Modern salinity leaching technology of agricultural land reclamation (A case study from Bukhara region, Uzbekistan)

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Abstract. This article discusses the impact of the development of water-saving salinity leaching technology on the conditions of meadow-alluvial, moderately saline and medium sandy soils of Bukhara oasis according to its mechanical composition using Biosolvent compounds and the impact of the scientifically based irrigation regime on the reclamation regime of irrigated lands. In a saline-washed field with a Biosolvent combination, the Bukhara-102 variety of Gossypium received irrigation soil moisture at the beginning of vegetation when watered at 70-80-65 percent compared to LFMC, the amount of chlorine in the active (0-100 cm) layer of soil is 0,008%, the amount of sulfate is 0,036% and the amount of dry residue is 0,204% by the end of the growing season, these values are 0.020; 0.047 and 0.350%, with a seasonal salt accumulation coefficient of 2.37; 1.3; 1.72 respectively and compared to the control variant, it decreases by 0,50; 0,20; 0,13 and its yield is 40.5 cwt·ha^{-1}, with an additional 3.9 cwt·ha^{-1} of cotton yield compared to the control, which allows to save 53.7 cbm of river water used for growing 1 cwt cotton yield.

1 Introduction

Today in the world there are about 1 billion hectares of arid and saline areas, which account for 25-30 percent of the land use. Of the 275 million hectares of irrigated land, 45 million hectares are occupied by saline and saline-prone soils, while saline areas account for 62 million hectares worldwide. In 75 countries of the world, mainly located in arid (arid) regions, the problem of salinity has taken a serious toll (Australia, China, India, Mexico, Pakistan, the United States, etc.). The yield of exactly 32 million hectares of land is directly affected by the salts contained in the soil. This leads to a decrease in the yield of agricultural crops.

In connection with the negative impact of salinity on productivity and crop quality in most countries, which grow agricultural crops in the conditions of global climate change

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and increasing water scarcity in the World, extensive research is being carried out by scientists of the world on the prevention and fight against soil salinization in certain scientific directions. Multifactorial research in the field of improving salinity leaching technology in saline soils, optimizing the water-salt balance of soils with the widespread use of chemical and biological reclamation measures is important.

According to scientists around the world, salts in the soil, especially readily soluble salts, can cause serious damage to the development of agricultural crops and send a sharp drop in their yields [1-9]. There are a number of measures to improve the reclamation of irrigated lands, including phytomelioration (improving land reclamation by planting saline-resistant (halophyte) crops), biomelioration (fertilizing, growing alfalfa), chemical reclamation, electricity (permanent electric tillage of the soil) and hydraulic reclamation (removal of salts from the soil by ditches and salt washing) [1-9, 18-20].

A number of scientists from the USA, England and Australia [10] have conducted extensive research on the formation of soil salinization, as well as on combating this problem, i.e. on improving land reclamation based on a number of agro-reclamation measures. Mohammad Zaman et al. [11] argue that in order to combat salinization, it is necessary to develop a salinization control strategy that will prevent the spread of salinization and reduce the impact of salinization in the future. To achieve this goal, a number of measures were recommended, in particular, the cultivation of deep-rooted plants in areas with water scarcity, the correction of LGW through drainage and the washing of saline soils.

Based on the results of scientific studies conducted by Chinese scientists Yuzhi Zhang, Ruishan Chen and Yao Wang [12] in 1998-2015 on trends in improving land reclamation in the coastal areas of Shanghai using the ArcGIS program and the InVEST model, taking into account the successes achieved in the development of the coastal zone and contradictions in environmental policy, it was decided to take measures to improve and assess the land reclamation state, it was noted that today at the level of the government of the Chinese state a tough policy is being pursued with respect to the use of innovative ideas in restoring the land reclamation state necessary to respond to the work done earlier and prepare to the future.

S. Boltaev [13] recommended that on the conditions of moderately saline irregular soils of the Surkhandarya region, using unconventional organic-mineral composts as an ameliorant, i.e. a solution of SPER SAL and Biosolvent, along with savings in the total amount of 4500-4750 $cbm \cdot ha^{-1}$ of river water consumed for seasonal irrigation and desalination, it is possible to increase the yield of cotton by 3.8 $cwt \cdot ha^{-1}$ and improve the ameliorative condition of the soil.

The results of many years of research by Yu.Shirokova and other scientists [14] on the use of Biosolvent ameliorant in salinity leaching in moderately saline soils of Mirzaabad district of Syrdarya region showed that Biosolvent, dry residue content was 18%, chloride ion 17%, calcium ion 13%, the potassium element washed away 16 percent more salts, saved 50 percent of the water used in salt washing, and yielded an additional 7.5 $cwt \cdot ha^{-1}$ of cotton.

