Remediation of Saline Soils using *Apocynum Lancifolium* and *Chenopodium Album*

AHMAD HAMIDOV
Water Resources Management Department
Research Institute of Market Reforms of Uzbekistan
28 Avenue Halklar Dustligi, 700029 Tashkent
UZBEKISTAN

VALENTINA KHAYDAROVA
Water Resources Department
Uzbek State Uzgipromeliovodhoz Institute
44 Navoiy street, 700011 Tashkent
UZBEKISTAN

MUHAMMADKHON KHAMIDOV
Faculty of Hydro-amelioration
Tashkent Institute of Irrigation and Melioration
39 Kary Niyaziy street, 700000 Tashkent
UZBEKISTAN

ALCINDA NEVES
Faculty of Engineering of Natural Resources (FERN)
University of Algarve
Campus de Gambelas, 8000-139 Faro
PORTUGAL

JOSE BELTRAO
Faculty of Engineering of Natural Resources (FERN)
University of Algarve
Campus de Gambelas, 8000-139 Faro
PORTUGAL

Abstract: Large expansion of irrigated area in the northern part of Uzbekistan has caused a substantial damage on land and water resources in that region. A shallow groundwater table associated with poor irrigation management and inappropriate drainage systems have resulted in secondary soil salinization with significant decrease of cotton and wheat productions. Rehabilitation of these areas by means of installation of appropriate drainage infrastructures requires major financial investments. The potential capacity of *Chenopodium album* and *Apocynum lancifolium*, native naturally grown wild species, have been evaluated under this study to its removal of ions from the salt-affected soils of Khorezm Region, northwest of Uzbekistan. Salt content, soil physical and chemical properties were determined to characterize the soil in the study area. Salt accumulation in the plants, salt removal capacity and potential plant yield were determined. This preliminary study has clearly demonstrated that *Chenopodium album* produced the highest dry biomass 3.25 tons ha^{-1} and accumulated 569.6 kg ha^{-1} dry matter. Hence, it can be used to rehabilitate and to bring salt-affected soils back into the former production because it is low cost and could be adopted by resource poor farmers. Although, *Apocynum lancifolium* was developed in high saline soils, but had removed very low amount of salts and thus, can be considered as a salt-tolerant and not as salt-removing species.

Key-Words: Soil salinity, salt extraction, halophytic wild plants, phytoremediation, environmental pollution, crop yield

1 Introduction

Soil salination is one of the major threat to the environment and is especially problematic where human interventions have disturbed natural ecosystems [7, 14]. Anthropogenic activities have increased soil salinity by changing the natural balance of the water cycle, by allowing excess recharging of saline groundwater and salt accumulation through its concentration [17]. Moreover, groundwater contamination is also an important negative environmental impact, which is intensified due to seawater intrusion in the coastal zones [4].

With a land mass covering 447,400 square kilometer, Uzbekistan is one of the countries in Central Asia most heavily rely on irrigated agriculture. The contribution of agriculture to the national economy is 24.1% of Gross National Product (GNP), 60% of foreign currency income, and 45% of employment [28]. The total land area of Uzbekistan amounts to 44.7 million hectares, of which 4.3 million hectares are potentially suitable for irrigation [13]. Almost 85% of Uzbekistan's territory is covered by desert or semi-desert, including the largest desert in Central Asia, the Kyzylkum Desert. The most serious threat to agricultural production and ecosystem safety in the north of Uzbekistan is high salt accumulation and secondary soil salinization of irrigated soil. This has mostly resulted due to mis-management of water and land resources over the last forty years [26]. In addition, elevated water tables associated with the long-term irrigation and poor drainage systems have led to secondary salinization of crop lands and major waterlogging problems resulting in significant declining cotton and wheat productions [19]. When soils become highly saline, farmers tend to abandon the salt-affected fields resulting in large tracks of saline/waterlogged soils.

