This indicates that, the differences in the salt content of the three types of soils make *Atriplex halimus* to show significant difference of mean survival percentage attained between soils from the three sites. There is also significant difference in mean height attained between soil from site type A & B and A & C. However, the mean height significant difference is not observed between soil from site B & C. Which indicates the growth attained by *Atriplex halimus* in soils from site C is not able to make significant difference with soils from site B.

Table 9. Mean difference of survival percentage and height of *Atriplex halimus* between soils from the three sites.

Dependent Variable	(i)S.T.	(j) S.T.	Mean difference (i-j)	Std. Error	Sig.
S. P.	A	B	6.56385*	.71211	.000
		C	4.08000*	.71211	.000
	B	C	-2.48385*	.71211	.001
Hg.	A	B	.98769*	.18706	.000
		C	.51385*	.18706	.009
	B	C	-.47385	.18706	.016

*. The mean difference is significant at the .01 level

S. P. – survival percentage, S. T- soil type Hg. – height

The response of *Chloris gayana* between soils from the threes sites

The mean survival percentage and height of *Chloris gayana* attained between soils from the three sites showed significant difference (P < 0.01) see Table 10. In Table 10 the significance (P value) was less than 0.01, which is 0.00. This indicates, the different salt content between the three types of soils showed a significant effect on average survival percentage and average height of *Chloris gayana* attained between soils from the three sites.

In table 10, it was possible to see the presence of significant difference of mean survival percentage and length attained by *Chloris gayana* between soils from the three sites. The significant difference of mean survival percentage was observed between soil from site A and B, A and C and B and C (Table 11). However the mean height significant

difference was observed only between soils from site A and B, A and C. but between soils from site B and C there was no mean height significant difference (Table 11). Because the height attained by *Chloris gayana* on soil from site C was small to make a difference with soil from site B, on which there was no germination or growth was recorded.

Table 10. ANOVA result for the response of *Chloris gayana* between soils from the three sites.

Source of variation		Sum of Squares	Df	Mean Square	F	Sig.
S.P.	Between Groups	16421.502	2	8210.751	254.155	.000
	Within Groups	1163.021	36	32.306		
	Total	17584.522	38			
Hg.	Between Groups	5596.682	2	2798.341	16.219	.000
	Within Groups	6211.433	36	172.540		
	Total	11808.116	38			

S.P. - survival percentage and Hg.- height

Table 11. Mean difference of survival percentage and height of *Chloris gayana* between soils from the three sites.

Dependent Variable	(i)S.T.	(j) S.T.	Mean difference (i-j)	Std. Error	Sig.
S. P.	A	B	48.84462*	2.22939	.000
		C	34.69077*	2.22939	.000
	B	C	-14.15385*	2.22939	.000
Hg.	A	B	25.97538*	5.15214	.000
		C	24.80846*	5.15214	.000
	B	C	-1.16692	5.15214	.822

P. G.- survival percentage, S. T- soil type, Hg.- height

4.4.2. The response of all plants on soils from each sites

As it was mentioned before, the ANOVA result from SPSS, software analysis of survival percentage data of each species showed a significant difference between soils from the three sites. The following ANOVA and LSD table indicates there was also significant difference in survival percentage between species on soils from the same sites.

Response of all species on soil from site A

Even though the salt content of soil from site A was high, when compared with the other two soil from the two sites it has the lowest salt concentration. That was why soil from site A was good for species growth, than the other two soil types. However due to its high salt content, there was significant difference in mean survival percentage attained between species on this soil type. The four species that had been sown in soil from site A showed significant difference in their mean survival percentage ($P<0.01$) see Table 12.

Table 12. ANOVA table for survival percentage of all species on soil from site A

Source of variation		Sum of Squares	Df	Mean Square	F	Sig.
S.P.	Between Groups	21597.630	3	7199.210	938.653	.000
	Within Groups	368.147	48	7.670		
	Total	21965.776	51			

S. P. – survival percentage

Table 13. Mean difference between all species mean survival percentage on soil from site A.

