ANNOTATION

on the dissertation of Ulbosyn Makhanova, « Development of a biological method of a desalinization of the saline soils means of cultivation of glycyrrhiza naked (*Glycyrrhiza glabra* L.)», submitted for the degree of Doctor of Philosophy (PhD) in the specialty 6D080800 - Soil Science and agrochemistry

Relevance of the research topic

Saline soils form primarily in arid climates as a result of natural or anthropogenic processes that lead to the accumulation of soluble salts and reduce their fertility. In the republic, saline and solonetzic soils occupy 111.6 million hectares, accounting for 41.0% of the total area. The proportion of solonchaks in the soil structure increases significantly in the southern half of the republic. Here, the desert climate and poor drainage of the flat lands have contributed to the widespread occurrence of saline soils. Of the irrigated lands in the Turkestan region (566,550 hectares), 42% are saline, and 30% are slightly saline. Currently, the poor condition of irrigation and drainage networks, along with their non-compliance with design standards, has led to a sharp deterioration in the soil and drainage conditions of irrigated areas. Soils in poor drainage conditions are affected by salinization on 42,912 hectares, rising groundwater levels on 80,005 hectares, and both factors on 24,909 hectares.

Until recently, the primary method for reclaiming saline soils was leaching, followed by removal of the leached water through a drainage and collector network. This desalination method requires between 3,000 and 20,000 m^3 of water per hectare, depending on the region and the degree of soil salinity. A disadvantage of this method is the high volume of leaching water required, which is not only unproductive but also a source of large quantities of saline drainage water discharged into natural watercourses, leading to contamination and environmental degradation in irrigated areas. Restoring these areas requires significant technical resources and financial investment, necessitating the wider use of phytomelioration using salt-tolerant crops.

One of the most effective and cost-effective methods for combating secondary soil salinization is phytomelioration using licorice (*Glycyrrhiza glabra L.*), a valuable raw material. Kazakh licorice has long been popular in countries such as China, Japan, Canada, the USA, Turkey, Germany, India, and South Korea. However, uncontrolled and predatory harvesting of licorice roots for export in the Kyzylorda, Turkestan, Zhambyl, West Kazakhstan, and Almaty regions also poses a real threat to this species. First and foremost, licorice is a key ingredient in pharmaceuticals, supplying pharmaceutical raw materials (rhizomes) for the production of drugs, growth stimulants, and fungicides. Thanks to the effective shading of the soil surface by the aboveground soil and the pumping functions of biological drainage, licorice crops significantly reduce physical evaporation, lower the groundwater level, and remove salts from the aboveground soil, thereby promoting soil desalination. Therefore, growing licorice in saline soils is a pressing

issue for effectively combating salinization not only in the southern region of Kazakhstan but also in other areas with similar conditions.

Thus, given the saline soil conditions of the Turkestan region, there is a pressing need to develop and field-test a biological method for desalinization through the domestication of licorice. This will make it possible to restore the productivity of saline soils, integrate them into agricultural production by creating highly productive forage biocenoses, improving the soil's melioration status, and increasing soil fertility.

The purpose of the dissertation research:

Development of a method for growing licorice (*Glycyrrhiza glabra L.*) and increasing its productivity, aimed at desalination and improvement of the chemical and agrophysical properties of saline soils in Southern Kazakhstan.

Research tasks:

- Conducting a field reconnaissance survey of representative pilot areas to select pilot farms and studying the initial soil-reclamation state of saline meadow-sierozem soils;
- Conducting a large-scale (1:10,000) salt survey of representative pilot farm areas and entering the data into a common database of the dataset's information system;
- Determining the impact of two licorice growing seasons on the nutrient status of soils with varying salinity levels based on analytical data and annually compiled thematic cartograms of soil nutrient availability;
- Determining the impact of two growing seasons of licorice on the salt regime of soils with different salinity levels based on analytical data and annually compiled soil salinity maps;
- Determining biometric indicators and productivity of licorice depending on the soil salinity level of pilot plots;
- Developing a biological method for desalinizing saline soils using licorice under conditions combining traditional agricultural practices and ongoing droughts.

Research methods:

The study focused on the soil cover of the right-bank part of the Shaulder irrigation system in the Turkestan region.

