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Resource-saving restoration technologies of the degraded irrigated lands in Southeastern Kazakhstan

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ABSTRACT

Violation of agricultural technology, the structure of crop rotations led to a decrease in crop yields, and irrational water use led to soil salinization and deterioration of the environment. This study was aimed at developing resource-saving technologies for the restoration of degraded irrigated lands in the south-east of Kazakhstan. The degraded resalinized irrigated lands were rehabilitated by the planting of salt-tolerant crops – phyto-ameliorants, treatment of their seeds, and spraying the aerial parts of cultures with PA-2,1 preparation (adaptogen) solution. Due to the intensive growth and development, and accumulation of the above-ground mass, the studied phyto-ameliorants contributed to obtaining high yields.

Key words : *Salt-tolerant crops, Feed unit, Drip irrigation, Phyto-amelioration, Adaptogen (PA-2,1), The least moisture-holding capacity.*

Introduction

The growing deficit of irrigation water around the world, including in southeastern Kazakhstan, does not allow restoring degraded saline lands using old methods, i.e. by washing salts from the soil with high water discharge (2,000-2,500 m^3/ha).

In this regard, scientific research aimed at the development of low-cost water-saving methods for the restoration of degraded saline irrigated lands, providing increased productivity of these lands, is of undoubted relevance (Atakulov *et al.*, 2020; Kaldybayev *et al.*, 2019).

In the set of measures to increase the productivity of saline lands, an important role belongs to the cultivation of crops that are able to successfully resist the harmful effects of soil salts while giving stable high yields and having a versatile effect on the soil.

The scientific novelty of this work is associated with the developed and adopted resource-saving agrobiological and land reclamation techniques for the restoration of degraded resalinized irrigated lands, which reduce operating costs and irrigation water consumption through the widespread exclusion of leaching and introduction of drip irrigation at the farms of this region. The only remaining problem is the acquisition and installation of drip irrigation systems at small farms.

The practical significance of the work is related to the fact that development and introducing into the production of water-saving-innovative technologies on unproductive saline soils are extremely relevant today. The research results open fundamentally new directions in the fight against soil salinization on irrigated lands of Kazakhstan.

Materials and Methods

To develop low-cost and water-saving methods for restoring degraded saline lands, field studies were carried out in two directions: agrobiological (phyto-amelioration by sowing salt-tolerant crops of maize, Sudanese grass, sorghum and soybeans) and agromeliorative (the use of the PA-2,1 adaptogen); as well as laboratory tests were done (determination of NPK and soil salinity level). Field studies were conducted to develop methods for increasing the productivity of saline irrigated lands on gray-brown takyr-like soils of the Akdala irrigation basin in the Almaty region from 2015 to 2017. The conducted studies were published for the first time and with a delay, since in 2018-2019, the results of field studies were processed. Then, the recommended resource-saving agrobiological and land reclamation techniques for restoring degraded resalinized lands were introduced at Baknur farm located in the Akdala irrigation array. The introduction of these techniques made it possible to significantly reduce operating costs and irrigation water costs (by 60%) due to the widespread introduction of drip irrigation.

The objects of the study were the gray-brown soil, maize, Sudan grass, sorghum, soy, drip irrigation, and PA-2,1 adaptogen. The PA-2,1 preparation was obtained from brown coals of grade 3B from the Oi-Karagai and Kiyakty deposits, wild medicinal plants of Kazakhstan and other substances of a special ingredient composition. The developers of this preparation were the employees of the Research Institute of Soil Science and Agrochemistry named after U.U. Uspanov (Mamonov A. and Saparov A.). The dynamics of salt content in the soil before planting, before crops harvesting, and the effect of the adaptogen on the growth and development of phyto-ameliorant plants were studied. The seeds were treated with 2% adaptogen solution before sowing, and the vegetating plants were sprayed with 0.03 – 0.05% aqueous solution of this preparation during the beginning of plant growth and development.

The total area of the experiment was 0.3 ha, the plot area was 120 m^2; the experiment was repeated three times (Dospekhov, 1985). During the experiments, the following surveys, observations and analyses were carried out using traditional generally accepted methods: monitoring the growth and development of the phyto-ameliorant plants during the main phases of development, accounting for the dynamics of biomass accumulation (by sampling plants from area of 0.3 m^2 and analyzing the number of plants, height, accumulation of wet and dry mass of these plants) (Rudnev, 1950); monitoring the soil humidity for determining the soil moisture storage (by thermostatic-weight method, every 8-10 days); determining the content of nutrient elements in the soil (the content of humus, nitrogen, phosphorus, potassium by taking soil samples to determine the content of these elements in soil) (Tyurin, Arinushkina, 1970), the structural-and-aggregate composition of the soil (by sampling soils to determine the bulk density, water resistance and aggregate composition) (Savvinov, 1975). The content of humus and other elements in the soil was low.