Dependent Variable	(i)spp	(j)spp	Mean difference (i-j)	Std. Error	Sig.
S. P.	Ah	Cg	-42.28077*	1.08626	.000
		Ss	6.56385*	1.08626	.000
		Pm	6.56385*	1.08626	.000
	Cg	Ss	48.84462*	1.08626	.000
		Pm	48.84462*	1.08626	.000
	Ss	Pm	.00000	1.08626	1.000

*. The mean difference is significant at the .01 level, S. P. – survival percentage

Ah- *Atriplex halimus,* Cg-*Chloris gayana,*

Ss- *Setaria sphacelata* and Pm- *Panicum maximum*

In the above ANOVA table 12 it was possible to know the presence of significance mean survival percentage difference ($P<0.05$) between all species on soil from site A. The LSD table showed which mean of species survival percentage made a significant difference see Table 13. In Table 13 it was possible to see a significant difference in the

mean survival percentage between species *Atriplex halimus* and *Chloris gayana*, *Atriplex halimus* and *Setaria sphacelata*, *Atriplex halimus* and *Panicum maximum*, *Chloris gayana* and *Setaria sphacelata*, *Chloris gayana* and *Panicum maximum* on soil type A. However, between the two species namely *Panicum maximum* and *Setaria sphacelata* there was no difference in mean survival percentage on from site A. Because these two species did not even germinate.

Response of all species on soil from site B

In soil type B, all species did not grow or even germinate. Therefore, the growth and survival response of all species in this soil type was the same.

Response of all species on soil from site C

There was growth of species on soil type C, but the growth was not that much satisfactory. Table 14 showed the presence of significant difference in the true mean survival percentage between species on this soil type ($P<0.05$).

Table 14. ANOVA table for survival percentage of all species on soil from site C

Source of variation		Sum of Squares	Df	Mean Square	F	Sig.
S.P.	Between Groups	1784.869	3	594.956	31.261	.000
	Within Groups	913.536	48	19.032		
	Total	2698.405	51			

S. P.- survival percentage

Table 15. Mean difference between species survival percentage on the soil from site C.

Dependent Variable	(i)spp	(j)spp	Mean difference (i-j)	Std. Error	Sig.
S. P.	Ah	Cg	-11.67000*	1.71114	.000
		Ss	2.48385	1.71114	.153
		Pm	2.48385	1.71114	.153
	Cg	Ss	14.15385*	1.71114	.000
		Pm	14.15385*	1.71114	.000
	Ss	Pm	.00000	1.71114	1.000

*. The mean difference is significant at the .01 level S. P. – Survival percentage
Ah-*Atriplex halimus,* Cg-*Chloris gayana,* Ss-*Setaria sphacelata* & *Pm-Panicum maximum*

Table 15 shows the mean survival percentage difference on soil from site C was observed between species *Atriplex halimus* and *Chloris gayana*, *Chloris gayana* and *Setaria sphacelata*, *Chloris gayana* and *Panicum maximum*. However, there was no significant difference of mean survival percentage between species *Atriplex halimus* and *Setaria sphacelata*, *Atriplex halimus* and *Panicum maximum.* Because the survival percentage of *Atriplex halimus* on this soil type was not satisfactory to make a difference with *Setaria sphacelata* and *Panicum maximum*.

4.5. Comparison of survival percentage and growth over time

Mean survival percentage of two species *Atriplex halimus* and *Chloris gayana* on soil from site A and C versus time of growth in month, showed reduction in survival percentage with in the consecutive months (Figure 7, 8, 9 & 10). In both soil from site A and C, in the first month, high survival percentage was recoded and the least survival percentage was recorded in the third month. The reason could be more seeds of *Atriplex halimus* and *Chloris gayana* were able to germinate in both soil types but through time, they could not resist the structural problem of the soil. High survival percentage reduction was observed by *Atriplex halimus* than *Chloris gayana* through time on soil from site A and C (Figure 7, 8, 9 &10).

Figure 7. Mean survival percentage reduction of *Atriplex halimus* on soil from site A on different months.