I. Khudaynazarov et al. [15] as a result of scientific research carried out in laboratory conditions on highly saline soils to simulate desalination using a Biosolvent compound at a concentration of 0.5-10% (normally 500-1000 $cbm \cdot ha^{-1}$ during desalination), it was found that the higher the concentration of the Biosolvent compound, the greater the desalination of salt can be achieved, as well as the leaching of divalent cations of calcium, magnesium increases the alkalinity of the soil, It was observed that sodium salt was washed in 0.05% solution (61%), 1% solution (57.1%) in 2% solution (51.4%), and potassium salt in 0.05% solution (19%). As a result of laboratory analysis, they recognized the Biosolvent compound as the optimal concentration of 2% solution.

In laboratory studies conducted by I. Khudaynazarov and others [16], it was observed that Biosolvent combination washes soil anions in 2.23 times more than water, cations in 2.20 times more, and soil porosity increased by 1.5 times. In addition, the Biosolvent compound was also used in Sayhunabad and Ak-Altyn districts of Syrdarya region and effective results were achieved. As a result of the research carried out, it was recommended that the use of biosolvent compound in the work of salinity leaching is effective in the process of salt leaching and harmless to the crop, as well as improve the soil composition.

2 Materials and methods

“Methods of field experiments, determination of water-physical, agrochemical properties of soil and the amount of salts” and “Methods of studying the agrochemical, agro-physical and microbiological properties of irrigated areas of cotton” of the Research Institute of Cotton Breeding, Seed Production and Agro-technology, and the accuracy and reliability of the data obtained were analyzed mathematically in the method of dispersion analysis in the source of B.A.Dospexov's “Methods of Field Experiments”.

3 Results and Discussion

Scientific research works were conducted in 2017-2019, the groundwater of the State Unitary Enterprise “Training and Scientific Center” of the Bukhara branch of TIIAME, located in the territory of Khoja Yakshaba rural citizens' counsel, Kagan district, Bukhara region, 1.5-2.0 meters, alluvial meadow, moderately saline, mechanical composition performed on medium sandy soils.

In the option 1 of the experiment to determine the effectiveness of saline leaching, soil salinity leaching was carried out at a rate determined on the basis of V.R. Volobuev's formula. In the variant 2 of the study, using a Biosolvent compound, the saline wash was performed at a rate 30% lower than the saline wash standard determined using V.R. Volobuev’s formula. In the variant 3 of the experiment, the traditional method, i.e., the leaching rate was performed on the basis of actual measurements.

Classification of Biosolvent compounds. The Biosolvent compound was created by scientists of the Research Institute of Bioorganic Chemistry named after O. Sodikov under the Academy of Sciences of the Republic of Uzbekistan. Substances that make up the Biosolvent compound have a biopharming property and are fully compliant with the requirements for bio-degradable substances. Biosolvent is a polymer (polyanion) with a molecular mass of 2000–5000 Daltons. It ensures that the salts in the soil dissolve easily and quickly in water and is harmless to the soil and plant. The compound decomposes under the influence of the external environment, i.e. sunlight, rain and snow. And also salinity leaching with polymaleic acid, such as SperSal 35, Stop-Sal, NON SAL, recommended among the preparations for saline soils [17].

Experimental results on soil saline leaching based on Biosolvent compound. Periodic experiments conducted in 2017–2019 took into account the amount of salts in the soil (chlorine ion, sulfate ion and dry residue), the type of salinity, its mechanical composition and the specific natural and climatic indicators of the region. In determining the rate of saline leaching, the water-physical properties of the soil were calculated by the following formula of V.R. Volobuev on one meter of soil layer (formula 1):

$$N_{s.s.l.n.} = 10000 \cdot lg\left(\frac{S_i}{S_{adm}}\right)^{\alpha}, \qquad \text{cbm}\cdot\text{ha}^{-1}, \qquad (1)$$

Note: Here: α - free salt transfer coefficient, S_i, S_{adm} - salts in the soil before saline leaching and the specified amount, in% of weight.

Comparing the three-year average results, it was found that the saline leaching rate was the highest in control option 3, using Biosolvent compound, and consumed an average of 1514 cbm·ha^{-1} more water than in saline wash option 2. During the experiments, the lowest water consumption for saline washing was observed in option 2, the average seasonal saline leaching rate was 2499 cbm·ha^{-1}, or water resources were saved by 30% compared to option 1, 38% compared to option 3 (Figure 1).

