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RESULTS OF ENVIRONMENTAL STABILIZATION THROUGH THE USE OF CHEMICAL MELIORANTS IN IMPROVING THE MELIORATIVE STATE OF SALINE SOILS

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Abstract. *This article presents the results of field experiments conducted to improve the melioration status of moderately saline soils in the Karshi, Kasbi, and Mirishkor districts of Kashkadarya Region using the chemical ameliorant SPERSAL and to conserve water used for salt leaching. Improving the melioration status of saline soils in Kashkadarya Region requires 8,000–10,000 m³/ha of water per season. Allocating this amount of water for salt leaching is impossible in the region, as 82% of the water used for irrigation in our region comes from transboundary rivers such as the Amu Darya and Zarafshon Darya. The remaining 18% of the water is generated in our region. The observed increase in air temperatures in the region requires the economical use of available water resources. For this purpose, it is advisable to use water-saving irrigation technologies, such as drip and sprinkler irrigation, not only for watering but also for leaching saline soils. This article discusses improving the reclamation of saline lands using chemical drainage technologies.*

Key words: *innovative technology, chemical meliorant SPERSAL, irrigation rate, furrow irrigation, soil, salinization, water-saving technology.*

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SHO‘RLANGAN TUPROQLARNI MELIORATIV HOLATINI YAXSHILASHDA KIMYOVIY MELIORANT QO‘LLASH ORQALI EKOLOGIK HOLATNI BARQARORLASHTIRISH

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Annotatsiya. *Maqolada Qashqadaryo viloytining Qarshi, Kasbi va Mirishkor tumanlari hududlarining o‘rtacha sho‘rlangan tuproqli yerlari meliorativ holatini yaxshilash maqsadida SPERSAL kimyoviy meliorantini qo‘llab, tuproq meliorativ holatini yaxshilash va sho‘r yuvishga sarflanadigan suv tejamkorligi masalalari bo‘yicha o‘tkazilgan dala tajribalari natijalari keltirilgan. Qashqadaryo viloyatining sho‘rlangan tuproqlarining meliorativ holatini yaxshilash uchun bir mavsumga 8000 – 10000 m^3/ga suv zarurati mavjud. Viloyatda sho‘r yuvish uchun bu miqordagi suvni ajratishni iloji yo‘q. Chunki, mintaqamizda sug’orish uchun ishlatiladigan suvning 82% Amudaryo va Zarafshondaryo kabi tranchegaraviy daryolar orqali keltiriladi. Qolgan 18% suv esa viloyatimizda shakllangan suvlar hisoblanadi. Mintaqada kuzatilayotgan havo haroratining ko‘tarilishi mavjud suvlardan tejamli foydalanishni taqozo etadi. Buning uchun tomchilatib sug‘orish, yomg‘rlatib sug‘orish kabi tejamkor sug‘orish texnologiyalari qo‘llash faqat sug‘orishda emas, balki zax qochirishda ham qo‘llash maqsadga muvofiq. Mazkur maqolada aynan zax qochirishda kimyoviy texnologiyalarni qo‘llab, sho‘rlangan yerlarning meliorativ holatini yaxshilash masalalari yoritilgan.*

Kalitli so‘zlar: *innovatsion texnologiyalar, kimyoviy meliorant SPERSAL, sug‘orish me’yori, egatlab sug‘orish, tuproq, sho‘rlanish, suv tejamkor texnologiya.*

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УЛУЧШЕНИЯ МЕЛИОРАТИВНОГО СОСТОЯНИЯ ЗАСОЛЕННЫХ ПОЧВ С ПРИМЕНЕНИЕМ ХИМИЧЕСКИХ МЕЛИОРАНТОВ ДЛЯ СТАБИЛИЗАЦИИ ОКРУЖАЮЩЕЙ СРЕДЫ

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Аннотация. *В статье представлены результаты полевых экспериментов, проведенных по вопросам улучшения мелиоративного состояния среднезасоленных почв на территориях Каршинского, Касбийского и Миришкорского районов Кашкадарьинской области с использованием химического мелиоранта SPERSAL и экономии воды, используемой для выщелачивания солей. Для улучшения мелиоративного состояния засоленных почв в Кашкадарьинской области за сезон требуется 8000–10000 м³/га воды. Выделить такое количество воды для выщелачивания солей в регионе невозможно, поскольку 82% воды, используемой для орошения в нашем регионе, поступает по трансграничным рекам, таким как Амударья и Зарафшондарья. Остальные 18% воды формируются в нашем регионе. Наблюдаемое в регионе повышение температуры воздуха требует экономичного использования имеющихся водных ресурсов. Для этой цели целесообразно использовать вщдосберегаюшие технологии орошения, такие как капельное и дождевальное орошение, не только для полива, но и для промывки засоленных почв. В данной статье рассматриваются вопросы улучшения мелиоративного состояния засоленных земель путем применения химических технологий именно при рассолении.*