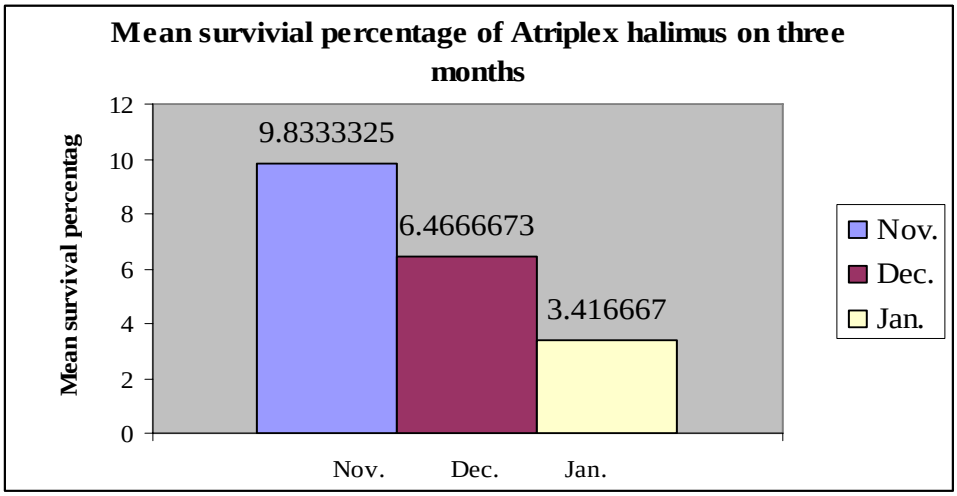


Figure 8. Mean survival percentage reduction of *Atriplex halimus* on soil from site C in different months.

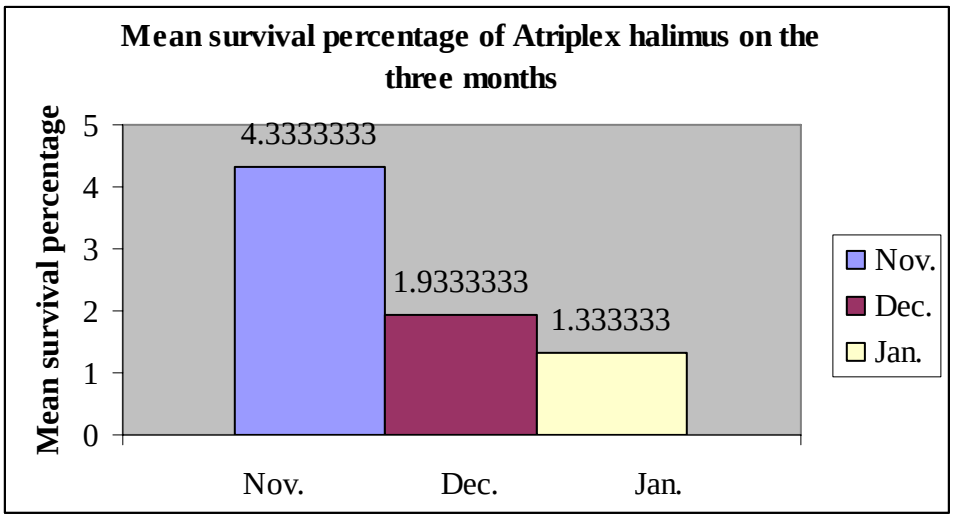


Figure 9. Mean survival percentage reduction of *Chloris gayana* on soil from site A in different months.

