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MOISTURE AND SALT TRANSFER IN THE INITIAL PERIOD OF PLANT DEVELOPMENT

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Abstract

In Uzbekistan, the use of groundwater in agriculture is 3-5 km3 per year. This creates the basis for achieving high yields of agricultural crops in conditions of low water. Water - as moisture, has essential role in all biochemical processes of plants, all vital processes, occurring in a vegetative organism, can proceed normally only under condition of sufficient saturation of cages by a moisture. 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, on an area with a groundwater level of 1-3 m and a mineralization of 1-3 g/l. Results of theoretical researches on dynamics of ground humidity have shown: (1) similarity of physical processes of change of humidity of soil on different irrigated areas. (2) hysteresis of the nature of humidity at an irrigation and drainage. (3) sharp recession of humidity of soil in the root zone.

Keywords: *mathematical model, water stress factor, salinity, irrigation, mechanical composition of soil, hydromodular areas.*

◆

Introduction. Among the main factors in the arid zone, an important role is played by the water and thermal regimes of soils, which mainly determine the fate of the crop of irrigated crops. This is explained by the fact that the subsoil processes are closely related to weather conditions and, depending on their behavior, the need for appropriate ameliorative impacts on the agricultural field is established.

The conducted studies to date have proved the inconsistency of the interpretations of the management of the productivity of agroecosystems, when only a few isolated indicators were taken into account or the informativeness of the integral indicators was usually judged from the data of correlation and regression analyzes that do not always reflect the actual processes taking place in the soil- plant". In the methodology for assessing soils as an object of intensive agricultural use, a new stage has come-the transition from bathing assessments, studies of individual optimal parameters to the analysis of the productivity of agroecosystems on the basis of their mathematical modeling[3; 4; 5].

Methodology study. The spatial-temporal dynamics of soil moisture were investigated in several Water Consumers Association.

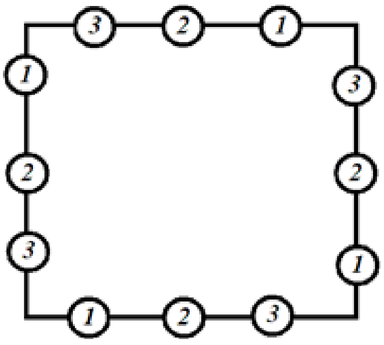

Fig 1. Sampling arrangement with fourfold replication of moisture determination.

On the demonstration sites cotton was grown; space between the rows was 90 cm. Five sampling sites (four under cotton grown area and one at non-vegetated area – control) with four replications of each were selected randomly. Soil samples were collected annually during 2019-2020.

The experiment consists of two parts: The first is the analysis of the dynamics of soil moisture based on the irrigation frequency. The soil moisture was measured right before and after the irrigation, the next were as well as 1, 2, 3 and 5 days before and after the irrigation. The sampling was replicated four times. Moisture is determined from 10-cm layers, and in the root and top soil - from 0.5 and 5-10 cm layers. The sampling arrangement is shown in Fig. 2.

In the initial period of plant development under steady-state conditions, when transpiration of Em can be neglected, the following mathematical model will be used for a two-layer medium consisting of arable and subarable layers [1; 2;8;9].

With soluble salts and small content in the solid phase (for example, chlorine), the equation of salt transfer satisfactorily describes the distribution of salts observed in nature and experiments without the last term $\gamma(c_s - c)$, ie:

We note that in this case D takes into account the peculiarities of the motion of solutions in a nonsolvent medium (the so-called longitudinal and transverse effects) and is not equal to the usual diffusion coefficient in a resting solution[4; 5;6].