Uzbekistan's Khorezm region is a semi-arid area which is badly affected by soil salinity of which the main causes are the geographical proximity to the ecologically degraded Aral Sea, poor irrigation management and inappropriate drainage infrastructures. The region's irrigated area is equal to 275,300 hectares and is fully (100%) affected by salinity [27]. In this region, soil salinity is controlled by leaching of the soil with extra freshwater. Djanibekov (2005) pointed out that on average, 4300 m^3 ha^{-1} of water is applied for leaching on 85% of the irrigated land in Khorezm [8]. However, the intense use of this leaching technique attracted public awareness of environmental pollution and the impact on aquifers. For instance, the World Bank (2002) highlighted that application of huge amounts of water to wash the salts from the soil in Khorezm led to raise the groundwater level near the surface resulting in large amount of salts moving from the lower soil strata to the surface layers [29]. Consequently, this strategy increases the risk of resalinization in the root zone [11]. As a result, soil leaching process has to be repeated every cropping season in order to avoid build-up of high salt concentrations. Furthermore, after leaching, water runs into the drainage systems and when the salt-contaminated drainage water returns to the river, it has severe impact on the ecosystems of the river and wetlands [15]. It can be presumed that drainage water contains not only salt but also pesticide residue, fertilizers, defoliants and other agrochemicals, which enter the rivers, destroys the fine balance of nature and deteriorates water quality in these water bodies.

There are several management practices to remediate soil salts and to maintain the sustainability of agricultural lands [5, 21, 23]. However, some of them are not possible in some situations or not economically and environmentally practical in other situations. The best way to avoid salinization and to maximize agricultural crop productivity in the salt-affected soils is to combat the salinization processes through environmentally safe and clean techniques. Phytoremediation – salt (ion) removing species have become one of the best techniques to remediate saline soils and decontaminate the environment [2]. The ideal plant to remediate soil salts would be a high biomass producing crop that can not only tolerate to high salinity but also accumulate high salts [10]. The best way to select salt removing species is to assess native naturally grown halophytic species since the salt tolerance of a plant relates to its resistance and ability to grow under conditions of high winds, salt spray and infertile sandy soils.

The present study was undertaken to evaluate the potential capacity of *Chenopodium album* and *Apocynum lancifolium*, naturally grown wild species, to remove ions from the salt-affected soils of Khorezm Region and to rehabilitate saline soils. Moreover, the crop productions of above-mentioned species were also estimated as to its importance to create highly productive fodder systems.

2 Materials and methods

A field experiment was established in the Gurlan district, Khorezm Region, northwest part of Uzbekistan, in the lower reaches of Amudarya River (100 meters above sea level), which is the major water source for all water sectors in Khorezm. The region covers an area of about 6,100 km^2 and is spread between 40.49-41.97 N and 60.21-62.18 E of the Greenwich meridian, or about 245 km south of the remainder of the Aral Sea. The region is characterized as having an extremely continental climate with long hot dry summers, infrequent rains in spring-autumn and very cold temperatures during winter. Annual precipitation of the region is determined as 100-120 mm, which falls mostly outside of growing season in autumn-winter period. The local potential Ivanov´s evapotranspiration is about 1,600 mm $year^{-1}$ greatly exceeds rainfall [12].

Two wild halophytic plants grown naturally – *Apocynum lancifolium* and *Chenopodium album* - were evaluated on their efficiency to remove ions from the salt-affected soils. The plants were grown in the field that had been abandoned due to the presence of high salinity.

Briefly, *Apocynum lancifolium* belongs to the Apocynaceae family and is a perennial shrub species that grows to a height of 2 m. The plant has a fusiform root system with numerous suckers that are often more than 0.5 m in length. This plant usually can be cultivated in the salt-barren zones, desert margins, alluvial flats, riversides. The species has fragrant flowers and is grown as a honey plant [6].