Research to determine the effectiveness of a biological soil desalination method was conducted on three pilot farms in the Otrar district, covering an area of 600 m² (200 m² each) by planting licorice (*Glycyrrhiza glabra L.*). The licorice was grown on long-fallow, slightly saline soils of the Bakyt farm, on moderately saline soils of the Mukhit farm, and on highly saline soils of the Birzhan farm.

Before planting naked licorice vegetatively, pre-sowing soil preparation and moisture-replenishing irrigation were performed. Soil moisture was maintained at 70-75% of the lowest water-holding capacity (LWC). When planting naked licorice, rhizomes were cut 15-30 cm long and installed vertically in bunches, maintaining polarity. Within rows, the distance between cuttings was 30 cm, and the width between rows was 70 cm. Selected naked licorice cuttings were planted 2-4 cm deep, ensuring their tips protruded 2-3 cm above the soil surface.

When planting licorice root, the root system (planting material) was 10-15 cm long and 1.0-1.5 cm in diameter. Three to four buds were left on each root, planting them vertically and horizontally, observing polarity. Roots were planted at a depth of 15-20 cm in the fall and 10-15 cm in the spring. Row spacing was 70 cm, and between nests, 10-15 cm. Vegetative irrigation was carried out in May. The first cutting of the aboveground mass of naked licorice for the fall planting variant was carried out during the budding phase - the beginning of flowering (the third ten days of May), the second cutting - in the second ten days of October. For the spring planting variant, one cutting of the aboveground mass was carried out in the fall, at the beginning of October.

Before the start of field research (spring 2019), after the first growing season (fall 2019), and at the end of the second growing season (fall 2020) of licorice, the chemical composition of soils was studied using mixed humus horizon samples on three pilot farms. This resulted in the compilation of soil nutrient supply maps.

A detailed salt survey was conducted on the three pilot farms during the above-mentioned licorice cultivation periods. Fifteen soil samples were collected from the above-mentioned pilot plots at depths of 0-20, 20-50, and 50-100 cm (in spring and fall). The degree of soil salinity was then determined to a depth of 1 m. Based on these results, soil salinity maps were compiled, which were used to determine the effectiveness of licorice phytomelioration on saline soils. Using this method, comparative changes in soil salinity were determined over two licorice growing seasons. Our assessment of salinity was based on three main criteria: salinity chemistry (type), degree of salinity, and the depth of the salt horizon. To compile the soil salinity maps, we used a computer-based digital mapping method using MapInfo Professional software. Statistical processing of the data was carried out using the Excel-97 and Atte Stat analysis package programs.

The main provisions submitted for defense

- The initial meliorative conditions of secondary-saline meadow-gray soils of the Shaulder irrigation massif in the desert zone of southern Kazakhstan were determined;

- The phytomeliorative effectiveness of licorice in the nutrient and salt regimes of weakly, moderately, and highly secondary-saline soils in the desert zone of southern Kazakhstan was determined for the first time;

- The biometric and productivity characteristics of licorice in weakly, moderately, and highly secondary-saline soils in the desert zone of southern Kazakhstan were determined for the first time under ongoing drought conditions;

- A biological method for improving weakly, moderately, and highly secondary-saline soils using licorice was developed and implemented under industrial conditions in the desert zone of southern Kazakhstan.

Description of the main results of the study

Results of biological testing showed that growing naked licorice (*Glycyrrhiza glabra L.*) had no noticeable effect on the humus content of slightly, moderately, and highly saline soils. However, it had a significant effect on the available nutrient levels at all levels of soil salinity. This is confirmed by data from soil nutrient supply cartograms. The content of readily hydrolyzable nitrogen increased with the

cultivation of naked licorice from 36.96 to 44.24 mg/kg in slightly saline soils, from 27.44 to 42.28 mg/kg in moderately saline soils, and from 26.32 to 33.60 mg/kg in highly saline soils. By the end of the growing season, the content of available phosphorus increased only in moderately saline soils, reaching 26.8 mg/kg. In relation to exchangeable potassium, it increased from 492 to 582 mg/kg in slightly saline soils, from 392 to 452 mg/kg in moderately saline soils, and from 556 to 629 mg/kg in highly saline soils; a noticeable upward trend was observed.