$$\begin{cases} 0 \le z \le z_1 \\ \frac{d}{dz}\left[D_1(W_1)\frac{dW_1}{dz}\right] - \frac{dK_1(W_1)}{dz} = 0, \\ \frac{d}{dz}\left[D_{N_1}(W_1)\frac{dN_1(W_1)}{dz}\right] - \frac{dV_{N_1}(W_1)}{dz} = 0, \\ z_1 \le z \le L \\ \frac{d}{dz}\left[D_2(W_2)\frac{dW_2}{dz}\right] - \frac{dK_2(W_2)}{dz} = 0, \\ \frac{d}{dz}\left[D_{N_2}(W_2)\frac{dN_2(W_2)}{dz}\right] - \frac{dV_{N_2}(W_2)}{dz} = 0 \end{cases} \tag{1}$$

$$W_1(0) = W_{ib} = const, \tag{2}$$

$$N_1(0) = N_{ib} = const \tag{3}$$

$$W_1(Z_1) = W_2(Z_1) \tag{4}$$

$$N_1(Z_1) = N_2(Z_1) \tag{5}$$

$$\left[K_1(W_1) - D_1(W_1)\frac{dW_1}{dz}\right]_{Z=Z_1} = \left[K_2(W_2) - D_2(W_2)\frac{dW_2}{dz}\right]_{Z=Z_1} \tag{6}$$

$$V_{N_1}(W_1) - D_{N_1}(W_1)\frac{dN_1(W_1)}{dz}\bigg|_{Z=Z_1} = V_{N_2}(W_2) - D_{N_2}(W_2)\frac{dN_2(W_2)}{dz}\bigg|_{Z=Z_1} \tag{7}$$

$$W_2(L) = W_{mc}, \tag{8}$$

$$N_2(L) = N_{mc} \tag{9}$$

where the following designations are entered for the arable and sub-plow layers respectively: W_1, W_2 – volumetric humidity; coefficients of moisture conductivity are adopted in the form [1; 3]:

$$K_1(W_1) = A_1 e^{A_2 z}, K_2(W_2) = B_1 e^{B_2 z}. \tag{10}$$

the speed of water movement in the ground is taken as [1]:

$$V_{N_1} = R_1 e^{R_2 Z}, \quad V_{N_2} = P_1 e^{P_2 Z} \tag{11}$$

In view of the fact that the stationary regime is considered for the diffusivity coefficients, their mean values

$$D_1(W_1) = D_1 = const, \quad D_2(W_2) = D_2 = const \tag{12}$$

$$D_{N_1}(W_1) = D_{N_1} = const, \qquad D_{N_2}(W_2) = D_{N_2} = const, \tag{13}$$

where: L – groundwater depth, m;

Z₁- boundary between arable and subsoil layers, m;

W_{ib}- some intermediate moisture capacity between wilting moisture W₃ and the maximum moisture capacity W_{iib}, т.е.

$$W_3 \prec W_{mc} \prec W_{iib} \tag{14}$$

where: W_{mc}- full moisture capacity;

Z - vertical coordinate directed down from the earth's surface.

Also N_{ic} -it is an intermediate concentration of the salts between the concentration of the salts in the wash water N_W and the concentration of the limiting saturation of water N_S, i.e.

$$N_W \le N_{ic} \le N_S \tag{15}$$

As a result of these notations, we rewrite the boundary value problem (1) - (9) as follows

$$\begin{cases} D_1 \dfrac{d^2 W_1}{dz^2} - A_1 A_2 e^{A_2 Z} = 0 \\ D_{N_1} \dfrac{d^2 N_1}{dz^2} - R_1 R_2 e^{R_2 Z} = 0 \\ D_2 \dfrac{d^2 W_2}{dz^2} - B_1 B_2 e^{B_2 Z} = 0 \\ D_{N_2} \dfrac{d^2 N_2}{dz^2} - P_1 P_2 e^{P_2 Z} = 0 \end{cases} \tag{16}$$

$$A_1 e^{A_2 Z} - D_1 \left.\frac{dW_1}{dz}\right|_{Z=Z_1} = B_1 e^{B_2 Z} - D_2 \left.\frac{dW_2}{dz}\right|_{Z=Z_1}, \tag{17}$$

$$R_1 e^{R_2 Z} - D_{N_1} \left.\frac{dN_1}{dz}\right|_{Z=Z_1} = P_1 e^{P_2 Z} - D_{N_2} \left.\frac{dN_2}{dz}\right|_{Z=Z_1} \tag{18}$$

where A_1, A_2, B_1, B_2, D_1, D_2, R_1, R_2, P_1, P_2, D_{N1}, D_{N2}- are some constants determined by comparing the analytical solution with the experimental data [1];

