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Salt balance of promising halophytes Climacoptera lanata L. and Tamarix hispida L. in the Kyzylkum Desert

Balance de sal de halófitos prometedores Climacoptera lanata L. y Tamarix hispida L. en el desierto de Kyzylkum

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ABSTRACT

Introduction: The relevance of the investigated problem lies in the problem of improving the condition of degraded and saline soils, on which plants of representatives of Chenopodeaceae and Tamaricaceae families grow, adapted to life in such conditions. In this regard, the aim of this article is to study the ecology, salinity accumulation and salt excretion of Climacoptera lanata and Tamarix hispida, determining the adaptation abilities of Climacoptera lanata and Tamarix hispida in Kyzylkum Desert conditions. **Material and Methods:** The main methods that were used to achieve the goal: generally accepted methods of soil determination – spectrophotometric, potentiometric, manometric. **Results and Discussion:** The main results that were achieved in this study: salt balance of halophytes was revealed on the example of C. lanata and T. hispida species, groups on plant resistance, on the quality of salt accumulator and salt extractor, on dry residue (2-3.4; Cl^- 0.1-0.3, SO_4^{2-} 1.5-1.9%) were identified, saline soils were determined. Leaf respiration intensity ranged from 111-323 mm^3 O_2. Bioecological features of C. lanata and T. hispida, as well as chemical composition of soil and water in Central Kyzylkum and mineral composition of biomass of the studied plants, were revealed. **Conclusion:** The main ecological problems in the conditions of Uzbekistan were determined. The practical significance of the study is that methods of adaptation of Climacoptera and Tamarix species to saline soils in areas with low water level (2-3.5 m) can be used for similar biotypes in order to reduce damage from soil salinity.

Keywords: Salinity; Salt tolerance; Euhalophytes; Xerophytes; Phreatophytes; Soil composition.

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INTRODUCTION

Soil salinity poses major challenges for arid regions, negatively impacting agricultural productivity and land sustainability. Central Asia is especially vulnerable, with extensive areas affected by high salinity due to features like closed drainage basins. Remediation requires ecologically sound solutions leveraging native plants adapted for saline settings through evolutionary mechanisms.

This research delves into the ecological and physiological adaptations of plant species in Uzbekistan's steppe and semidesert zones, focusing on their resilience to arid conditions, atmospheric and soil drought, and salinity(1). Salt-tolerant native flora classified as halophytes possess biochemical, physiological and anatomical attributes enabling their growth in harsh saline environments. Two prime examples from Central Asia's botanical diversity are the annual succulent *Climacoptera lanata* (family *Chenopodiaceae*) and the perennial shrub *Tamarix hispida* (family *Tamaricaceae*). A key adaptation mechanism, haloaccumulation – the selective assimilation of water-soluble mineral salts – is explored as a critical functional adaptation enabling these plants to thrive in the arid and saline conditions prevalent in these zones(2). This paper explores their distinctive adaptations conferring salinity resilience.

Identifying patterns of salt accumulation in plants is a very important, fundamental task on a global scale. Solving this problem opens the way to adaptation to salinity conditions and a deeper understanding of the phenomena of resistance, as well as the ability to control one's vital functions. Due to the drying up of the Aral Sea, the processes of salinization of land and water in a fairly vast territory of the Aral Sea region are becoming dangerous. Increasing water scarcity and deteriorating water quality cause the degradation of flora and fauna, as well as a decrease in the efficiency of irrigated agriculture (3).

Issues of plant resistance to salinity have been studied mainly when grown under conditions of gradient salinity. However, when water-soluble salts of ecological niches enter plant tissues, they have a predominantly osmotic effect and partially accumulate – they begin to have a specific and toxic effect (4). *Climacoptera lanata (C. lanata)* thrives on highly saline soils across arid steppe/semideserts via specialized water storage tissues and salt intracellular compartmentalization. *Tamarix hispida (T. hispida)* utilizes salt glands on leaves to exude excess salts(5,6). Despite the fact that the phenomenon of salt accumulation in plants, depending on their adaptation to saline conditions, is of great practical and theoretical importance, previously it was given little importance, and they were poorly studied. This study is based on the study of the specific properties of salt separation and salt accumulation of two halophytic plants – Climacoptera lanata and Tamarix hispida, which grow in the same biotope. Investigating these adaptive distinctions can inform agricultural practices plus salinity remediation programs through halophyte cultivation(7).

