RESEARCHES ON THE EFFICACY OF SOLID MOISTURE RELEASE BY RANGE OF AEROSPACE AREAS AND CONSERVATION OF HUMIDITY AREA

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Movement of water in the ”soil-plant” system is carried out by the inflow of moisture from the soil through the roots into the plant and the expenditure of moisture by the plants on evaporation into the atmosphere. The speed of motion is determined by the intensity of transpiration, which depends on the intensity of atmospheric conditions. Investigations of Averyanova S.F., Golovanova A.I., Nikolyskovo Yu.N. (1974) [1] found that the distribution of moisture absorption over the depth of the aeration zone depends on the moisture content of the soil and as the humidity increases from the wilting moisture to its maximum value, the amount of absorption increases. Since the proportion of water that takes part in the construction of organic matter is very small in comparison with transpiration, the water costs of plants are determined by the intensity of transpiration, which is an indicator of the moisture content of plant tissues. In many cases, the function of moisture selection is an integral part of complex mathematical models and only in their framework is`t manifested well [3, 10, 13]. The analysis has shown the importance and necessity of determining the functions of moisture selection by the root system of the grown crops from the dried soil profile, since taking into account the spatial features of the processes of moisture absorption by the plant roots. Makes it possible to predict the moisture regime of the root layer of the soil and conduct drainage and moisturizing measures in the reclaimed lands of the humid zone more reasonably and qualitatively. Spiet D.A., (1982) as well as Gardner W.R., Taylor H.M., proposes to find the value of transpiration by assuming that the flow from the soil to the root systems is of a radial nature [4, 11, 15]. Therefore, when choosing the structure of models of moisture absorption by cultivated crops along the depth of the root-layer of soil, first of all, sufficient simplicity and reliability of obtaining experimental information for the purpose of using these models in production conditions were taken into account.

Key words: aeration zone, perennial grasses, selection of moisture by plant roots, soil moisture, transpiration.

„Moisture reserves on part of the country's territory have reached the critical threshold.”

Introductıon

Modern theories of determining the magnitude of transpiration are based on concepts developed in the fundamental works of Gradman and Van Den Honert, which appeared in 1928 and 1940 respectively. If we ignore the work of Hubert (1924), then Gradman was the first to draw an analogy between the constant electric current in the resistance circuit and the steady filtration of water through the roots, stems and leaves of plants. The ideas of Gradman were not successful until they were generalized 20 years later by Van Den Honert. He showed that under the prevailing conditions the rate of moisture movement through parts of plants is directly proportional to the potential difference in these parts and inversely proportional to the resistance of the moisture flow [9].

In a series of works published in 1958 by Philip (1959), a quantitative description of the process of moisture transfer in plant tissues was given for the first time. It is believed that detailed quantitative studies of the absorption of moisture by plant roots began with research by W.R. Gardner [4].

To find the quantity E_t, at present, there are a number of models, in the development of which two approaches are used. In the first case, with a low density of plants and their root systems, the vertical distribution of moisture is not taken into account, so the original equation of moisture transfer is recorded in polar coordinates. In the second case, the high density roots horizontal flow neglected and considered only vertical movement.

W.R. Gardner (1975) considers the root of a plant as a cylinder of infinite length with the same radius along the entire length and the same ability to absorb moisture, suggesting also that soil moisture can move in the radial direction. As a result, we plotted the changes in the water potential of the soil as a function of the distance from the root, determined the dependencies for finding the potential on the root surface to estimate the influence of the soil potential on the rate of inflow of moisture to the root.

Using a common resistance model, the scientist established the relationship between the distribution of roots and the absorption of moisture, as well as the influence of soil moisture and moisture conductivity on the distribution of roots. The obtained equation is used in the longest for the prediction of the distribution of plant roots. In his studies, the correspondence between the calculated and experimental data was not satisfactory, since the experimentally determined number of roots at a certain depth exceeded the calculated one. This fact is partly due to the fact that the magnitude of the potential in the middle of the root was assumed constant.

