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Research Paper

Rootzone salinity monitoring and management in *Acacia ampliceps* irrigated with three water salinity levels in Entisols of United Arab Emirates

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Abstract. A three years (2014-2016) trial was conducted at the experimental station of Dubai based International Center for Biosaline Agriculture. The objective of this project was to assess the adoptability of *A. ampliceps* trees in sandy desert conditions by irrigating with three water salinities (ECiw 10, 20, 30 dS/m). Bubler irrigation system was used to irrigate the trees in basins. Soil salinity (electrical conductivity of soil saturation extract-ECe) was assessed at two depths (0 to 25 and 25 to 50 cm) over a period of three years. Root zone salinity was the lowest in 2014 and the highest in 2016. The root zone salinity at both depths in the years 2014, 2015 and 2016 was higher than the irrigation water salinity (ECiw = 10 dS/m). Salinity at both depths was almost similar where same irrigation water was used. The soil salinity was less than the water salinity of the respective irrigation waters (20 and 30 dS/m) during 2014, revealing soil salinity is well managed. In contrary to 2014, during 2015 and 2016 the soil salinities of the trees irrigated with water salinities of 20 and 30 dS/m were higher than the irrigation water salinities. The results reveal that it is possible to manage salinity during first year compared with subsequent years. The soil salinity with the application of fertilizer is insignificantly higher but within the range of standard deviation. Among two salinity assessment scenarios, the scenario ECe/ECiw > 1.5 fits well to assess salinity management efforts in sandy soil conditions.

Keywords: Sandy soil, desert condition, *A. ampliceps*, salinity management, typic torripsamments.

INTRODUCTION

In hot hyper-arid environment of the United Arab Emirates, the major constraints to agriculture production are arable land, water scarcities and ground water salinity. The fresh water scarcity necessitates the use of saline/brackish water under desert conditions (Pasternak *et al.,* 1993) to offset water requirements of crops. The mismanagement of such a high salinity water may result into soil salinization to a level where agricultural farms are abandoned due to low productivity leading to uneconomical returns. Historical perspectives of soil salinization have been presented by Shahid *et al*. (2018c). 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 irrigation system, water movement restriction, capillary rise, and evaporation to salts crystallization. The United Nations University-Institute for Water, Environment and Health (UNU-INWEH, 2014) states that irrigated lands cover some 310 million hectares, an estimated 20 percent (UNU-INWEH, 2014) 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). Where the soil salinity is widespread such as Australia a national action plan was implemented (Malcom, 1996).

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). The crops irrigated with saline/brackish waters cause soils to become saline, where salinity assessment helps understand current salinity level while monitoring determines periodic changes in soil salinity (Shahid *et al.,* 2018b; Shahid and Rahman, 2011). Predicting root zone salinity is important to assure the root zone salinity is not reached above the threshold salinity level (Shahid et al*.,* 2008, 2010, 2011).

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 (TSE), 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, where 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.,* 2018a, b). 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. 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 (Zaman *et al.,* 2018a, b). The irrigation method chosen should be determined by the depth of irrigation, leaching, zones of salt accumulation, runoff, and the uniformity of applying the irrigation water.

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 *A. ampliceps* among trees stands better. Multi-purpose *A. ampliceps* have the potential to form an integral component of Agricultural systems. Many decades of research and domestication has identified well adapted acacia species such as *A. ampliceps*. It grows rapidly, is well adapted to infertile soils, produce seeds that can be easily harvested and processed. They produce large quantities of fuel wood and construction timber, can be used as windbreaks, improve soil fertility (leguminous tree-N fixing) and may have a significant role as multi-purpose trees in sustainable Agroforestry systems. Considering the multipurpose benefits of *A. ampliceps,* this has been used in Agroforestry systems in various countries.

