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Phytoextraction of salts by indigenous weeds in arid land

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Abstract

Reclamation of saline soil is becoming one of the most requirements for boosting crop production and sustainable agriculture. This study was conducted to investigate the capacity of three indigenous weeds growing naturally in arid land on west of Saudi Arabia. Salts content and biomass production for each weed species was evaluated. Salts concentration at three depths 0-10, 10-20 and 20-30 cm was estimated at growing and none growing sites for each weed species. The salts content for the weeds was found to be 6.26%, 16.80% and 5.83 % for Setariaverticillata, Dipterygiumglaucum and Tribulusterrestris respectively. Biomass production based on the dry weights was 13.37, 9.24 and 5.63 t ha-1 respectively. The removal efficiency was varied according to soil depth and initial soil salinity concentration.

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Introduction

Salts released into agricultural lands by various human activities and natural sources are of great concern. Accumulation of salts in the soil has serious effect on plants growth or death under severe conditions (Munns and Tester 2008). Salinity can affect plant in several ways such as water uptake even under wet conditions, toxicity or damage caused due to excess of Na^+ and Cl^- and deficiency of nutrients.

Saline soils can be treated by such ways including drainage improvement, chemical treatment, reducing evaporation, leaching and a combination of more than one method. However, all these methods are not economical or feasible in some arid conditions where the perception is very low, irrigation water is extremely poor and chemical fertilizers are used excessively.

Among the methods that applied for salinity remediation is phytoextraction, in which, plants uptake salts and accumulate them in their above ground tissues, and then the biomass of the plants can be disposed later to another place away from the treated site. These kinds of plants are known as halophytes which can achieve their optimum growth and yield potential at salinity (EC) of 6-20 dS/m, most of the crops cannot survive (.Al-Oudat, and Qadir, 2011). Some halophytes can grow in coastal regions and in arid inland deserts with high salt content, where the EC is 45 dS/m (seawater) and above(Stuart 2012, ManousakiandKalogerakis 2011).Tolerance of halophytic plants to severe salinity stress was reported by (Christian *et al.*, 2013) who classified 11 coastal halophytes depending on their tolerance to soil salinity that they grow in, their study concluded that the average of salinity sites was 92 dS/m, where, the highest salinity level reached 135 dS/m. in another study, application of seawater for irrigation have been used successfully for producing halophytes crops(Glenn *et al.* 1997).Phytoextraction of salts by indigenous weeds growing naturally in salt affected soil is nondestructive technology, environmental friendly, cost effective and potentially efficient. In arid regions such as west of Saudi Arabia, scarcity of fresh water for irrigation is a serious problem, therefore, phytoextraction of salts by halophytic plants remain the only economical solution for reclaiming salt affected soil. Setariaverticillata, Dipterygiumglaucum and Tribulusterrestris are common weeds species grown naturally in arid land of west Saudi Arabia, where the salinity is varied from none saline to severe saline soil. Application of conventional techniques to remediate these soils is very cost in addition to the negative environmental consequences results from these techniques application. Finding environmentally friendly alternative for integrated and sustainable solution is urgently needed. The aim of this study was to introduce these three weeds species and evaluate their capacity for salts uptake and biomass production.

Materials and methods

Study Site Description

The study was carried out at agricultural research station, king Abdulaziz University, Saudi Arabia. The distribution of the soil particles was 83% sand, 15.6% silt and 1.4% for clay, the soil was classified as sandy loam soil. The salts content of the soil was greatly varied, it ranges from 2 mS/cm up to 44 mS/cm and the pH average was around 7.5. The quality of irrigation water was poor; it has constant electrical conductivity 3.72 mS/cm.

Soil Sampling

The soil samples were collected from the weeds sites and none growing sites to represent the control. The control sites received the same amount of water quality during the whole experiment; however the weeds were managed manually. Soil samples were taken from three depths 0-10 cm, 10-20 cm and 20 -30cm. Roughly, 500g for each soil sample was taken to the laboratory for ECe determination. After drying and sieving, saturated soil paste from each sample was prepared using distilled water. After 24 hours, electrical conductivity was measured by calibrated EC meter for the extracts of the samples.

Assessment of biomass production

Above ground biomass production of one meter square for each weed species was harvested for the estimation of the fresh and dry weight, the production was expressed in t / ha.

Weeds samples preparation and salt content determination

Weeds shoot samples were washed with running tap water, rinsed several times with distilled water, and then dried at 72 °C till they reached stable weight. The samples grinded by electrical blinder passed through 2-mm sieve and kept in sealed plastic bags until they analyzed for salts content.