Ключевые слова: *инновационная технология, химический мелиорант SPERSAL, поливная норма, бороздковой полив, почва, засоление, водосберегающая технология.*

Introduction

The volume of water in the Aral Sea is now less than 10 percent of its 1960 level. The total water volume has decreased by almost 15-fold. The remaining water is divided into three separate basins: the West Aral Sea, the East Aral Sea, and the Small Aral Sea. Over the past 55 years, the new Aralkum desert has emerged on the dry seabed of the Aral Sea, covering an area of 5.2 million hectares. Like any other desert in the world, the Aralkum lacks the infrastructure necessary for people to lead fulfilling lives, for socio-economic development, and for supporting biodiversity and the ecosystem, as well as other conditions essential for social progress and well-being. Climate change is one of the main factors exacerbating the region's pressing socio-economic, environmental, and public health problems. A large part of the Aral Sea region is arid, and a significant portion of Uzbekistan's land area is classified as an arid zone susceptible to degradation and desertification [1].

The annual volume of Central Asia's water resources is approximately 116 km3, 90% of which is formed by two major river systems: the Amu Darya and the Syr Darya. The volume of groundwater in the region is approximately 43.49 km3. About 80% of water resources are used for agriculture, nearly 7-8% for industry, and the remainder for domestic use, the service sector, and other purposes [14].

In the irrigated agricultural regions of Central Asia, the annual river water resources amount to 114 km3, including 74.7 km3 in the Amu Darya basin (along with the Zarafshan and Kashkadarya rivers), 39 km3 in the Syr Darya basin, and 2.4 km3 in the Tejen and Murghab basins. Water resources are unevenly distributed geographically; although they originate in the mountains, they are primarily used on the plains via an extensive network of irrigation canals [3].

According to estimates, the use of drip irrigation technology in cotton cultivation in Uzbekistan in 2020 resulted in the following average savings and improvements per hectare: water consumption was reduced by 40-50%; fuel was saved by 60%; the efficiency of mineral fertilizers increased by

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30%; costs for labor and wages were saved; the biological maturation period of cotton was shortened by 12-15 days; and the yield increased by 20-30 centners [3].

Materials and Methods

In our republic, an additional 2,500–6,000 m^3/ha of water is required for salt leaching in areas with varying degrees of soil salinity. Such challenges necessitate the development of new water-saving technologies to improve the reclamation status of irrigated lands.

These circumstances provide a scientific basis for our researchers to work on solving a number of environmental problems. From this perspective, we present our scientific research conducted on the saline soils of the Karshi, Kasbi, and Mirishkor districts of the Kashkadarya region.

In 2008–2010, we conducted scientific research based on the following variants [8] to improve the irrigation technique for the "Bukhara-6" cotton variety and to scientifically substantiate the effect of the SPERSAL chemical ameliorant on the soil's water-salt regime. The study was performed in the Karshi district, under conditions of moderately saline, sulfate-chloride type, heavy-textured, meadow-takyr soils:

1. Conventional cotton seed sowing, furrow irrigation based on moisture deficit (Control).
2. Sowing seeds under plastic film, with furrow irrigation at 70-70-60% of FFC.
3. Applying chemical ameliorant (5 kg/ha) to the soil, sowing seeds under plastic film, with furrow irrigation at 70-70-60% of FFC.
4. Sowing seeds under plastic film, with furrow irrigation at a rate 25% lower than the norm, based on the 70-70-60% of FFC regime.
5. Sowing seeds under plastic film, with furrow irrigation at a rate 25% higher than the norm, based on the 70-70-60% of FFC regime.
6. Applying chemical ameliorant (5 kg/ha) to the soil, sowing seeds under plastic film, with furrow irrigation at a rate 25% higher than the norm, based on the 70-70-60% of FFC regime.
7. Sowing seeds under plastic film, with furrow irrigation at a rate 50% higher than the norm, based on the 70-70-60% of FFC regime.
8. Applying chemical ameliorant (5 kg/ha) to the soil, sowing seeds under plastic film, with furrow irrigation at a rate 50% higher than the norm, based on the 70-70-60% of FFC regime.