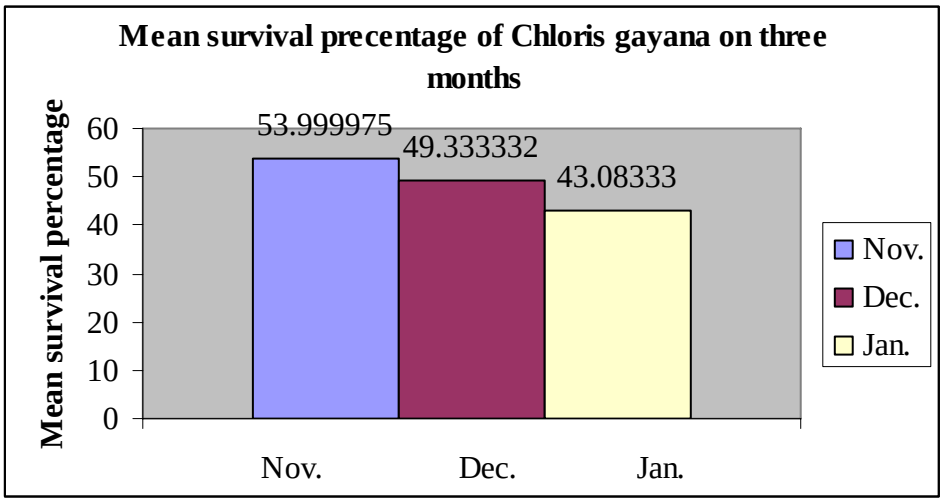
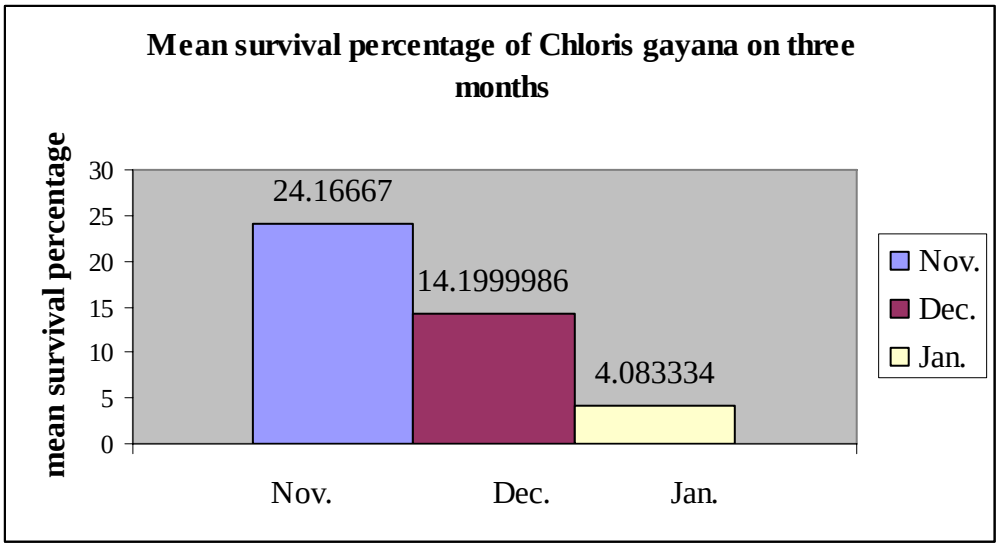


Figure 10. Mean survival percentage reduction of *Chloris gayana* on soil from site C at a different months.



5. Conclusion and Recommendation

5.1. Conclusion

Both soil sample analysis in the laboratory and greenhouse experiment using three grass species and one shrub confirm the presence of salt in the study area. All of the soils were saline-sodic. Even though the problem of salt content in the area was in the same category, the absolute concentration of salt was different between soil types. The different responses of each species on different types of soils were corresponding to the salt contents of soils. The soil with high salt content has low plant growth and soils with low salt content showed high growth.

From the two species that were able to grow on the soil type, *Chloris gayana* can be selected as a high salt tolerance grass for the salt content found in soil type A by observing its survival percentage. However, the survival percentage of other tolerant species, *Atriplex halimus* decrease drastically through time both on soil type A and C and the survival percentage of *Chloris gayana* was low on soil type C. So that it is difficult to select *Atriplex halimus* as salt tolerant plant for soil type A, C and similar other soils and *Chloris gayana* for soil type C and similar other soils.

Generally, from this study it is possible to conclude that even though the salt problem in the area was high or severe, portion of the area of the soils can support some salt tolerant species. However, in combination with these salt tolerant plants it is good to practice other reclamation method especially in areas with high salt concentration. Because most of the soils of the area could not support even high salt tolerant species. This helps to support most salt tolerant plants with high yield.