This circumstance was taken into account by M.N. Nimah and R.J. Hanks (1973). Using their model, it`s possible to predict the change in the moisture content along the depth of the root layer of the soil, taking into account the absorption of moisture by the plants. The results of the calculations are in good agreement with the data of field studies, although the model does not take into account the growth dynamics of the root system.

The model is modified by R.A. Feddes (1974). The verification of its correspondence to field research data showed that the calculated rates of evaporation and transpiration are in good agreement with the actual ones, in contrast to the humidity in the depth of the aeration zone. Later, he developed a simple function of absorbing moisture by plant roots. The moisture absorption is calculated depending on the soil moisture pressure and the maximum absorption rate.

Since the process of obtaining experimental data for estimating the functions of the root system is very time-consuming, then such characteristics as the root density, their distribution, length, which vary with depth and with time, R.A. Feddes does not take into account (1976). The root system here is characterized only by the depth of the root zone [5].

Investigations of S.F. Averyanova, A.I. Golovanova, Yu.N. Nikolsky (1974) found that the distribution of moisture absorption over the depth of the aeration zone depends on the moisture content of the soil and as the humidity increases from the wilting moisture to its maximum value, the amount of absorption increases.

I. Sudnitsyn (1977, 1980) substantiated the existence of a proportional dependence between the concentration of plant roots and the rate of relative water flow from a certain layer of soil in the range of its humidity change from field moisture capacity to the lower limit of moisture available to plants. Consequently, the magnitude of moisture absorption from a specific soil layer is directly proportional to the concentration of roots in this layer.

G.I. Afanasik also proposes to determine the amount of moisture absorption by the root system as a function of the root mass per unit volume of soil, but also takes into account the permeability of the root walls, moisture and the potential of soil moisture (1980).

S.V. Nerpin (1975), when finding the amount of moisture absorption by plant roots, makes use of a number of assumptions, namely, in view of the fact that the magnitude of energy dissipation when the moisture moves in the root system is insignificant compared to the dissipation of energy during its transition from soil to plant roots. The limiting the suction power of the root system is determined by the varietal features of plants, the phase of their development and does not depend on meteorological conditions.

Materıals and methods

S.V. Nerpin and M.G. Sanoyan (1977) proposed a dependence for various soil moisture regimes. Using the works of F.D. Whisler, A. Klute, R.J. Milington (1968), M.N. Nimah and R.J. Hanks (1973), while finding the transpiration magnitude Z.M. Dubrovsky, M.G. Hublaryan takes into account the properties of plants, meteorological and other external factors through empirical function [2, 6].

H.M. Taylor, B. Klepper (1975), taking into account the effect of soil temperature, aeration conditions, root system density and root xylem resistance, found that the maximum moisture absorption rate decreases linearly with depth.

N.M. Tylor, W. Klepper (1975) confirmed experimentally the assumptions of W.R. Gardner (the resistance of the ground to the flow and the radial direction to the root is much greater than the resistance to the flow inside the root. The amount of moisture that is absorbed by the root system, in proportion to the root density. The rate of moisture absorption is proportional to the pressure difference in the soil and on the root surface) formed the basis for deriving the dependence of the radial moisture flux on the root [7].

D.A. Spiet (1982) as well as W.R. Gardner, N.M. Taylor, proposes to find the value of transpiration by assuming that the flow from the soil to the root systems is of a radial nature.

Calculations I.R. Philip (1969) are based on the dependence of the intensity of moisture absorption on the permeability coefficient of the root walls, the surface area of the absorption, the volume of the root part that absorbs, and the total potential of soil moisture in the surface of the root. Since the capillary-sorption potential depends on the soil temperature, and the osmotic potential depends on the content of salts dissolved in groundwater, the amount of moisture absorption by the roots also depends on the temperature and the content of the dissolved substances.