For this research, we selected an experimental field with a plot size of 1440 m2, a slope of 0.002, a furrow length of 200 m, and row spacing of 0.9 m. The research site has an open drainage channel where the groundwater level is 2.2–2.5 m below the field surface. The number of replications was four. The pre-irrigation soil moisture was set at a 70-70-60% system relative to FFC for the "Bukhara-6" variety, as is standard for this region [4].

To conduct the research, we first experimentally determined that the field's final field capacity (FFC) was 21.6% and the soil bulk density was 1.44 g/cm3. When we calculated the irrigation norm using S.N. Ryzhov's formula for the 70-70-60% of FFC regime, we determined it to be 780 m3/ha for the 0-70 cm layer during the pre-flowering and squaring period. We also determined that irrigations during the flowering-squaring to ripening period amounted to 1083 m3/ha for the 0-100 cm layer [5].

The agrotechnical measures applied in the experimental field were carried out based on the scientifically substantiated farming system developed by PSUEATI and its Kashkadarya branch. The annual mineral fertilizer rates were NPK-200, 140, and 70 kg/ha. Of this, 50% of the phosphorus and 70% of the potassium fertilizers were applied before plowing. The remaining phosphorus was applied during flowering, potassium during squaring, and nitrogen was applied at the 2-3 true leaf stage, during squaring, and during the flowering period.

During the research, the following calculation, determination, and observation were performed:
- description of the soil profile by morphological features and genetic horizons;
- determination of soil mechanical composition;
- determination of volumetric and specific soil masses;
- determination of soil water absorption and minimum water capacity;
- determination of the capillary moisture rise height;

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- determination of humus, total and mobile nitrogen, phosphorus, and potassium content in the soil;
- determination of the amount of water-soluble salts in soil, irrigation water, drainage, and groundwater;
- studying the dynamics of soil moisture;
- maintaining records of water supplied to the experimental plot for leaching and irrigation;
- conducting phenological observations of cotton growth and development and accounting for cotton yields.

In organizing and performing the aforementioned determinations, observations, and laboratory analyses, the methods of UzPITI, ISMITI, and TIQXMMI used in most research works on land reclamation and irrigated agriculture were utilized. To obtain detailed information about the experimental plot, soil profiles, salt surveying points, permanent observation sites, observation wells, and hydrometric posts were installed.

When installing elements of furrow irrigation technology on saline lands, the cross-section of the furrow changes, which affects the water-permeable capacity of the furrow. For example, S.M. Krivovyaz (1981) believes that on a small slope, the furrow cross-section should be filled to 0.6 h (where h is the furrow depth, cm). This is explained by the fact that mineral fertilizers, especially easily soluble nitrogen fertilizers, deposited in the inter-row spacing are washed away when the water movement in the furrow exceeds 60%. Our observations regarding the state of the furrow cross-section showed that at low plasticity up to 6.8 and a natural slope angle of 0.56-0.71 (slope angle tangent), the slope decreases to 0.53-0.67 units when the furrow is moistened by the gravitational force of soil particles equal to 0.012...0.009 kg/cm2.

In the presence of capillary saturation from groundwater and the influx of salts through it, this slope angle decreases to 0.42-0.56, i.e., slope erosion is observed. This situation occurs through the following relationship:

$$\theta = \frac{m_o \cdot \gamma_{gr}}{\gamma_g} ,$$

where θ - in saline soils, the failure angle of the furrow slope, the wetted angle of the slope; γ_g – bulk density of the soil above the furrow, g/cm3; γ_{gr} – bulk density of the sub-plow layer, g/cm3.

The presence of salts in the soil reduces the friction forces between soil particles, which hold soil aggregates on the slope, by 1.3–1.5 times. We used this situation in the process of measuring the cross-section of the furrow, which depends on the length of the furrow and the water flow rate in it. That is, the cross-sectional area ω of the furrow is determined.:

$$\omega = 0{,}048 \frac{0{,}6q}{i^{0{,}4}} ,$$

where i – ground slope.

Based on the above situation, the water depth depends on its flow rate; to determine the flow depth in the furrow, we used the following relationship:

$$q = 0{,}97 \cdot i^{0{,}5} h,$$

where q- is the water flow rate, in l/s; h - is the water depth in the furrow, determined by the stability condition of the wetted slope, in cm; i- is the furrow gradient (for low-slope areas). We used the ratio of dry to wetted slopes to determine the furrow depth (H).

$$H = \frac{(0{,}5a - c)m_o}{1 + \sqrt{1 + \frac{m_o}{m_1}}},$$

where a – furrow spacing, cm; c – distance from the water level to the top of the furrow, cm; mo – dry; m 1 – wet slope (tg θ).