Chenopodium album (Fat Hen) belongs to the Chenopodiacea family and is a fast-growing, upright, weedy annual species of goosefoot, very common in temperate regions, growing almost everywhere in soils rich in nitrogen, especially on wasteland. Furthermore, Fat Hen can be eaten as a vegetable, either steamed in entirely, or the leaves cooked like spinach as a leaf vegetable.

An experiment was carried out during the summer, 2006. The soil samples were taken from 5 layers (0-10, 10-20, 20-30, 30-40, 40-50) using auger instrument to determine the general physical characteristics and element status. To determine the salt removing capacity, different soil depth samples (0-15, 15-30, 30-45) were collected from every plant species. The samples were analyzed in the laboratory of Uzbek Research Institute of Cotton-Growing, Uzbekistan.

A complete plant was taken, plant fresh weight and height was measured, divided into shoots and roots, washed up with tap water and distilled water, oven dried at 70^{o}C, re-weighed and ground. The plant chemical properties were determined at the Campus of Gambelas of the University of Algarve, Portugal.

Specifically, the soil samples were air-dried and passed through a 2.0 mm sieve pores. Soil texture was determined according to the United States Department of Agriculture (USDA) soil texture triangle method. The soil salinity was determined according to the Machigin's (1963) method using an aqueous extract of the soil (ratio 1:5, i.e. 30 gram of air-dry soil and 150 mL of distilled water) [20]. This USSR classification of soil salinity, used in Central Asia, based on laboratory measurements of the Total Dissolved Solids (%), was converted according to FAO classification, in electrical conductivity of saturated soil extract (ECe).

The Kjeldahl digestion method was used for total nitrogen and the Machigin's method was applied to determine available phosphorous [25]. The total humus content was determined according to Turin's method using potassium chromate solutions [3].

Plant materials were extracted to measure chloride (Cl^{-}), sodium (Na^{+}), potassium (K^{+}), calcium (Ca^{2+}) and magnesium (Mg^{2+}) concentrations. Chloride was extracted using cold water at room temperature (23-25^{o}C), according to the procedure proposed by Drew and Saker (1984), whereas the cations were extracted by a dry-ash method at 550^{o}C incinerator using a Thermolyne, Type 1500 Furnace [9, 30].

Sodium and potassium concentrations were quantified by flame photometry, while calcium and magnesium levels were measured by atomic absorption spectrophotometry using a Shimadzu, AA-680 model spectrometer. Chloride levels were determined in the aqueous extract by potentiometer using a Crison, pH meter GLP 22 after extraction in cold water.

Statistical analyses were made with an SPSS 14.0 for Windows (SPSS, 2005) computer program. One-way analyses of variance (ANOVA), least significant difference and Duncan's multiple-range tests ($P<0.05$) for comparison between mean values of three replicated chloride ions were conducted.

3 Results and discussion

Soil physical and chemical properties

General soil physical characteristics of the experimental site showed that the soils are partially stratified. According to the USDA classification [16], the topsoil layer (0-10 cm) was light loamy whereas the subsoil layers (10-50 cm) contained more sands, thus was classified as sandy loam. The bulk density averaged 1.60 g cm^{-3} within 0-50 cm soil depths.

It is known that the growth and development of crops depend on the availability of nitrogen, phosphorous and humus contents in the soil. The total nitrogen (N) in the soil, available phosphorous (P_2O_5) and humus content in the investigated field is shown in Fig. 1. As can be seen in Fig. 1, the soil had higher contents of humus than P_2O_5 and total N. According to Musaev's (2001) classification, total N and P_2O_5 were very low in the experimental fields [22]. Meanwhile, Krasnouhova *et al.* (1998) classified the field as very poor in humus content [18].

