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RESTORATION OF SALINITY IRRIGATED LAND USING GLYCYRRHIZA GLABRA L.

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Abstract:

The use of a biological method for restoring abandoned irrigated lands using licorice (Glycyrrhiza glabra L.) was studied in the conditions of Uzbekistan, in the Bayavut district of the Syrdarya region. Initial studies of licorice development, changes in soil salinity and fertility, and groundwater levels and salinity were conducted in a 13-ha field (10-ha control). Soil salinity in a field sown with licorice decreased by 30 t/ha or 14%. The green biomass of licorice plants increased from 0.5 t/ha in the initial years to 5.11 t/ha, and the root yield, respectively, amounted to 1.9, 4.58 and 8.5 t/ha.

Three main factors have been identified for the restoration of abandoned and saline soils by growing licorice (Glycyrrhiza glabra):

1) reduction of groundwater level in the experimental field;
2) reduction of salt content in the soil profile;
3) increasing soil fertility.

Keywords: Salinity, licorice (Glycyrrhiza glabra), groundwater level, restoration, humus.

INTRODUCTION

Soil salinization is one of the most pressing problems of modern irrigated agriculture in Central Asian countries, which has a negative impact on food security in this region (Bucknall et al, 2003). In Uzbekistan, according to the Ministry of Agriculture and Water Resources, about 50% of the 4.3 million hectares of irrigated land are salinized to varying degrees. Salinization processes occur due to the aridity of the climate with an index of 0.12-0.3 (Chembarisov and Bahriddinov, 1989), and the use of imperfect methods of irrigated agriculture, expressed in excessive water supply for irrigation, leading, in conditions of a poorly functioning on-farm drainage network, to a rise in the groundwater level above the permissible ~ 2.5 m from the surface of the earth. According to the annual reports of the hydrogeological and reclamation expedition of the Syrdarya region, the gradual accumulation of salts in the root layer of soils leads to the withdrawal of about 2% of irrigated land from agricultural circulation, in some years.

For the rehabilitation of degraded lands, a special state program has been adopted, providing for the allocation of significant funds for land reclamation. As a result, approximately 50% of the annual budget allocated to water management in Uzbekistan is devoted to cleaning the collector-drainage network (Kushiev et al. 2005). Land reclamation, as a rule, is limited mainly to purely technical measures, consisting in the construction and maintenance of a drainage network in working condition, and the annual washing of saline lands. These activities require significant funds, equipment and other resources, and at the same time very often do not lead to the expected results, which is reflected in the preservation of a significant area of saline and wetlands. Unfortunately, alternative methods of combating soil salinity have not been used in the practice of land reclamation services. Traditional saline remediation measures require the support of state farmers for their implementation, the vast majority of whom in the secondary salinity zone are financially and resource-inadequate (Rudenko and Lamers 2006). In addition, the decision to invest limited funds in a planned system with a strictly fixed set of crops, sanctions for shortages of planned crops and other risks should be accompanied by a guarantee that the investment will lead to "quick and tangible" results (Noble et al., 2006). Farmers are the main decision-makers within their lands, on whom success in controlling salinization on a large scale depends.

Consequently, there is a need for an approach to saline land reclamation that can be widely applied by farmers and will create the possibility of generating direct income by contributing their own funds to the restoration of abandoned lands. Consequently, there is a need to find and implement alternative, economically affordable methods that, on the one hand, will be effective in combating salinity, and on the other, will be attractive for widespread use by individual farmers, with the possibility of obtaining additional income. In the context of Uzbekistan, such methods should become part of the national agricultural policy in order to be widely disseminated.

One of the alternative, highly effective and most cost-effective methods of combating soil salinity is phytomelioration, that is, the use of halophyte plants with reclamation and other useful properties. The application of these methods meets the above requirements. Halophytes are ecologically, physiologically and biochemically specialized plants that can function and develop normally in a saline environment and irrigation with mineralized water. The ability of halophytes to form relatively tall, branched above-ground organs provides transpiration of a large amount of water, leading to a decrease in the groundwater level.

In addition, the branched crown of plants contributes to a dense coating of the soil surface and to a reduction in evaporation from its surface, which, in turn, will lead to a decrease in the concentration of salts in the root thickness of the soil. The ability of halophytes to function normally and form a relatively high feed and medicinal mass in a saline environment is associated with their specific ecological and physiological-biochemical characteristics. Some methods of ecological restoration of secondary saline irrigated soils using halophytes are reflected in the works of Shamsutdinov (2002), Nigmatov and Tukhtaev (1991).