Thus, the furrow depth obtained for the experimental plot with parameters a = 90 cm, c = 4.8 cm, m_o = 0.62 cm; m_1 = 0.59 is:

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$$H = \frac{(0{,}5 \cdot 90 - 4{,}8) \cdot 0{,}62}{1 + \sqrt{1 + \frac{0{,}62}{0{,}59}}} = 23 \text{ sm.}$$

Plowing was carried out annually in the autumn using trailed PYA-3-33 plows at a depth of 30-35 cm. To preserve soil moisture and control weeds, harrowing and harrowing were performed annually in late March or early April, and high-quality pre-sowing work was carried out in the experimental field on April 19, 2008, March 31, 2009, and March 20-22, 2010. During the row-by-row sowing of seeds according to the 90x10x1 scheme, inter-row cultivation was performed 5-6 times using a KRX-4 cultivator, and 1-2 manual weeding operations were performed against various types of weeds [6-7].

During the growing season, chemical agents were used to control cotton diseases and pests; to prevent cotton growth and overgrowth, ensure the growth of lateral branches, and achieve higher yields, two manual cuttings were performed. The harvested cotton was collected in 3 harvests [8-9].

According to the composition of the SPERSAL chemical ameliorant, the base consists of polymer butenedietic polymalenic acid, 30% homopolymer, 6% linear sulfate alkylbenzene, and 64% other inert substances [5, 9].

The essence of the physicochemical effect of the SPERSAL chemical ameliorant is as follows: when SPERSAL chemical ameliorant is applied to the soil, an exchange reaction of calcium and magnesium cations occurs as a result of the displacement of sodium cations in the soil absorption complex [6-10].

Water-soluble salts such as chloride, sodium sulfide, and sodium bicarbonate, which remain in the soil of the plant's root layer in ionic form, dissolve with the water provided for crop irrigation and fall into the lower layers. The sown area is removed from the soil layer through horizontal open drainage channels with the required working condition.

When the SPERSAL chemical meliorant is applied, an exchange reaction occurs in the soil. When applying the required amount of SPERSAL chemical meliorant to the soil before leaching, depending on the degree and type of salinity, the amount of specific costs for desalination of the water supply and the soil in which the root layer of the plant is located is reduced. That is, certain conditions will be created to reduce the leaching rate. Due to changes in the water-physical properties of the soil, the intensity of water absorption into the soil increases, and elements of irrigation technology also change [11-12].

According to the recommendation of the Swiss firm "Sibo-Novartis," the application rate of the SPERSAL chemical ameliorant in the conducted experiments was 5 kg/ha.

Results and Discussion

In order to study the change and direction of the water regime in the soil root layer, individual elements of water balance were identified in the 0-100 cm soil layer. Based on the average values obtained during the years of the study, the total water consumption from the cotton field across the compared variants ranged from 9,677 m3/ha (variants 7 and 8) to 10,398 m3/ha (variant 1).

Experimental data show that with an increase in soil moisture by 25 and 50% relative to the norm of 70-70-60% of FC, the water consumption per unit area decreases. That is, while the water consumption in the control variant was 10398 m3/ha, in the 2nd and 3rd variants using polyethylene film and the SPERSAL chemical ameliorant, the water consumption decreased by 515 m3/ha. When the irrigation rate was reduced by 25% relative to FC, this difference was 820 m3/ha compared to the control (variant 4). When sowing seeds under film and applying SPERSAL to the soil at a rate of 5 kg/ha (variants 5 and 6), the difference in total water consumption was very small and amounted to 106 m3/ha [12-14] (Figure 1).