A three years (2014 to 2016) trial was conducted on salt-tolerant tree "*A. ampliceps*" with the objective to assess its performance under three different water salinity levels (ECiw 10, 20 and 30 dS/m) and to monitor root zone salinity at two depths (0 to 25 and 25 to 50 cm). Salinity assessment and monitoring helps understand the levels of salt accumulation in the root zone, 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 root-zone salinity is accumulated to a certain level (ECe ≥ 4 dS/m; US Salinity Lab Staff, 1954) it becomes saline soil. Salinity is a measure of the concentration of all the soluble salts in soil or water as electrical conductivity (EC). 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 "*halophytes*" can be used for forage and livestock production (Masters *et al.,* 2007). Based on the salinity information decision is made which crops can be planted with a better understanding as how the specific crop might behave.

Why *A. ampliceps*?

Multi-purpose *A. ampliceps* have the potential to form an integral component of agricultural systems. Many decades of research and domestication has identified well adapted acacia species such as *A. ampliceps*. It grows rapidly, is well adapted to infertile soils, produce seeds that can be easily harvested and processed. They produce large quantities of fuel wood and construction timber, can be used as windbreaks, improve soil fertility (leguminous tree-N fixing) and may have a significant role

Table 1. Physical and chemical characteristics of sandy soil at trial site.

Depth		ECe	SP	$CaCO_3$	BD	Porosity	OM	SAR	Sand	Silt	Clay	Textural class (USDA)
cm		dS/m	%	%eq.	g/cm^3	%	%	$(mmoles/l)^{0.5}$	%	%	%	
0-25	8.11	0.74	24.61	54.60	1.63	39	0.40	3.00	98.0	1.0	1.0	Sand
25-50	8.52	0.73	24.50	57.80	1.62	39	0.23	5.20	97.0	1.5	1.5	Sand

BD (bulk density); SP (saturation percentage); pHs (pH of saturated soil paste); ECe (electrical conductivity of soil saturation extract); OM (organic matter); SAR (sodium adsorption ratio); OP (osmotic pressure); MC (moisture content)

as multi-purpose trees in sustainable Agroforestry systems. Considering the multipurpose benefits of *A. ampliceps* we trialed this tree by irrigating with three different water salinity levels (10, 20, 30 dS/m) over three years (2014 to 2016) in sandy soils of UAE “Entisols”.

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

MATERIALS AND METHODS

The trial was conducted at the experimental station of Dubai based International Center for Biosaline Agriculture during three years (2014 to 2016). There exist three groundwater sources (ECiw 10, 20 and 30 dS/m) those were used to irrigate *A. ampliceps* trees over three years period. In half of the trees fertilizer was used in others fertilizer was not use. The water salinity was monitored on a regular basis. The trial site belongs to soil order Entisols and soil taxonomic class is “Carbonatic, Hyperthermic, Typic torripsamments” 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 to 99% sand, 1 to 2% silt and 0 to 1% clay (Soil Science Division Staff, 2017). Table 1 shows the analyses of the native sandy soil prior to the trial initiation. Native sandy soil is strongly calcareous, non-saline and non-sodic and the pH is in the range of moderately to strongly alkaline.

Raising nursery of *A. ampliceps*

To initiate *A. ampliceps* plants, seeds were sown in 1 L volume plastic bags with hole at the bottom. A mixture of soil and compost (4:1 by volume) was prepared and properly mixed to have uniform mixture. The soil/compost mixture was added to plastic bags and one seed of *A. ampliceps was* placed at 1 cm depth in each pot and irrigated with fresh water. All seeds were germinated within 4 to 6 days. The pots were separated into three lots and the propagules in each lot were acclimatized for 8 weeks to finally accomplish irrigation with ECiw of 10, 20 and 30 dS/m. The acclimatization took place in green house where final salinity achieved through stepwise increase of water salinity, e.g., final EC of 10 dS/m was reached from 2.5, 5, and 10 dS/m over a period of 8 weeks, similarly EC 20 was achieved through 4 steps (5, 10, 15 and 20 dS/m) and 30 dS/m (5, 10, 20 and 30 dS/m).

