Salt Removal Potential of *Portulaca Oleracea* Golden Purslane

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Abstract: Conventional techniques, namely soil leaching and the use of enhancing fertilization are methods used to mitigate soil salinity and to increase the salt tolerance of agricultural crops grown in salt-affected soils. However, the intense of these techniques has also attracted public attention due to the environmental pollution caused and the contamination of groundwater resources. Recently, a new environmentally safe and clean remediation technique, whereby salt (ion) removing species are planted in the salt-affected soils, has been introduced to address salinity problems. The salt removal potential of *Portulaca oleracea* golden purslane has been evaluated under this study. The field experiments were carried out in the Khorezm Region, in the northwest of Uzbekistan, during the summer, the most sensitive period for salt-affected soils. *Portulaca oleracea* was planted in two different salt-affected soils, with and without irrigation practices. The results have revealed that no irrigation was required, when the water table remained at a depth of about 1.1 m, to remove the highest soil salts and to obtain the highest biomass production in *Portulaca oleracea* golden purslane; the capillary rise from the groundwater has played a significant role in meeting the demand of plants for water, increasing plant transpiration. The highest salt accumulation was 497 kg ha^{-1}, which eventually, removed about 16.8 % of the total soil salts, at a depth of 10 cm. Meanwhile, the highest biomass production was 3948 kg ha^{-1} with no irrigation practices. This study indicated that *Portulaca oleracea* golden purslane could become potential species used to control and to combat salinity in the northern part of Uzbekistan and could also be integrated into cultivation/rotation programmes to remediate saline soils.

Key-Words: soil salinity, phytoremediation, salt removing species, conventional techniques, clean techniques, salt extraction

1 Introduction

Salinity of agricultural lands is one of the most important issues in the semi-arid areas, north of Uzbekistan, mainly due to the mismanagement of water and land resources over the last forty years. More than half of the 2.32 million hectares of irrigated land in Uzbekistan is salt affected and build-up salinity is a seriously threatening agricultural productivity [8]. Every year, 75 million tons of salt is spreading with a 1000 km radius into other Central Asian countries [11].

Before the collapse of the Soviet Union in 1991, Uzbekistan was a major producer of cotton, which is one of the most salt-tolerant crops. In order to obtain an increasing amount of cotton, the country was using enormous amounts of water resources from the two main rivers – the Amudarya and the Syrdarya. These rivers supply the Aral Sea. Furthermore, farmers have been pursuing extensive agricultural development through the use of high levels of fertilizers and pesticides in order to increase crop productivity. The consequences of using enormous amounts of water resources and heavy application of chemicals has resulted in rising groundwater tables, secondary salinization problem and the well-known ecological disaster around the Aral Sea [13]. Moreover, low irrigation efficiencies – caused by unlined canals and a poor drainage networks – has led to major waterlogging and salinization that has now affected about 55 percent of irrigated land in the country [6].

In addition, many scientists pointed out that capillary rise may have a negative affect on crop production, when the groundwater table is about 0.6 m from the soil surface and salinized. On the other hand, low irrigation practices can be used to obtain high biomass production, when the groundwater table is about 1 m and slightly saline [14]. As an example for Uzbekistan, Kurambaev (1969) highlighted that low irrigation practices are required to maximize crop productivity in the northern regions, especially in cotton fields, when the groundwater table is at 1-1.2 m depth and only slightly saline [9].

The Khorezm Region has been selected as the focus of this work as it is one of the areas in Central Asia most strongly affected by secondary soil salinization. In this region, the dominant approaches adopted by farmers to mitigate salinity is to apply excessive amounts of water to salt-affected fields in order to leach the salts into the root zone allowing infiltration of salts to deeper layers. This approach has two outcomes – firstly, when there is an impermeable layer, salts are accumulated above this layer and secondly, when there is no impermeable layer, groundwater contamination can be observed [1]. An alternative approach used in the region to combat soil salinity and to maximize agricultural crop production is the heavy application of fertilizers; in this case the tolerance of plants to saline conditions is increased, but contamination by hazardous chemicals will also be increased due to the higher amount of fertilizers applied [3].

