Environmentally Useful Technique - *Portulaca Oleracea* Golden Purslane as a Salt Removal Species

A. HAMIDOV[1], J. BELTRAO[2], C. COSTA[2], V. KHAYDAROVA[3], S. SHARIPOVA[4]

[1] Water Resources Management Department
Research Institute of Market Reforms of Uzbekistan
28 Avenue Halklar Dustligi, 700029 Tashkent
UZBEKISTAN
a_hamidov@yahoo.com

[2] Faculty of Engineering of Natural Resources (FERN)
University of Algarve
Campus de Gambelas, 8000-139 Faro
PORTUGAL
jbeltrao@ualg.pt mcorada@ualg.pt

[3] Water Resources Department
Uzbek State Uzgipromeliovodhoz Institute
44 Navoiy street, 700011 Tashkent
UZBEKISTAN
khaydar@glb.net

[4] Faculty of Hydro-amelioration
Tashkent Institute of Irrigation and Melioration
39 Kary Niyaziy street, 100000 Tashkent
UZBEKISTAN
shavkat.sharipov@gmail.com

Abstract: The application of large volumes of freshwater and the heavy use of chemical substances (fertilizers and pesticides) are methods which have been used to mitigate salinity and increase the salt tolerance of agricultural crops in salt-affected soils. However, the intense use of these conventional techniques has attracted public attention due to the environmental pollution and to the contamination of groundwater resources. In recent years, a new environmentally safe and clean technique of planting salt (ion)-removing species in the salt-affected soils has been introduced to mitigate the salinity problems. The salt removal potential of *Portulaca oleracea* golden purslane has been assessed under field experiments conducted in the Khorezm Region, northwest of Uzbekistan. *Portulaca oleracea* was planted during the summer in two different salt-affected soils, with and without irrigation. The results have revealed that, when a slightly saline groundwater table remained at a depth under surface near 1.1 m., no irrigation was required as capillary rise from the groundwater played a significant role in meeting the demand of plants for water and increasing transpiration. A high ion accumulation was observed (497 kg ha^{-1}), which corresponds to 16.8% of the total amount of soil salts in the 0-10 cm topsoil layers. Furthermore, the highest dry biomass production was 3948 kg ha^{-1}, without any irrigation practices (in comparison to 489 kg ha^{-1} with irrigation practices). Results of this study clearly indicate that *Portulaca oleracea* golden purslane could be used to combat salinity and rehabilitate saline soils in the northern part of Uzbekistan.

Key-Words: soil salinity, conventional techniques, phytoremediation, salt removing species, salt extraction, *Portulaca oleracea* golden purslane.

1 Introduction

Soil salinity in agricultural lands is one of the most central issues in the north of Uzbekistan, mainly due to the mismanagement of water and land resources over the last forty years [1]. More than half of the 2.32 million hectares of irrigated land in Uzbekistan is salt affected and built-up salinity is seriously threatening agricultural productivity [2]. Every year, 75 million tons of salt is spreading with a 1000 km radius across the other Central Asian countries [3].

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 increase the amount of cotton, the country used enormous amounts of water resources from the two main rivers – the Amudarya and the Syrdarya – that drain into the Aral Sea. Furthermore, agricultural policy was aimed on the extensive development of agriculture through application of high amount of fertilizers and pesticides in order to increase the crop's salt tolerance and productivity. The consequences of such practice have resulted in rising groundwater tables, secondary salinization problem and the well-known ecological disaster of drying up of the Aral Sea [4]. Moreover, low irrigation efficiencies – caused by poor canal construction and the absence of drainage network – has led to serious waterlogging and salinization that has now affected about 55 percent of irrigated land in the country [5].

Many scientists insist that capillary rise may have a negative effect on crop production, when salinized groundwater table is about 0.6 m from the soil surface [6]. On the other hand, low irrigation rates can be used to obtain high biomass production, when the groundwater table is about 1 m and only slightly saline [7]. As an example for Uzbekistan, Kurambaev (1969) highlighted that low irrigation rates 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 under surface and only slightly saline [8].

The Khorezm Region is the area in Central Asia most strongly affected area by secondary soil salinization. In this region, the dominant approach adopted by farmers to mitigate salinity is the application of excessive amounts of water to salt-affected fields in order to leach the salts through the root zone into the deeper layers. This approach has two outcomes depending on the existence or not of an impermeable layer: when there is an impermeable layer, salts are accumulated above this layer and when there is no impermeable layer, groundwater contamination can be observed [9]. An alternative approach used in the region to increase the salt crop tolerance and to maximize agricultural crop production in the salt-affected soils is the application of huge amount of fertilizers. In this case the tolerance of plants to saline conditions can be increased, but at the same time contamination by hazardous chemicals will also be increased due to the higher amount of fertilizers and pesticides [10]. It should be stated that annually significant irrigated lands of the Khorezm Region are being lost for crop production due to salinization. The rehabilitation of these salinised areas requires a detailed technical expertise and significant financial investment. The rehabilitation cost has been assessed by the World Bank to be more than USD $3 billion [11].