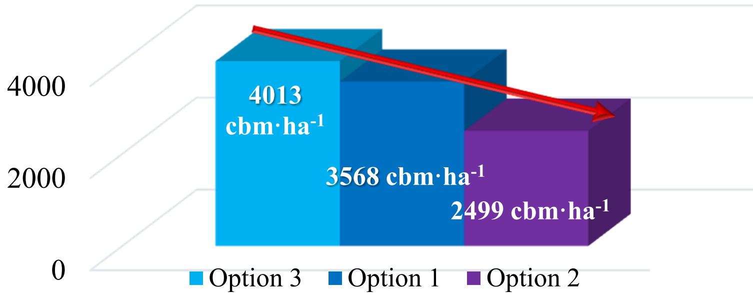

Fig. 1. Soil salinity leaching norms in the experimental field (average 3 years).

The effect of cotton on the growth, development and yield of Bukhara-102 variety was studied in a leaching soil salinity experimental field using a Biosolvent compound. Field experiments conducted on following system (Table 1):

Table 1. Field experiment system on cotton irrigation.

№	Soil moisture before irrigation,% of LFMC	Irrigation norm, cbm·ha^{-1}
1.	production control	actual measurements
2.	70–80–65	On the moisture deficit in the layer of 70–100–70 cm
Note: here: a scientifically based irrigation regime for cotton was experimented in option in which a Biosolvent compound was used in soil salinity leaching experiments. In the traditional soil salinity leaching by delyans, the control option replaced the cotton irrigation period.		

The field experiments were conducted on 2 options 3 repetitions, in both options same fertilization norm and cotton variety. Options, the furrow consists of 8 rows with a spacing of 90 cm, all the calculations were done in the middle four, the two rows next to it are protective rows. All laboratory, field, production experiments, their observation, analysis and calculations were carried out on the basis of "Methods of conducting field experiments" (UzCSRI 2007) adopted by Research Institute of Cotton Breeding, Seed Production and Agro-technology.

Irrigation regime of cotton. The aim of the research is to determine the optimal irrigation regime for saline leaching process in soils with a mineralization of 1–3 g·l^{-1}, groundwater at a depth of 1.5–2.0 m, moderately saline medium sandy soils using Biosolvent compound. In the study of the optimal irrigation regime, the norms, timing and number of each irrigation, as well as the norms of seasonal irrigation were determined, depending on the established soil moisture levels and specific climatic indicators. Every irrigation norm was measured and copied down using a “Chipoletti VCh-75” water measurement device.

In calculating the irrigation norm, taking into account the water-physical properties of the soil and the depth of wetting, calculated according to the S.N. Ryjov's (1948) formula (formula 2).

$$M = 100 \cdot h \cdot d \cdot (W_{LFMC} - W_{FM}) + k, \quad \text{cbm·ha-1}, \tag{2}$$

Note: here: W_{LFMC}– limited field moisture capacity relative to soil weight, %; W_{FM}– actual moisture before irrigation relative to soil weight, %; d– weight density of soil, g·cm-3; h– calculated soil layer, m; k– water consumption for evaporation in irrigation, $cbm \cdot ha^{-1}$ (10 percent of the moisture missing in the calculated soil layer).

During the experiments, average for 3 years in the first production control option, irrigation during the growing season was 1–3–1 system, a total of 5 times, the irrigation norm was 877–1086 $cbm \cdot ha^{-1}$, and the seasonal irrigation norm was 5049 $cbm \cdot ha^{-1}$.

When the pre-irrigation soil moisture was 70–80–65% of the LFMC, the irrigation scheme was 1–3–1, the irrigation norm was 655–752 $cbm \cdot ha^{-1}$, and the seasonal irrigation norm is 3414 $cbm \cdot ha^{-1}$, which is less than the control, and 1635 $cbm \cdot ha^{-1}$ (32%) of river water was saved. In this option, the interval between irrigations was 16–22 days, which was 3–5 days shorter than in the control variant.

Dynamics of groundwater level in the experimental field. Observation wells were installed to determine changes in the depth and mineralization of the groundwater table in the experimental cotton cultivated field. An observation well was also installed in the middle of the control field, where the groundwater level was measured every 10 days and the water samples were chemically analyzed.