The absorption model of T.J. Molz (1968) is similar to the model W.N. Herkelrath (1977).

W. Boonyatharokul, W. Wolker (1979), the rate of moisture absorption by the root system for a particular type of crop is determined through the biological parameters of the plant, soil moisture conductivity, climatic parameters, and moisture reserves in the soil layer. For the upper layer of the root zone, the absorption distribution curve is constructed taking into account the costs of physical evaporation (evaporation) [3, 5, 11].

F.J. Molz (1970), L.M. Ayra, N.M. Taylor, W. Klepper (1975) experimentally proved the fact that the hydraulic resistance of the root system dominates the resistance of the soil around the roots. Therefore, according to F.J. Molz (1981), those absorption models in which only ground characteristics are taken into account, are conceptually erroneous.

Over the past 15 years, research into the processes of selection of moisture by plant roots has continued. Developments are aimed at evaluating nonlinear moisture absorption patterns for a number of crops (cotton, wheat, maize, etc.).

Simulation models have been developed that make it possible to determine the amount of pod consumed during a certain time by cultivated crops and the rate of its absorption at a certain stage of growth. These models are used to calculate irrigation schedules for regions with water scarcity.

As the base, imitational nonlinear models that describe the macroscopic movement of moisture and dissolved substances in the root layer of soil in the direction of the root system are chosen. An up-to-date trend in modern research is the development of models for the selection of moisture by the roots of cultivated crops in order to determine the effect of the concentration of solutes on transpiration and the effect of salt content on the depth of root propagation in the soil profile (Rode, 2008).

Models describing the moisture flux in the soil and the movement of heavy metals dissolved in heavy metals, namely cadmium, which has been identified as the most toxic to humans, are presented in the literature [8]. It was revealed that the presence of cadmium and its accumulation in the root zone leads to a decrease in the yield of agricultural crops [13].

These studies are aimed at developing methods for modeling the movement of heavy metals in the soil and studying their absorption by plant roots in order to minimize the contamination of cultivated crops and the entry of heavy metals into food.

In the considered models of moisture absorption, plant roots take into account a number of parameters, among which are the conductivity of the roots per unit length, density function, hydraulic resistance, relative specific surface area, absorbent surface area, root radius, water wall permeability coefficient, properties of plants, dimensionless variables, constants, empirical parameters, etc.

In many cases, the function of moisture selection is an integral part of complex mathematical models and only in their framework is it manifested well.

Most of the considered functions of moisture absorption by plant roots are developed on the basis of a macroscopic approach.

RESULTS

W.N. Herkelrath (1977) suggests a semiempirical dependence of the determination of the amount of absorption, obtained from the assumption that the gradient of the water potential around the roots is insignificant. Empirically, the resistance at the contact surface of the soil-root system is taken into account. This approach allows us to explain why the total resistance to the moisture flow in the ”soil plant” system increases with the drying of the soil, whereas, according to theory, the resistance should be insignificant. The results obtained are in good agreement with others. In addition, both studies state that the main resistance to moisture absorption takes place in the roots with little resistance to the flow of moisture from the xylem of the roots [17].

H.R. Rowse (1978) gives the results of a comparison of the numerical calculations of the moisture transfer model with field data. The results of numerical modeling of moisture transfer in the system ”soil-roots” are given by P.A. Raats (1976), L.M. Ayra, R.C. Rise, D. Hillel (1976).

The use of most of the available absorption functions obtained for individual types of crops and soil types is limited by the complexity of determining their initial parameters, so they can not always be used in practice. In most cases, there are no data directly experimental testing of these models. It should be noted that the analysis of these functions does not give a definitive and unambiguous answer about the appropriateness of considering certain factors as determining and determining the formation of a soil moisture regime.

Obviously, it makes no sense to develop moisture transfer models in soils containing roots, considering separately the moisture transfer to each root hair of the whole root system of the plant. Since a detailed description of the geometry of the root system is impossible, especially since it varies with time and the moisture content in the roots depends on their permeability, which changes along their length.