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 [12, 13]. Phytoremediation is defined as the use of plants to remove pollutants from the environment and to render them harmless [14]. 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 [15].

The main aim of this study was to evaluate the potential of using *Portulaca oleracea* golden purslane for salt removal and rehabilitation of salt-affected soils of the northern region of Uzbekistan.

2 Materials and Methods

The research investigation was carried out in the *Vazir* water users association, Gurlan district, Khorezm Region, Uzbekistan, during the summer of 2006.

The Amudarya River is a supplier of water for the whole Khorezm Region and in the last years, the water amount in the river has been tremendously reduced because of intensive upstream diversion [16]. The river provides irrigation water for 231,000 ha of which more than 12% are severely saline. The region contributes to 15% of the national Uzbekistan river water withdrawals. And water withdrawal for agriculture is estimated at 94% of the whole regional water withdrawals. The region has become particularly vulnerable to short and long-term droughts and, as a result, during 2000 and 2001 growing seasons, resulted in major crop failures [17]. Consequently, the agricultural Gross Domestic Product (GDP) has become one of the lowest in Uzbekistan. In addition, the socio-economic and public health situation in the region has been worsening due to geographical proximity to the ecologically degraded Aral Sea [18].

Portulaca Oleracea Golden Purslane was planted in two different salt-affected soils of Khorezm Region and reported as field 1 (16 m^2 size) and field 2 (49 m^2 size) in this study. Field 1 was not irrigated while field 2 was irrigated twice during the experimental period with 0.78 dS m^{-1} salinity level of canal water. In field 2, irrigation was of 30 and 25 min duration which allowed the soil to be completely saturated and flow rates recorded as 0.43 and 0.14 m^3 min^{-1}. Research was carried out during the summer period (July, August and September) and the duration of the experiment was 49 days for field 1 and 58 days for field 2. The plants in both fields were harvested in the seedling stage.

The study area is located in the Central Asian semi-desert zone with an extremely continental climate. The climatic conditions during the experimental period are presented in Table 1 where potential evapotranspiration (ETp) was calculated based on Ivanov´s method [19]. The irrigation, drainage and groundwater table data were measured for total dissolved solids (*TDS*) using titration method (Table 2). The soil samples were analyzed for agro-physical and agro-chemical properties in the Central Laboratory of the Uzbek Research Institute of Cotton Growing (Tashkent Region, Uzbekistan). Soil properties of the experimental fields 1 and 2 are shown in Tables 3 and 4, respectively. The selected crop is characterized by a short vegetation period, low water consumption, high biomass production potential, tolerance to arid climate, easy crop management, and wide usage by local people 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]	RH [%]	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

Plant samples were taken in the seedling phase and plant height was measured. Samples were weighed for crop yield determination, washed with tap water and distilled water, oven dried at 70ºC for 48 hours and 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 amounts of Na^+ and K^+ were determined by flame photometry, while the amount of the remaining cations were determined by atomic absorption spectrophotometry, using a Shimadzu, AA-680 model spectrometer. Chloride (Cl^-) ions were determined in the aqueous extract by potentiometry using a Crison pH meter GLP 22 with a selective chloride electrode (Mettler Toledo 302 ISE Reference Electrode) after extraction in cold water. The chemical analysis of the plants was performed at the University of Algarve, in Portugal.

Table 2. Chemical Irrigation, Drainage and Groundwater Content

Field №	Water	GWT[1] [m]	*TDS* [*g* L^{-1}]	FAO classification EC_w [dS m^{-1}]
1	Irrigation		0.55	0.86
	Drainage		1.40	2.19
	Groundwater	1.11	3.96	6.19
2	Irrigation		0.50	0.78
	Drainage		1.95	3.05
	Groundwater	0.59	7.21	11.2

[1]Groundwater Table

Table 3. Soil Properties at Field 1

Properties	Soil layer [cm]		
	0 – 10	10 – 20	20 –30
Sand [%]	35	33	33
Silt [%]	47	48	51
Clay [%]	18	19	16
Texture	Loamy	Loamy	Silt Loamy
Bulk density [g cm^{-3}]	1.35	1.36	1.37
Θ_{WP}* [m^3 m^{-3}]	0.21	0.26	0.26
Θ_{FC}* [m^3 m^{-3}]	0.31	0.29	0.28
Electrical conductivity [dS m^{-1}]	1.17	1.02	0.92
Total dissolved solids [%]	0.15	0.13	0.11
Nitrogen [%]	0.08	0.07	0.06
Humus [%]	0.82	0.75	0.66
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 at field capacity [Θ_{FC}]

The data were analyzed using the standard One-Way ANOVA procedure of the SPSS 14.0 software for Windows (SPSS, 2005). Mean values of three replicated Cl^- concentrations, obtained through the potentiometric method, were compared. 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 4. Soil Properties at Field 2