Transplantation of tress to trial sites

Nine weeks old acclimatized trees were transplanted in the trial site. Tree to tree distance was 3 meters and line to line 5 meters. Prior to transplantation, pits of 50 cm wide and 50 cm deep were prepared as per trial layout plan. The pits were then filled with mixture of soil and compost (4:1 volume basis) and trees were transplanted. Half of the trees received eighty grams of compound 20:20:20 (N : P_2O_5 : K_2O) fertilizer that was mixed with the upper 15 cm of soil surface in the pit once a year and pits were irrigated through bubler irrigation system using water salinity of 10, 20 and 30 dS/m. The mature trees are shown in Figure 1.

Basin irrigation system – Bubler system

In basin irrigation, bunds are created around the circular basin to prevent the water flowing out, thus, confining the irrigation water to the target area. This method is commonly practiced for date palms and trees grown in small basins, with the tree being planted in the center of the basin. It should be kept in mind that the basin method is most suitable for sandy soils where water

Figure 1. *A. ampliceps* in trial plot (top), pruned trees (bottom).

leaches down quickly. If the trees are sensitive to ponding water, this method should be avoided. In basin irrigation system, surface salinity is controlled, although at the subsurface wetting zone soil salinity will develop. In the basin a bubler is installed for irrigation which supplies water as circular water system. After transplantation each tree was irrigated through bubler irrigation system at the rate of 40 litres per day (one application) for the first four months. During the next 4 months (4 to 8 months) the irrigation volume was increased to 50 litres per tree and after 8 months the irrigation was increased to 60 liters per tree and continued till the trial completed in 2016. The rainfall during three years was 21.64 mm (14 days), 18.15 mm (22 days) and 16.91 mm (28 days) per annum during 2014, 2015 and 2016 respectively (https://www.worldweatheronline.com/dubai-weather-averages/dubai/ae.aspx).

Soil salinity assessment

Soil samples were collected from the tree basins using standard auger at two depths on a regular basis from all

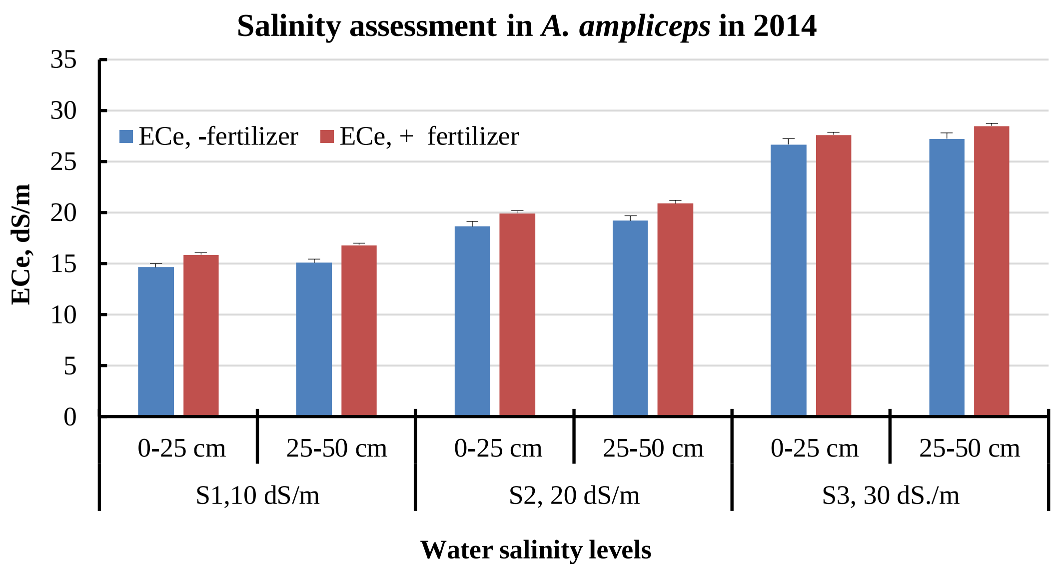

Figure 2. Comparative root-zone soil salinity at two depths with increasing irrigation water salinity and fertilizer application in the year 2014.