It is estimated that annually between 8-10 % of the irrigated area of the Khorezm Region – one of the largest irrigated regions of Uzbekistan – is taken out of crop production due to salinization. The rehabilitation of these salinised areas requires major technical expertise and financial investment. The rehabilitation cost has been assessed by the World Bank to be more than USD $3 billion [15].

Recently, a new environmentally safe and clean technique known as phytoremediation has been introduced to address the salinity problem. This includes the introduction of salt (ion) removing species to control salinity and to maintain the sustainability of agricultural fields [5][10]. Phytoremediation is defined as the use of plants to remove pollutants from the environment and to render them harmless [12]. Large-scale decontamination of soils and underground water using phytoremediation techniques requires plants with high salt uptake rates, large biomass and tolerance to a wide array of environmental conditions and constraints [7].

The main aim of this study was to develop recommendations for soil remediation for the northern region of Uzbekistan and to rehabilitate salt-affected soils using phytoremediation techniques. Moreover, the specific research objective was to evaluate *Portulaca oleracea* golden purslane in the salt-affected soils of northern Uzbekistan for its ability to remove salts.

2 Materials and methods

The research investigation was carried out in the Vazir Water Users Association, Khorezm Region, Uzbekistan (Fig. 1), during the summer period.

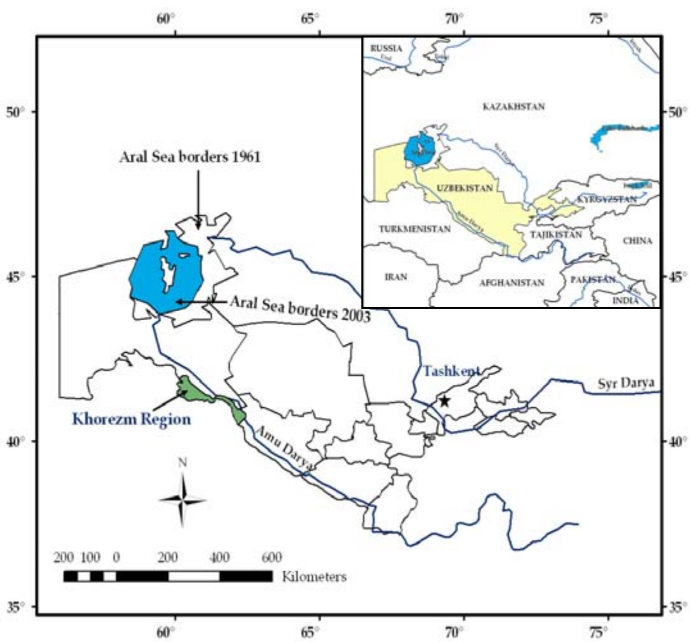

Fig. 1 - Location of the study region

Briefly, *Portulaca oleracea* Golden Purslane was planted in two different salt-affected soils of Khorezm Region and reported as field 1 and field 2 in this study. Furthermore, field 1 was not irrigated while field 2 was irrigated twice with 0.78 dS m^{-1} salinity level of channel water. The duration of experiment was 49 days for field 1 and 58 days for field 2. The climatic conditions of this region during the field visit are presented in Table 1. Soil physical and chemical properties are analyzed by the Central Laboratory of the Uzbek Research Institute of Cotton Growing (UzRICG), Tashkent Region, Uzbekistan and the results for two experimental fields are shown in Tables 2 and 3, respectively. The selected crop is characterized by a short vegetation period, low water consumption, high biomass production potential, tolerance to hot conditions, easy crop management and good acceptance by local consumers as a leafy vegetable.

Table 1. Monthly mean values of air temperature (T), relative humidity (RH), wind speed (W), precipitation (P) and potential evapotranspiration (ET_p), at the Urgench meteorological station, Khorezm, 2006

Month	T [ºC]	HR [%]	W [m s^{-1}]	P [mm]	ET_p [mm]
July	27.1	38	3.3	1.4	280.2
August	26.9	40	2.6	0.6	230.6
September	18.8	47	2.7	0.5	176.6

The plants were harvested in the seedling phase of *Portulaca oleracea* golden purslane. All plant samples were taken, plant height was measured, they were weighed for crop yield determination, washed up with tap water and distilled water, oven dried at 70º C for 48 hours, re-weighed, finely ground in a mill and used for analysis of chloride (Cl^-), sodium (Na^+), potassium (K^+), calcium (Ca^{2+}) and magnesium (Mg^{2+}). The levels of Na^+ and K^+ were determined by flame photometry, while the remaining cations were assessed by atomic absorption spectrophotometry using a Shimadzu, AA-680 model spectrometer. Chloride (Cl^-) ions were determined in the aqueous extract by potentiometer using a Crison, pH meter GLP 22 after extraction in cold water. The plant chemical properties were analyzed at the Campus of Gambelas of the University of Algarve, Faro, South Portugal.