The research objectives are assessing the salt accumulation/excretion capacities of Climacoptera lanata and Tamarix hispida using Kyzylkum Desert samples, analysing the mineral composition of their biomass and soils, quantifying leaf respiration rates and ultimately appraising their soil desalination potential plus competence as promising bio-ameliorants for marginal lands. The objectives of the study are to determine the adaptive characteristics of Climacoptera lanata and Tamarix hispida in the Kyzylkum Desert. The objects of study are C. lanata and T. hispida salt-tolerant plants growing in the central part of the Kyzylkum Desert. Findings will expand halophyte agronomic knowledge and environmental management strategies.

MATERIAL AND METHODS

This study presents a comprehensive analysis of soil and water samples, along with an examination of plant biomass, to understand the chemical composition and interactions within a natural ecosystem. Utilizing standard procedures, soil samples were analysed for organic and mineral substances, revealing the presence of various compounds such as calcium, magnesium, sodium, bicarbonate, chloride, and potassium. The study extends to the assessment of plant biomass at different stages of development, focusing on the aerial parts which were dried, crushed, and subjected to chemical analysis. Advanced techniques such as ion chromatography and atomic absorption spectrophotometry were employed to detect and quantify elements and ions like chloride, nitrate, and sulphate in both soil and plant samples. Furthermore, the study delves into the dynamic processes of salt accumulation and separation in plants, employing methods like potentiometry and spectrophotometry to measure ion concentrations and the effects of various compounds on these processes. This multifaceted approach provides a detailed insight into the chemical dynamics of the ecosystem, contributing valuable data for ecological and environmental research.

In this research, standard methodologies were employed to collect and analyse water and soil samples, as described in Grigore and Vicente [8]. The soil sample analysis indicated the presence of both organic (humic substances) and inorganic mineral components. Specifically, the aqueous extract of the soil displayed a composition inclusive of ions such as Ca^{2+}, Mg^{2+}, Na^{+}, H2CO3, Cl^{-}, and K^{+}. The investigation extended to the analysis of plant biomass, with samples procured at the initial, median, and final stages of plant development. The biomass analysis involved desiccating the aerial segments of the plants, followed by comprehensive pulverization. Subsequently, an aqueous extract of this biomass was prepared by immersing 0.1 g of the dried material in 100 ml of ionized distilled water. This mixture was homogenized using a magnetic stirrer for a duration of 60 minutes and then filtered through a 0.45 µm membrane filter. The resulting solution was then subjected to ion chromatography using a DIONEX ICS-ion 1000 system, a technique that facilitates the separation of ions and polar molecules based on their interaction with the ion exchange resin.

Moreover, the plant material underwent a multi-elemental analysis employing a Varian AA 240 FS atomic absorption spectrophotometer. This technique was instrumental in quantifying various elements within the plant tissues. For the preparation of samples for this analysis, the plant biomass was incinerated at 600°C for a period of one hour to produce ash. Additionally, the electrical conductivity of the aqueous plant solutions was measured in compliance with the GOST 26423-85 standard, offering insights into the ionic content and overall solute concentration within the plant extracts.

Sodium, potassium, and chlorine ions in the biomass were measured potentiometrically using ion-selective electrodes. The accumulation of salts and their separation from plants was studied during the entire growing season using cut leaves. They were examined using a trinocular clinical microscope with a cross-section of the n604e brand, magnifying 40 times, and microphotographs of the Sapop 1000D brand were obtained in a glass chamber with a microlens. The samples to be studied were taken from plants growing in natural conditions. Determination of the content of ammonia and ammonium ions in water using Nessler's reagent by spectrophotometry. The determination method is approved in accordance with RH 52.24.383-95. This method is based on the property of ammonia to form a yellow compound with an alkaline solution of mercury (I) iodide. At low concentrations of ammonia and ammonium ions, a colloidal solution is formed, convenient for colorimethylation. In the case of large quantities (>3 mg/l) a dark precipitate will form, in which case the determination must be made after diluting the sample with ammonia-free water. The detection limit is 0.05 mg/l NH^{+4}. The range of measured ammonium ions in the sample is 0.005-0.15 mg.