5.2. Recommendation

To make this study complete, there is a need of some additional information. These are listed below as a recommendation:

- ✓ Seasonal analysis of soil characteristics is needed because the salt content of the soil differ from season to season. As germination, stage is susceptible to high soil

salinity, to choose the appropriate time of sowing or planting it is needed to check seasonal soil salinity characteristics.

- ✓ Research on identification and use of plants, which are found around the study area for the improvement of the salt affected soil, should be conducted.

- ✓ -There is a need of plant and soil analysis after the plantation of halophyte on the soils of the study area. This is used to know the phytoremediation ability or tolerance character of the plant and the salt reduction of soil due to the plant.

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Appendix

Data gathering table for survival percentage and height of species grown in the Greenhouse

Block (soil type)	Grass, soil type, replication and height	Survival percentage and height(cm) per week												
		November				December					January			
		3	10	17	24	1	8	15	22	29	5	12	19	26
A	$1A_1$	21	21	21	19	16	16	16	14	14	13	10	9	9
	Length(cm)	0	0	0	2	2.5	3	3.5	3.5	3.5	3.5	3.5	5.5	8
	$2A_1$	42	40	40	39	39	37	37	35	33	30	30	29	29
	Length(cm)	0	0	0	6	8	10	15	20	30	35	40	45	50
	$4A_2$	0	0	0	0	0	0	0	0	0	0	0	0	0
	Length(cm)	0	0	0	0	0	0	0	0	0	0	0	0	0
	$3A_2$	0	0	0	0	0	0	0	0	0	0	0	0	0
	Length(cm)	0	0	0	0	0	0	0	0	0	0	0	0	0
	$3A_1$	0	0	0	0	0	0	0	0	0	0	0	0	0
	Length(cm)	0	0	0	0	0	0	0	0	0	0	0	0	0
	$2A_2$	60	60	60	58	58	58	53	53	50	50	49	47	47
	Length(cm)	0	0	0	8	12	20	25	40	50	55	60	60	65
	$4A_3$	0	0	0	0	0	0	0	0	0	0	0	0	0
	Length(cm)	0	0	0	0	0	0	0	0	0	0	0	0	0
	$1A_2$	9	9	9	9	9	4	4	4	0	0	0	0	0
	Length(cm)	0	0	0	1	2	2.5	2.5	2.5	0	0	0	0	0
	$3A_3$	0	0	0	0	0	0	0	0	0	0	0	0	0
	Length(cm)	0	0	0	0	0	0	0	0	0	0	0	0	0
	$2A_3$	63	63	63	60	60	58	58	58	53	53	53	50	50
	Length(cm)	0	0	0	5	10	12	22	35	45	50	55	60	65
	$4A_1$	0	0	0	0	0	0	0	0	0	0	0	0	0
	Length(cm)	0	0	0	0	0	0	0	0	0	0	0	0	0
	$1A_3$	0	0	0	0	0	0	0	0	0	0	0	0	0
	Length(cm)	0	0	0	0	0	0	0	0	0	0	0	0	0
B	$3B_2$	0	0	0	0	0	0	0	0	0	0	0	0	0
	Length(cm)	0	0	0	0	0	0	0	0	0	0	0	0	0
	$1B_3$	0	0	0	0	0	0	0	0	0	0	0	0	0
	Length(cm)	0	0	0	0	0	0	0	0	0	0	0	0	0

In the second column, the number before the letter indicate the type of species and the subscribed number after letter indicate the number of replication and the letter indicate the soil type. Number 1 is *Atriplex halimus*, 3. *Setaria Sphaselata*
2. *Chloris gayana*, 4. *Panicum maximum*
Species type indicated by number 3 and 4 did not perform in all soil types.