The salinizing effect of halophytes consists of the following elements. With a phytomass of the above-ground part of 8 - 12 t/ha and a root mass of 10 - 14 t/ha, licorice, in the arid conditions of the Russian Federation, contributed to a decrease in soil salinity by 0.089% and chlorine by 0.013% (Shamsutdinov, 2002). By shading the soil, halophytes prevent evaporation and the associated pulling of salts into the topsoil. When draining, Washing and flushing irrigation regime, salts are only redistributed in the soil profile, but at the same time they are removed from the biological cycle in a small volume. Reducing soil salinity with the help of bioameliorant plants is a way to remove salts harmful to cultivated plants from the soil. The developed technology for the creation of agroforestry (Khamzina et al., 2006) or the technology for the restoration of saline soils using halophytes (Dagar et al., 2004, Kushiev et al., 2005, Toderich et al., 2006) gave positive results in salting and increasing the fertility of saline soils, as well as obtaining additional income for farmers.

Properties of Glycyrrhiza glabra

A particularly promising bioameliorant for the effective development of saline irrigated lands is licorice - *Glycyrrhiza glabra L.* (Mikhailova, 1966, Khaydarov, 1971, Kerbabaev 1971, Pauzner, 1971, Nigmatov et al. 1991, Ashurmetov, Karshibaeva, 1996, Badalov, et al., 1996, Kushiev et al., 2005). Licorice is both a valuable medicinal and fodder crop. Due to its healing properties, licorice is sometimes put on the same level as ginseng. Licorice root has anti-inflammatory and expectorant properties, mineralocortical-like action, which leads to the restoration of impaired water-salt metabolism in the body.

Glycyrrhizic acid is an antagonist of poisons that cause allergic diseases and has an antipodean effect and is therefore used in the treatment of food and drug intoxications. Licorice flavonoids are characterized by anti-ulcer action. Along with this medicinal value, licorice is used in the food industry (fizzy drinks, sweets, coffee surrogate, etc.). From the roots, you can get paint for dyeing koshmas and woolen fabrics, leather, etc. For 4-5 years of growing licorice, its roots have a high market value. The green mass of licorice has nutritional value and can be used by farmers as livestock feed.

This article presents the results of many years of research conducted in the Hungry Steppe on the cultivation of licorice for the restoration of abandoned saline lands.

RESEARCH METHODOLOGY

Three of the ten selected experimental fields, with an area of 10, 14.2 and 16 hectares, were selected for detailed data collection and analysis. Data from the experimental plots were analysed and compared with three control adjacent plots of 4.5, 5 and 7 ha. Data collection covers the period of licorice cultivation from planting to ripening (2018-2017) and later (until 2023) to analyze changes in soil conditions. Soil samples were taken from depths of 0-15, 15-50 and 50-100 cm in triple repetition at each of the sites. Soil salinity, electrical conductivity and dry residue were measured with an electric conductivity meter. In addition, the samples were subjected to a reduced aqueous extract. The analyses were carried out according to the methodology of SoyuzNIHI (1973), VIIR, UzPTII and the Research Institute of Soil Science and Agrochemistry of the Ministry of Agriculture of the Uzbek SSR (1976), as well as the "Guidelines for conducting chemical and agrophysical analyzes of soils in land monitoring" (T. 2004). During the assessment of the degree of soil salinity, due to the relative complexity of determining the dense residue and the simplicity of measuring electrical conductivity, the relationship between these values was established for quick recalculation. Soil fertility was assessed by the content of humus, available nitrogen and phosphorus, as well as exchangeable potassium in soils. Groundwater level and mineralization were measured once a month during 2015-2023 for three observation wells installed at each of the selected sites (9 wells in total) and one at the control well. Statistical analysis of ANOVA variations was used to assess differences between soil salinity, groundwater level and mineralization, and soil fertility in pilot and control plots before and after licorice harvesting using the SPSS program. As necessary, the logarithm of data transformation was used to obtain normalized values.

Land preparation and agricultural techniques for growing licorice

Licorice can be propagated by seeds, vegetative and rhizomatous cuttings. Before sowing licorice rhizomes, the soil is cleared of weeds and the main plowing is carried out to a depth of 25-27 cm. Superphosphate and potassium salt at a rate of 150-200 kg/ha are applied for plowing, and ammonium nitrate at a rate of 100-150 kg/ha is applied for cultivation (Kushiyev, 2008). Licorice seeds are sown in early spring in a wide-row way. The width of the row spacing is 90 cm in size, the seeding rate on medium-saline soils is 3-4 kg / ha, on highly saline soils - 6-7 kg / ha, the depth of seed embedding is 1-2 cm.