During the analysis, amines, chloramines, acetone, aldehydes, alcohols, and other organic compounds that act on the Nessler reagent are inhibited. In this case, after administration, the ammonia concentration is determined. The inhibitory effect of water hardness is eliminated by adding a solution of Rochelle salt. If there is a large amount of iron, sulphides and turbidity, their effect is lost due to the discolouration of the water sample by the zinc salt. To do this, add 1 ml of zinc sulfate to 100 ml of sample (100 g of $ZnSO_4 \cdot 7H_2O$ is dissolved in water without ammonia and the volume is adjusted to 1 l) and the mixture is thoroughly mixed. The mixture is then adjusted to 10.5 by adding a 25% solution of potassium or sodium hydroxide, which is checked with a glass electrode or indicator paper. After the formation of residual particles, they are separated by centrifugation or filtration through a glass filter. In the Warburg apparatus, respiration was determined using the manometric method.

In conclusion, this comprehensive study utilizing a multifaceted approach has significantly advanced our understanding of the chemical dynamics within a natural ecosystem. Through meticulous analysis of soil and water samples, along with detailed examination of plant biomass, this research has illuminated the intricate chemical interactions and processes occurring in these environmental matrices. The application of sophisticated analytical techniques, such as ion chromatography, atomic absorption spectrophotometry, potentiometry, and spectrophotometry, has allowed for the precise quantification and characterization of various organic and inorganic substances, ions, and elements present in the soil, water, and plant samples.

RESULTS

Description of *C. lanata* and *T. hispida* and their features

Salt balance of halophytes using the example of the species C. lanata and T. hispida. On lands with highly saline and partially drained groundwater surfaces, annual halophyte communities form [9]. Halophytes, depending on their resistance to salinity conditions, are divided into three groups: salt accumulators, salt excretors and low-absorbing ones.

1. The first group is succulents that accumulate salt in their tissues.
2. The second group is salt-producing plants, in which salt is released without accumulating in their cell sap.
3. The third group is low-absorbing: the cell membrane of plant roots absorbs less salt.

The Climacoptera community is closely associated with saline soils and alkaline soils. C. intellicana, C. damn, C. crassa, C. transoxana, C. longistylosa, C. karshinsky, C. turkomanica participate in the formation of the Climacoptera community – halophytic succulents that accumulate salt by more than 25%. Their high occurrence in the vegetation indicates the presence of a small amount of salt in a meter layer of soil (dry residue 2-3.4; Cl^- 0.1-0.3, SO_4^{2-} 1.5-1.9%).

Climacoptera lanata –annual, plant 10-60 cm high, bluish, branched from the base, covered with long, protruding hairs, woolly pubescence; leaves alternate, semi-folded; grows on saline soils, the branched root is spreading to a not very deep layer of soil. The growing season begins in March. In the early period of life, it grows slowly, in summer – in June, it grows very intensively. It blooms during the hottest and driest period at the end of July-August (Figure 1). The seeds ripen in late October – early November. C. lanata is used as animal feed, which is needed in autumn and winter. 100 kg of Climacoptera dry food is 25-37 food units. Biological characteristics of C. lanata: the seed is round, brown, 2 mm in diameter. They are located inside a transparent inflorescence, which is adjacent to each other with wings. During the virginal period, seeds begin to germinate in mid-March. The seed pods live for 15 days, the shape is lanceolate, lamellar.

