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RESEARCH ARTICLE

ROOT ZONE SALINITY MONITORING AND MANAGEMENT IN THE SALT TOLERANT GRASSES IRRIGATED WITH THREE WATER SALINITY LEVELS AND GROWN IN THE ENTISOLS OF THE UNITED ARAB EMIRATES

[1,*]Khalil UR Rahman, [2]Ramachandran Subramanian and [3]Shoaib Ismail

[1]PhD Student BITS Pilani, Dubai Campus, Dubai International Academic City, United Arab Emirates
[2]Associate Professor, BITS Pilani, Dubai Campus, Dubai International Academic City, United Arab Emirates
[3]Senior Fellow, International Center for Biosaline Agriculture, Dubai United Arab Emirates

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ABSTRACT

A three-year (2014-2016) trial was conducted at the experimental station of Dubai based International Center for Biosaline Agriculture. Two grasses (*Sporobolusarabicus and Paspalumvaginatum*) were grown in typical sandy soil of UAE "Entisols" and irrigated with three water salinity levels (EC 10, 20, 30 dS/m). Sprinkler irrigation system was used to irrigate grasses. Soil salinity (ECe) was assessed at two depths (0-25 & 25-50 cm) over a period of three years (2014-2016). The salinity monitoring results revealed it increases at both depths, lowest being in 2014 and the highest in 2016. The surface (0-25) as well as subsurface (25-50 cm) salinity is almost similar within the plots where same irrigation water was applied. Where difference occurs between soil salinity at two depths, it is insignificant and within standard deviation range. The root zone salinity at both depths in the years 2014, 2015 & 2016 is higher than the irrigation water salinity (EC = 10 dS/m). However, within same year the soil salinity is less than the water salinity of the respective irrigation waters (20 & 30 dS/m) during 2014, revealing salinity is well managed at higher irrigation water salinity. The root-zone salinity of both grasses in general increases with the increase of irrigation water salinity i.e., 10, 20 and 30 dS/m at both depths 0-25 & 25-50 cm. Relatively the higher soil salinity is recorded at the subsurface (25-50 cm). The highest root zone salinity being in *Paspalumvaginatum* grass with the application of fertilizers and irrigation with 30 dS/m water. Both grasses survived three water salinity levels and hence have the potential for further exploitation in the UAE and other GCC countries where similar soil and environmental conditions prevail. Other forages such as alfalfa (*Medicago sativa)* and Rhodes grass (*Chloris guyana*) require large quantities of water – from 15,700 to 48,000 $m^3\ ha^{-1}\ yr^{-1}$ depending on soil and climate – often drawn from non-renewable groundwater sources.

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INTRODUCTION

In hot arid environment such as the case of United Arab Emirates, the major constraints to agriculture production are water and arable land scarcity, groundwater salinity and poor water use efficiency. This often necessitates the use of saline/brackish water under desert conditions (Pasternak *et al.,* 1993) to offset water requirements of crops. Globally the misuse of saline waters has abandoned many agricultural farms due to low productivity. The United Nations University-Institute for Water, Environment and Health ((UNU-INWEH) states irrigated lands cover some 310 million hectares, an estimated 20 percent (UNU-INWEH) of it is affected by salinity and sodicity(62 million hectares) yielding an estimate of global economic losses at US$27.3 billion per year (Qadir *et al.,* 2014). It further states that every day for more than 20 years, an average of 2,000 hectares of irrigated land in arid and semi-arid areas across 75 countries have been degraded by salt (UNU-INWEH). In the context of the Middle East and North Africa (MENA) region, water scarcity is one of the most important food-security issues, with fresh water availability in the region expected to drop 50% by 2050 (World Bank, 2007) and the farming community will mostly rely on marginal quality water such as saline/brackish and treated sewage effluent, for the latter communities raise their concerns that it might cause diseases and may be used for selected crops where fruit is not in direct contact with water, forages are devoid of this limitation. To minimize the effects of saline water on root zone salinity, a suitable irrigation method must be selected, one which does not invoke soil salinity hazard (Zaman *et al.,* 2018). The irrigation method chosen is determined by the depth of irrigation, leaching, zones of salt accumulation, runoff, and the uniformity of applying the irrigation water. A

***Corresponding author:*Khalil UR Rahman,**
PhD Student BITS Pilani, Dubai Campus, Dubai International Academic City, United Arab Emirates.

three year (2014-2016) trial was conducted on two grasses by irrigation with three water salinity levels (EC 10, 20, 30 dS/m) to manage and monitor root zone salinity. Salinity assessment and monitoring helps understand the root zone salinity levels, whether below or above threshold level of crop in the field. The latter will require extra water to be applied based on the leaching fraction to maintain the root zone salinity below crop threshold (Maas and Hoffman, 1977; Allen *et al.,* 1998) salinity (salinity level where decrease in crop yield begins). Once salinity is accumulated in soil it becomes saline soil. Salinity is a measure of the concentration of all the soluble salts in soil or water as electrical conductivity (EC). In agricultural fields, the irrigation through any modern irrigation system is unlikely be applied uniformly; therefore, the behavior of salinity development would be heterogeneous spatially at the farm level. By knowing water salinity of irrigation water and soil salinity at the seeding or planting stage, suitable salt-tolerant crops can be selected (Glenn *et al.,* 1999) and those not suitable are eliminated from the list because increasing salinity levels reduce choice of crops. In extreme salinity cases biosaline agriculture can be used for forage and livestock production (Master *et al.,* 2007). Based on the salinity information decision is made which crops can be planted the farms and even in various regions with a better understanding of how the crops might behave. Where the soil salinity is widespread such as Australia a national action plan was implemented (Malcolm, 1996).Recently Shahid *et al.* (2010) have hypothesized salinity development cycle to describe the sequence of soil salinity development, including various facets, such as leaching, seepage from system, water movement restriction, capillary rise, and evaporation to salts crystallization.