The analysis showed the importance and necessity of determining the functions of moisture selection by the root system of cultivated crops from the drained soil profile, since taking into account the spatial peculiarities of the processes of moisture absorption by plant roots makes it possible to predict the moisture regime of the root-inhabitable soil layer. Conduct drying-moisturizing measures on ameliorated lands of the humid zone is more justified and qualitatively. Therefore, when choosing the structure of models of moisture absorption by cultivated crops along the depth of the root-layer of soil, first of all, sufficient simplicity and reliability of obtaining experimental information for the purpose of using these models in production conditions were taken into account.

The use of a field tensiometric setup made it possible to obtain experimental data for finding the transpiration value over layers of 0.1 meter in the aeration zone. For this, on one of the lysimeters during the growing season with layered water supply, the plants were not grown, the vegetation cover was only simulated to provide adequate soil shading conditions. Thus, in the process of water balance calculations on this lysimeter, evaporation was determined.

The determination of the evaporation (physical evaporation) indicates a different intensity in the depth of aeration and the dependence of its magnitude on meteorological conditions. To determine the value of physical evaporation and analyze its dynamics, the results of measurements were used in non-rain periods, when infiltration of groundwater levels was absent.

Figure 1 (a, b and c) shows the monthly values of evaporation along the layers of the root zone. A continuous decrease in the intensity of evaporation is typical for depth. Evaporation of moisture from the deeper layers of the soil (from a depth of 0.4 m) is quite insignificant and apparently occurs because of the presence of a temperature gradient.

