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# Impact of changes in groundwater regime on crop yields

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**Abstract.** In Uzbekistan, groundwater use in agriculture is 3-5 km$^3$ per year. This creates the basis for achieving high yields of agricultural crops in conditions of low water. The article presents the results of scientific research on the impact of groundwater level, salinity, amount, and rate of irrigation on the yield of winter wheat in the Syrdarya region in an area with a groundwater level of 1-3 m and a mineralization of 1-3 g/l. The experiments were carried out in slightly, medium, and highly saline areas of the Syrdarya region. As a result, at a groundwater level of 1.5 m in areas with high salinity, the yield was 26.8 q/ha, in areas with medium salinity – 51.2 q/ha and in areas with low salinity – 58.5 q/ha.

## 1 Introduction

The socio-economic development of our country, as in other regions, largely depends on natural resources, particularly water resources. Today, the rational use of water has become one of the key issues for the sustainable development of our country. This is becoming increasingly important and relevant in the new economic, political, social, and environmental processes taking place in the region due to the shortage of water resources and the deterioration of their quality [2-4]. Studies show that with the introduction of water-saving technologies in the use of water resources in the country, the reduction of water consumption, the regulation of river flow, with a constant increase in the efficiency of irrigation and drainage systems, as well as the creation and planting of drought-resistant crop varieties, it is possible to mitigate water shortages [5-7;].

Along with this, to solve these problems, the most rational way is to improve the method of managing the reclamation regime of irrigated lands, as well as the method of directing groundwater for irrigation of agricultural crops, to mitigate the shortage of water resources [2, 3, 8, 9, 10]. An important task in research is to improve the methods of managing the reclamation regime of irrigated lands and the possibility of directing groundwater for irrigation of agricultural crops on meadow soils of the Syrdarya region when cultivating winter wheat [2, 3, 11, 12].

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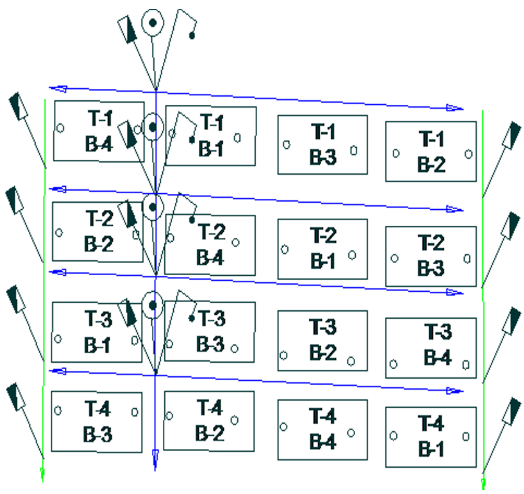
## 2 Materials and Methods

In conditions of low water, experiments were carried out on sub-irrigation of winter wheat on the land farms of A. Khodzhaev, "Chinor", and "Baraka" of the Khavas district of the Syrdarya region.
All experiments were carried out in four repetitions, and the area of the option was 2500 $m^2$ (50 m long and 50 m wide). In the plan, the plots were systematically arranged in four tiers (according to the groundwater level) [2, 3, 13, 14, 15].




**Conventions**

B-1, B-2 - options
T-1, T-2, - repetitions
- temporary tray
- collector
- field road
-observation calodus
- collector locking device
- device water meter

**Fig. 1.** Schemes for conducting experiments

To determine the level and degree of groundwater mineralization in the experimental plots, 4 wells were drilled in the form of an envelope to the depth of groundwater, and during the season, every 10 days, measurements were made using a Progress-2 conductometer [2;3;16;17;18].

## 3 Results and Discussion

In particular, in the zone with increased salinity of the farm "Chinor" with a groundwater level of 1.5 m, the yield was 26.8 q/ha, in areas with medium salinity – 51.2 q/ha and in areas with low salinity – 8.5 q/ha (Fig. 2). Along with this, on moderately saline soils of the Baraka farm, with a groundwater level of 2.0 m, the wheat yield was 54.8 q/ha, with a groundwater level of 0.8-0.9 m – 51.7 q/ha [2, 3].