Data gathering table for survival percentage and height continued---

	$4B_1$	0	0	0	0	0	0	0	0	0	0	0	0	0
	Length(cm)	0	0	0	0	0	0	0	0	0	0	0	0	0
	$2B_2$	0	0	0	0	0	0	0	0	0	0	0	0	0
	Length(cm)	0	0	0	0	0	0	0	0	0	0	0	0	0
	$2B_1$	0	0	0	0	0	0	0	0	0	0	0	0	0
	Length(cm)	0	0	0	0	0	0	0	0	0	0	0	0	0
	$4B_2$	0	0	0	0	0	0	0	0	0	0	0	0	0
	Length(cm)	0	0	0	0	0	0	0	0	0	0	0	0	0
	$3B_3$	0	0	0	0	0	0	0	0	0	0	0	0	0
	Length(cm)	0	0	0	0	0	0	0	0	0	0	0	0	0
	$1B_1$	0	0	0	0	0	0	0	0	0	0	0	0	0
	Length(cm)	0	0	0	0	0	0	0	0	0	0	0	0	0
	$4B_3$	0	0	0	0	0	0	0	0	0	0	0	0	0
	Length(cm)	0	0	0	0	0	0	0	0	0	0	0	0	0
	$2B_3$	0	0	0	0	0	0	0	0	0	0	0	0	0
	Length(cm)	0	0	0	0	0	0	0	0	0	0	0	0	0
	$3B_1$	0	0	0	0	0	0	0	0	0	0	0	0	0
	Length(cm)	0	0	0	0	0	0	0	0	0	0	0	0	0
	$1B_2$	0	0	0	0	0	0	0	0	0	0	0	0	0
	Length(cm)	0	0	0	0	0	0	0	0	0	0	0	0	0
C	$2C_3$	20	20	20	19	16	16	9	5	5	0	0	0	0
	Length(cm)	0	0	0	0.5	1	1.5	1.5	1.5	1.5	0	0	0	0
	$3C_1$	0	0	0	0	0	0	0	0	0	0	0	0	0
	Length(cm)	0	0	0	0	0	0	0	0	0	0	0	0	0
	$1C_1$	4	4	4	4	4	0	0	0	0	0	0	0	0
	Length(cm)	0	0	0	1	1	0	0	0	0	0	0	0	0
	$4C_2$	0	0	0	0	0	0	0	0	0	0	0	0	0
	Length(cm)	0	0	0	0	0	0	0	0	0	0	0	0	0
	$3C_2$	0	0	0	0	0	0	0	0	0	0	0	0	0
	Length(cm)	0	0	0	0	0	0	0	0	0	0	0	0	0
	$1C_2$	9	9	9	9	9	4	4	4	4	4	4	4	0
	Length(cm)	0	0	0	0.5	0.5	1	1	1	1.5	2	3	3	0
	$2C_1$	25	25	25	20	16	16	12	12	10	7	5	5	0
	Length(cm)	0	0	0	0.5	1	1	2	2	2.5	2.5	2.5	2.5	0
	$4C_3$	0	0	0	0	0	0	0	0	0	0	0	0	0
	Length(cm)	0	0	0	0	0	0	0	0	0	0	0	0	0

In the second column, the number before the letter indicate the type of species and the subscribed number after letter indicate the number of replication and the letter indicate the soil type. Number 1 is *Atriplex halimus*, 3. *Setaria Sphaselata*
2. *Chloris gayana*, 4. *Panicum maximum*
Species type indicated by number 3 and 4 did not perform in all soil types.

Data gathering table for survival percentage and height continued---

	$1C_3$	0	0	0	0	0	0	0	0	0	0	0	0	0
	Length(cm)	0	0	0	0	0	0	0	0	0	0	0	0	0
	$3C_3$	0	0	0	0	0	0	0	0	0	0	0	0	0
	Length(cm)	0	0	0	0	0	0	0	0	0	0	0	0	0
	$2C_2$	30	30	30	26	25	20	19	19	13	10	9	8	0
	Length(cm)	0	0	0	1	2	2	2	2	2.5	2.5	2.5	2.5	0
	$4C_1$	0	0	0	0	0	0	0	0	0	0	0	0	0
	Length(cm)	0	0	0	0	0	0	0	0	0	0	0	0	0

In the second column, the number before the letter indicate the type of species and the subscribed number after letter indicate the number of replication and the letter indicate the soil type. Number 1 is *Atriplex halimus*, 3. *Setaria Sphaselata*
2. *Chloris gayana*, 4. *Panicum maximum*
Species type indicated by number 3 and 4 did not perform in all soil types.