Figure 1. Flowering of Climacoptera lanata in the Kyzylkum Desert

In C. lanata, during the juvenile period, the first leaves appear and the stem is rosette-shaped and pubescent. in mid-April, 12-18 leaves 1.5 cm long are formed. The leaves are fleshy and woolly. There are 2-4 leafy lateral branches in the leaf axils. It grows very quickly in the early stages of ontogenesis, the height of plants increases by March 10 (reaches 40-60 cm). The state is adult virginal. It grows actively and is characterized by the formation of stems and leaves. Since mid-May, a vegetative state of C. lanata has been observed. The height is 15-20 cm. Flowering begins in mid-June and lasts until July. The plant is 30-35 cm high and comes into harvest until August. Ripens in September-October. The length of the stem during this period reaches 18-25 cm. The water regime of C. lanata is its distinctive feature. The water content in the assimilating organs is 86.5%. It is a low transpiration plant; transpiration rate 65-186 mg/g. h. C. lanata is well adapted to drought, indicating that transpiration is low in summer. C. lanata is a member of the succulent-type hyperxerophyte group [(10)]. The phase of intensive plant respiration takes place at a temperature of 20-25℃ (in May). The intensity of leaf respiration is in the range of 111-323 mm^3 O_2 relative to 1 g of mixed mass. Thus, low respiration rate and saturation of tissues with water in a wet state are a characteristic feature of succulent halophytes.

T. hispida – large shrub, halophyte, salt-producing. A phreatophyte plant is characterized by the fact that the root system of the plant reaches the ground horizons of the soil. Communities of this plant are indicators of highly saline soils and saline soils. T. hispida can reach 2-3 m in height. According to the classification, it is a crinohalophyte [(11)]. The leaves are small, green coins. Salt is released from the top of the leaf blade. The flowering period lasts from May to August. The flowers are small, the flower calyx consists of pink inflorescences and 4-5 petals. The flowers are collected in long leaves. Fruits in the form of opening slime. The seeds are finely pubescent (Figure 2).

Figure 2. Tamarix hispida flowering in the Kyzylkum Desert

In conclusion, the study of halophytes, specifically *C. lanata* and *T. hispida*, in saline and partially drained groundwater environments has provided vital insights into their unique salt management strategies. *C. lanata*, a succulent halophyte, thrives in saline soils by accumulating salt in its tissues, a trait exemplified by its physiological adaptations such as low transpiration rates, high water content in assimilating organs, and a robust growth pattern during the hottest and driest periods. This species, with its ability to grow efficiently in arid conditions and produce viable biomass, holds potential for use in animal feed. On the other hand, *T. hispida*, a salt-producing, large shrub halophyte, demonstrates a distinct salt excretion mechanism, indicative of its ability to thrive in highly saline environments. The classification of *T. hispida* as a crinohalophyte underscores its specialized adaptation for survival in harsh saline conditions. The contrasting yet effective salt management strategies of these two species highlight the diverse adaptations of halophytes to saline environments, offering valuable insights for ecological and environmental studies in arid and semi-arid regions with saline soils.

The ratio of the content of mineral salts in soil and plants

The ratio of the content of mineral salts in soil and plants. It is known from literature sources that T. hispida is well adapted to groundwater. The main mechanism of their adaptation to such conditions is salt secretion. According to this feature, it belongs to the halophytes. The main mechanism of adaptation of C. lanata to saline and arid climates is its juiciness and the accumulation of salts in the body. It was necessary to determine the growing conditions of the studied species in the soil and determine the ratio of the amount of salts in the soil with biomass [12]. The quantitative and qualitative composition of the soil where plant roots are located was studied. One of the studied species is a perennial plant, and the other is an annual plant, and with long-term growth in the habitat, the amount of salts in the area where the root systems are located is 0.06-0.08%. The amount of salts in the root soil horizon at a depth of 80-100 cm reaches 0.048%, close to the soil surface 0.082%. C. lanata grows at higher salt levels than T. hispida (Table 1).