According to established practice and scientific recommendations, licorice rhizomes are prepared by hand before sowing with cuttings 15-30 cm long, with the presence of 2-3 buds. They are planted in autumn or early spring at a distance of 25-30 cm with a row spacing width of 90 cm. Cuttings are installed vertically, deepening into the soil in such a way that their tops do not protrude above the surface of the earth. As a rule, shoots appear a month after planting. In the first year in autumn, dry stems are cut, and the plants are fed by applying 2-3 t / ha of rotted manure or 150-200 kg / ha of mineral fertilizers, and dig up the soil. In the spring, ammophos is given at the rate of 150-200 kg / ha. When cultivated, the productivity of rhizomes reaches 25 t / ha, dry aboveground mass - up to 7-8 t / ha (Kushiev et al., 2005, 2006, 2010).

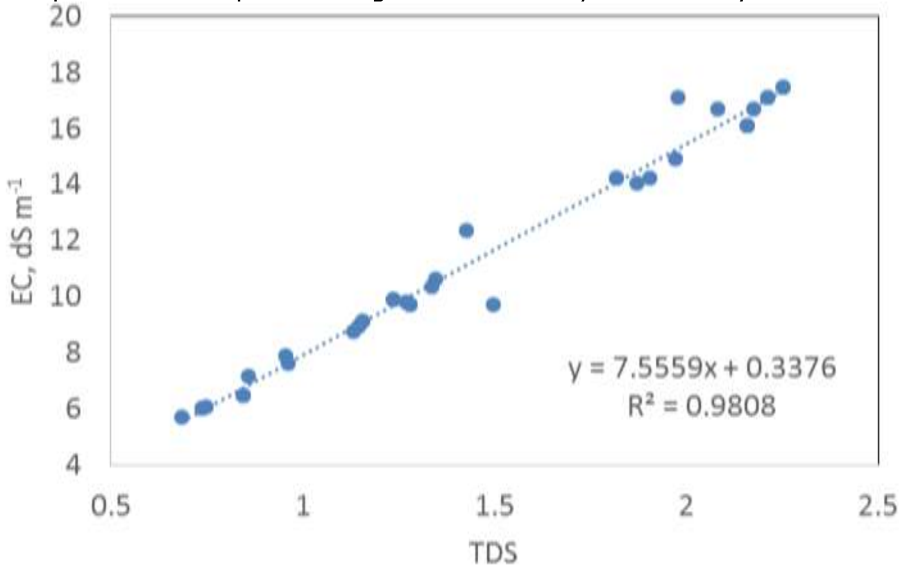
Watering and fertilization

In the first year of cultivation, licorice requires 3-4 watering, even in soils with a close depth of groundwater. In the second year, watering can be reduced to 3 times, and in other years - up to 2, with a water supply volume of 800-1000 m3 / ha. If groundwater occurs at a depth of 3 m or more, the number of irrigations should be increased by 1-2 times.

RESEARCH RESULTS

Reduction of soil salinity

The correlation between the dense residue of salts and electrical conductivity was quite high (R2 = 0.98, Fig. 1). Thanks to this connection, it was possible to compare the degree of soil salinity in different years.



Rice. 1. Correlation between the dense residue of soils and the electrical conductivity of the aqueous extract.

Assessment of soil salinity in experimental fields before licorice cultivation (in 2015 – 2016) and in control plots showed that the top layer of soils of 0 – 15 cm is characterized as medium-saline, but highly saline at a depth of 15-100 cm (Table 1). Laboratory analysis of individual cations and anions showed that the salinization of soils is of the sulfate type, typical for the Syrdarya region.

Table 1.
Descriptive statistics of soil salinity (electrical conductivity, dS $^{m-1}$), measured from three horizons in the licorice and control plots of the Galaba farm in 2005 – 2013.

Depth, cm	2015	2017	2019	2023
Licorice field				
0-15	7.41 (±1.62)*	6.73 (±1.72)	5.65 (±1.53)	4.64 (±1.27)
15-50	9.69 (±0.95)	9.93 (±1.9)	8.15 ± (1.14)	7.27 (±1.16)
50-100	15.23 (±1.36)	15.62 (±.04)	13.9 (±.58)	12.31 (±0.54)
Control				
0-15	7.44 (±1.98)	7.57 (±1.99)	7.7 (±1.89)	7.73 (±1.95)

15-50	11.06 (±2.66)	11.33 (±2.88)	11.18 (±2.55)	11.37 (±2.87)
50-100	17.02 (±0.36)	17.31 (±0.43)	17.16 (±0.3)	17.28 (±0.42)

*Standard deviation

Regular measurements of soil salinity revealed the absence of its change in the meter layer of the control plot. However, the analysis showed a statically significant change in salinity in the experimental fields. These changes were observed in each of the soil layers during the licorice cultivation period. Statistical analysis of ANOVA revealed no differences in soil salinity in experimental fields under licorice during 2015-2017, that is, during the initial development of roots and plant biomass (Table 2).