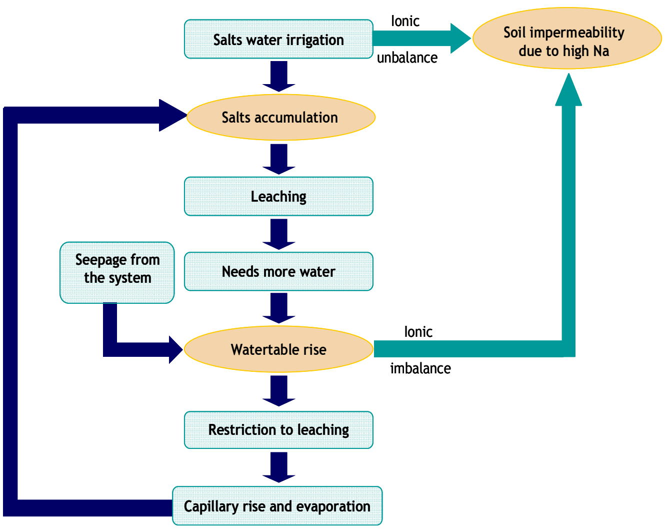

Figure 1. Hypothetical salinization cycle (Shahid *et al.*, 2010)

In agricultural fields the water distribution through irrigation cannot be applied uniformly; thus the salinity development is heterogeneous (Shahid and Rahman, 2010) therefore, the salt concentrations in soil vary widely, both vertically and horizontally (Shahid, 2014). The extent of the salts variability depends on conditions such as differences in soil texture, growing plants, which transpire soil water and also absorb salt, quality of irrigation water, hydraulic conductivity, wetting zone and the type of irrigation system being used, etc. The snapshots of root zone salinity can help understand the level of salinity development and help develop salinity management plan. The salinity assessment helps understand current salinity level while monitoring determines periodic changes in soil salinity (Shahid *et al.,* 2018a). Predicting root zone salinity is important to assure the root zone salinity is not reached above the threshold salinity level. When electrical conductivity of soil extract from saturated paste (ECe) equals or exceeds 4 dS/m at 25°C, the soil is said to be saline (US Salinity Lab Staff, 1954). The salinity (EC) is measured as millimhos/cm (mmhos/cm), the old unit which is now obsolete. Currently used standard international (SI) units are milli-Siemens per cm (mS/cm) or deci-Siemens per meter (dS/m). The use of dS/m is preferred over the unit mmhos/ cm. The units can be presented as 1 dS/m = 1 mmho/cm = 1 mS/cm = 1,000 micro-Siemens per cm (1,000 µS/cm). The EC units are very well described and presented by Shahid *et al.* (2018a). Readings are usually taken and reported at a standard temperature of 25°C. For accurate results, EC meters should be checked with 0.01-N KCl solution, which should give a reading of 1.413 dS/m at 25°C. While salinity is largely a concern in irrigated areas and in areas with saline soils, it is not so important in rainfed agriculture. However, with increasing use of brackish irrigation, there will be greater emphasis on EC measurement in the future. Intensifying forage crop production to meet future demand would further cause enormous water stress in many countries. For example, in the Arabian Peninsula, expanded cultivation of alfalfa (*Medicago sativa*) and Rhodes grass (*Chloris gayana*) in response to the increased demand for livestock feed has resulted in a drastic reduction in groundwater levels and an increase in salinity due to seawater intrusion (Rao *et al.,* 2017). Both these species require large quantities of water – from 15,700 to 48,000 m^3 ha^{-1} yr^{-1} depending on soil and climate – often drawn from non-renewable groundwater sources (Peacock *et al.,* 2003). To reduce the pressure on fresh water, non-conventional sources of water (saline and brackish water) will have to be tapped into to meet the needs of agriculture, especially in the dry areas. Therefore other potential plants which are salt-tolerant and consumes less water should be considered as potential forages in the region, in this regards *Paspalumvaginatum* and *Sporobolusarabicus* stands better than alfalfa and Rhodes grass, therefore form the focus of the present study.

Classes of Soil Salinity and Plant Growth

Electrical conductivity of the soil saturation extract (ECe) is the standard measure of salinity. US Salinity Lab Staff (1954) has described general relationship of ECe and plant growth.

- Non saline (ECe 0-2 dS/m) - salinity effects mostly negligible
- Very slightly saline (ECe 2-4 dS/m) - yields of very sensitive crops may be restricted
- Slightly saline (ECe 4-8 dS/m) - yields of many crops are restricted
- Moderately saline (ECe 8-16 dS/m) - only salt tolerant crops exhibit satisfactory yields
- Strongly saline (ECe>16 dS/m) - only a few very salt tolerant crops show satisfactory yields

Maas and Hoffman – crop yield and salinity relationship: Crops can tolerate salinity up to certain levels without a measurable loss in yield (this is called threshold level). At salinity levels greater than the threshold, crop yield reduces linearly as salinity increases. Using the salinity values in a salinity/yield model developed by Maas and Hoffman (1977), predictions of expected yield loss can be made (Maas, 1984).