Integrating the first equation of system (16) we will successively find

$$\frac{d^2 W_1}{dz^2} - \frac{A_1 A_2}{D_1} e^{A_2 Z} = 0$$

$$\frac{dW_1}{dz} = \frac{A_1}{D_1} e^{A_2 Z} + C_1$$

$$W_1 = \frac{A_1}{A_2 D_1} e^{A_2 Z} + C_1 z + C_2 \tag{19}$$

Results. Relation (4) with allowance for (21), (22) and (26) allows us to determine C1 from equality

$$W_{mc} - \frac{B_1}{B_2 D_2}\left[e^{B_2 L} - e^{B_2 Z_1}\right] - C_1 \frac{D_2}{D_1}\left[L - Z_1\right] =$$

$$= W_{\Pi P} - \frac{A_1}{A_2 D_1}\left[e^{A_2 Z_1} - 1\right] + C_1 Z_1$$

From where we find

$$C_1 = \frac{W_{mc} - W_{ic} - \dfrac{A_1}{A_2 D_1}\left[e^{A_2 Z_1} - 1\right] - \dfrac{B_1}{B_2 D_2}\left[e^{B_2 L} - e^{B_2 Z_1}\right]}{\dfrac{D_2}{D_1}\left[L - Z_1\right] + Z_1} \tag{20}$$

It is possible to establish the value of *C₃* from equation (18), (19), and

$$N_{mc} - \frac{P_1}{P_2 D_{N_2}}\left[e^{P_2 L} - e^{P_2 Z_1}\right] - C_3 \frac{D_{N_2}}{D_{N_1}}\left[L - Z_1\right] =$$

$$= N_{ic} - \frac{R_1}{R_2 D_{N_1}}\left[e^{R_2 Z_1} - 1\right] + C_3 Z_1$$

Hence we find

$$C_3 = \frac{N_{mc} - N_{ic} - \dfrac{R_1}{R_2 D_{N_1}}\left[e^{R_2 Z_1} - 1\right] - \dfrac{P_1}{P_2 D_{N_2}}\left[e^{P_2 L} - e^{P_2 Z_1}\right]}{\dfrac{D_{N_2}}{D_{N_1}}\left[L - Z_1\right] + Z_1} \tag{21}$$

Substituting the values of arbitrary *C₁, C₂, C₃* and *C₄* in (19) and (20) we obtain the distribution of volumetric moisture and salt concentration in the arable layer as a function of z.

$$W_1 = W_{ic} + \frac{A_1}{A_2 D_1}\left[e^{A_2 Z} - 1\right] + \left[\frac{W_{mc} - W_{ic} - \dfrac{A_1}{A_2 D_1}\left[e^{A_2 Z_1} - 1\right] - \dfrac{B_1}{B_2 D_2}\left[e^{B_2 L} - e^{B_2 Z_1}\right]}{\dfrac{D_2}{D_1}\left[L - Z_1\right] + Z_1}\right] z \tag{22}$$

$$N_1 = N_{ic} + \frac{R_1}{R_2 D_{N_1}}\left[e^{R_2 Z} - 1\right] + \left[\frac{N_{mc} - N_{ic} - \dfrac{R_1}{R_2 D_{N_1}}\left[e^{R_2 Z_1} - 1\right] - \dfrac{P_1}{P_2 D_{N_2}}\left[e^{P_2 L} - e^{P_2 Z_1}\right]}{\dfrac{D_{N_2}}{D_{N_1}}\left[L - Z_1\right] + Z_1}\right] z \tag{23}$$

$$0 \leqslant z \leqslant Z_1$$

The definite values of the constants *C₅ C₆, C₇*, and *C₈* in (21) and (22) yield the distribution of the volumetric moisture content and the salt concentration in the subpolar layer as a function of z.