Setariaverticillata Family: Poaceaefamily: Dipterygiumglaucum Capparaceaefamily: Tribulusterrestris Zygophyllaceae

Fig. 1. halophyte weeds species investigated in the study.

Results and discussion

Figure 2 shows the average of the salts in *Kg* that can be added by each cubic meter of salineirrigation water in the study area. Shortage of high quality irrigation water is forcing the use of this water which increases the risk of soil salinization. In case of arid land which is low in precipitation and high in evaporation due to higher average of daily temperature throughout the year, the salt concentrate in the upper soil depths, therefore, the crops will be affected considerably by the salinity. Variable increases of salts on upper soil depths as a result of saline water application was reported by (Wenjun *et al.*, 2008).

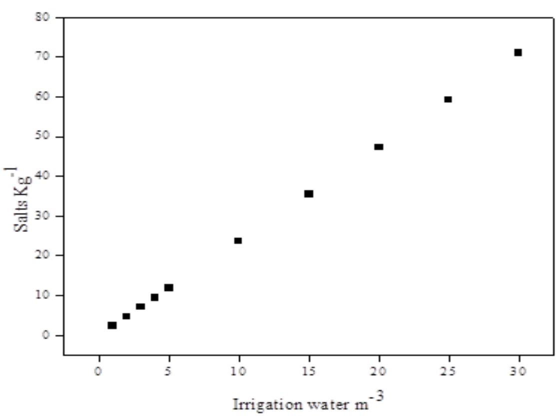

Fig. 2. Salinity increase pattern as influenced by saline irrigation water.

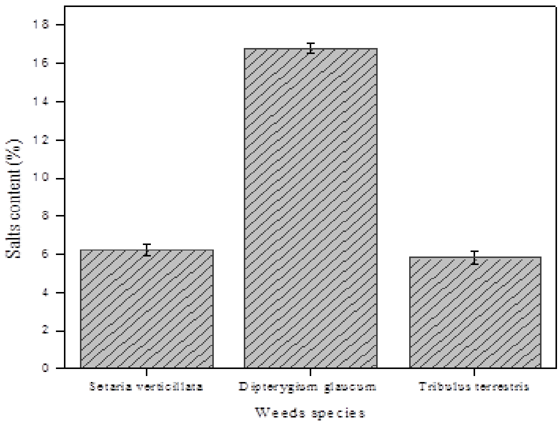

Fig. 3. soluble salts content in different weeds species.

Figure 3 shows the salt content for investigated weeds species, Dipterygiumglaucum was the highest in salt accumulation, the proportion was 16.8% of the total dry biomass above the ground, where the proportion for the other two species were only 6.3% and 5.8% for Setariaverticillata and Tribulusterrestris respectively. These proportions of salt content in the weeds is not fixed, it changes depending on the initial soil salt content where the weeds are growing, environmental factors , soil moisture contents and soil properties. The capacity for salts accumulation is considerably high for all investigated weeds, consequently, they should be removed out of the remediation site when they use for salinity management.

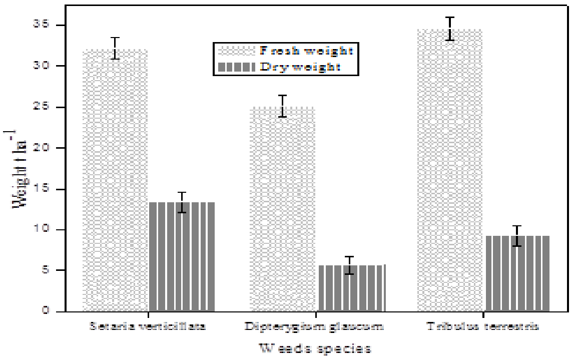

Fig. 4. Fresh and dry weight of biomass production of the different weedsspecies per hectare.

Figure 4 Shows the yield of fresh and dry biomass produced by the weeds species. Based on the dry matter production, Setariaverticillata was the highest (13.37 t/ha), followed by Tribulusterrestris (9.24 t/ha) and Dipterygiumglaucum (5.63 t/ha). The maximum biomass production potentialities of these weeds could be higher; however the water scarcity during the growth stages could limit the productivity of these weeds. High biomass production is very important criterion for halophytes to be selected for salts extraction. Study contacted by (Glenn *et al.*, 1996) showed that some halophytes such as Batis maritime L have a capacity of producing up to 34 t/ha/year of dry matter under saline water irrigation.