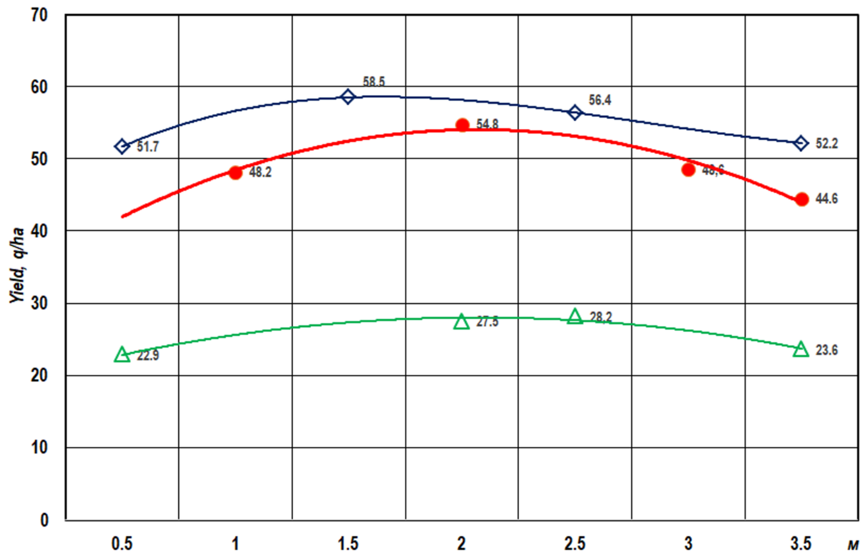



**Fig. 2.** Changes in yield of winter wheat depending on level of groundwater

On the sown areas of A. Khodzhaev's farm with low salinity, the average wheat yield was 56.4 t/ha at a groundwater level of 2.5 m and below, and at a groundwater level of 0.7-0.9 m, the yield was – 51.7 t/ha (Fig. 3).

When studying the change in the yield of winter wheat on the degree of soil salinity on highly saline soils of the Chinor farm at a groundwater level of 2.3 m, the yield of winter wheat according to the FAO was 2-12 dS/m or 80-100% of the total yield.

On moderately saline soils of the Baraka farm, with a groundwater level of 2.0 m, the yield of winter wheat was 4–16 dS/m or 57–100% of the crop, also, on slightly saline fields of A. Khodzhaev's farm, with a groundwater level of 1.8 meters, the average yield was 2-12 dS/m or 80-100% of the total yield.

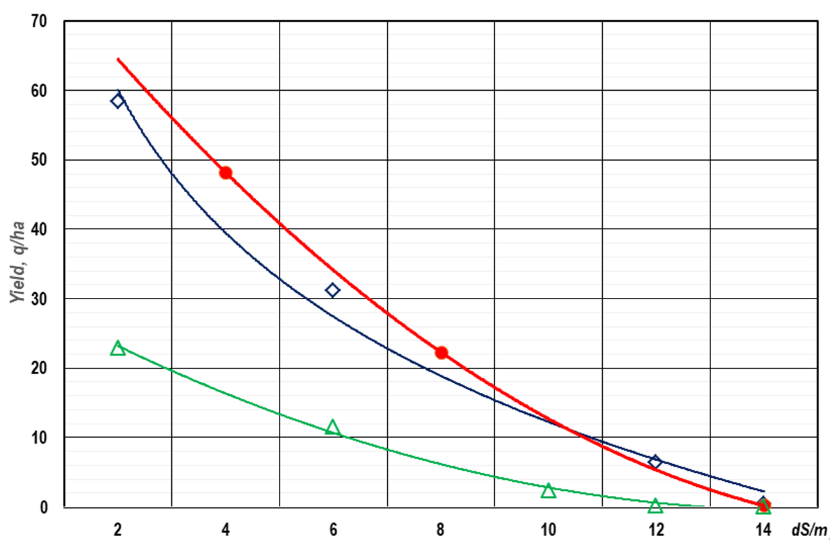



**Fig. 3.** Changes in yield of winter wheat depending on soil salinity

Figure 4 shows that when winter wheat was irrigated 2-3 times on highly saline soils of the Chinor farm, the average yield was 23.0 q/ha, according to FAO 16 dS/m or 57% of the total yield.