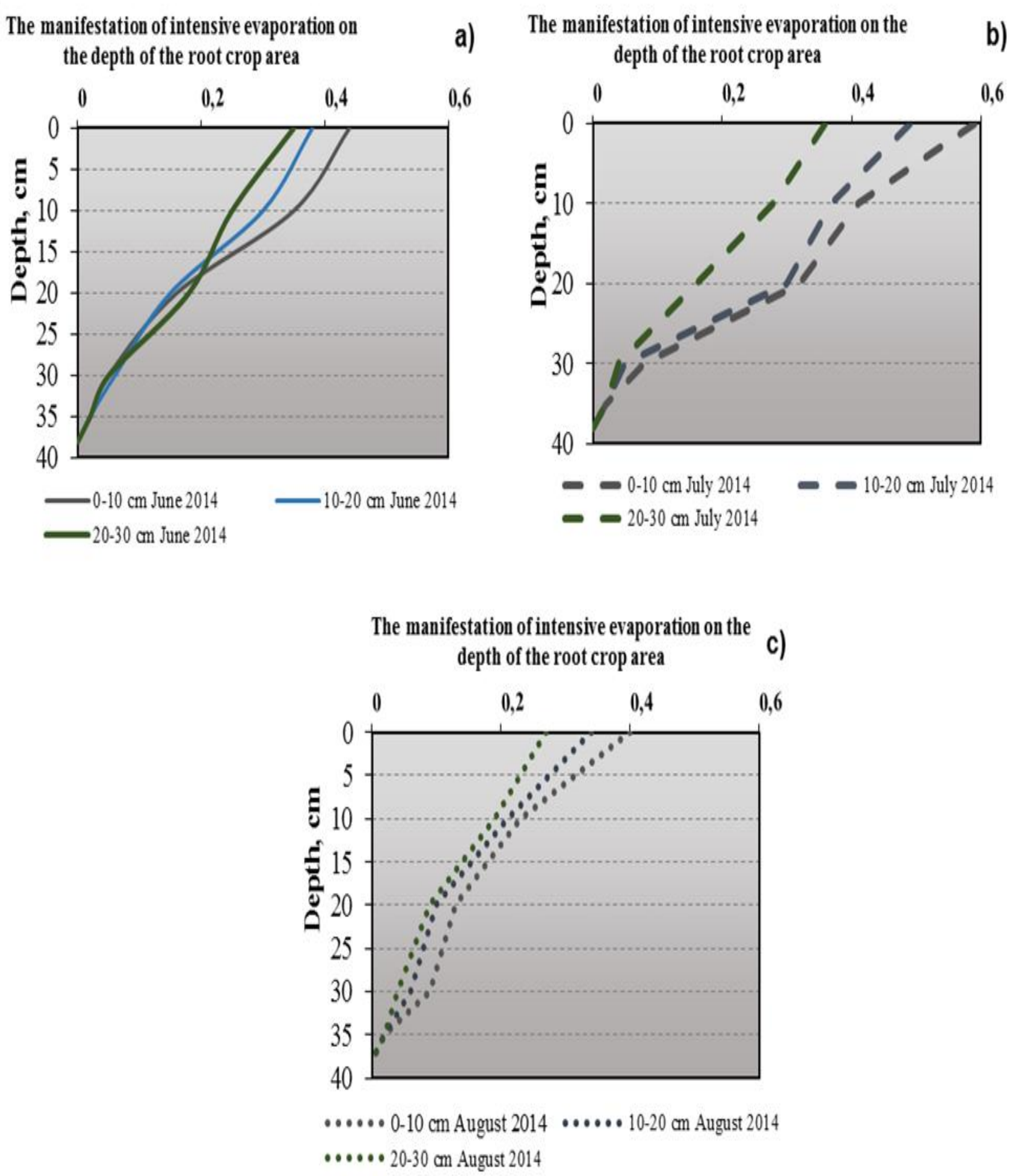

Figure 1. Distribution of intensity of evaporation along the depth of the root zone of crops.

In all cases, the decrease in the indicated depth is typical, and the average maximum value falls on the upper 0.1 - meter layer and is 0.35 mm. The use of a field tensiometric device allows obtaining experimental information on the value of the total evaporation and evaporation from the results of measurements of the lysimeters (Fig. 1a, b and c).

Calculation of transpiration of perennial grasses for each 0.1 - meter layer is carried out according to the formula [5, 7, 14, 16]:

$$E_T^{(i)} = \left(Q_i^{(1)} \pm \Delta W_i^{(1)}\right) - \left(Q_i^{(3)} \pm \Delta W_i^{(3)}\right) \quad (1)$$

The value of the mean transpiration values for decades of development of perennial grass cuttings is given in Figure 2.