Results

The results of the field experiments showed that treatment of the seeds of the studied crops contributed to germination two days earlier, compared to the variants where the seeds had not been treated with the adaptogen solution.

The growth and development of phyto-ameliorant plants in the main phases of their development were monitored. The results of monitoring the growth, development, and accumulation of the above-ground mass showed that in the variants without treatment, the raw mass in the phase of the 4th leaf for Sudan grass and sorghum amounted to 402 – 310.3 g in the area of 0.30 m^2; in the variant with treatment with the adaptogen, it amounted to 444 – 330.3 g (Table 1).

The weight of maize and soy biomass amounted to 421.3 – 325.6 g per 0.30 m^2, and in the variant with the adaptogen, it was 446.3 – 361.6 g. The height, the number of plants per one square meter, and the weight of the wet and the dry mass of the studied phyto-ameliorant plants were determined. The weight of dry biomass of these crops amounted to 148 – 130.2 g, and in the variant with the adaptogen — to 62.30 -144.6 g (Table 1).

Monitoring of the growth and development of phyto-ameliorant plants continued. Accumulation of the wet mass before harvesting on the area of 0.3 m^2 for Sudan grass, sorghum and soy in the variant with adaptogen was 1,833 g, 2,013 g, and 1,186 g, respectively, and in the variant without adaptogen — 1,450 g, 1,540 g, and 950 g, respectively (Table 2).

Intensive growth and development were observed in the phyto-ameliorant plant named Sudan grass, where the height of plants averaged up to 266 cm, and in the variant without adaptogen — 257.0 cm (Table 2). In the soils prone to salinization, intensive growth and development were observed in soy.

Due to its active growth and development, this crop suppressed weeds well and formed beans very well.

To study and determine the effect of the agrobiological and agromeliorative techniques of fighting soil salinization, the authors took samples of the soil during the planting period and determined the primary content of salts in the soil.

Annually in September, before harvesting of phyto-ameliorant plants, samples of soil were taken again, and the amount of residual salts in the soil after phyto-ameliorant plants was determined and laboratory tests were carried out in the accredited laboratory of the Kazakh Research Institute of Farming and Crop Production. The results of analyzing the salt content during planting (the initial content) and before harvesting of phyto-ameliorant plants (the residual content) are shown in Table 3.

The recommended technologies exclude leaching of saline lands with a large amount of water (2,000-2,500 m^3/ha), it is recommended to carry out drip irrigation with the small amount of water (150-160 m^3/ha) due to which only the upper (0 -20 cm) soil layers are watered, which prevents the rise of the groundwater level.

By introducing this resource-saving technology into production, collective and peasant farms ben-

Table 1. Results of monitoring the growth, development, and accumulation of the above-ground mass of phyto-ameliorant plants in the area of 0.30 m^2, average data for 2015-2017

Experiment variants, phyto-ameliorant plants	Seed treatment with PA-2,1 adaptogen	Average			
		Number of plants	Plant height, cm	Weight of the wet mass, g	Weight of the dry mass, g
Sudan grass (the four	with treatment	47	60	444	177.6
leaves phase)	without treatment	40	55.3	402	160.8
Maize (branching phase)	with treatment	53	45	446.3	162.3
	without treatment	45	43	421.3	148
Sorghum (8 leaves)	with treatment	50	44	330.3	160
	without treatment	44	43.6	310.3	127
Soy (branching phase)	with treatment	58	41	361.6	144.6
	without treatment	48	38	325.6	130.2

Table 2. The results of monitoring the growth and biomass accumulation of the phyto-ameliorant plants, 0.30 m^2, average data

Experiment variants, phyto-ameliorant plants	Seed treatment with PA-2,1 adaptogen	Plant height, cm	Weight, g	
			of the wet mass, g	of the dry mass, g
Sudan grass (emergence of	with treatment	266	1,833	733
panicles, two mowings)	without treatment	257	1,450	580
Sorghum (grain filling)	with treatment	156	2,013	805
	without treatment	153	1,540	616
Soy (wax ripeness)	with treatment	98	1,186	475
	without treatment	95	950	380