Table 2.
Statistical processing of the results of the assessment of the degree of soil salinity (Electrical conductivity, dS $^{m-1}$) between measurement periods in experimental fields using ANOVA

Year of sowing	Measurement period	Average. difference	Standard error	Stat. difference*	95% confidential difference interval, boundaries	
2015	2017	0.02	0.37	0.966	-0.88	0.91
	2019	1.54*	0.36	0.005	0.66	2.42
	2023	2.70*	0.33	0.000	1.90	3.51
2017	2019	1.52*	0.18	0.000	1.07	1.97
	2023	2.69*	0.23	0.000	2.13	3.24
2019	2023	1.16*	0.14	0.000	0.83	1.49

*. Average. The difference is significant at the level of 0.05

However, a statistically significant difference ($p<0.05$) in soil salinity between 2019 and 2023 indicates the salting effect of licorice cultivation. A significant difference between salinity in the experimental and control fields can be traced starting from 2019 The decrease in salinity can be explained by the development of licorice roots during the synthesis of glycerrhizic acid.

Reduction of groundwater level and mineralization

Mean groundwater levels measured prior to the development of licorice roots ranged from 0.97 to 1.22 m in 2016 and 0.82 to 1.13 m in 2017, indicating a level close to the earth's surface. The average mineralization of groundwater was 4 - 6 g l-1; These values, the level and salinity of groundwater, are the threat of soil salinization.
The results of the ANOVA statistical analysis show that the difference in groundwater levels in licorice fields in the period 2015-2017 is statistically insignificant due to the fact that licorice roots have not yet reached groundwater (Table 3).

Table 3
Results of the ANOVA analysis between the groundwater level at the experimental and control sites in the period 2016 – 2023.

Years	Average difference	Станд. ошибка	Stat. difference	95% confidential difference interval, boundaries	
				Lower	Top
2016	0,09	0,14	0,53	-0,19	0,37
	-0,35*	0,12	0,01	-0,61	-0,10
	-0,92*	0,12	0,00	-1,16	-0,67
2017	-0,44*	0,14	0,02	-0,73	-0,15
	-1,01*	0,14	0,00	-1,28	-0,73
2022	-0,56*	0,12	0,00	-0,81	-0,32

*. Average. The difference is significant at the level of 0.05

However, in 2022 and 2023, this level difference was already statistically significant at $p<0.05$, indicating that licorice plants used moisture requirements for evapotranspiration from groundwater. Statistical comparison of groundwater levels in licorice and control fields shows the expected absence of difference in levels in the period 2006 - 2007 and a significant difference in levels in the period 2012 and 2013 (Table 4). In the period 2022 – 2023, reduced groundwater levels led to minimal salt pulling into the soil horizons, while at the same time ensuring sufficient moisture intake by developed licorice roots.

Table 4
Statistical analysis of ANOVA between groundwater levels at licorice and control plots in the period 2022 – 2023