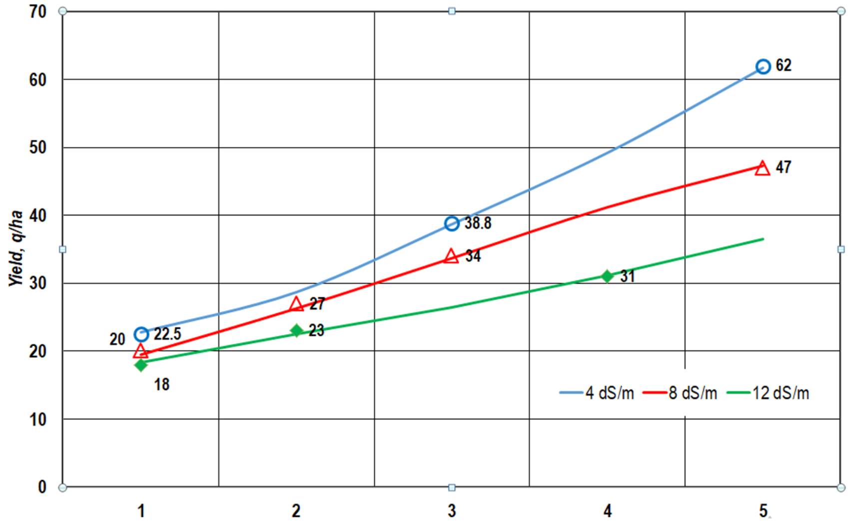



**Fig. 4.** Change in yield of winter wheat depending on number of irrigations

On the sown areas of medium salinity of the Baraka farm, when winter wheat was irrigated 3-4 times, the average yield was 38.8 t/ha, which was 8 dS/m according to FAO or 98% of the total yield. In addition, in the fields with low salinity of the farm of A. Khodzhaev, when winter wheat was watered up to 5 times, the average yield was 62.0 q/ha, according to FAO - 4 dS/m or 100% of the total yield [2;3].
On highly saline soils of farms of WUA im. Kh.The average yield of Norchaeva, with an irrigation rate of 2100 m3/ha, in the farm "Chinor" - 28.8 t/ha, in the farm "Baraka" – 34.5 t/ha, in the farm of A. Khodzhaev – 39.7 t/ha.

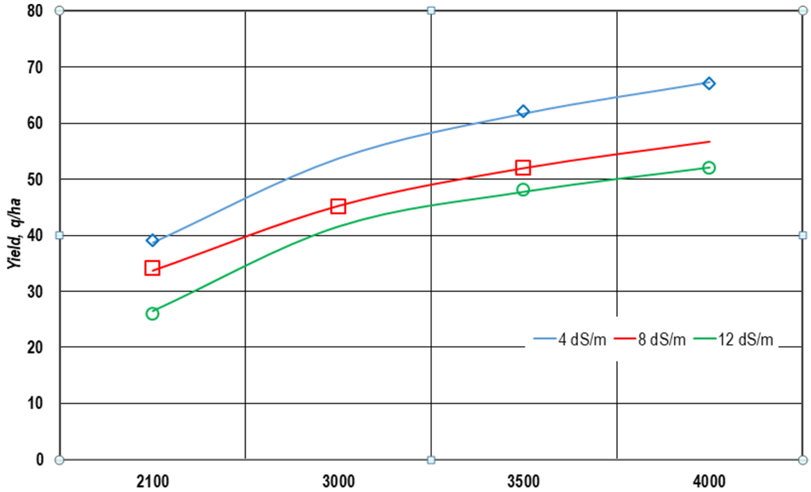



**Fig. 5.** Change in yield of winter wheat depending on irrigation rates

With an irrigation rate of 2800 $m^3$/ha, the average yield of winter wheat was: on the farm "Chinor" – 36.3 t/ha, "Baraka" – 40.6 t/ha and A. Khodzhaev – 44.9 t/ha (Fig. 5).
Based on the above, the following dependence is obtained:

$$\overline{Y} = f\left(\frac{h_{gw}}{H_{dr}}, C_T, n, M\right) \quad (1)$$

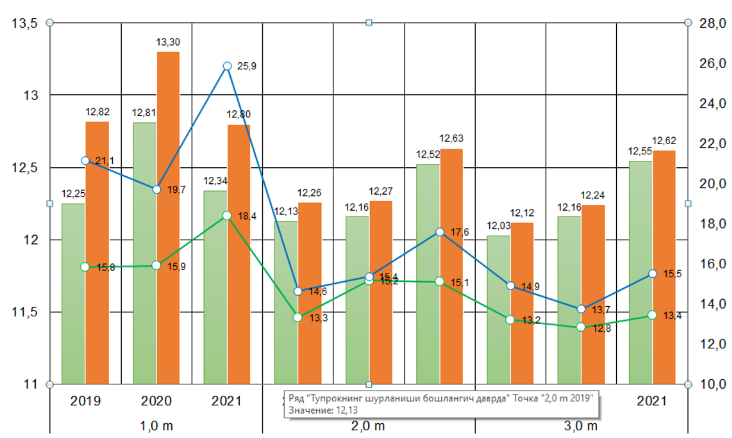
here: $\frac{h_{gw}}{H_{dr}}$ is the ratio of the depth of groundwater to the depth of horizontal drainage; $C_T$ is the degree of salinity of the soil, dS/m; $n$ is the amount of watering; $M$ is irrigation rate of irrigation, $m^3$/ ha.
Based on this, the formula for predicting the yield of winter wheat has the following form:

$$y = 0.0061 \cdot h^{\alpha} \cdot S^{\beta} \cdot n^{\gamma} \cdot M^{\delta} \quad (2)$$

here:

*α=20.95 + 2.628 ln n ln M– 16.93 ln S – 1.713 ln S ln n ln M*
*β = 4.295 + 0.4155 ln n ln M –2.882 ln n – 0.63 ln M*
*γ = 13.835 ln S ln h –21.17 ln h–0.4 – 0.0041 ln M*
*δ = 1.172 +2,117 ln S ln h – 2.658 ln h*

In studies conducted during 2019-2021, when the groundwater level was 1.0 m, precipitation was 2860-3540 $m^3$/ha, the irrigation rate was 950-1150 $m^3$/ha, with the volume of groundwater inflow of 1562-1718 $m^3$/ha, the amount of evaporation and transpiration was 5015-5287 $m^3$/ha, the amount of salts per 1.0 ha was 6.7-7.6 t/ha. When the groundwater level was 2.0 m, the irrigation norm was 2213-2248 $m^3$/ha, in the absence of groundwater inflow, with constant precipitation, as well as evaporation and transpiration of salt intake to the cultivated areas, was not observed. In conditions of a groundwater level of 2.0 m, when the amount of irrigation water 3.0 is 2604-2624 $m^3$/ha, in the absence of groundwater inflow, in the absence of precipitation, as well as in the absence of evaporation and transpiration in the soil, the accumulation of salts in the cultivated areas was not observed.




- salinity of the soil in the initial period (ECe), dS/m; - salinity of the soil in the final period (ECe), dS/m; - soil moisture in the initial period, %;
- soil moisture in the final period, %.