Typically, plant growth is suppressed when a threshold value of salinity is exceeded.

Maas and Hoffman expressed salt tolerance of many crops by this relationship:

$$Yr = 100 - s(ECe - t),$$

Where:

Yr = percentage of the yield of crop grown in saline conditions relative to that obtained on non-saline conditions;
t = threshold salinity level where yield decrease begin;
s = percent yield loss per increase of ECe (dS/m) in excess of t.

In this model it is assumed that crops respond primarily to the osmotic potential of soil solution, and specific ion effects is of secondary importance. Once it reaches above threshold value it affects plant growth and crop production. This allows to take timely action to manage root zone salinity to avoid its deleterious effects on crops.

MATERIALS AND METHODS

The trial was conducted at the experimental station of Dubai based International Center for Biosaline Agriculture Dubai. There exist three groundwater sources (EC 10, 20 and 30 dS/m) those were used to irrigate grasses over three years period. The water salinity was monitored on a regular basis. The trial site belongs to soil order Entisols and soil taxonomic class is "Carbonatic, Hyperthermic, Typictorripsamments" based on US Soil taxonomy (Soil Survey Staff, 2014a;Shahid and Abdelfattah, 2008; Shahid *et al.,* 2014). The soil texture was fine sand, with 97-99%sand, 1-2% silt and 0-1% clay. Two grasses were used for the trial (*Paspalumvaginatum and Sporobolusarabicus*). Unlike the conventional forages, these grasses are known to tolerate foliar injury though irrigated with highly saline water and do not accumulate salts in response to salinity (Bell and O'Leary, 2003).

Sporobolusarabicus

The *S. arabicus* Boiss is a perennial stoloniferous grass that prefers a saline or desert habitat. Genus Sporobolus R.Br. (Poaceae) is known for high salt tolerance because its many species are known to inhabit saline habitats, and they show considerable tolerance to high salinity. *S.arabicus*Boiss. species is a dominant component of vegetation in the Salt Range, where a large area of the foothill zone is affected by sodium chloride (Qadir *et al.,* 2005).

Paspalumvaginatum

The *P. vaginatum* belongs to Poaceae family, its common names are Biscuit grass. It has lance-shape, fine textured leaves which grow in short, upright plantlets. It spreads via stolons underground, lateral stems and rhizomes and form dense mats of thick turf. It is highly salt-tolerant, excellent wear tolerance and is drought tolerant. Seashore *paspalum*is the most salt tolerant warm season turfgrass species and also holds great promise for reclamation and soil stabilization of unmanaged salt-affected sites (Loch *et al.,* 2003). Peacock and Dudeck (1995) mentioned that seashore *paspalum* cv. FSP-1 can tolerate salinity of synthetic sea water up to 35-40 dS/m.

Rootzone soil samples collection and processing

There exists real time automated salinity logging system at ICBA (Shahid *et al.,* 2008) installed in other long time trialed grassy plot (Shahid *et al.,* 2008). Random samples were collected from many representative sites from each treatment where different water salinity (5, 10, 15 dS/m) levels were applied. Rootzone soil samples were collected by standard soil auger at two depths (0-25 and 25-50 cm) from both grassy plots (*Sporobolus and Paspalum*) and processed (air-dried, passed through 2 mm sieve) for analyses. The salinity monitoring results are presented based on salinity (ECe) assessment at the upper depth (0-25 cm), whereas salinity assessment efforts have been assessed on both depths (0-25 and 25-50 cm) as described in later section. Saturated soil paste was prepared (Soil Survey Staff, 2014b) to collect extract under vacuum (saturation extract) and to measure EC. This measure, known as electrical conductivity of the soil saturation extract (ECe), is now the generally accepted measure of soil salinity (US Salinity Lab Staff, 1954; Shahid, 2013).

Irrigation Systems and zones of salinity development

Each irrigation system develops salinity at a specific soil zone and thus needs to be carefully monitored. Shahid (2014) has recently introduced zones of soil salinity development for a range of different irrigation systems. In our experiments we used sprinklers (irrigation to grassy plots).As per Shahid (2014) sprinkler irrigation system develop relative salinity zones as described below.

With sprinkler irrigation (SI), strong streams of water sprayed through the air to spread on the soil surface at the beginning before establishing the grasses, later sprayed both on grass and soil. Irrigation by sprinkler allows efficient and economic use of water and reduces losses through deep percolation of water through the soil. If water applied via SI is in close agreement with crop needs (ETc plus leaching), excessive drainage and high-water table problems can be greatly reduced, thus improving salinity control. In the grassy plots SI was used trough fixed sprinklers. The windbreaks around the experimental plots helped reduce the negative effects of strong wind. Under SI the salinity builds up occurs at the soil subsurface. Thus, the SI system is highly effective in leaching salts from the surface and providing a soil environment which is conducive for seed germination and early stage of plant growth.