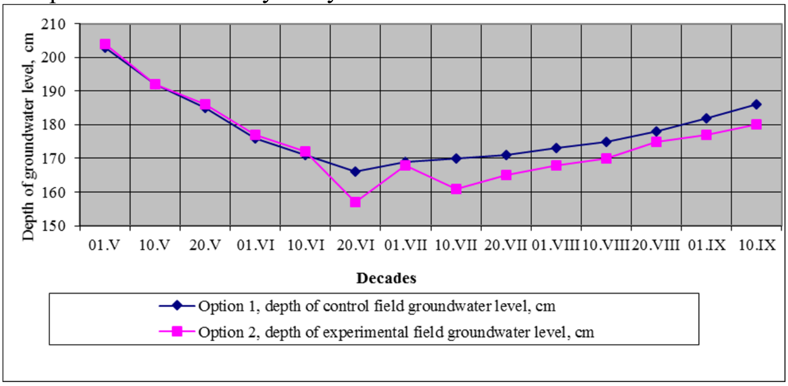

Fig. 2. Graph of changes in groundwater level in the experimental field.

Data on changes in the groundwater level in the cotton experimental field are shown in Figure 2, and the average groundwater level in the cotton experimental field at the beginning of the growing season was 203–204 cm. The results of observations of groundwater levels at the experimental production site every ten days showed that its level was high during the growing season. In the experimental field, irrigated on the basis of the optimal irrigation regime, the groundwater level in July and August of the growing season was 166–178 cm.

According to the results of the study of the dynamics of changes in groundwater levels in the experimental cotton cultivated field, the following can be concluded: the deepest groundwater level in the experimental cotton cultivated field was observed at the beginning of the growing season, averaging 203–204 cm, and during the growing season, as a result of irrigation of the experimental field and the surrounding fields in general, it was closest to the ground and result was in the control variant 157–161 cm, in the 2^{nd} variant it was 166–170 cm.

As a result of field irrigation, a certain increase in groundwater level was observed. In the control option, the amplitude of GWL changes averaged 48 cm, which was 12 cm lower than in the 2^{nd} option.

Changes in the mineralization of groundwater. The mineralization of groundwater in the experimental cotton cultivated field was 2.18–2.81 g·l^{-1}. According to the results of the determination of groundwater mineralization was middle mineralized (1–3 g·l^{-1}).

The average value of the research conducted in 2017-2019 illustrated that, in production control option 1, the mineralization of groundwater increased to 3.28–3.75 g·l^{-1} in July and August due to the large-scale cotton irrigation, i.e. the addition of groundwater-soluble salts to the groundwater along with irrigation water observed.

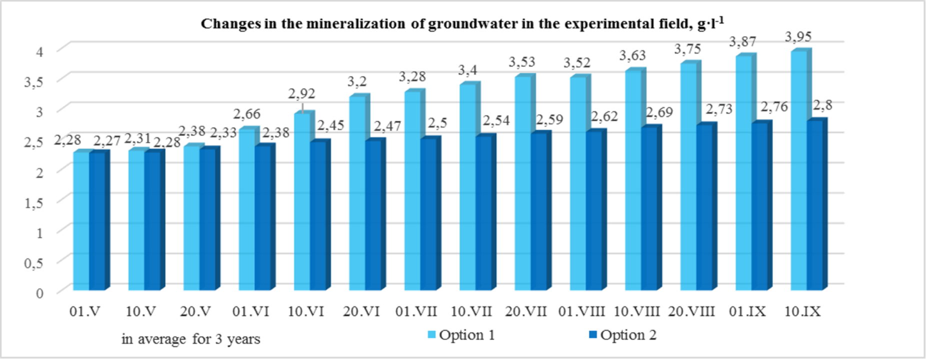

Fig. 3. Graph of changes in mineralization of experimental field groundwater.

In Option 2, where cotton was irrigated at 70–80–65% of the LFMC, excessive water consumption and less salt leaching from the soil and other minerals in groundwater were observed in the ditches. In this variant, the mineralization of salts during the growing season was observed at a minimum of 2.50–2.80 g·l^{-1}.

Thus, in the control variant of the experiment, as a result of excessive water consumption as a result of high-rate irrigation of cotton, leaching of salts and other toxic substances into the groundwater, when irrigating cotton, it was observed that the mineralization of groundwater was 0.78–1.15 g·l^{-1} higher than the irrigated variant by 70–80–65% compared to the LFMC.