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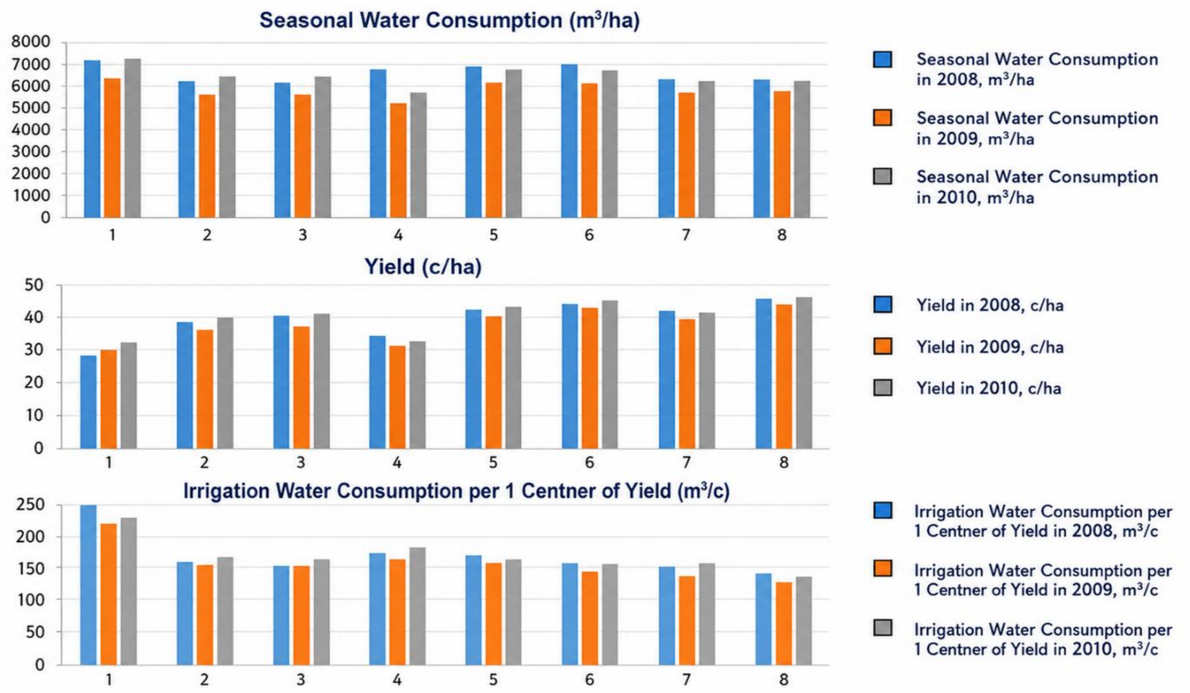

Figure 1. Seasonal water consumption, yield, and irrigation water consumption for obtaining 1 centner of raw cotton by variants during the experimental years.

Under the same experimental conditions, but with the irrigation rate increased by 50% relative to the 70-70-60% of FFC moisture regime (variants 7 and 8), 721 m3 less water was used per hectare of the cotton field compared to the control variant. At the given total water consumption volumes, the amount of atmospheric precipitation in variants 1, 2, and 3 was almost identical, accounting for 24.3–25.3%. Characteristically, when moisture was increased by 25% (variants 5 and 6) and 50% (variants 7 and 8) relative to the 70-70-60% of FFC regime, the share of atmospheric precipitation in the total water consumption was nearly the same, at 19.6% and 18.6%, respectively [8, 10] (Figure 1).

As the experimental data show, the greatest reduction in the amount of salts in the 0–100 cm soil layer at the end of the growing season compared to the spring period was observed in variant 7, which was irrigated at rates increased by 50%, and in variant 8, where an additional 5 kg/ha of SPERSAL chemical ameliorant was applied. In these variants, it was observed that the total amount of salts decreased by 2.4–2.5 times, the chloride ion by 2.3–2.6 times, and the sodium and potassium content decreased 0.83–1.81 times (Figure 1).

The calculation of the hypothetical salt composition and the change in its quantity during the period under review showed the following. In the studied soil layer, water-soluble salts were arranged in descending order: $CaSO_4$, $NaCl$, Na_2SO_4, $MgSO_4$, and $Ca(HCO_3)_2$; $MgCl_2$ was not observed in the soil. During the growing season, a decrease in water-soluble salts was noted in almost all variants, with the exception of variants 1 and 2, where the Na_2SO_4 content increased by 1.3 and 1.8 times, respectively. Very little change was observed in the amounts of $Ca(HCO_3)_2$ and Na_2SO_4. In the soils of variants 5, 6, 7, and 8, the amount of $CaSO_4$ decreased by 2.3, 3.6, 3.7, and 3.9 times, respectively; $MgSO_4$ by 2.3, 4.4, and 4 times; and NaCl by 2.2, 2.3, 2.3, and 2.6 times [7, 12, 13, 14]. 3.7 and 3.9 times; $MgSO_4$-2, 3; 4.4 and 4 times, NaCl - 2.2; 2.3; As can be seen from the data in the table, seasonal irrigation rates decreased in variant 5, irrigated at a 25% increased rate; in variant 6, which was treated with an additional 5 kg/ha of SPERSAL chemical ameliorant; in variant 7, irrigated at a 50% increased rate; and in variant 8, where an additional 5 kg/ha of ameliorant was applied. This is because the soil of the experimental plot is heavy loam. Due to the ability of such soils to retain water for a long time, the interval between irrigations extended from 17–19 days to 27–28 days. As a result, while the control variant was irrigated 7 times according to the 2-4-1 scheme, variant 5, with a 25% increased irrigation rate, was irrigated 5 times according to the 1-3-1 scheme. Similarly, variant 6, irrigated under the same regime as variant 5 but with an additional 5 kg/ha of SPERSAL chemical ameliorant, was also irrigated 5 times according to the 1-3-1 scheme.