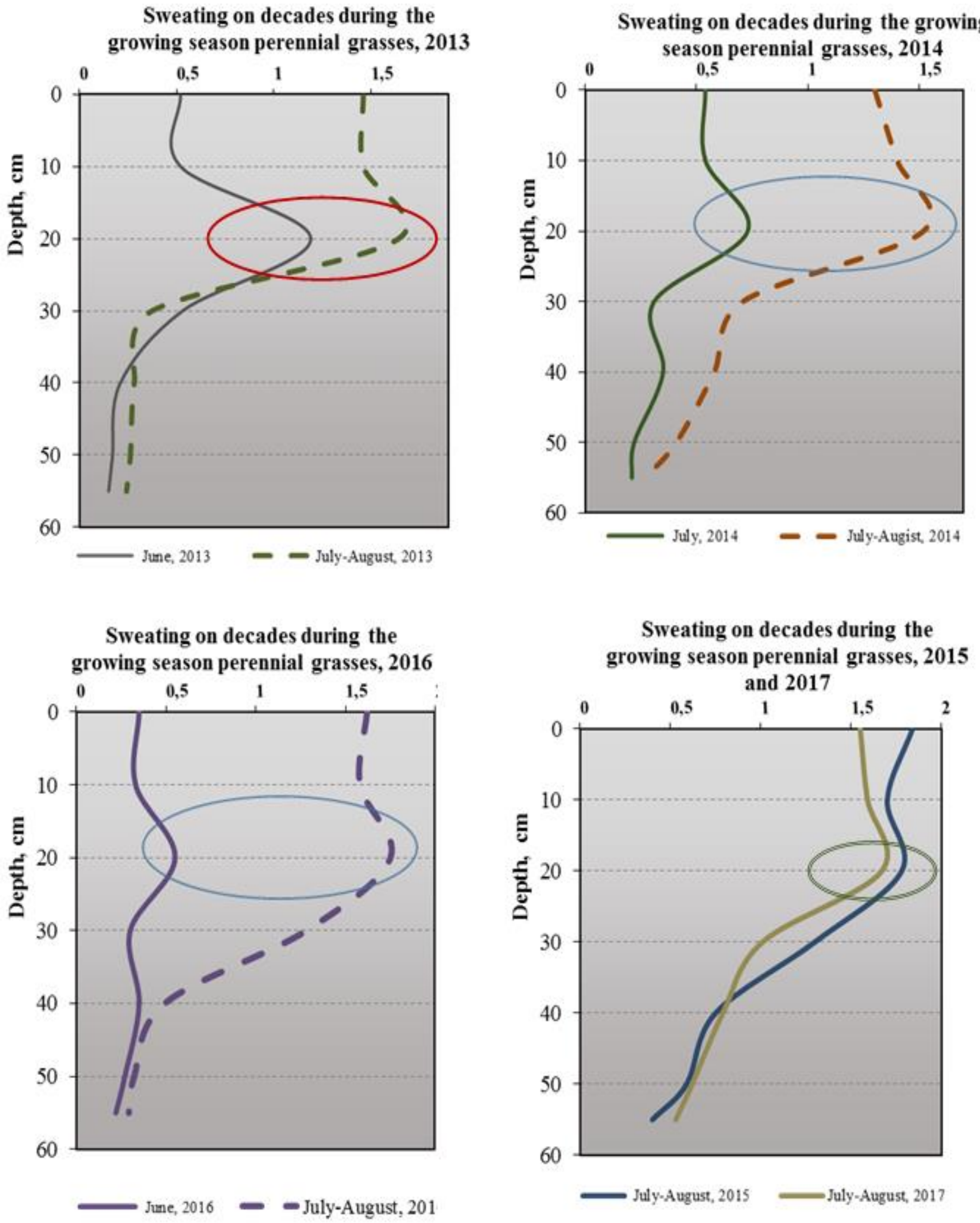

Figure 2. Dynamics of average ten-day transpiration values for the phases of development of perennial grass cuttings along 0.1-meter layers of the root zone

Where:

$Q_i^{(1)}$- determined experimentally the daily moisture costs from the ”i” th burette on the ”i” feed probe for 1 lysimeter at the time point t_i;

$\Delta W_i^{(1)}$- the daily changes in the moisture reserves in the same soil layer at the same time are determined from the magnitude of pressure changes over a daily time interval $t_1 - t_{i-1}$ with using the disappearance of the water-holding capacity curves for the corresponding soil horizons for 1 lysimeter, where the total water consumption was measured;

$Q_i^{(3)}$ - certain experimentally moisture losses from the ”i” burette on the ”i” feed probe for the 3 lysimeters at the time point t_i;

$\Delta W_i^{(3)}$ - daily changes in moisture reserves in the same soil layer at the same time are determined from the magnitude of pressure changes over a daily period of time $t_1 - t_{i-1}$, c using the curves of the water-holding capacity of the soil for the corresponding soil horizons for 3 meters, where physical evaporation (evaporation).

Analysis of the dynamics of layered transpiration during the vegetation period (Figure 2) and the moisture absorption diagram of the root system of perennial grasses (Figure 3 and 4) shows that the maximum moisture costs for transpiration fall on a layer 0.3 m thick from the soil surface where the maximum root concentration (according to field studies).

Thus, the experimental data obtained confirm the earlier conclusions [2, 9, 15, 16], where the amount of moisture absorption by the root system is proposed to be determined depending on the root mass.

