RESOURCE-SAVING TECHNOLOGIES IN AGRICULTURE AS A WAY TO REMOVE FOOD SECURITY RISK

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Abstract

The article deals with the possibility of reducing the food security risks by creating optimal conditions for plant growth and development in accordance with climatic conditions. To do this, it is necessary to know the evapotranspiration of plants for the studied period of times. On the example of the study of on apple's seedlings evapotranspiration depending on meteorological and biological conditions under different watering schedule with drip irrigating in central region of Russia, the obtained regression equations for definition of evapotranspiration are given.

Keywords: resource-saving technologies, risk, food security, evapotranspiration, differentiated irrigation schedule, drip irrigation, apple seedlings, irrigation rate

I. Introduction

The Decree of the President of the Russian Federation "On the approval f the Doctrine of food security oa the Russian Federation" is indicated that ensuring the country's food security involves risks that can significantly affect it.

With the existing climate change, which is characterized by global instability, new risks are emerging in all areas of human activity and, as a first - in agriculture. This is due to increasing frequency of hurricanes, floods, and droughts, which can lead to a sharp decrease in gross output or complete loss, which is directly related to the risk of food security. One of the mechanisms for managing climate risks is to maintain an optimal water-air regime of the soil during the crop's cultivation throughout the growing season in accordance with the changing requirements of plants according to the phases of their development.

Resource-saving technologies aimed at rational nature management and environmental protection play an important role in such conditions, which ensure the saving of irrigation water, protection of soils, as well as surface, groundwater and water resources from pollution. A scientifically based irrigation regime developed in accordance with plant water requirements, as well as rational irrigation techniques meet the principles of resource saving.

The main indicator used in the justification of irrigation schedule is the evapotranspiration of crops, which serves as a measure of the moisture need of plants. This indicator allows determining the irrigation quantity and rate in specific condition and therefore this is the basis of plants water management. There are experimental and calculated methods of evapotranspiration determination [2,3,4].

Evapotranspiration, or total water consumption, is a function of external and internal factors. External factors include meteorological conditions, the level of agricultural technology, soil moisture; internal factors include the physiological characteristics of the plant (type and phase of development). With optimal moisture reserves in the soil, evapotranspiration is more dependent on the temperature regime of the external environment and the influx of solar radiation, that is, it has a bioclimatic character [1, 14].

During the growing season, evapotranspiration changes in accordance with the changing requirements of plants to the water regime due to the passage of different phases of development, as well as meteorological conditions. The greatest intensity of evapotranspiration is observed when the periods of maximum plant water demand coincide with the most intense meteorological conditions [1,3,12].

Since evapotranspiration largely depends on the type of crop, the phase of its development, and growing conditions, it is necessary to determine its values experimentally for certain types of crops grown in various soil and climatic conditions over the required period of time [13]. It is especially important to know the daily water consumption of a crop with drip irrigation, which makes it possible to accurately regulate soil moisture and maintain it within the required limits for a given crop throughout the growing season. In this case, the irrigation rate for drip irrigation should correspond to evapotranspiration for a certain period, which will allow maintaining soil moisture in the required range.

The existing methods for determining evapotranspiration are divided into experimental (direct measurement methods) and computational methods based on establishing the relationship of water consumption with climatic and biological factors [14]. Experimental methods make it possible to obtain the most accurate result, but are characterized by high labor intensity and low efficiency, which is due to the influence of many external and internal factors. It is the great variability of evapotranspiration over time and in accordance with natural and climatic conditions that has led to the creation of a large number of computational (empirical) methods. To be able to use computational methods, it is necessary to experimentally obtain additional coefficients or coupling equations that correspond to specific conditions and the cultivated crop.

II. Materials and methods

As a result of studies of the water regime of apple seedlings grown under drip irrigation in the conditions of the Moscow region under various irrigation regimes, the values of evapotranspiration of seedlings for three years with different availability of temperature and precipitation were obtained.