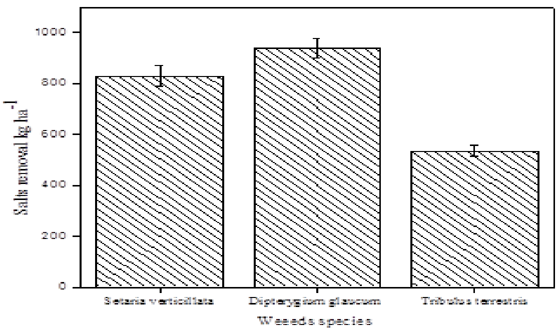

Fig. 5. The average of annual quantities of salts that can be removed by the different weeds species per Kg.

Figure 5 shows the average of annual quantity of salts that can be removed by the different weeds species, the highest salts removal was achieved by Dipterygiumglaucum which removed 940.52 kg/ha, the biomass production of this weed was the lowest among the investigated weeds, however the salts content on the biomass was the highest. The lowest salts removed was recorded by Tribulusterrestris, which was around 500 Kg/ha. All investigated weeds proved high potentiality for salts extraction and therefore can be used for salinity management to balance secondary soil salinization that causes by poor irrigation water and chemical fertilizers.

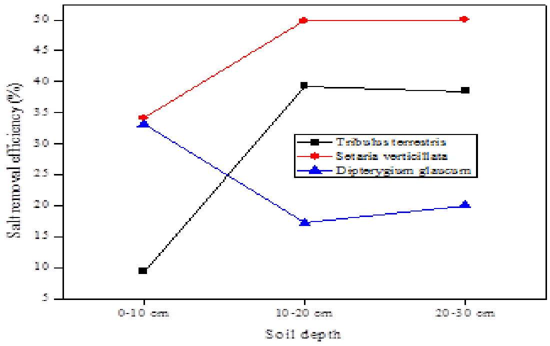

Fig. 6. Efficiency of the different weeds species on salts removal from different soil depths.

Figure 6 shows the efficiency of the weeds on salinity removal from different soil depths, there was big variation among the investigated weeds. The efficiency of Setaria verticillata and Tribulus terrestris was increased with the depths increasing while for Dipterygiumglaucum, the efficiency was decreased sharply with the depth increase. The variation in efficiency removal can be attributed to roots length and distribution on the soil, total biomass production and initial soil salinity.

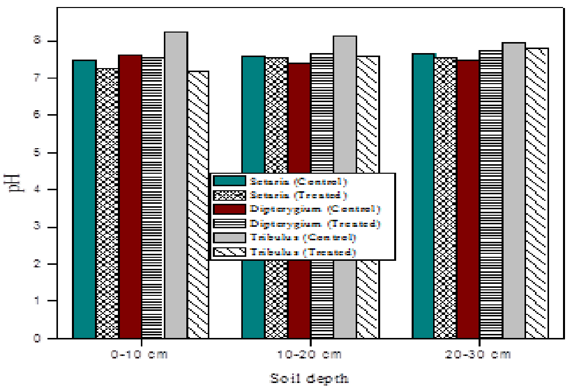

Fig. 7. Effect of the different weeds species on soil pH on various soil depths.

The figure shows that the pH was changed in a different way according to weed species and soil depth. Although a little change was showed, however, this change could be attributed to root exudates compound solutions such as organic acids and sugars. Halophytic plants can handle the high concentrations of salts by either avoidance through special salt glands in their leaves or through accumulation, in which halophytic plants can tolerate high levels of salts and continue the biochemical processes to prevent the osmotic stress and assist the storage of salts (Stuart 2012, Manousaki and Kalogerakis 2011). Accumulation of salts into halophytes tissues was assumed to maintain low water potentiality in cells or the halophytes are less selective in ions absorbance such as using sodium instead of potassium in some cells functions (Stuart 2012, Broadly *et al* 1999). It was evidenced that some halophytes might be more effective in salts accumulation even in non-saline soils (Jaier *et al* 2010, Fional *et al* 2002). The weakness of using halophytes plants in salts extraction is that, low production of biomass compared to glycophytes (Zaier *et al.*, 2010), some halophytes absorb and accumulate metals and therefore, the decrease the presence of sodium salts (Lefevre *et al.*, 2009) and some halophytes don't perform well in none saline soil (Stuart 2012)

Conclusion

The study demonstrated the efficiency of indigenous weeds in removing salts from salt-affected soil in arid land. Based on biomass production, *Setariaverticillata* can be classified as the most efficient among the investigated weeds species. Further research on physiological mechanisms that make these weeds are tolerant to severe salinity stress are encouraged. These weeds can also be examined for contaminants removal.

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