Table 1. Chemical composition of soil in Central Kyzylkum

	Soil horizon, cm	EC, MSM/cm	HCO_3	Cl^-	SO_4^{2-}	Ca^{2+}	Mg^{2+}	Na^+	TDS	K_2O, mg/kg	P_2O_5, mg/kg	$N\text{-}NO_3^-$, mg/kg
			air – dry mass (%)									
Plot	0-20	0.21	0.029	0.011	0.026	0.012	0.002	0.012	0.082	216.7	6.5	3.5
	20-40	0.2	0.027	0.011	0.024	0.011	0.002	0.011	0.08	156.5	4.4	3.5
	40-60	0.11	0.034	0.004	0.01	0.008	0.002	0.007	0.052	144.5	4.1	4.9
	60-80	0.1	0.033	0.004	0.01	0.008	0.002	0.007	0.052	144.5	4.1	2.8
	80-100	0.09	0.029	0.004	0.01	0.008	0.002	0.006	0.048	132.4	3.5	4.4
Saline soil	0-20	9.8	0.029	0.626	3.004	0.252	0.032	1.506	5.728	366	12.8	17.4
	20-40	5.15	0.021	0.356	0.96	0.076	0.023	0.569	2.266	308.2	8.8	12.3
	40-60	4.47	0.015	0.428	0.83	0.228	0.041	0.342	2.08	192.6	6.5	12
	60-80	4.04	0.017	0.418	0.74	0.2	0.041	0.325	1.856	156.5	5	11
	80-100	3.35	0.018	0.349	0.53	0.118	0.031	0.293	1.404	144.5	5	9.8

Notes: EC – Electrical conductivity; TDS – Total dissolved solids (dry remainder).

When measuring the electrical conductivity of the soil in a layer (0-100 cm), where the roots are not deep, it is possible to see that in areas where Tamarix grows, at this depth the soil is slightly saline (up to 0.21 MSM/cm). High salinity was observed in the area where Climacoptera grow (3.35-9.8 MSM/cm). The results of determining the chemical composition of the ground surface and artesian waters in the areas where Climacoptera and Tamarix grow showed a large amount of SO_4^{2-}, Cl^-, I^-, Na^+ ions (Table 2). Irrigation (artesian and drainage) waters in the tested area contain weak hydrocarbonates and a large amount of Ca^{2+} and Mg^{2+} ions, as evidenced by the high-water hardness (20 mEq/l).

Table 2. Chemical composition of water in Central Kyzylkum

	pH	**mg/l**									**Hardness, mg-Eq/l**
		NO_2^-	**NO_3^-**	**HCO_3^-**	**Cl^-**	**SO_4^{2-}**	**Ca^{2+}**	**Mg^{2+}**	**Na^+**	**K^+**	
Artesian well 1	7.86	0.154	4.772	138.307	555.433	960.122	221.767	96.067	457.692	7.867	18.967
Artesian well 2	7.84	0.288	3.796	147.457	597.173	915.345	189.733	124.033	433.8	7.367	19.667
Drainage. water	7.58	0	2.48	129.665	534.565	978.123	206.4	117.95	411.905	6.850	20

Determination of the chemical composition of plant biomass showed that approximately 40% of the dry mass belongs to mineral components (Table 3). In Climacoptera, it should be noted that the rate is 42.8% compared to 37.1%, which is slightly higher than Tamarix.

Table 3. Mineral composition of Climacoptera lanata and Tamarix hispida biomass

	Humidity	Ash	Cl^-	NO_3^-	SO_4^{2-}	Na^+	K^+	Mg^{2+}	Ca^{2+}	Al^{3+}	Fe^{3+}
		dry weight (%)									
Climacoptera lanata	72%	42.8	16.8	0.06	8	111.45	1.23	0.41	0.18	0.5	0.12
Tamarix hispida	34.4%	37.1	18.8	0.11	7.09	5.78	0.71	0.95	0.8	0.3	0.99

In the biomass of T. hispida, there is Cl^- 7.09% and Na^+ 5.78% of dry weight. Cl^- (18.8% sq. m.), SO_4^{2-} and the excess amount of ions was determined. When studying the mineral composition of the soil surface in the biomass of C. lanata, a high level of Na^+ ions was determined – 11.45%, Cl^- and SO_4^{2-} ions were 16.8% and 8% in accordance with the above. The ratio of Na^+ to K^+ was 8 and 1 in Tamarix, 9 and 3 in Climacoptera. As it is known, the property of selective absorption of Na^+ ions directly depends on the salt tolerance of plants. Experimental data confirm that C. lanata can develop under high salinity conditions. It is for this reason that Climacoptera species are considered one of the plants adapted to saline soils along with other plant species and form plant communities. In turn, Tamarix belongs to the group of salt-tolerant plants that dominate and grow well in areas with low water levels of 2-3.5 m.