trees (12) irrigated with different water salinity (10, 120, 30 dS/m) levels. The soil samples were air-dried and processed to pass through 2 mm sieve prior to salinity analysis. The salinity assessment efforts have been made on both depths (0 to 25 and 25 to 50 cm) and described in this paper. 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; Shahid *et al*., 2018a, b; Soil Survey Staff 2014b). Each irrigation system develops salinity at a specific soil zone and thus needs to be carefully monitored. Recently (Shahid, 2014; Zaman *et al.,* 2018a) zones of soil salinity development for a range of different irrigation systems have been described. In the current trial we used bubler irrigation system in tree basin.

RESULTS AND DISCUSSION

In this section, results of three years trial with focus on salinity development over three years (2014 to 2016) are presented. Based on the root zone salinity monitoring results over 3 years period following have been observed. It should be noted that biomass assessment was not the objective of this study which will be dealt in a separate paper.

Salinity assessment of *A. ampliceps*

Soil samples from 0 to 25 and 25 to 50 cm depths of *A. ampliceps* trees were collected and monitored over three years during (2014, 2015 and 2016) and analyzed for EC of soil saturation extract (ECe). The results ate presented in Figures 2, 3 and 4. Following are the observation from three years monitoring results.

Root zone salinity at both depths increased over a period of three years (Figures 2, 3 and 4); the lowest being recorded in 2014 (Figure 2) and the highest in 2016 (Figure 4). The surface (0 to 25) as well as subsurface (25 to 50 cm) salinity is almost similar within the tree where same irrigation water was applied. Where difference occurs between soil salinity at two depths, it is insignificant and within standard deviation (SD) range. The root zone salinity levels at both depths in the years 2014, 2015 and 2016 are higher than the irrigation water salinity (ECiw = 10 dS/m). During 2014 the soil salinity at both depths is lower than the water salinity of the respective irrigation waters (20 & 30 dS/m), revealing salinity is well managed at higher irrigation water salinity during first year. In contrary to 2014, during 2015 and 2016 the soil salinities of the trees irrigated with water salinities of 20 and 30 dS/m were higher than the irrigation water salinity suggesting over years salinity has developed (Shahid *et al*., 2008, Shahid, 2013). The results clearly reveal that it is possible to manage salinity at early stage (during year 1) compared to subsequent years (2015 and 2016). The soil salinity with the application of fertilizer is slightly higher but within the range of standard deviation. This is true for all trees investigated.

Assessment of root zone salinity management efforts

We used two scenarios as proposed by Shahid *et al*. (2013) for light textured soils to assess the salinity