The data were subjected to standard analysis of variance using the One-Way ANOVA procedure of the SPSS 14.0 for Windows (SPSS, 2005) to compare mean values of three replicated Cl^- concentrations, obtained through potentiometric method. Differences at the $P \leq 0.05$ level were used as a test of significance and means were separated using the Duncan post hoc t-test.

Table 2. Soil properties at Field 1

Properties	Soil layer [m]		
	0.00 – 0.10	0.10 – 0.20	0.20 – 0.30
Sand [%] Silt [%] Clay [%]	35 47 18	33 48 19	33 51 16
Texture	Loamy	Loamy	Silt Loamy
Bulk density [g cm^{-3}]	1.35	1.36	1.37
Θ_{WP}* [m^3 m^{-3}] Θ_{FC}* [m^3 m^{-3}]	0.210 0.304	0.258 0.286	0.265 0.281
Electrical conductivity [dS m^{-1}]	1.17	1.02	0.92
Total dissolved solids [%]	0.146	0.127	0.114
Nitrogen [%]	0.077	0.066	0.059
Humus [%]	0.817	0.752	0.666
P_2O_5 [mg kg^{-1}]	47.2	41.6	37.2
K_2O [mg kg^{-1}]	140	140	120

* Volumetric soil water content at wilting point [Θ_{WP}] and field capacity [Θ_{FC}]

Table 3. Soil properties at Field 2

Properties	Soil layer [m]		
	0.00 – 0.10	0.10 – 0.20	0.20 – 0.30
Sand [%] Silt [%] Clay [%]	27 55 18	27 53 20	28 54 18
Texture	Silt Loamy	Silt Loamy	Silt Loamy
Bulk density [g cm^{-3}]	1.41	1.43	1.43
Θ_{WP}* [m^3 m^{-3}] Θ_{FC}* [m^3 m^{-3}]	0.313 0.319	0.287 0.300	0.283 0.300
Electrical conductivity [dS m^{-1}]	4.24	2.88	1.80
Total dissolved solids [%]	0.530	0.360	0.225
Nitrogen [%]	0.066	0.056	0.049
Humus [%]	0.709	0.645	0.559
P_2O_5 [mg kg^{-1}]	43.0	38.6	31.6
K_2O [mg kg^{-1}]	80	80	60

3 Results and discussion

Despite the fact that the field 2 was irrigated during the vegetation period, the dry biomass of *Portulaca oleracea* at the harvest time was very low averaging 489 kg ha^{-1} (Fig. 2). It can be presumed that other factors significantly influenced the decrease of production of biomass at field 2. These could have been: higher degree of soil salinity, higher rate of upward water movement from a shallow water table and no plucking the weeds after the irrigation. Moreover, the groundwater table in field 2 was 0.5-0.6 m below the soil surface. A shallow groundwater in this field could mainly be due to either inefficient drainage or drainage that is artificially blocked by farmers to raise the groundwater to meet the crop water demand. The farmers within the area pointed out that the area sometimes face the irrigation water shortages and thus, groundwater resources is used as a source of moisture for crops. However, a shallow groundwater table caused anaerobic conditions and hampered the development of the *Portulaca oleracea* root system.

Interestingly, with no irrigation of field 1, high dry biomass production of *Portulaca oleracea* averaging 3948 kg ha^{-1} was obtained.

A mean stem length of *Portulaca oleracea* at the harvest time varied from 19.7-17.8 cm in fields 1 and 2, respectively (Fig. 2). Moreover, the root depths of the plant varied from 5-10 cm in both experimental fields. The higher degree of soil salinity in field 2 did not greatly affect to the plant height.