Assessment of Rootzone Salinity Management

We used two scenarios as proposed by Shahid *et al.* (2013) for light textured and heavy textured soils to assess the salinity management efforts in the root zone.

Scenario I (Light texture-sandy soil)

To check salinity development in the root zone in relation to irrigation water salinity (ECiw). The ratio between ECe/ECiw> 1.1 indicates poor salinity management; leaching fraction was not used properly.

Scenario II (Soils heavier than sandy and loamy sand soils)

The ratio between ECe/ECiw> 1.5 indicates poor salinity management; leaching fraction was not used properly.

RESULTS AND DISCUSSION

The root zone salinity (ECe) in the grassy plots (*Sporobolus and Paspalum*) was monitored over three years (2014-2016) at two depths i.e., 0-25 and 25-50 cm. The soil salinity (ECe) is assessed with respect to the application of irrigation water of different salinity (EC 10, 20, 30 dS/m) and with fertilizer (+F) and without fertilizer (-F) application.

Root zone soil salinity (ECe) assessment and monitoring – 2014-2016

The soil salinity monitoring results of year 2014, 2015 and 2016 are presented in figures 2,3,4 respectively. The results clearly show the root-zone salinity of both grasses in general increases with the increase of irrigation water salinity i.e., 10, 20 and 30 dS/m at both depths 0-25 & 25-50 cm. Relatively the higher soil salinity is recorded at the subsurface (25-50 cm). The highest root zone salinity being in Paspalum grass with the application of fertilizers and irrigation with 30 dS/m water. In the year 2014, the trend of root zone salinity development at both depths with the irrigation of 10 dS/m water is being in the order of Sporobolus (no Fertilizer)<Sporobolus (with fertilizer) and contrarily Paspalum (with fertilizer)<Paspalum (no fertilizer).However, the difference is not significant. In the year 2015, the trend of root zone salinity development at both depths with the irrigation of 10 dS/m water is being in the order of Sporobolus (no Fertilizer) <Sporobolus (with fertilizer) and Paspalum (with fertilizer) <Paspalum (with fertilizer). However, the difference is not significant. An increasing but variable trend is recorded with the application of 20 dS/m irrigation water. of root zone salinity increase with the irrigation of 30 dS/m water is being in the order of Sporobolus (no Fertilizer) <Sporobolus (with fertilizer) <Paspalum (no fertilizer) <Paspalum (with fertilizer). Regardless of fertilizer treatment the rootzone salinity is higher relative to that in Sporobolusrootzone. In the year 2016, a similar trend of soil salinity is found as in 2015, however, the salinity values are higher than those recorded in 2014 & 2015. Both grasses have shown great promise for irrigation with highly saline water (Ashour *et al.,* 1997).

Assessment of salinity management using Scenario-1 (Sandy soil)

The root zone soil salinity development depends on many factors including but not necessarily limited to, irrigation water salinity, soil texture, hydraulic properties, water retention, leaching fraction, climatic factors etc. Assuming all factors well under control the rootzone salinity in sandy soils is nearly equal to the irrigation water salinity (ECe = EC iw i.e., ECe/ECiw = 1), therefore, if ECe/ECiw is > 1.1, then it is considered that root zone salinity is not well managed. Figures 5, 6, 7 show the assessment of scenario 1, over period of three years. Of 24 sites investigated in the entire grass fields, 13, 10 and 3 sites in the years 2014, 2015 and 2016 respectively have been recorded where root zone salinity was well managed (ECe/ECiw< 1.1), whereas 11, 14 and 21 sites in the years 2014, 2015 and 2016 respectively were found where ECe/ECiw was more than 1.1 and hence considered poorly salinity managed sites. Over the period from 2014 to 2016 the root zone salinity (0-50 cm) increased over the water salinity levels.