**Fig. 6.** Water-salt balance of sown area of winter wheat farm A.Khodzhaev

Figure 6 shows that in studies on the salt balance of lands under winter wheat in farm A. Khojaev, according to the FAO method, showed that at the beginning of irrigation (groundwater level 3.0 m) in the control variant, soil salinity was 2019 - 3.03 dS/m, 2020 - 3.16 dS/m and 2021 - 3.55 dS/m. At the end of irrigation, soil salinity in the control variant (groundwater level 3.0 m) was 3.30 dS / m - in 2019, 3.24 dS/m - in 2020, and 3.62 dS/m - in 2021.

In the experiment, soil salinity at the beginning of irrigation (groundwater level 2.0 m) was 3.13 dS / m - in 2019, 3.16 dS / m - in 2020, and 3.2 dS / m - in 2021 year, and at the end of watering soil salinity was, respectively, 3.26 dS / m - in 2019, 3.27 dS / m - in 2020, and 3.63 dS / m - in 2021.

Theoretical studies on moisture and salt exchange are given, taking into account the development of the root system during the growing season and moisture and salt exchange during the non-vegetative period, i.e., in the initial period of plant development.

The distribution of moisture from the root layer is as follows:

$$W_1(z)=W_{in}+\frac{A_1}{A_2D_1}\left[e^{A_2z}-1\right]+\frac{D_1^*D_2G_2}{G_1}z-\frac{12E_T}{7D_1(\delta+u_*)}\left[\frac{z^2}{2}-\frac{z^3}{12(\delta+u_*)}-\frac{z^4}{24(\delta+u_*)^2}\right] \tag{3}$$

Change of salts in the root layer by depth:

$$N_1=\left(N_{in}-R_1R_2\widehat{G}_1-\frac{\beta_1N_S}{\beta_1-\mu(\delta+u_*)}\right)ch\sqrt{\frac{\beta_1-\mu(\delta+u_*)}{D_{N_1}}}z++R_1R_2\widehat{G}_1e^{R_2z}+\frac{\beta_1N_S}{\beta_1-\mu(\delta+u_*)} \tag{4}$$

The dynamics of moisture in the arable layer in depth are determined as follows:

$$W_1^*(z)=W_{in}+\frac{A_1^*}{A_2^*D_1^*}\left(e^{A_2^*z}-e^{A_2^*(\delta+u_*)}\right)+\left[\frac{D_1}{D_1^*}E_T+\frac{D_1D_2G_2}{G_1}\right]z+ \tag{5}$$
$$+\left[\frac{D_2G_2}{G_1}\left(D_1^*-D_1\right)-E_T\left(\frac{9}{14D_1}+\frac{D_1}{D_1^*}\right)\right](\delta+u_*)+\frac{A_1}{A_2D_1}\left(e^{A_2(\delta+u_*)}-1\right)$$

The dynamics of salts in the depth of the arable layer are determined by:

$$N_1^*=\frac{\theta_0+R_1\theta_1}{ch\sqrt{\frac{\beta_1^*}{D_{N_1^*}}(\delta+u_*)}}ch\sqrt{\frac{\beta_1^*}{D_{N_1^*}}}z+R_1^*R_2^*\widehat{G}_1^*e^{R_2^*z}+N_S \tag{6}$$

The plot of the change in the humidity of the subsurface soil layer looks like this:

$$W_2(z)=W_{in}-\frac{B_1}{B_2D_2}\left[e^{B_2L}-e^{B_2z}\right]-\left(\frac{D_1}{D_2}E_T+\frac{D_1D_1^*G_2}{G_1}\right)(L-z) \tag{7}$$

The plot of salt changes in the subsurface soil layer is as follows:

$$N_2 = \left( \frac{1}{ch\sqrt{\frac{\beta_2}{D_{N2}}}z_1} \left[ (\theta_0 + R_1\theta_1) \frac{ch\sqrt{\frac{\beta_1^*}{D_{N_1^*}}}z_1}{ch\sqrt{\frac{\beta_1^*}{D_{N_1^*}}}(\delta + u_*)} + R_1^* R_2^* \bar{G}_1^* e^{R_2^* Z_1} - P_1 P_2 \bar{G}_2 e^{P_2 Z_1} \right] \right) ch\sqrt{\frac{\beta_2}{D_{N2}}}z + P_1 P_2 \bar{G}_2 e^{P_2 z} + N_S \quad (8)$$