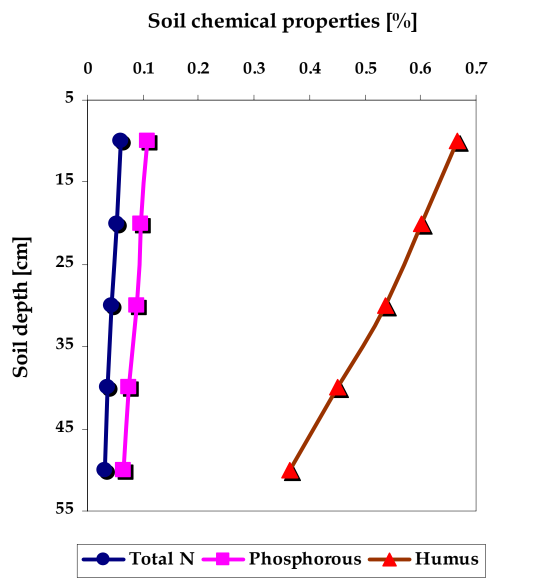

Fig. 1. Content of Total Nitrogen, Available Phosphorous and Humus in 0-50 cm soil depth

According to Abrol *et al.*, (1988) classification, the electrical conductivity of soil ECe (expressed as dS m^{-1}) examined during the experimental period mostly corresponded to the degree of salinity ranging between moderate and high [1]. Moreover, values above 10 dS m^{-1} have been observed (Fig. 2 & 3). Such deviations towards a strong degree in soil salinity were more prominent in the *Apocynum lancifolium* field.

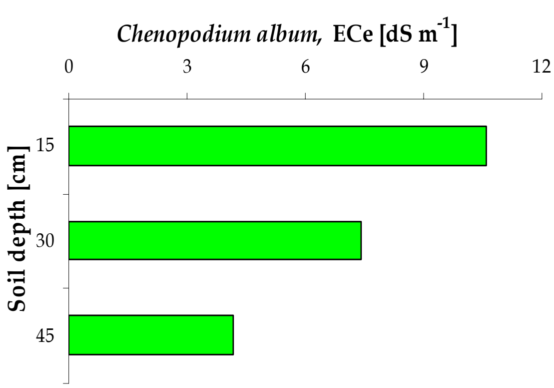

Fig. 2 – Electrical conductivity of soil saturated extract [dS m^{-1}]

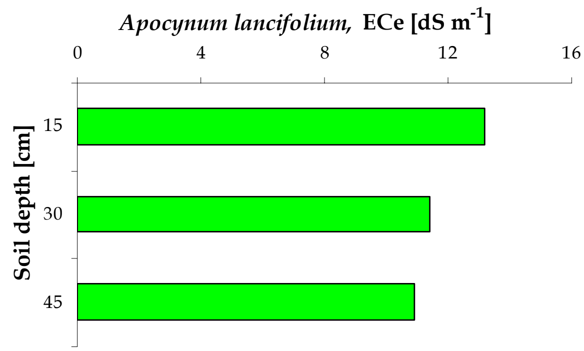

Fig. 3 – Electrical conductivity of soil saturated extract [dS m^{-1}]

It should be stated that due to accessibility and adequate quality of the groundwater resources in the field, the plant species exposed to soil ECe levels over 10 dS m^{-1} did not show any visual symptoms of salt stress.

Crop yield and vegetative growth

Results related to crop yield have shown that *Chenopodium album* had the highest biomass production compared to *Apocynum lancifolium* (Fig. 4). The dry yield of *Chenopodium album* was 3.25, while *Apocynum lancifolium* had 1.84 t ha^{-1} at harvest.

Furthermore, the analysis of plant height data revealed that *Chenopodium album* stem height reached a mean value of 0.82 m at harvest while a mean root length was 0.25 m. The stem length of *Apocynum lancifolium* was almost the same as that *Chenopodium album*, i.e. 0.85m, but the root length was deeper ranged 0.55 m.