In the nursery of the Michurinsky garden of the Russian State Agricultural Academy named after K.A.Timiryazev in 2011-2013, studies were conducted on the formation of seedlings of apple trees White infusion and Honeydew under various irrigation regimes. The following humidification regimes were studied: option I – soil moisture was maintained in the range of 70-95% HB; II – humidity was maintained in the range of 60-85%HB; III variant is differentiated – in the first year of sapling development, humidity was similar to option I, and in the next two years, similar to option II; IY variant (control) – without irrigation [7]

The soils of the pilot area are sod-podzolic on the cover loam, medium loamy. Watering was carried out by drip lines arranged according to the scheme 0.9x0.3m with built-in droppers with an auto-compensation system, which made it possible to maintain a constant flow rate of 3.8 l/h droppers. The moisture layer changed over the years in accordance with the depth of development of the root system. In the first year it was 30cm, in the next two years it was 40 and 50 cm. Soil moisture was determined using tensiometers, the readings of which were compared with the humidity determined by the thermostatic-weight method.

Evapotranspiration of apple seedlings was calculated based on changes in moisture reserves in the active soil layer. It is quite difficult to plan irrigation with drip irrigation according to the evaporometer data in humid regions, this is due to the uneven distribution of precipitation in time and space, which does not allow considering their effect on the available moisture content in the soil. In this regard, in humid areas, it is advisable to use a method for calculating water consumption based on measuring the actual soil moisture, which eliminates the need to consider the amount of precipitation [5]. Then evapotranspiration for the estimated period E will correspond to the difference in the values of moisture reserves in the soil at the beginning and end of the period under consideration (WH-Wk) plus precipitation (P) and groundwater recharge (Vg)

Knowing the actual values of soil moisture, it is possible to calculate moisture reserves at the beginning and end of the decade and determine evapotranspiration using the water balance equation [3, 4, 6, 7, 8, 9, 10]:

$$W_k = W_н + P + Z - E \pm V_g,$$

где W_k и $W_н$ – moisture reserves in the soil layer at the end and beginning of the calculation period, m3/ha;

P – precipitation, m3/ha;

Z – condensation of water vapor during the calculation period, m3/ha, with a decadal calculation of soil moisture dynamics, condensation of water vapor is insignificant;

E – evapotranspiration, m3/ha;

Vg– groundwater recharge, m3/ha. (This value was insignificant due to the deep occurrence of groundwater and the light granulometric composition of the soil.

III. Research results

The obtained values of evapotranspiration of one-, two- and three-year-old apple seedlings for three years of different availability are shown in Table 1. The table data confirm the direct dependence of evapotranspiration on the degree of soil moisture: thus, the highest values were obtained in 2013, as the wettest, in all variants. Over 3 years of research, the maximum values were noted in the most humidified variant I, where evapotranspiration increases from 3,561 in 2011 to 4,239 m3/ha in 2013. The minimum values of evapotranspiration were obtained in 2012: in the II variant – 3068 m3/ha, in the III – 3056 m3/ha (soil moisture within 60-80% HB) and in the control – 2301 m3/ha. This is due to the fact that in 2011, in all variants, survival irrigation was carried out at a rate of 410 m3/ha, and 2012 was characterized by a lower amount of average daily temperatures, more precipitation and a lower inflow of total solar radiation.

Changes in evapotranspiration during the growing season are determined by both climatic factors and the phase of apple seedlings growing. The maximum value of evapotranspiration of annual seedlings was obtained in the 3rd decade of July: from 183 m3/ha to 355 m3/ha in accordance with variants. During this phase, the leaf surface area is still small, and moisture evaporates intensively from the soil surface. The second peak of evapotranspiration is observed in the 3rd decade of July, which is associated with the development of the maximum leaf surface area, which contributes to intensive transpiration against the background of high average daily temperatures and a large inflow of solar radiation.