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Variant 7, with a 50% increased irrigation rate, was irrigated 4 times according to the 1-2-1 scheme, and variant 8, irrigated under the same regime as variant 7 but with an additional 5 kg/ha of SPERSAL chemical ameliorant, was also irrigated 4 times according to the 1-2-1 scheme [8-14].

In variant 5 of the conducted experiments, 6960 m^3/ha of water was used, and the average three-year cotton yield was 41.27 c/ha; in variant 6, 6960 m^3/ha of water was also used, and the yield was 43.5 c/ha. In variants 7 and 8, these indicators were 41.2 and 45.0 c/ha, respectively.

Based on the data provided, regarding the irrigation water consumption to produce 1 centner of cotton, the highest water consumption was in the control variant at 232.9 m^3/c, while in variants 5 and 6, it was 161.0 and 152.6 m^3/c, and in variants 7 and 8, this figure corresponded to 149.27 and 136.3 m^3/c [8-13].

Based on the data above, we can say that when irrigating with a 25% increased rate relative to FFC, the yield increased due to a decrease in the amount of salts in the soil. It was determined that when irrigating under the same regime with an additional application of 5 kg/ha of SPERSAL chemical ameliorant, the yield increased by another 2.23 c/ha. In variant 7, which was irrigated with a 50% increased rate, this indicator did not show a significant change. However, a significant increase in yield was observed when irrigating under the same regime with the additional application of the ameliorant.

Conclusion

In soils with moderately saline sulfate-chloride soils of heavy mechanical composition, increasing the water supply for irrigation by 25–50% from the deficit (5; 6; Variants 7 and 8) with the application of an additional 5 kg/ha of SPERSAL chemical meliorant before irrigation, the reclamation state of the soil is improved, and the yield increases by 3-5 c/ha per hectare.

Based on the results of experiments conducted to conserve water in the conditions of water scarcity in the Karshi district (Variant 4), it was established that irrigation at rates reduced by 25% relative to FC by 70-70-60% on medium-saline soils is inappropriate. This is because the irrigation regime of 70-70-60% of field capacity is insufficient for moisture reserves in the soil layer, and the number of irrigations increases due to the reduction of the inter-irrigation period. Due to the low efficiency of irrigation equipment and irrigation networks, water losses increase during each irrigation.

These data were introduced into production in 2019 on an area of 5 (five) hectares of the "Mahmudov Alpomish" farm belonging to the "Chillabuloq" WUA of the Kasbi district of the Kashkadarya region, and in conditions of moderately saline soils with a heavy mechanical composition of the Mirishkor district, on an area of 6 (six) hectares of the "Bukhoro-6" cotton variety of the "Umidullaev Shamshodbek" farm belonging to the "Mirishkor Chashmasi" WUA, and a certificate from the Ministry of Water Resources of the Republic of Uzbekistan was obtained regarding the positive results obtained.

Consequently, this technology can be utilized as innovative techniques and technologies for the sustainable development of agriculture in the Aral Sea region under conditions of climate change and water scarcity. In areas with water scarcity, the reclamation state of saline soils is improved by applying SPERSAL chemical ameliorant at a rate of 5 kg/ha before the first irrigation and organizing irrigation at rates with a 25% and 50% increase in field capacity, or by applying the same rate before leaching during the dry season. As a result, instead of 3500-4500 m3/ha, it is possible to achieve the intended goal using less than 2500-3000 m3/ha of water. In the same way, we will increase the efficiency of water use. Therefore, this method can be classified as a "Water-saving technology for improving the reclamation state of soils."

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