Properties	Soil layer [cm]		
	0 – 10	10 – 20	20 –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}]	0.31 0.32	0.29 0.30	0.28 0.30
Electrical conductivity [dS m^{-1}]	4.24	2.88	1.80
Total dissolved solids [%]	0.53	0.36	0.23
Nitrogen [%]	0.06	0.05	0.05
Humus [%]	0.71	0.64	0.56
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} in that field (Fig. 1). It can be presumed that other factors significantly influenced the decrease of production of biomass at field 2. These could have been due to higher degree of soil salinity, higher rate of upward water movement from a shallow water table and growth of weeds after the irrigation. The groundwater table in field 2 was only 0.5-0.6 m below the soil surface. Shallow groundwater in this field could 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 faces irrigation water shortages and thus, groundwater is used as a source of wetting the soil. However, a shallow groundwater table in field 2 caused anaerobic conditions and hampered the development of the *Portulaca oleracea* root system.

Interestingly, with no irrigation of field 1, much high dry biomass production of *Portulaca oleracea* averaging 3948 kg ha^{-1} was obtained, when the slightly saline groundwater table remained at a depth of 1-1.2 m below the soil surface. It should be pointed out that before the experiment, field 1 was used as a pasture for cattle and sheep, and the input of manure from these animals might also have positively influenced production.

Mean stem length of *Portulaca oleracea* at harvest averaged 19.7cm in field 1 and 17.8 cm in field 2 (Fig. 1). Moreover, the root depths of the plant ranged from 5-10 cm in both experimental fields. It is interesting to note that the higher degree of soil salinity in field 2 did not greatly affect the plant height.

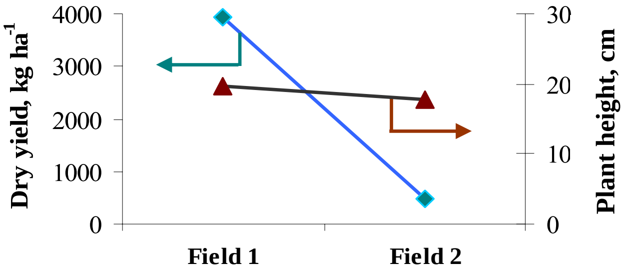

Fig. 1 – *Portulaca Oleracea* Plant Dry Yield and Height at Harvest in the Investigated Fields

The analysis of plant salt extraction by *Portulaca oleracea* golden purslane is shown in Table 5. Chloride ion concentration in dry matter was 69.4 mg g^{-1} in field 1 and 56.7 mg g^{-1} was observed in field 2. In the case of sodium, field 1 *Portulaca oleracea* tissues accumulated, in average, 8.2 mg g^{-1} dry matter whilst 24.9 mg g^{-1} dry matter in field 2. Magnesium and calcium ion concentrations were 37.9 and 11.2 mg g^{-1} dry matter in field 1, and 18.9 and 10.8 mg g^{-1} in field 2, respectively. Potassium ion concentrations showed the lowest values ranging from 2.8-2.5 mg g^{-1} in fields 1 and 2, correspondingly.

Extraction of total soluble salts by *Portulaca oleracea* revealed that despite low soil salinity levels in field 1, the highest salt uptake, 497 kg ha^{-1} was obtained (Table 5). As shown in Table 5, total salt accumulation in field 2 decreased 50 kg ha^{-1} during the examined period, most probably due to low biomass production and to low plant density. Meanwhile, our analysis showed that *Portulaca oleracea* golden purslane in field 1 extracted 16.8% of the total amount of soil salts. It should be stated that the plant can remove the salts only from 5-10 cm of the topsoil layer because of its root length. Due to low plant density and high soil salinity, the extraction of salts from the soil was much lower in field 2 (0.5%).

Table 5 – Capacity of *Portulaca Oleracea* Golden Purslane to Remove Soil Salts

Field №	Root depth [m]	Soil salts [kg ha^{-1}]	Salt extraction [kg ha^{-1}]	Soil salt removal [%]
1	0.10	2957	497	16.8
2	0.10	11210	50	0.5

4 Conclusions

This evergreen *Portulaca oleracea* golden purslane species showed to be relatively tolerant to saline conditions and can be planted with minimum irrigation rates in the salt-affected soils of Khorezm Region, Uzbekistan. Experimental results have confirmed that the *Portulaca oleracea* golden purslane can be cultivated in salt-affected soils in order to remove a high amount of salts from the 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 application of salt removing species in the rotation programmes (e.g. *Portulaca oleracea*) could potentially solve both environmental and economical problems, provided that they can be utilized as vegetables, ornamentals or fodder, and by such a way to rehabilitate saline soils.

Finally, it must be noted that these are preliminary results applicable to local conditions and thus, additional research is needed for better understanding the plant mechanism associated with the salt removal from soil under various geographical and climatic conditions.

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