The dependence of plants on a single holistic mechanism of adaptability, which operates at the level of cells, tissues, and the whole organism, has been confirmed in many studies [13]. It is important to note that the methods of adaptation of Climacoptera to salinity differ somewhat from Tamarix. Since the plant retains a lot of water in its tissues and selectively absorbs sodium and chlorine ions in its vacuoles, Climacoptera are salt-accumulating hyperhalophytic succulents. Tamarix tends to be primarily a salt-producing halophyte (crinohalophyte); has the property of removing excess salt through special cellular structures consisting of secretory (separating) and basal (collecting) cells [14].

Since one of the pressing environmental problems in the conditions of Uzbekistan is the issue of soil salinization and its optimization, in their scientific works the authors attached great importance to the effect of reducing the salt content in the soil to study the specific features of the research objects. As a result of this research work, the following data was obtained: the amount of salt in the soil in the areas where the research objects grew was as follows:

1. Where Tamarix communities grow, the amount of salt in a horizon 1-meter-deep is 0.048%, in the surface part of the soil – 0.082% (0-20 cm), that is, the amount of salts on the soil surface is 2 times greater.
2. 1.404% in the 1-meter horizon in areas where Climacoptera communities are common, 5.728% in areas close to the soil surface. At the same time, the concentration of salts in the soil surface is 4 times higher.

From the presented data, it is possible to conclude that the presence of salts on the surface of the soil is formed on the basis of the absorption of salts by plants through the roots. The studied species differ in the characteristics of soil desalination; in the Climacoptera lanata community, soil salinity is significantly lower under conditions of a changed climate. Based on the presented data, the following can be noted: salt-tolerant halophyte plants, common in natural biocoenoses in the conditions of Central Kyzylkum, are characterized by the ability to desalinize the soil and, maybe recommended for soil desalination. These species can also be used for biotechnological processes. Halophytes, depending on their resistance to salinity conditions, are divided into three groups: salt-accumulating, salt-releasing and those that do not absorb salt. C. lanata accumulates salts, while T. hispida secretes salts through its glands. Experimental data confirm that C. lanata can develop normally under high salinity conditions.

DISCUSSION

Anthropogenic climate change is negatively impacting the productivity of saline, arid and degraded lands in Central Asia, including in Uzbekistan. In this regard, the use of innovative approaches, which consist of a set of scientific research on the use and management of limited natural resources, is a necessary condition for ensuring stable, sustainable development of food security. The flora of any landscape zone is the most sensitive component, which adapts to environmental conditions and human activity. Therefore, in terms of vegetation cover, scientists have been studying for many years such characteristics of the Kyzylkum Desert as uneven distribution of precipitation, sharp changes in seasonal and daily fluctuations in air temperature, and fluctuations in the level of the desert itself. After the Arai Sea dried out, the plant cover located on the bottom underwent secondary salinization and groups of halophytes formed [15]. Since that time, the attention of scientists around the world has been drawn to assessing the salt balance of promising halophytes for the sustainable development of agriculture and optimization of all anthropogenic zones on the planet. The peculiarity of halophytes is that they undergo a full life cycle in a saline environment.