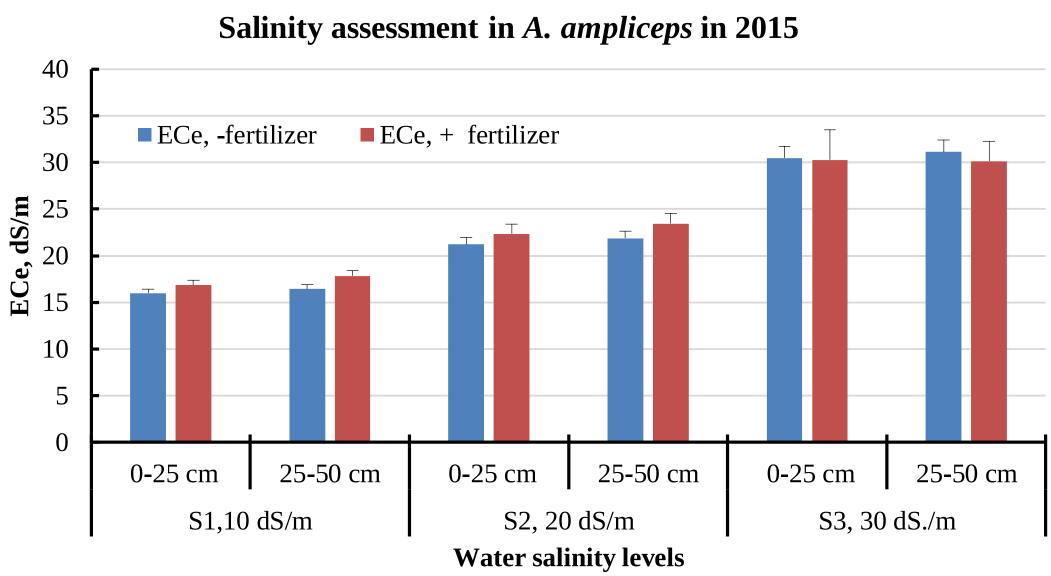

Figure 3. Comparative root zone-soil salinity at two depths with increasing irrigation water salinity and fertilizer application in the year 2015.

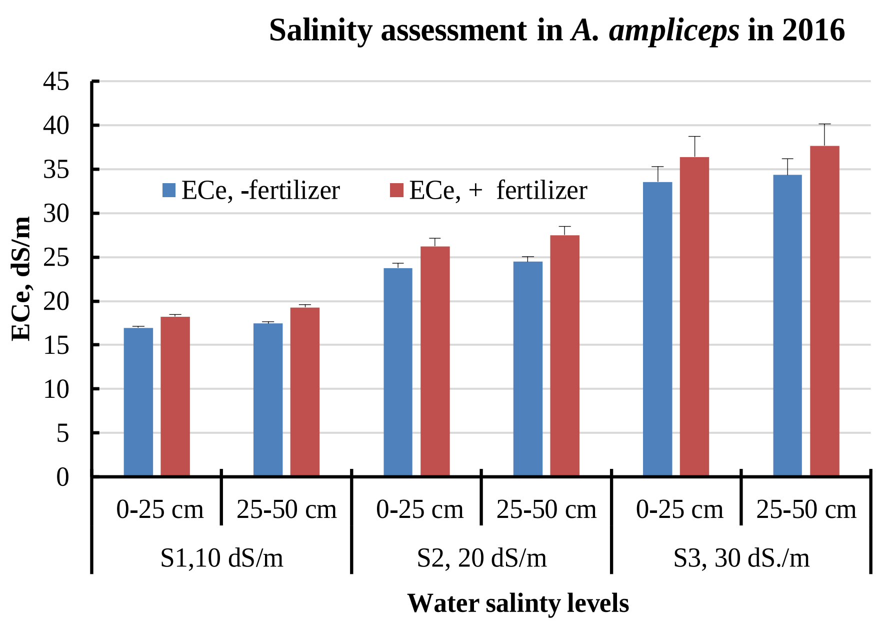

Figure 4. Comparative root-zone soil salinity at two depths with increasing irrigation water salinity and fertilizer application in the year 2016.

management efforts in the root zone.

Scenario I

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

Scenario II

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

The results of both scenarios are presented in Figures 5, 6 and 7 (ECe/ECiw > 1.1) and Figures 8, 9 and 10 (ECe/ECiw > 1.5). Following observations have been made. As described above that salinity management was better in 2014 compared to the next two years (2015 and

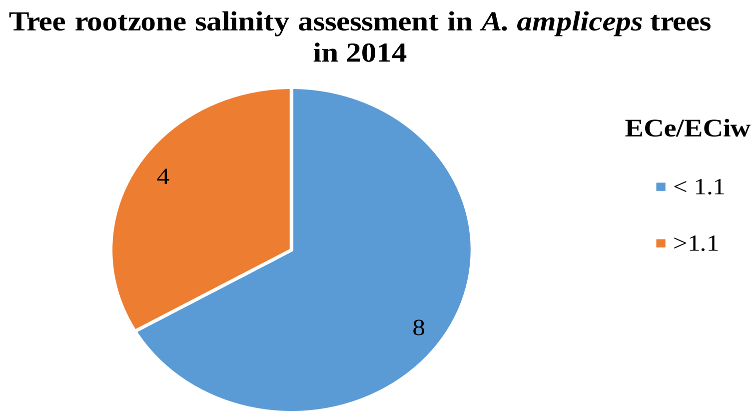

Figure 5. Assessment of salinity management efforts in 2014 (ECe/ECiw > 1.1) in *A. ampliceps* trees.