It should be noted that the control variant, in which did not consider the first two decades of May in connection with engraftment irrigation. In 2012, the maximum water consumption was also noted in the 3rd decade of July: from 234 m3/ha to 382 m3/ha. In the third year of research, the greatest importance of evapotranspiration was in the 2nd decade of May, when a combination of high temperatures and an inflow of total solar radiation was observed. In addition, this period is characterized by an intensive growth of seedlings. It is necessary to pay attention to the III differentiated variant, where, compared with the I variant, water consumption for three years of research was 1519 m3/ha less, and the quality and yield of seedlings are the same as in the I variant [7]

After irrigation is stopped, evapotranspiration levels out in all variants and reaches minimum values.

Table 1: *Evapotranspiration of apple seedlings under various soil moisture conditions for one, two and three-year-old seedlings, m3/ha*

Month	Decads	I variant (70–90% HB)	II variant (60–80% HB)	III variant (differ.)	Control (without irrigation)
1-st year					
May	1	223	220	220	219
	2	249	253	253	251
	3	312	282	316	158
June	1	303	268	301	154
	2	256	225	254	128
	3	295	259	293	150
July	1	272	244	270	151
	2	318	275	309	162
	3	355	312	354	183
August	1	226	198	224	114
	2	257	226	255	141
	3	152	157	158	153
September	1	137	132	131	133
	2	108	103	105	107
	3	99	97	96	96
Total		3561	3252	3538	2301
2-nd year					
May	1	268	199	196	150
	2	289	221	218	161
	3	322	277	274	209
June	1	266	197	194	145
	2	322	255	252	187
	3	337	258	255	192
July	1	357	281	278	212
	2	310	242	239	174
	3	382	313	311	234
August	1	348	273	270	199
	2	254	182	179	123
	3	109	111	117	111
September	1	115	113	115	106
	2	83	80	87	78
	3	65	66	71	62
Total		3828	3068	3056	2344
3-nd year					
May	1	287	234	233	182
	2	381	314	313	244
	3	284	231	232	180
June	1	364	305	300	241

	2	365	307	299	238
	3	377	305	310	234
July	1	372	303	306	233
	2	343	280	282	219
	3	271	221	222	172
August	1	330	269	272	210
	2	332	271	271	212
	3	276	225	226	175
September	1	103	106	103	99
	2	105	98	99	93
	3	49	51	47	44
Total		4239	3519	3515	2777

The general character of evapotranspiration dynamics for seedlings of the second year of growing is described by a polynomial trend line (Fig. 1). As can be seen from the figure, evapotranspiration, reaching its peak in the 2-nd decade of July, gradually decreases by the end of the growing season.