According to A.F.M. Ghanem et al. [16], the use of halophytes in the fight against extreme climate conditions is the most promising method to mitigate the negative consequences of the impact on the formation of landscapes. In addition, the use of this method is cheaper than the construction of special structures for protection from the sun and wind. The method of planting arid areas with halophytes is used by countries in the Middle East, Central Asia, and Africa, that is, with limited supplies of drinking water. Thus, in studies by Y. Wang et al. [17], closed, geochemically drainless territories in which the accumulation of easily soluble salts in soils and groundwater occur account for about 30% of the entire surface of the globe. The part of the world with the most saline land area is Australia – 37%, Asia – 53%, South America – 13%, Africa – 8%, 7% is occupied by Europe, North and Central America. Salinization occurs through continental rocks, as well as through mineral waters rising to the surface by capillary action. The gene pool of halophytes in the world numbers about 2000-2500 species, in Central Asia – 900. According to H. Yang et al. [10], this fact proves that halophytes have large global genetic resources that can be used as a source of introduction and the initial basis for selection. Thus, the ecotype of halophytes consists of forage, food, oilseeds, medicinal plants and bioameliorants – a qualitatively new class of halophyte genotype. Currently, there are many classifications and descriptions of halophytes, however, the most informative is the classification by D. Aronson in 1989, which contains comprehensive information about promising salt-tolerant plant species in the world [18].

The bioecological, physiological and biochemical properties and economically useful characteristics of halophytes are heterogeneous. So, M.N. Grigore and O. Vicente [8] argue that these plants are halotolerant, that is, the ability to grow and renew normally in a given species depends on the range of mineralization of the soil solution. According to the degree of response to excessive salinity of the soil environment, hyperhalophytes, euhalophytes, hemihalophytes, and haloglycophytes are distinguished. This study proved that Climacoptera is a hyperhalophyte, and Tamarix hispida is a euhalophyte. This fact confirms that these species can be used in a halophytic crop production program. Given the potential of halophyte resources, the US World Resources Institute emphasizes the development of a thorough system for selecting and evaluating halophytes that will participate in productive longevity [19-21]. Thus, researchers from different countries emphasize the fact that the experience of developing halophytes for economic purposes in arid regions of Central Asia is of great interest.

150 species of halophytes common in Australia, Mexico, Israel, and the USA are considered as food plants. The feeding characteristics of halophytes are their high nutritional value: complete protein and high content of essential amino acids, which creates conditions for a stable balance of feed across the seasons [22]. 13 species of the genus Atriplex L are considered to be the most resistant to salinity indicators. Research conducted by Z. Liu et al. [23] prove that the use of plants of this genus increases the biological productivity of arid pastures. Thus, over the past 25 years, Arizona State University (USA) has conducted a number of studies in which halophytes were irrigated with seawater. Countries such as Mexico, the United Arab Emirates, Hurghada, and Egypt took part in the experiment. As a result, it was revealed that when irrigated with mineralized water, the productivity of halophytes was average (17-34 t/ha of dry matter. Therefore, the main distinctive feature of Atriplex L. is considered not only to survive in extreme conditions, but also to form a large yield of biomass of high nutritional value advantages. The conclusion of this study is that the cultivation of a number of halophytes as a source of fodder plants irrigated with seawater can provide a yield equal to that of alfalfa irrigated with fresh water. Having evolved, halophytic plants acquired morphological, physiological and anatomical characteristics that allow not only survival in saline soils, but also benefit from them. In addition to the fact that halophytic plants extract salt from saline soils, they are also able to delay further salinization by restoring certain ions [24; 25]. Thus, in the studies of J. Li et al. [26] irrigation with salt water from underground sources gives positive results in the cultivation of traditional crops (alfalfa, wheat, rice).

In studies by I. Rakhmonov and U. Tashbekov [27], it was proved that the method of planting a halophytic plant increases the chances of secondary saline soils entering agricultural use. Thus, during the experiment, three options for cultivating licorice glabra were selected: planting licorice clones, sowing with seeds and planting licorice with root cuttings. As a result, it was found that all three methods are quite effective, since 8 tons were collected from 1 hectare. feed and licorice roots. Thus, it can be argued that halophytes are involved in solving multipurpose problems: as a source of fodder, oilseeds, and ornamental plants. Similar studies were carried out by K. Toderich et al. [1] within the framework of the "Bright Spots" project in the Syrdarya region of Central Kyzylkum. It was proven that licorice glabra is a promising biomeliorant, since 6-8 tons of hay and 8-10 tons of sweet root were collected from 1 hectare of saline irrigated land with close groundwater, and after 5 years, after the roots were removed from the ground, irrigated land can be used for planting less salt-tolerant crops (sunflower, barley, triticale). Today, in Central Asian countries, unconventional methods are being developed for the study and economical use of marginal mineralized waters and saline soils for the purpose of food use of desert pastures [28; 29]. Such production will help reduce poverty in the region by increasing food supply and improving the condition of agricultural and livestock ecosystems of small farms [30-32]. Thus, this study proves that carbon sequestration capacity occurs through large-scale biomass production, which leads to the formation of organic matter in soil through large-scale biomass production, resulting from leaf shedding. Therefore, the use of halophytes will enable marginal farmers to withstand the impacts of climate change [33; 34].