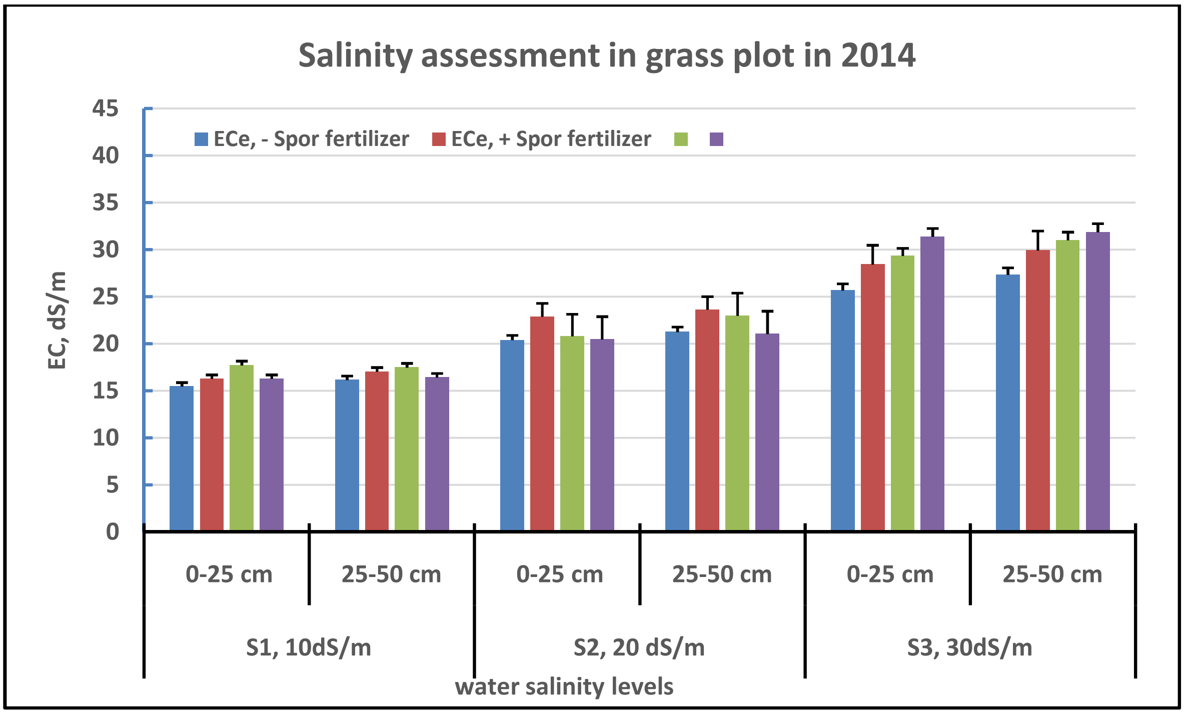

Figure 2. Comparative rootzone soil salinity at two depths with increasing irrigation water salinity and fertilizer application in the year 2014

The rootzone salinity at both depths with the irrigation of 20 dS/m water is higher relative to those with the irrigation of 10 dS/m irrigation water. An increasing or decreasing trend is obvious in figures 2,3,4. The highest rootzone salinity being with the application of fertilizer in sporobolus grass.The trend

This scenario is very strict and may apply to sandy soils where soil management conditions are very ideal and well managed due to high drainage capacity. However, in international literature, second scenario (ECe/ECiw> 1.5) is considered to evaluate salinity management efforts.

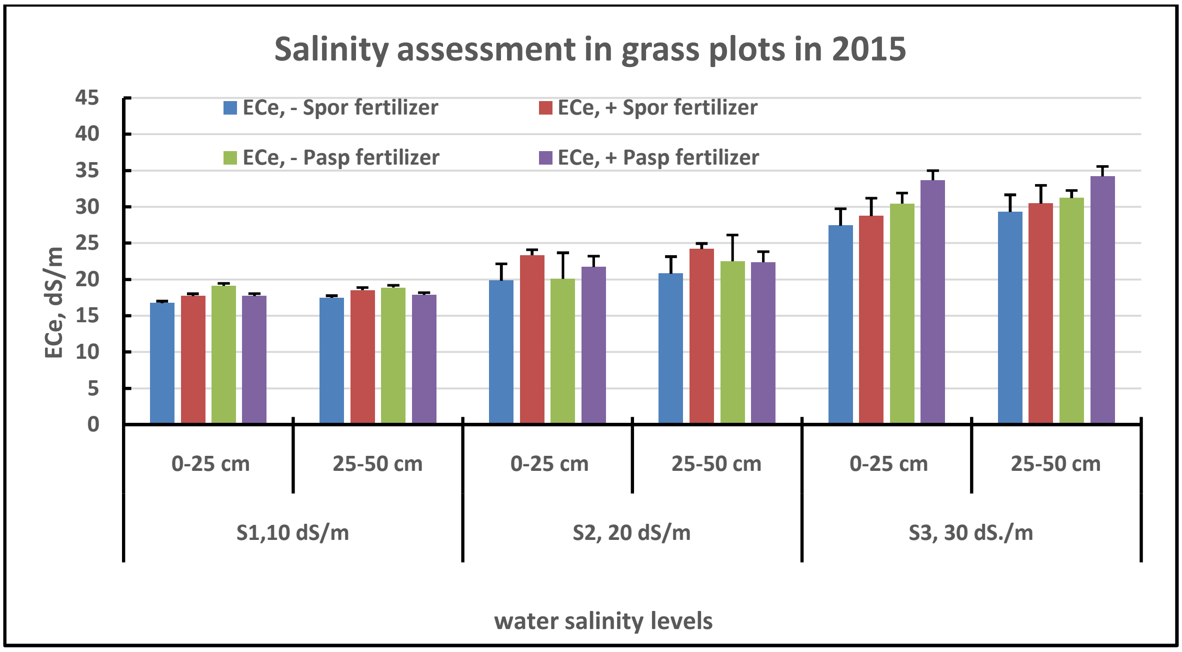

Figure 3.Comparative rootzone soil salinity at two depths with increasing irrigation water salinity and fertilizer application in the year 2015