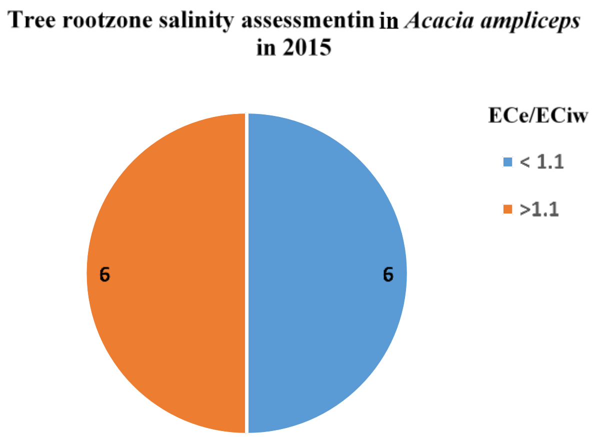

Figure 6. Assessment of salinity management efforts in 2015 (ECe/ECiw > 1.1) in *A. ampliceps* trees.

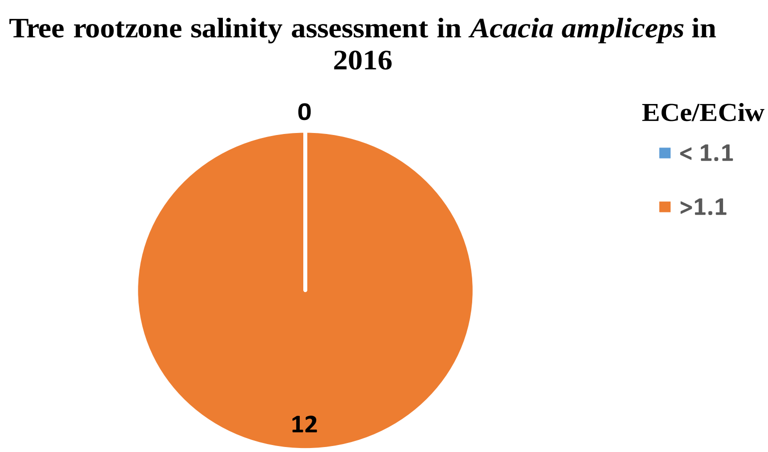

Figure 7. Assessment of salinity management efforts in 2016 (ECe/ECiw > 1.1) in *A. ampliceps* trees.

2016) when ECe/ECiw > 1.1 scenario is used (Figures 5 to 7). Of 12 trees assessed, 8 (Figure 5), 6 (Figure 6), 0 (Figure 7) trees show salinity well managed in the years 2014, 2015 and 2016, respectively.

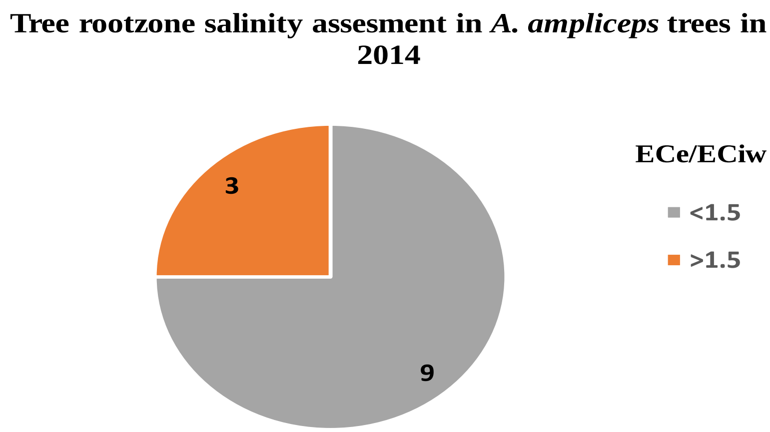

Figure 8. Assessment of salinity management efforts in 2014 (ECe/ECiw > 1.5) in *A. ampliceps* trees.