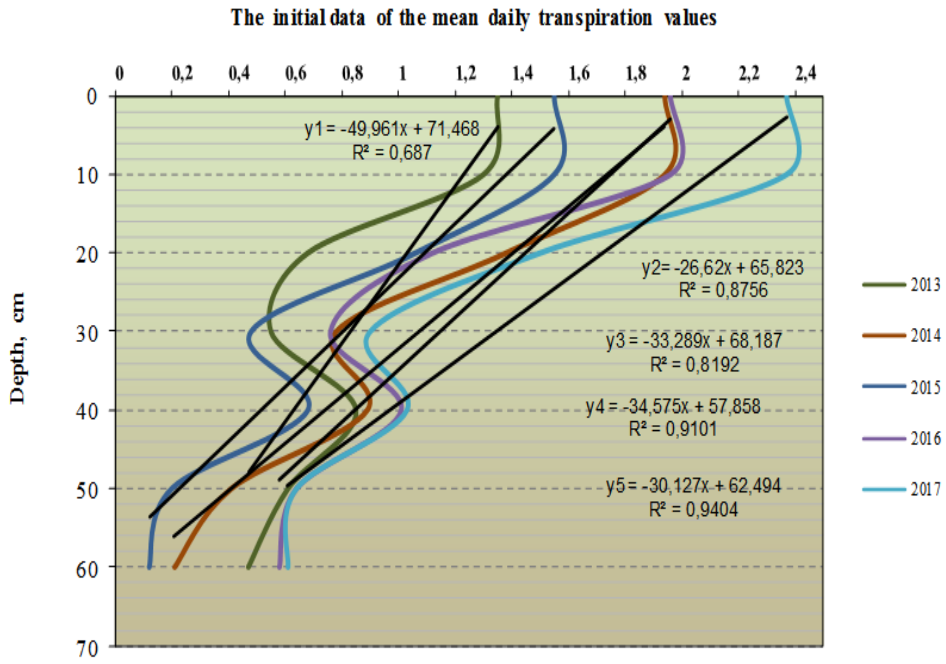

Figure 3. Diagrams of the distribution of the mean per perennial values of transpiration of perennial grasses along 0.1 - meter layers of the root zone.

As can be seen from the diagrams of the layered transpiration of perennial grasses (Figure 3). The rate of movement of moisture to the roots is determined by the intensity of atmospheric conditions, since the nature of the distribution of moisture absorption over the layers of the aeration zone for grasses of the first, second and third cuts has a different character.

The diagram of moisture absorption by roots for the period of growing grasses of the first and third cuttings shows a slight advantage in the amount of absorbed moisture by the three upper 0.1-meter layers (0-0.3 m) in May and September. For all the years of observation, the grass of the second cut (June-July) in the 0-0.3 m layer absorbs moisture more intensively.

During the cultivation of grasses of the second cut, peak maximum values of temperature and humidity deficit are noted, and these are extreme conditions for growing crops.

It is important to determine the distribution function of moisture absorption by the roots of cultivated crops and take into account these features in the depth of the root zone when carrying out the drying and moisturizing measures to create optimal conditions for their cultivation and in the appropriate phases of crop development to minimize crop losses.

The results of measurements of the average daily transpiration values are given in Figure 3 of the initial data for the determination of the dependence $E_T^{(i)}$ = f (z).