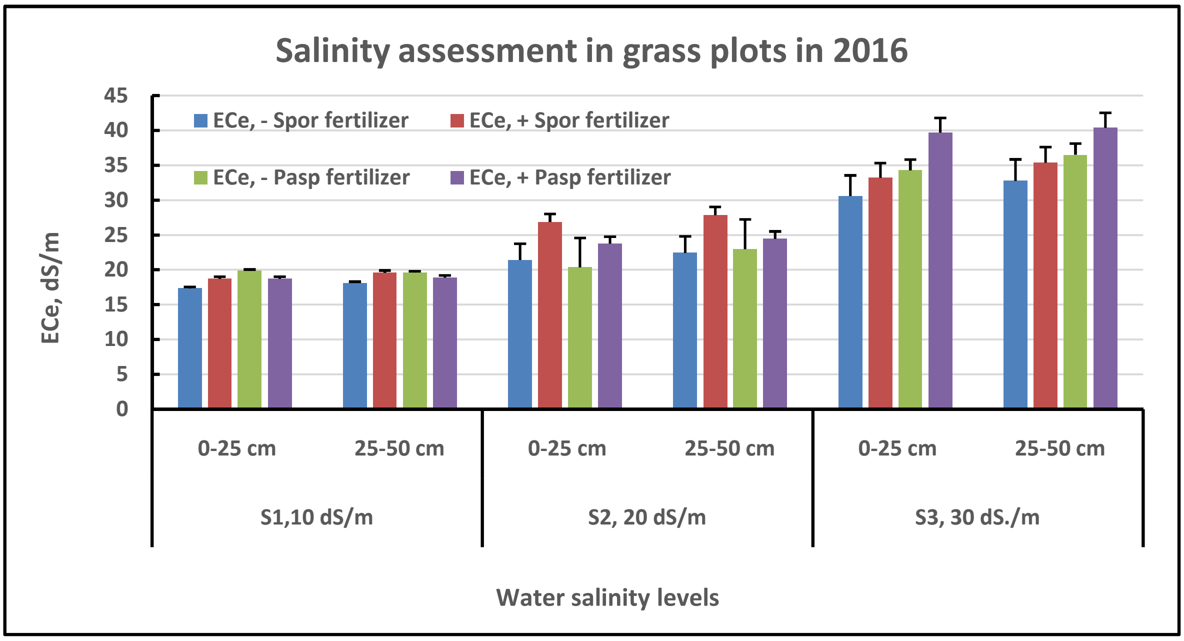

Figure 4.Comparative rootzone soil salinity at two depths with increasing irrigation water salinity and fertilizer application in the year 2016

Assessment of salinity management using Scenario-II (Sandy soil) ECe/ECiw>1.5

To check salinity development in the root zone in relation to irrigation water salinity (ECiw), the ratio between ECe/ECiw> 1.5 indicates poor salinity management; leaching fraction was not used properly. Following are the observations from figures 8, 9, 10. Of 24 sites investigated in the entire grass fields, 16, 17 and 16 sites in the years 2014, 2015 and 2016 respectively have been recorded where root zone salinity was well managed (ECe/ECiw< 1.5). Overall it appears that root zone salinity relative to water salinity was either remain same or reduced. Almost 33% samples show that root zone salinity was not optimally managed. This is quite passible where higher water salinity irrigation water is used. Overall it can be concluded that in the majority of the sites in the grassy plots the soil salinity was well managed, and, hence shows success story of using increasing salinity levels of irrigation waters. The findings of the present studies are supported by Rao *et al.* (2017) who has also shown that these grasses can survive higher salinity levels under UAE conditions.

Summary and Concluding Remarks

From three years trial of two salt-tolerant grasses *(Sporobolusarabicus and Paspalumvaginatum*) irrigated with three levels of water salinities (EC 10, 20 and 30 dS/m) it can be concluded that with the best management practices that is crop water requirement and leaching fractionthe increasing levels of water salinities can be used in both grasses, this has been revealed with the survival of both grasses over three years period. Therefore, these two grasses have shown great potential for their use where salt-sensitive forage such as alfalfa *(Medicago sativa)* and other sensitive cropscannot be

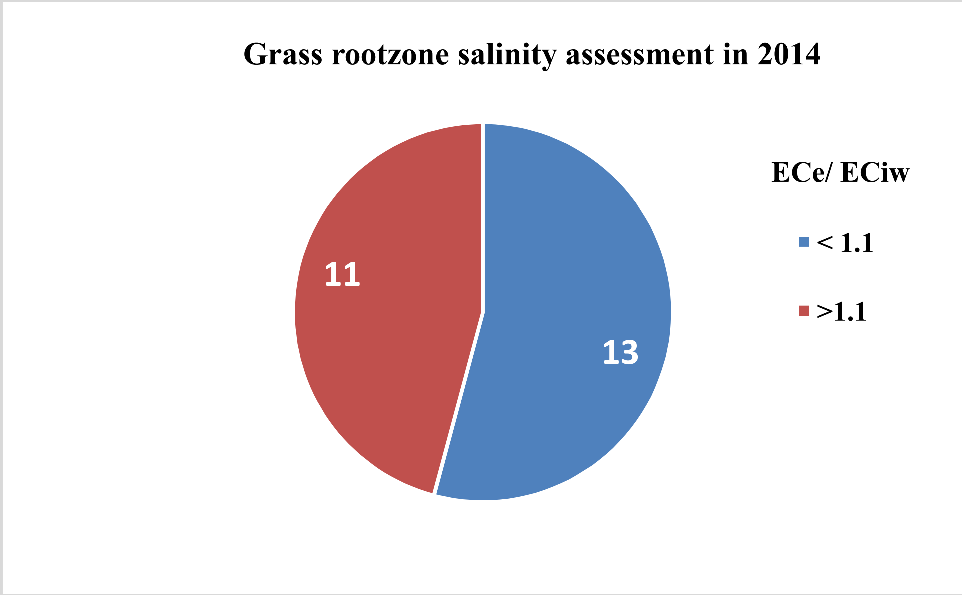

Figure 5.Assessment of rootzonesalinity management efforts in 2014 using scenario-I