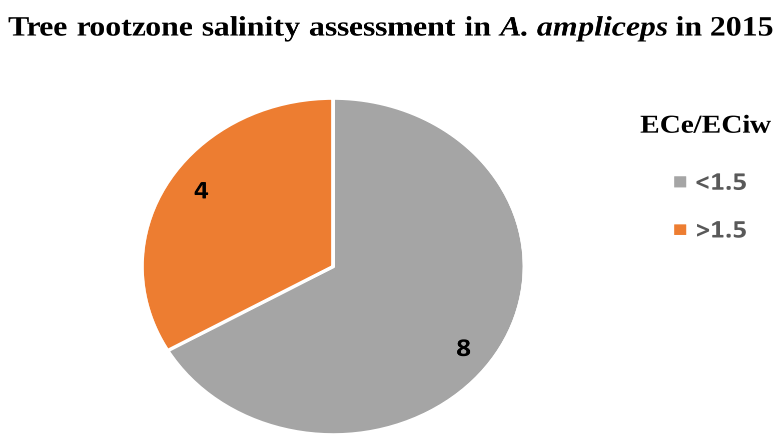

Figure 9. Assessment of salinity management efforts in 2015 (ECe/ECiw > 1.5) in *A. ampliceps* trees.

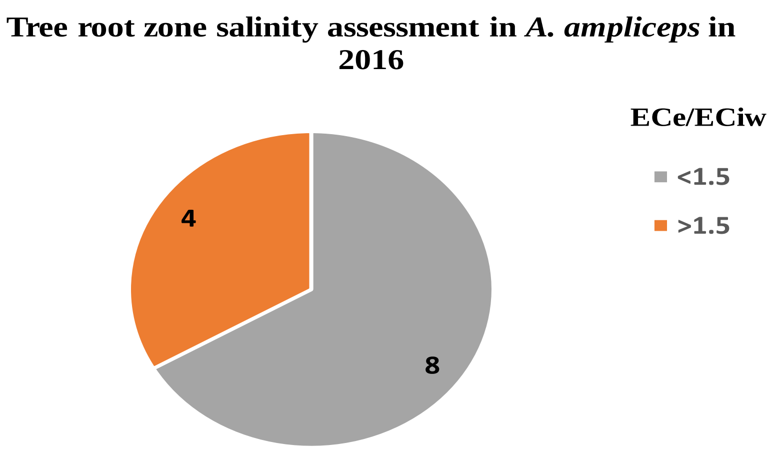

Figure 10. Assessment of salinity management efforts in 2016 (ECe/ECiw > 1.5) in *A. ampliceps* trees.

When the criteria were relaxed (ECe/ECiw > 1.5) the results significantly improved, such as, of 12 trees, 9 (Figure 8), 8 (Figure 9), 8 (Figure 10) trees were found to be well managed soil salinity in the years 2014, 2015 and

2016 respectively. The numerals in the figures show number of trees from where soil samples were collected and analyzed for soil salinity assessment.

CONCLUSIONS AND RECOMMENDATIONS

From the above observations, three conclusions are drawn, i) root zone salinity in *A. ampliceps* can be successfully managed with proper leaching fraction, using different irrigation water salinities; ii) the scenario ECe/ECw > 1.5 fits well to assess salinity management efforts in sandy soil covering over 75% of the UAE; iii) the study has revealed potential of *A. ampliceps* adoption where saline/brackish water is the only option for irrigation and biomass is needed to feed sheep and goats.

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