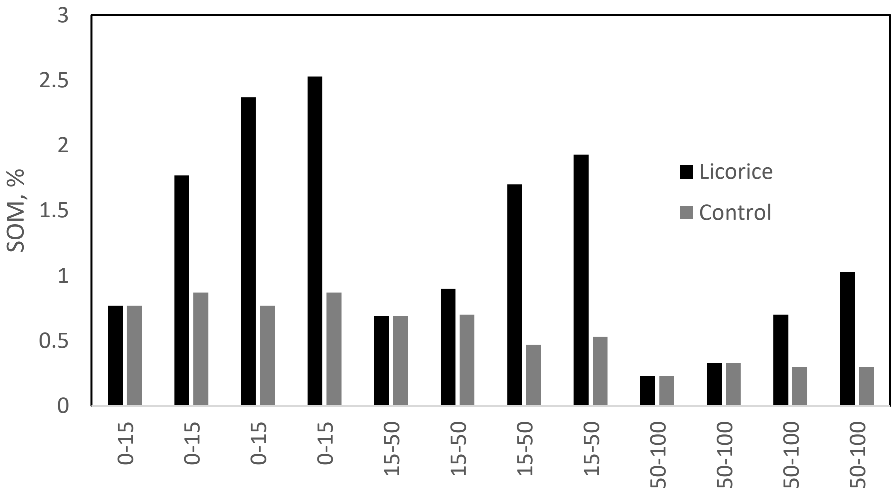
Period	Areas		Average difference	Standard error	Stat. meaning.	95% confidential interval differences, boundaries Lower	Top
	Control	Plot 1	-0,01	0,21	0,96	-0,45	0,43
2016		Plot 2	-0,31	0,21	0,16	-0,74	0,13
		Plot 3	-0,58*	0,22	0,02	-1,04	-0,13
	Control	Plot 1	0,29	0,22	0,17	-0,14	0,73
2017		Plot 2	-0,28	0,22	0,22	-0,74	0,18
		Plot 3	-0,22	0,11	0,05	-0,45	0,00
	Control	Plot 1	-0,18	0,12	0,13	-0,95	-0,42
2022		Plot 2	-0,93*	0,13	0,00	-1,19	-0,66
		Plot 3	-1,15*	0,13	0,00	-1,42	-0,88
	Control	Plot 1	-1,21*	0,14	0,00	-1,51	-0,91
2023		Plot 2	-1,47*	0,14	0,00	-1,77	-1,17
		Plot 3	-1,778*	0,148	0,000	-2,079	-1,476

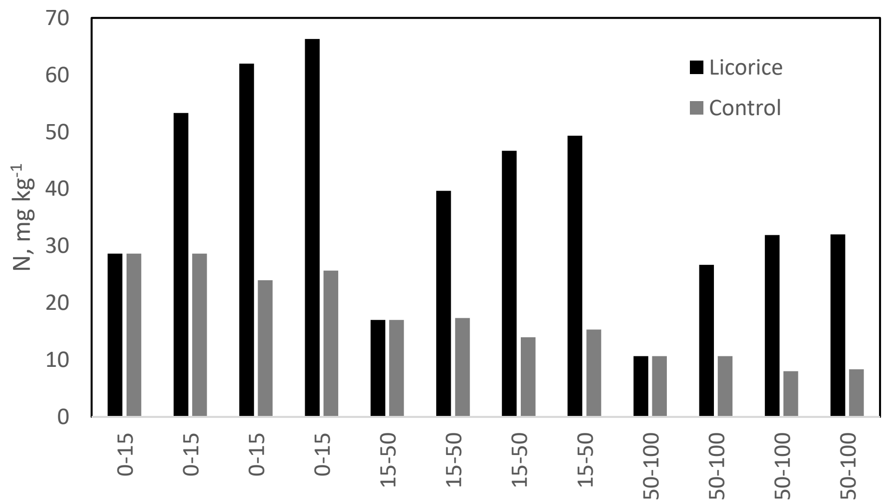
Evaluation of individual indicators of soil productivity showed that in 2015 the humus content in the soil in the control and licorice fields was at the level of low and medium (Krasnoukhova et al., 1988).

At all sites, the initial content of organic substances in the layer of 0-15 cm in 2015 – 2017 was 0.77 – 1.77%, in layers 15 – 50 and 50 – 100 cm 0.69 – 0.87%. According to Musaev (2001), the content of available N and P and exchangeable K is characterized as low in the 15 cm layer, decreasing to very low with depth.

With the growth and development of licorice, a statistically significant increase in organic matter was revealed (Fig. 2, a). The content of organic matter by 2023 on the entire meter layer of soils reached 2.53 ±0.12%, classified as very high (Krasnoukhova et al. 1988).

(a)





b)

Rice. 2. Change in the content of humus (a) and N (b) in the licorice field and in the control for the observation period (2015 – 2023).

On the contrary, the humus content in the control plots where there is no vegetation remained the same and even decreased. The phosphorus content in the period under review also increases markedly in the experimental field and decreases in the control field. At the same time, the content of exchangeable potassium is steadily decreasing during the entire observation period. Positively significant changes in the dynamics of humus and nitrogen, negative changes in potassium and the absence of phosphorus changes between licorice and control plots can be explained by the effect of licorice cultivation on these indicators of soil fertility.

CONCLUSION

Three main factors have been identified for the restoration of abandoned and saline soils by growing licorice (*Glycyrrhiza glabra*):

1) lowering the groundwater level in the experimental field;
2) reduction of salt content in the soil profile;
3) increasing soil fertility.

The biological method of reclamation of saline lands with licorice (*Glycyrrhiza glabra*) provides recovery, reducing the level of salinity, increasing the content of humus and vital nutrients. The decrease in salinity can be explained by the development of licorice roots during the synthesis of glycerhizic acid.

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