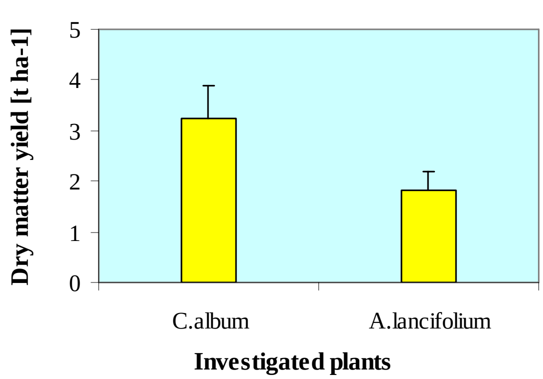

Fig. 4 - Dry matter yield for investigated fields in Khorezm Region

Salt extraction

Capacity of the wild plants to remove chloride, sodium, magnesium, calcium and potassium ions is shown in Fig. 5. It is clear from the figure that *Chenopodium album* was found to be the most effective in removing chloride ions from the soil of experimental fields. According to the shown results, *Chenopodium album* removed up to 104.5 (±3.99) mg g^{-1}, while *Apocynum lancifolium* up to 48.86 (±2.47) mg g^{-1} dry matters of chloride ions. Moreover, sodium extraction was also higher in *Chenopodium album* ranged 33.6, whereas *Apocynum lancifolium* removed only 12.1 mg g^{-1} dry matter. Potassium and magnesium concentrations were higher in the *Chenopodium album* tissues, while calcium concentration was higher in *Apocynum lancifolium* plant tissues.

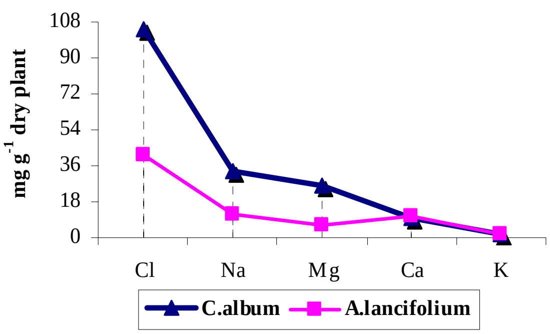

Fig. 5 – Salt (Cl^-, Mg^{2+}, Ca^{2+}, Na^+, K^+) contents in the tissues of wild plants

The data have also revealed that *Chenopodium album* was the most efficient wild plant in removing total ions, which eventually accumulated 569.6 kg ha^{-1} and removed 1.47 % of salts from the soil. The root depth is about 0.25-0.30 m, it can only remove the salts within that profile (Table 1). On the other hand, *Apocynum lancifolium* was the least efficient wild species in removing soil salts. The tissues of *Apocynum lancifolium* accumulated 130.3 kg ha^{-1} and eventually it removed 0.12 % of total ions within 0.55 cm soil depth.

It is interesting to note that *Apocynum lancifolium* was developed in high saline soils but had removed very low amount of salt, and thus can be considered as a salt-tolerant but not a salt removal species. In contrary to that, *Chenopodium album* was developed in relatively low saline soils but had extracted the highest amount of salts from the soil and therefore, can be accounted as potential salt removal species.

Table 1. Removal of soil salts using wild species in the study areas

Plants	Root depth [m]	Salt extraction [kg ha^{-1}]	Soil salt removal [%]
C.album	0.25	569.6	1.47
A.lancifolium	0.55	130.3	0.12

4 Conclusion

From the present work, it can be concluded that:

- wild native plant species grown in the salt-affected soils of Khorezm region has very low nutritional balances in the soil;
- native plants showed the advantage of being highly adapted to the local climatic and edaphic conditions;
- *Chenopodium album* and *Apocynum lancifolium* have different capacities in removing chloride, sodium, magnesium, calcium and potassium ions from soil;
- the most efficient wild species in removing total soluble salts was *Chenopodium album*;
- *Apocynum lancifolium* could be used as salt-tolerant species not a salt-removal;
- *Chenopodium album* can be used in salt reduction in the salt-affected soils and can also be integrated into crop rotation programme

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