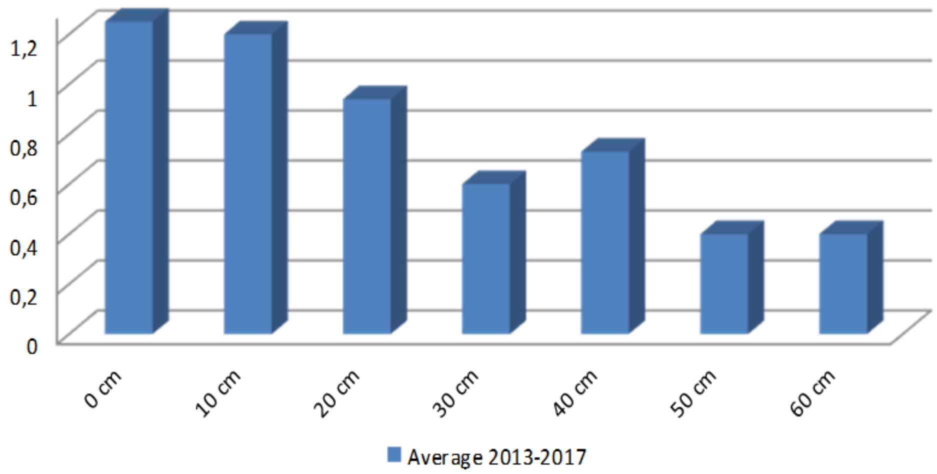

Figure 4. The average initial data of the average daily transpiration values

Proceeding from the physical model of transpiration it`s assumed that the distribution function of moisture absorption E (z) satisfies the requirements [5, 7, 14, 16]:

$$E(0) = E(m_r) = 0 \tag{2}$$

$$\sum_{i=1}^{n} \int_{\alpha_i}^{\beta_i} E(z) = E_T \tag{3}$$

Where:

$E(z) -$ moisture absorption distribution function;

α_i and β_i - the limits of integration (corresponding to the lower and upper boundaries of 0.1 m layer).

The function of the distribution of moisture absorption by plant roots, g (z), used to determine the intensity of moisture absorption along the vertical of the root layer, has the form [5, 7, 14, 16]:

a) for maize: $$g(z) = \frac{3}{m_r}(8.3 * \frac{z^3}{m_r^3} - 14.6 * \frac{z^2}{m_r^2} + 7.3 * \frac{z}{m_r} - 1) \tag{4}$$

b) for perennial grasses: $$g(z) = \frac{4z}{m_r^2}\,(4.6 * \frac{z^2}{m_r^2} - 5.4 * \frac{z}{m_r} + 0.8) \tag{5}$$

Conclusions

1. The analysis showed the importance and necessity of determining the functions of moisture selection by the root system of cultivated crops from the drained soil profile, since taking into account the spatial peculiarities of the processes of moisture absorption by plant roots makes it possible to predict the moisture regime of the root-inhabitable soil layer. Conduct drying-moisturizing measures on ameliorated lands of the humid zone is more justified and qualitatively. Therefore, when choosing the structure of models of moisture absorption by cultivated crops along the depth of the root-layer of soil, first of all, sufficient simplicity and reliability of obtaining experimental information for the purpose of using these models in production conditions were taken into account.

2. The use of a field tensiometric setup made it possible to obtain experimental data for finding the transpiration value over layers of 0.1 meter in the aeration zone. For this, on one of the lysimeters during the growing season with layered water supply, the plants were not grown, the vegetation cover was only simulated to provide adequate soil shading conditions. Thus, in the process of water balance calculations on this lysimeter, evaporation was determined.

3. Analysis of the dynamics of layered transpiration during the vegetation period (Figure 2) and the moisture absorption diagram of the root system of perennial grasses (Figure 3 and 4) shows that the maximum moisture costs for transpiration fall on a layer 0.3 m thick from the soil surface where the maximum root concentration (according to field studies).

4. The diagram of moisture absorption by roots for the period of growing grasses of the first and third cuttings shows a slight advantage in the amount of absorbed moisture by the three upper 0.1-meter layers (0-0.3 m) in May and September. For all the years of observation, the grass of the second cut (June-July) in the 0-0.3 m layer absorbs moisture more intensively.

5. It is important to determine the distribution function of moisture absorption by the roots of cultivated crops and take into account these features in the depth of the root zone when carrying out the drying and moisturizing measures to create optimal conditions for their cultivation and in the appropriate phases of crop development to minimize crop losses.

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