To determine the phytomeliorative effect on salt levels, soil salinity maps were compiled for licorice crops. Cultivation of licorice reduced the concentration of water-soluble salts in slightly and moderately saline soils. After two years of growing licorice, the salt content of slightly saline meadow-gray soils within a meter of the soil depth decreased from an average of 0.392 to 0.240%. This means that, as a result of licorice phytomelioration, the soil of the Bakyt farm became virtually saline-free, resulting in an average yield of 47 centners per hectare of the half-meter underground soil per year of cultivation, with an 81.63% plant survival rate. The profitability of the biological method on these soils was 92.4%. At the second pilot site of the Mukhit farm, by the end of the two-year vegetation period of licorice in the bare autumn, a decrease in water-soluble salts was also observed, on average, from 0.572 to 0.444%. This created relatively favorable conditions for the survival of naked licorice (53.23%) and an underground yield of 45.0 c/ha. The profitability of the method was 89.6%. Despite the cultivation of naked licorice, the third pilot plot of the Birzhan farm had no noticeable positive effect on the high salinity. Over two growing seasons, the salt content increased from 2.120% to 2.683%. Their licorice yield was 24.0 c/ha with a survival rate of only 9.01%. The profitability was 45.9%.

Thus, based on the results of long-term research conducted in the Shaulder irrigation system, it is recommended to plant licorice from root cuttings and cultivate it in areas with low to moderate soil salinity. Positive effects from growing licorice can be achieved in the first year of cultivation. However, on highly saline soils, achieving the full effect will require slightly longer (4-5 years) and a leaching regime during the summer months. Before and after phytomelioration, it is necessary to conduct a control salinity survey to verify the completion of reclamation work and to monitor changes in the seasonal dynamics of salinization and desalination processes. When cultivating licorice, the groundwater depth in weakly and moderately saline areas should be below the critical water level (2.5-3.0 m). In cases of close groundwater occurrence and in moderately and highly saline soils, licorice should be cultivated under leaching conditions with drainage.

Justification of the novelty and importance of the obtained results

In southern Kazakhstan, soil salinization has become the main constraint on agricultural development. Leaching, coupled with a drainage and collector network, is used to reclaim saline soils. This requires enormous amounts of water, which is a constraint on the use of leaching in southern Kazakhstan. The deterioration of soil conditions in irrigated lands in the Turkestan region due to the failure of irrigation and collector and drainage networks to meet design standards has led to the rapid development of secondary soil salinization. Therefore, the need to restore their

fertility in this region remains urgent. Given water shortages and the limited profitability of traditional saline soil reclamation methods, phytomelioration using licorice (Glycyrrhiza glabra L.) is the most effective and environmentally friendly. Its cultivation lowers groundwater levels, removes salts from aboveground soils, enriches the soil with organic matter, and increases biological activity.

The scientific and practical significance of this study lies in the fact that for the first time, the effectiveness of licorice, planted as cuttings in soils with varying degrees of salinity, has been determined in the arid conditions of southern Kazakhstan. Its positive impact on the nutrient and salt regimes of slightly and moderately saline soils was revealed. Implementation of the developed biological method will allow farms to increase their income by improving saline soils with licorice in conditions of water shortages and ongoing droughts. This, in turn, will contribute to improving the environmental situation in the region and expanding the range of licorice.

Compliance with scientific development directions or state programs

The dissertation work was completed within the framework of the project "Problems of irrigated saline soils of the Turkestan region and their solution based on the application of innovative technology for increasing soil fertility and crop yields", budget program 267 "Increasing the availability of knowledge and scientific research", subprogram 101 "Program-targeted financing of scientific research and events" (No. 0118PK01386).

Description of the doctoral student's contribution to the preparation of each publication

Under the guidance of a national scientific advisor, the doctoral student participated in developing the research program and methodology, as well as in establishing and conducting field experiments on pilot plots with licorice. In the laboratory, the doctoral student analyzed soil samples taken in the field at the beginning and end of the licorice growing season. She participated in processing the results and, ultimately, managed to solve the assigned problems and write this thesis. The author actively participated in publishing her results in domestic and international journals. The final results of her research on the dissertation topic resulted in the publication of five scientific papers, including four articles in journals recommended by the Ministry of Higher Education of the Republic of Kazakhstan, one article in a scientific journal included in the Scopus database, and two implementation certificates.

Volume and structure of the dissertation

The dissertation consists of 129 pages of computer text, including references, definitions, symbols and abbreviations, an introduction, four sections, conclusions, a bibliography, recommendations, and appendices. The bibliography contains 121 domestic and international titles. The dissertation structure consists of 19 tables, 24 figures, and appendices.