Under the appropriate conditions described in this study and well managed, halophytes can be used as indicators of soil physical and chemical properties and will be an effective method to facilitate the transfer of information from the laboratory to farmers. The relationship between vegetation and soil in saline areas has been described in many studies, and one of them proves the relationship between vegetation and soil in coastal marshy saline soils [5; 35; 36]. While studies to determine the main environmental factors influencing the distribution of vegetation cover in saline areas are negligible and, basically, they are limited only to the description of the botanical species. And observations of wild halophytes have shown that this type of plant is a strong competitor to traditional types of salt-tolerant crops both in saline areas and in natural improved pastures. In this regard, the method of restoring vegetation and soil resources by managing the water balance in saline areas, through the use of a certain number of halophytes, is an effective strategy for improving lands prone to salinity [37; 38].

In conclusion, the research on halophytes, particularly in the context of saline, arid, and degraded lands in regions like Central Asia, underscores their critical role in combating the adverse effects of anthropogenic climate change and promoting sustainable agricultural development. The unique physiological and biochemical traits of halophytes, such as their salt-tolerance and ability to thrive in extreme salinity, offer promising solutions for ecological restoration and food security. The successful cultivation of halophytic species like *Climacoptera* and *T. hispida* for various purposes, including fodder, oilseed, and bioamelioration, demonstrates their potential in enhancing the productivity of saline soils and contributing to carbon sequestration. Additionally, their use in marginal lands irrigated with mineralized or seawater illustrates their efficiency in resource utilization. These researches highlight the importance of integrating halophytes into agricultural systems as a sustainable approach to manage saline environments, thereby helping to mitigate climate change impacts, improve land productivity, and support the livelihoods of communities in arid regions.

CONCLUSIONS

This article argues that integrated natural resource management in drought-prone and salinity-affected agricultural marginal lands of Central Asia represents an innovative technology approach to manage and reduce salinity damage in production landscapes. One of these methods is the use of promising halophytes Climacoptera lanata and Tamarix hispida in the Kyzylkum Desert. This type of halophyte has successfully adapted to limiting environmental conditions, primarily to the lack of moisture associated with the osmotic and toxic effects of salts on plant organisms and the physiological dryness of the soil due to the increased content of ions in the soil solution. Thus, Climacoptera dominates among plants in the community because it is adapted to soil salinity. The dry biomass of C. lanata formed during the growing season of the year is also high and amounts to 1.5 tons per 1 hectare. Due to the fact that C. lanata is a promising salinity-tolerant and drought-tolerant dominant species and produces high biomass, the plant provides a double benefit if its biomass is used in biotechnological processes: the roots absorb salts from the soil and due to this, desalination of the soil occurs. T. hispida is an euhalophyte, in the plant community the roots penetrate into groundwater, and is part of the phreatophyte group. In such conditions, it is considered the dominant species. A distinctive feature is that the leaves remove salts and desalinate the soil. But when environmental conditions change and groundwater penetrates deeply, annual salinity prevails in these climatic conditions, they are resistant to salinity and drought and settle in their habitat. Consequently, T. hispida and C. lanata can be recommended for practice as promising species that reduce the salt content in saline soils.

The prospect of further research will be participation in the development of saline and sandy soils through the mobilization of phytogenetic resources. Therefore, additional research is needed on the biological characteristics of seeds and biomass, the effectiveness of which will be aimed at the selection and cultivation of arid halophytes. For example, the production and preservation of seed germplasm, which will be of great importance for the control of saline soils, their restoration and economic development.

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