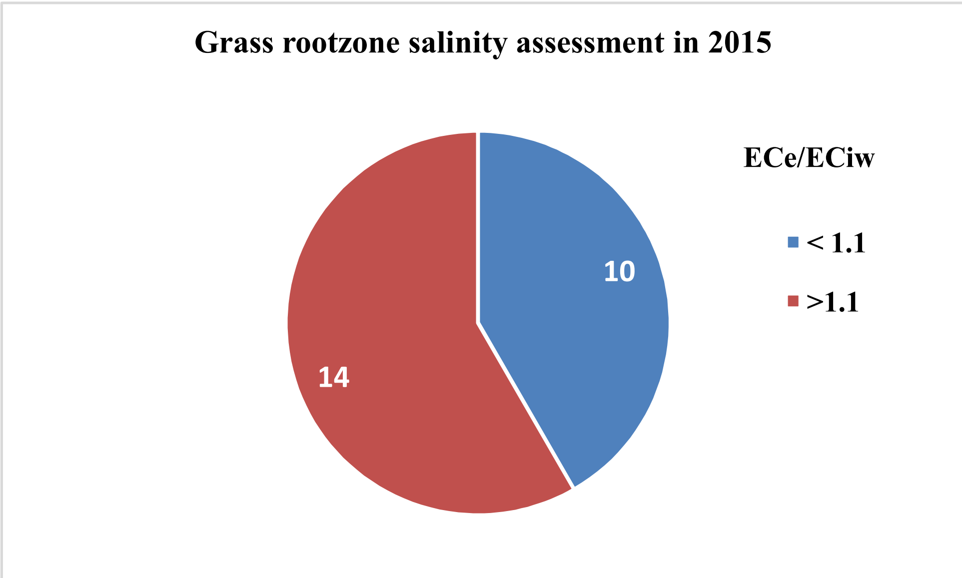

Figure 6. Assessment of rootzone salinity management efforts in 2015 using scenario-I

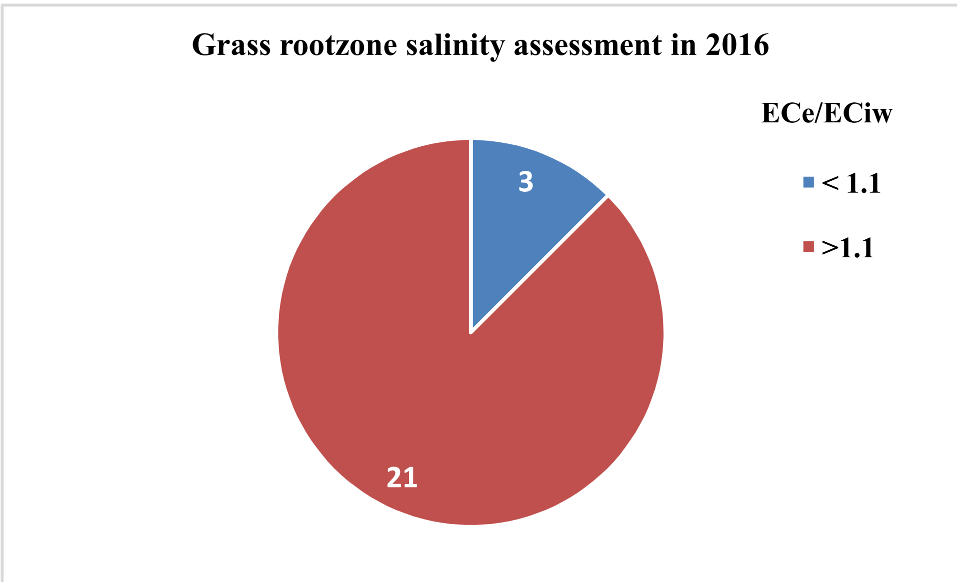

Figure 7. Assessment of rootzone salinity management efforts in 2016 using scenario-I