Table 3. The content of salts in the soil horizons before planting and before harvesting of phyto-ameliorant plants

Phyto-ameliorant plants	Depth, cm	Dense residue,%		HCO_3 ions, %		Sulfate ions, %		Sodium, %	
		before planting	before harvesting	before planting	before harvesting	before planting	before harvesting	before planting	before harvesting
Soy	0 – 20	0.78	0.51	0.13	0.06	0.21	0.18	0.18	0.01
	20 – 40	0.94	0.67	0.06	0.03	0.40	0.09	0.22	0.01
Sorghum	0 – 20	0.31	0.21	0.02	0.05	0.19	0.16	0.09	0.06
	20 – 40	0.20	0.16	0.05	0.05	0.09	0.12	0.09	0.07
Sudan grass	0 – 20	0.19	0.13	0.03	0.05	0.16	0.16	0.01	0.06
	20 – 40	0.21	0.16	0.03	0.05	0.19	0.08	0.01	0.07

Table 4. The yield of the green mass and grain of phyto-ameliorant plants under drip irrigation

Experiment variants, phyto-ameliorant plants	Seed treatment with PA-2,1 adaptogen	Years of the study 2015	2016	2017	Average, cwt/ha	The yield of fodder units, cwt/ha
Sorghum (green mass)	with treatment	-	767.7	787.5	777.6	171.0
	without treatment	737.0	731.2	752.3	740.4	162.9
Sudan grass (two mowings for green mass)	with treatment	-	985.4	995.2	990.3	217.9
	without treatment	921.1	954.4	965.7	947.0	208.3
Maize (green mass)	with treatment	-	795.3	810.8	803.0	201.0
	without treatment	789.3	786.0	783.4	786.2	197.0
Soy (grain)	with treatment	-	56.0	57.2	56.6	73.6
	without treatment	54.9	54.0	55.1	54.7	71.1

efit three times: firstly, low-cost, secondly, irrigation water saving, thirdly, reducing the salt content in the soil and providing high yields of forage crops – phyto-ameliorants (maize, Sudanese grass, sorghum and soybeans).

Intensive growth and development of the studied phyto-ameliorant plants contributed to high yields. The yield data are shown in Table 4.

As the data in Table 4 show, high yield of the above-ground mass of phyto-ameliorant plants such as sorghum and Sudan grass was formed in the variants treated with the adaptogen, averaging 990.3 cwt/ha for Sudan grass and 803.0 cwt/ha for maize. High yield was obtained for soybean, which averaged 56.6 cwt/ha. The methods of seed treatment with the adaptogen created good conditions for growth and development of the phyto-ameliorant plants, whereby the yield rate of the grain treated with the adaptogen was higher than that of the grain without PA-2,1 treatment.

The problem of increasing the yield rate of maize on salinized degraded lands was addressed by the scientists of the Kazakh Research Institute of Soil Science and Agrochemistry n.a. U. Uspanov. They noted the positive effect of the adaptogen, and obtained 70 cwt/ha of maize grain. They also found that on low-productive soils, the plants had used a quarter more nutrients from the soil and fertilizers.

Based on the results of the field experiments, field seminars were held with farmers in the region and recommendations being implemented in the Baknur farm located in the Akdala irrigation array, were drawn up.

Conclusion

1. The results of cultivating the phyto-ameliorant plants on the soils prone to salinization have shown that sorghum, Sudan grass, soy, and maize grow rapidly and accumulate the above-ground mass. The height of Sudan grass plants reaches 266 cm, and in the variant without treatment — 257 cm; it accumulates the above-ground mass from 950 to 2,013 g.
2. The intensive growth and development of the studied phyto-ameliorant plants contributed to obtaining high yields. For instance, the average yield of sorghum green mass was about 740.4 cwt/ha without treatment with adaptogen, and in the variant with adaptogen treatment, it was 777.6 cwt/ha. The yield rate of Sudan grass without treatment amounted to 947.0 cwt/ha, and with treatment, it was 990.3 cwt/ha, while the yield rate of soy seeds was about 56.6 cwt/ha with treatment, and 54.7 cwt/ha without treatment.
3. The intensive development of phyto-ameliorant plants contributed to the reduction of salts content in the topsoil horizon (0 – 20 cm) from 0.06% (for Sudan grass) to 0.10 and 0.27% (for sorghum and soy). In the lower soil layer (20 – 40 cm), the reduction of the salt content was insignificant, and amounted to 0.04 – 0.05%; under soy, the reduction was 0.27%.

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