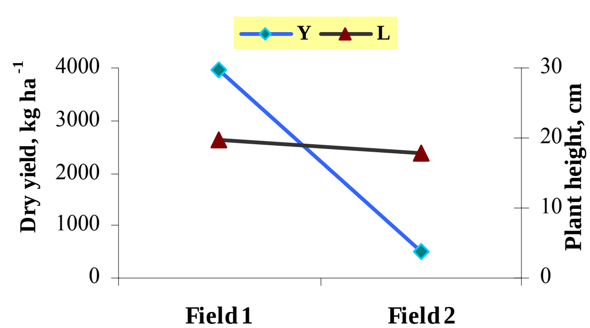

Fig. 2 – *Portulaca oleracea* plant dry yield (Y) and height (L) at harvest in the investigated fields

The plant salt extraction analysis showed that *Portulaca oleracea* golden purslane tissues accumulated the largest amounts of chloride and magnesium in field 1, whereas chloride and sodium in field 2 (Fig. 3). For instance, the highest chloride ion concentration was 69.4 mg g^{-1} dry matter in field

1, while 56.7 mg g^{-1} dry matters in field 2. In the case of sodium, field 1 *Portulaca oleracea* tissues accumulated, in average, 8.19 mg g^{-1} dry matter whilst 24.85 mg g^{-1} dry matter in field 2. Furthermore, magnesium and calcium ion concentrations varied from 37.86-11.16 mg g^{-1} dry matter in field 1 and 18.91-10.81 in field 2, respectively. Potassium ion concentrations showed the lowest values ranging from 2.83-2.50 in fields 1 and 2, correspondingly.

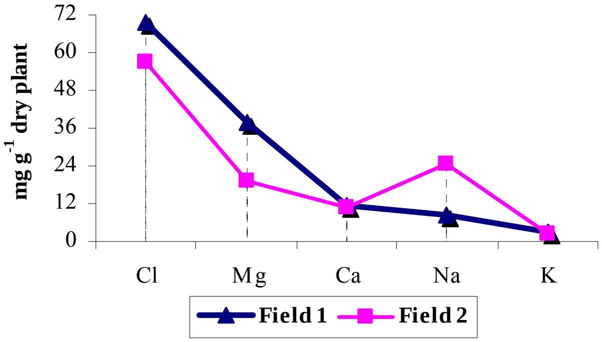

Fig. 3 – Salt (Cl^-, Mg^{2+}, Ca^{2+}, Na^+, K^+) contents in the tissues of *Portulaca oleracea* at two fields

In addition, the extraction of total soluble salts by *Portulaca oleracea* have revealed that despite low soil salinity levels in field 1, the highest salt uptake, 497 kg ha^{-1} was obtained (Table 4). As shown in Table 4, salt accumulation in field 2 was decreased drastically ranged 50.1 kg ha^{-1} during the examined period, most probably due to low biomass production and low plant density. Meanwhile, our analysis showed that *Portulaca oleracea* golden purslane extracted 16.81 % of the total soil salts. It should be stated that the plant can remove the salts only from 5-10 cm of topsoil layers because of its maximum root length. Due to low plant density and high soil salinity, the extraction of salts from the soil was much lower in field 2.

Table 4 - Removal of soil salts, using *Portulaca oleracea* plant in two different experimental fields

Field №	Root depth [m]	Soil salts [kg ha^{-1}]	Salt extraction [kg ha^{-1}]	Soil salt removal [%]
1	0.10	2957	497	16.81
2	0.10	11210	50	0.45

4 Conclusion

This evergreen *Portulaca oleracea* golden purslane species showed to be relatively tolerant to saline conditions and can be planted with minimum irrigation practices in the salt-affected soils of Khorezm Region, Uzbekistan. Based on results, the *Portulaca oleracea* golden purslane has the highest potential to mature in salt-affected soils, to remove high levels of salts from the soil and to develop on loamy soils, which represent the dominant soil texture in the region.

Furthermore, as cotton is the dominant crop in the northern region of Uzbekistan and low yields of cotton are mostly caused by soil salinity, the introduction of salt removing species (e.g. *Portulaca oleracea*) could potentially create both environmental and economical solutions, provided that they can be utilized as vegetables, ornamentals or fodder, and could also be integrated into cultivation/rotation programmes to remediate saline soils. However, additional research is needed and encouraged on these topics.

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