In these formulas, the values of $G_1$ and $G_2$ are equal:

$$G_1 = D_1 D_2 \left[ z_1 - (\delta + u_*) \right] + D_1^* D_2 (\delta + u_*) + D_1 D_1^* (L - z_1)$$

$$G_2 = W_{fh} - W_{in} - \frac{B_1}{B_2 D_2}\left[ e^{B_2 L} - e^{B_2 z_1} \right] - \frac{A_1^*}{A_2^* D_1^*}\left[ e^{A_2^* z_1} - e^{A_2^*(\delta + u_*)} \right] -$$
$$- \frac{A_1}{A_2 D_1}\left[ e^{A_2(\delta + u_*)} - 1 \right] + \frac{9E_T}{14 D_1}(\delta + u_*) - E_T D_1 \left[ \frac{z_1 - (\delta + u_*)}{D_1^*} - \frac{L - z_1}{D_2} \right] \quad (9)$$

where: $L$ is depth of groundwater occurrence, m.
$Z_1$ is the boundary between the arable and sub-arable layers, m.
$K_1$, $K_2$ are moisture loss coefficients.
$D_1$, $DN_1$, $D_2$, $DN_2$ are diffusion coefficients.
$W_{in}$ is the amount of intermediate moisture for the plant between the critical limit of soil moisture.
$W_3$ is full moisture capacity of the soil.
$W_{fh}$ is full humidity.
$Z$ is vertical coordinate pointing down from the surface of the earth.
$N_{in}$ is the intermediate salt concentration between the salt concentration in irrigation water NW and in the state of water maximally saturated with salt NS; (δ + u *) is the boundary of the root layer, m.
μ is relative value of moisture absorption by plant roots, 1/day;
Studies show a decrease in the rise of salts to the upper layer of the roots in conditions when the field is completely covered with vegetation. In this case, as the plant absorbs moisture through the roots, salts accumulate mainly in the root layer. Because the relative temperature at ground level is lower in the second half of the growing season than in the first half, during irrigation, "salty" water is absorbed into relatively deeper layers.

## 4 Conclusions

The results of the study of the influence of the groundwater level, soil salinity, the number of irrigations, and the irrigation rate showed that:

- the yield of winter wheat at a groundwater level of 1.5 meters was: in highly saline soils – 26.8 q/ha, in medium saline soils 51.2 q/ha and 58.5 q/ha in slightly saline soils, and at a level of groundwater 2.0 m in highly saline soils – 27.5 q/ha, in medium saline soils 54.8 q/ha and slightly saline soils – 56.4 q/ha;
- changes in winter wheat yield under saline soils were studied based on the FAO method; it was 57-100% of the yield, and on slightly saline sown areas 2-12 dS/m 80-100% of the yield.
- studies conducted to study the effect of the number of irrigations on the yield of winter wheat showed that on sown areas with high salinity, with 2-3 times of irrigation, the average yield was 23.0 q/ha, with 3-4 times of irrigation, the average yield was 38.8 q/ha, and with 5 times watering, the average yield was 62.0 q/ha. It should be noted the patterns

of yield increase with an increase in the number of irrigations up to a certain point.

- when studying the effect of irrigation rates on the yield of winter wheat, the average yield of irrigated crops in highly saline fields at a seasonal irrigation rate of 2100 $m^3$/ha, in moderately saline fields, the yield was 28.8 q/ha, in -39.7 q/ha. It should also be noted that with an irrigation rate of 2800 $m^3$/ha on medium saline soils, the yield was 36.3 q/ha, on medium saline fields – 40.6 q/ha, and slightly saline lands – 44.9 q/ha.

The conducted experiments make it possible to predict winter wheat yield in water scarcity conditions.

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