$$W_2 = W_{mc} - \frac{B_1}{B_2 D_2}\left(e^{B_2 L} - e^{B_2 Z}\right) - \left(\frac{W_{mc} - W_{ic} - \dfrac{A_1}{A_2 D_1}\left[e^{A_2 Z_1} - 1\right] - \dfrac{B_1}{B_2 D_2}\left[e^{B_2 L} - e^{B_2 Z_1}\right]}{\left[L - Z_1\right] + Z_1}\right)(L - z) \tag{24}$$

$$N_2 = N_{mc} - \frac{P_1}{P_2 D_{N_2}}\left(e^{P_2 L} - e^{P_2 Z}\right) - \left(\frac{N_{mc} - N_{ic} - \dfrac{R_1}{R_2 D_{N_1}}\left[e^{R_2 Z_1} - 1\right] - \dfrac{P_1}{P_2 D_{N_2}}\left[e^{P_2 L} - e^{P_2 Z_1}\right]}{\left[L - Z_1\right] + Z_1}\right)(L - z) \tag{25}$$

$$Z_1 \leqslant z \leqslant L$$

The change in moisture content and concentration of salts at various initial surface moisture indices without taking into account the development of the plant root system for the conditions of the Khavast region of the Syrdarya region is shown in Fig. 3.

Determination of the constants was carried out according to the acad. F.B. Abutaliev given in [1].

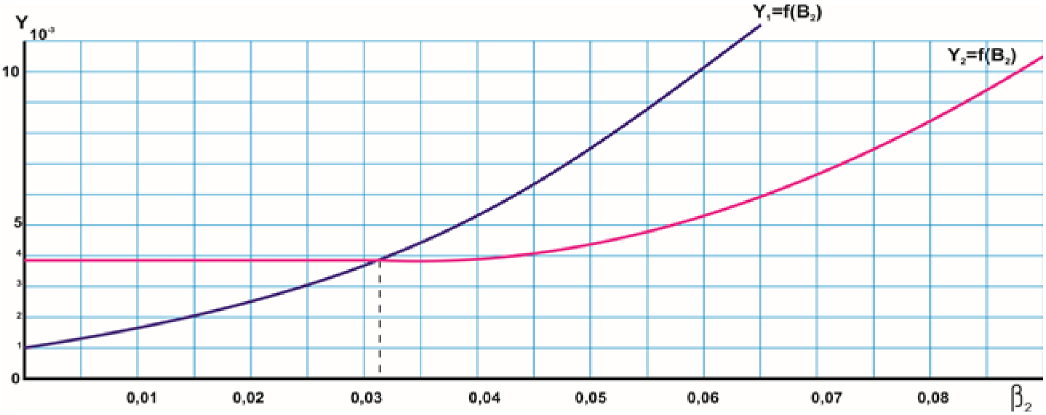

Fig 3. Determination of the value of β2 by the transcendental equation.

Table 1. Coefficients of the mathematical model for determining the parameters of moisture and salt transfer

Location of the object	Khavast district					
Farms	Baraka	Akhmad Khojayev	Chinor	Khavast simosi	Dariyev Ibodullo	Kushkecik
Mechanical composition	Heavyloam		Mediumloam		Lightloam	
$A_1 x 10^{-4}$	2,18	2,02	5,37	2,30	35,71	32,58
A_2	1,74	1,57	2,23	2,39	2,30	2,20
$B_1 x 10^{-4}$	3,41	1,67	2,26	1,53	50,71	36,40
B_2	2,51	2,43	2,42	2,64	1,83	2,09
$D_1 x 10^{-3}$	4,35	5,14	6,75	5,43	3,94	3,08
$D_2 x 10^{-3}$	1,71	2,29	12,19	18,76	6,74	7,70
$R_1 x 10^{-4}$	31,21	32,69	3,23	3,60	5,04	3,70
R_2	2,07	2,12	2,06	1,88	2,18	1,90
$P_1 x 10^{-4}$	34,87	41,45	1,82	2,97	6,29	1,97
P_2	1,96	1,84	2,50	2,42	2,38	2,43
$D_{N1} 10^{-3}$	2,91	3,31	5,77	4,98	2,88	5,94
$D_{N2} 10^{-3}$	7,35	6,88	11,08	6,48	9,12	7,24

Fig. 3. shows the change in soil moisture during the initial period of plant development (winter wheat). The bend point on the graph indicates the boundary between the arable and sub-plow layers (42 cm).

Conclusions:

1. The developed models (24) - (25) can be used in the calculation of moisture and salt transfer both in the initial period of plant development and in the calculation of washing of saline lands.

2. The use of models and the coefficients of the mathematical model to determine the parameters of moisture and salt transfer make it possible to calculate the reserve of soil moisture and optimize the sowing time at its maximum value.

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