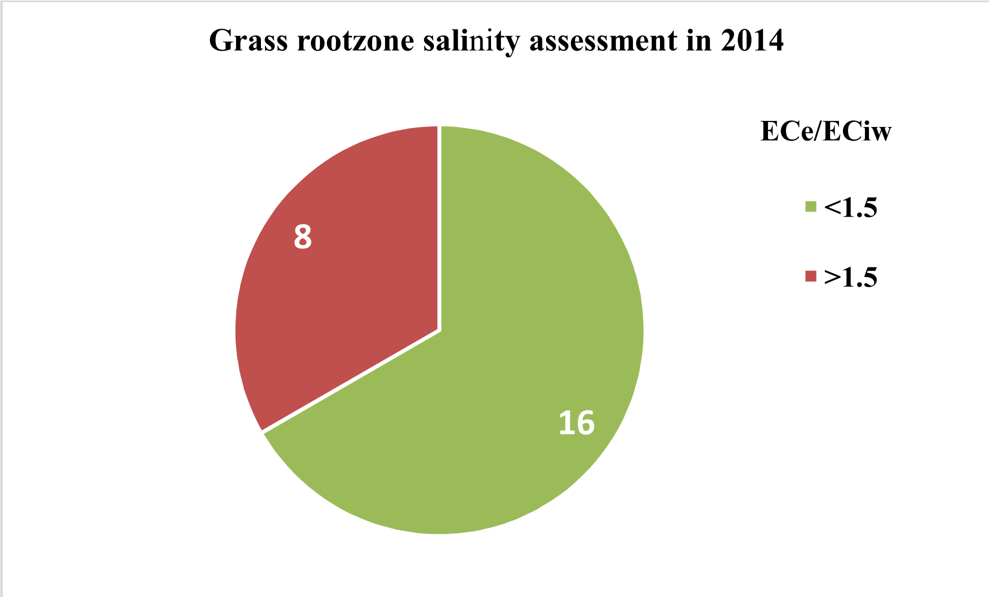

Figure 8.Assessment of rootzonesalinity management efforts in 2014 using scenario-II

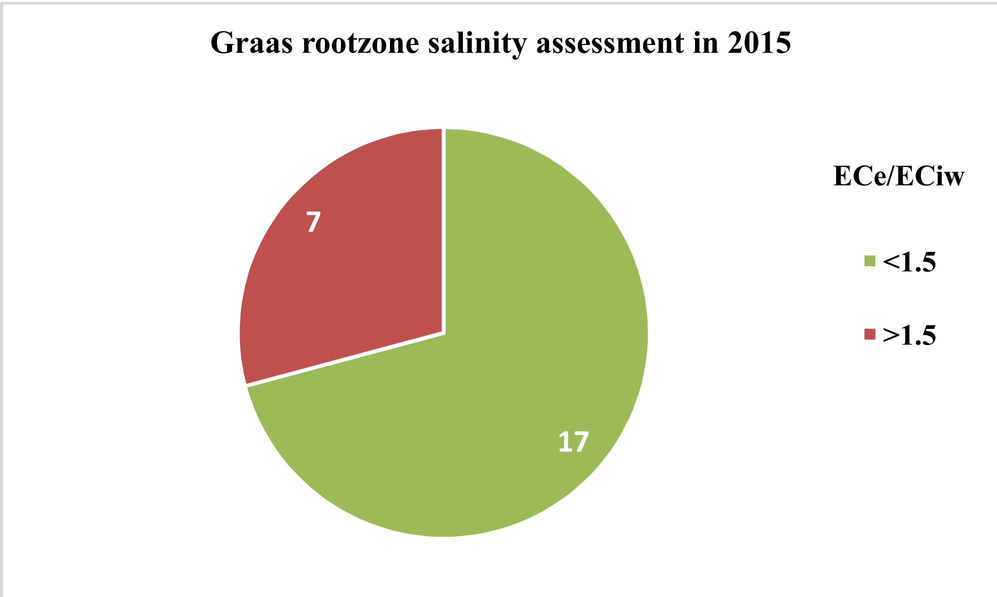

Figure 9.Assessment of rootzone salinity management efforts in 2015 using scenario-II

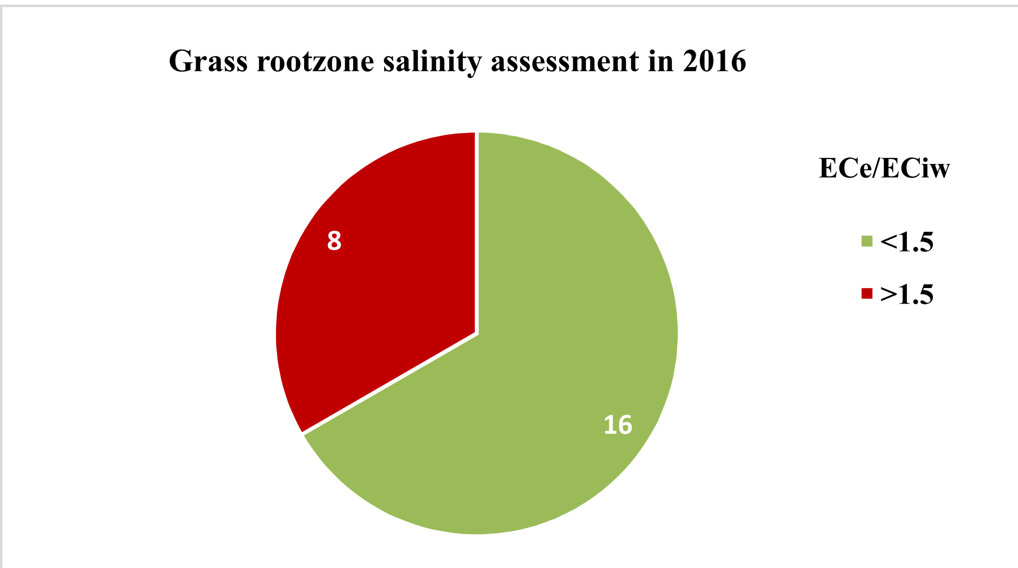

Figure 10.Assessment of rootzone salinity management efforts in 2016 using scenario-II

successfully and economically grown due to low salinity threshold level (such as alfalfa has salinity threshold ECe 2 dS/m). These grasses have been tested on sandy soils which represents over 75% UAE landscape and thus the results have wider application nationally and other GCC countries where similar soils and environmental conditions prevail.

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