Influence of saline leaching technology and irrigation regime on soil salt regime. As a result of the effect of Biosolvent compound on the salt regime of the experimental field, it was observed that from year to year the restoration of salts is reduced, i.e. optimal conditions for the development of cotton in the field are created. In Option 2, where the Biosolvent compound was used for saline washing, at the beginning of the growing season the active (0–100 cm) layer contained 0.008% chlorine, 0.036% sulfate and 0.204% dry residue, and by the end of the growing season these values were 0.020; 0.047 and 0.350 percent, respectively, the seasonal salt accumulation coefficient was 2.37; 1.3; 1.72 and respectively 0.50; 0.20; 0.13 was less than compared to the control option.

Influence of irrigation regime on cotton yield. Data on the yield of the Bukhara-102 cotton variety in the experimental cotton cultivated in the research field in 2017-2019 shows that in control option 1, an average of 138.0 cbm of river water was used to grow 1 quintal of cotton and a yield of 36.6 cwt·ha^{-1}. In the second option, when the soil moisture before irrigation was 70-80-65% relative to LFMC, 84.3 cbm of river water was used on cultivation 1 quintal of cotton, and the total yield of cotton was 40.5 t·ha^{-1}. According to the results of the study, scientifically based pre-irrigation soil moisture is maintained at 70–80–65% relative to the LFMC, with an additional not only 3.9 quintals of cotton per hectare of Bukhara-102 variety of cotton, but also 1 quantial of cotton allowed to save 53.7 cbm of river water.

Cost-effectiveness of soil salinity leaching and holding cotton irrigation process with using Biosolvent compound. In determining the economic efficiency of medium-fiber cotton Bukhara-102, the cost of all agro-technical measures was calculated according to the approved technological map for the region, including pumping water for irrigation, as well as the cost of Biosolvent and its application.

Irrigation of saline soils with Biosolvent and irrigation of cotton with pre-irrigation of soil moisture by 70-80-65% compared to LFMC, ie additional cost of 533.3 thousand soums compared to the control option, increased the yield of cotton by 3.9 t·ha^{-1}, and an additional net profit of 453.6 thousand sums was achieved, amounting to 2525.7 thousand soums. The level of profitability was 32.0%, which is 3.6% higher than the control.

4 Conclusions

On the basis of research on the impact of water-saving technology of saline soil leaching on soil reclamation and cotton yields in the conditions of meadow-alluvial, moderately saline and medium sandy soils of Bukhara oasis groundwater level of 1.5–2.0 m and mineralization of 1–3 g·l^{-1}, the following conclusions were done:

1. During the researches, the lowest water consumption for leaching soil salinity was observed on using Biosolvent compound, the average seasonal saline leaching norm was 2499 cbm·ha-1, or 38% of river water was saved compared to salt leaching in the control option.

2. When cotton soil was irrigated at 70–80–65% relative to the LFMC before irrigation, the irrigation scheme was 1–3–1, with an irrigation norm by 655–752 cbm·ha^{-1} and a seasonal irrigation norm was 3414 cbm·ha^{-1}, and 1635 cbm·ha^{-1} (32%) river water was saved compared to the control option.

3. Using Biosolvent compound in soil salinity leaching norm of 8.0 liters per 1 hectare in moderately saline soils, along with high efficiency in leaching of salts accumulated in the soil, increase the solubility of salts, increase soil water permeability in an average of 3 years, the chlorine ion content was 23%, the sulfate ion content was 20%, and the dry residue content was 13 percent lower.

4. According to the results of the study of the dynamics of changes in groundwater levels in the experimental cotton cultivated field, the following can be concluded: the deepest groundwater level in the experimental cotton cultivated field was observed at the beginning of the growing season, averaging 203–204 cm, and during the growing season, as a result of irrigation of the experimental field and the surrounding fields in general, it was closest to the ground and result was in the control variant 157–161 cm, in the 2nd variant it was 166–170 cm. Thus, in the control variant of the experiment, as a result of excessive water consumption as a result of high-rate irrigation of cotton, leaching of salts and other toxic substances into the groundwater, when irrigating cotton, it was observed that the mineralization of groundwater was 0.78–1.15 g·l^{-1} higher than the irrigated variant by 70–80–65% compared to the LFMC.

5. Irrigation of saline soils with Biosolvent and irrigation of cotton with pre-irrigation of soil moisture by 70-80-65% compared to LFMC, additional cost of 533.3 thousand soums compared to the control option, increased the yield of cotton by 3.9 t·ha^{-1}, 1 quantial of cotton allowed to save 53.7 cbm of river water and an additional net profit of 453.6 thousand sums was achieved, amounting to 2525.7 thousand sums. The level of profitability was 32.0%, which is 3.6% higher than the control.

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