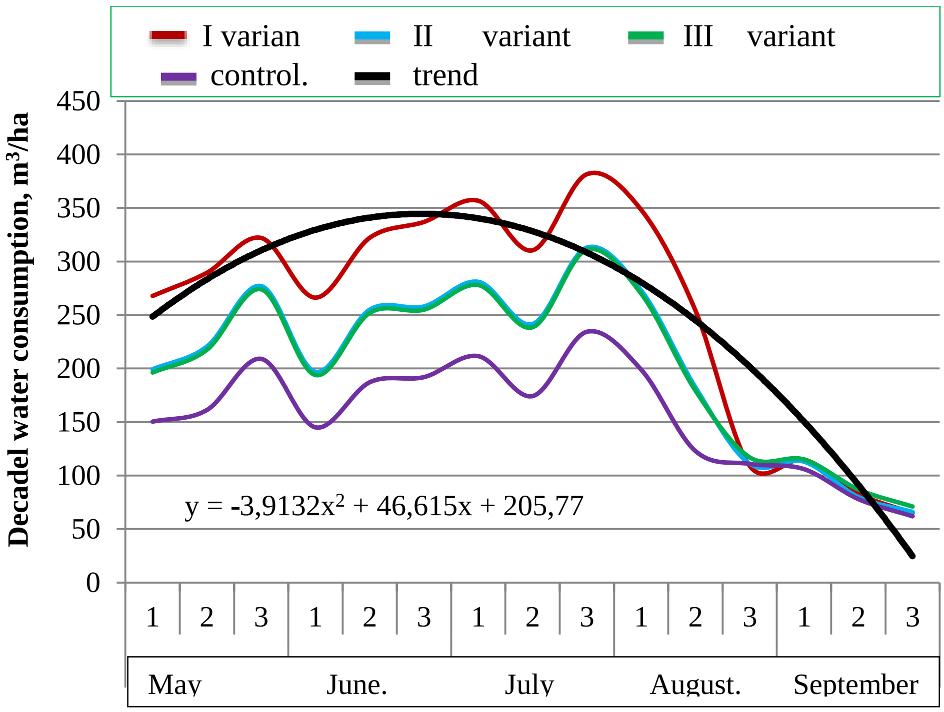

Figure 1: *Dynamics of decadal evapotranspiration of two-year-old apple seedlings described by a polynomial of the second degree*

IV. Discussion

During studies for three years of different security and seedlings of different ages, a linear dependence of evapotranspiration on such meteorological factors as the inflow of total solar radiation and the sum of average daily temperatures was established [11], which is described by the following regression equation (tab.2). In the equations under consideration E – evapotranspiration per decade, m^3/ha, t – sum of average daily temperatures per decade, Q – inflow of per decade, M j/m^2. It should be noted that these equations are valid only for the irrigated period. Evapotranspiration at the end of the vegetation is difficult to describe by these equations, as the average daily temperature, inflow of total solar radiation decreases significantly, and the amount of precipitation increases significantly.

On the basis of the obtained equations, a three-dimensional graph of the dependence of evapotranspiration on climatic factors for 1 variant of three-year seedlings according to the equation E=*7,4+0,81Q+0,91t* (*Fig*.2)

Table 2: *Dependence of evapotranspiration on the sum of average daily temperatures and inflow of total solar radiation*

Year	Experience option	Regression equation	Determination factor, R^2	Model error
2011	I (70–90% HB)	$E = -24{,}9 + 0{,}77t + 0{,}69Q$	0,89	± 4,4
	II (60–80% HB)	$E = -20{,}9 + 0{,}65t + 0{,}64Q$	0,83	± 0,5
	Control	$E = -10{,}2 + 0{,}46t + 0{,}29Q$	0,98	± 2,3
2012	I (70–90% HB)	$E = 30{,}2 + 0{,}76t + 0{,}73Q$	0,77	± 6,5
	II (60–80% HB)	$E = -42{,}3 + 0{,}64t + 0{,}86Q$	0,81	± 4,5
	Control	$E = -50{,}9 + 0{,}41t + 0{,}80Q$	0,74	± 2,5
2013	I (70–90% HB)	$E = 7{,}4 + 0{,}81t + 0{,}91Q$	0,89	± 0,5
	II (60–80% HB)	$E = 4{,}0 + 0{,}62t + 0{,}81Q$	0,92	± 2,9
	Control	$E = 1{,}3 + 0{,}44t + 0{,}63Q$	0,73	± 4,4

For annual apple seedlings, a general model for calculating evapotranspiration has been developed depending on the total solar radiation (Q), the sum of average daily temperature (t) and soil moisture (γ)

$$E = -101{,}3 + 0{,}62Q + 0{,}54t + 1{,}9\gamma \pm 11{,}4,\ R = 0{,}81.$$

The soil moisture parameter is set as follows: 70 - in the irrigation mode of 70-90% FC, 60 - in the irrigation mode of 60-80% FC and 0 - in the absence of irrigation.

Similar equations were obtained for two- and three-year-old seedlings, respectively.

$$E = -137{,}8 + 0{,}56Q + 1{,}09t + 1{,}5\gamma \pm 30{,}7,\ R = 0{,}74;$$
$$E = -56{,}6 + 0{,}62Q + 0{,}78t + 1{,}5\gamma \pm 20{,}8,\ R = 0{,}78$$

However, the best result was shown by a simple linear dependence of evapotranspiration on the total solar inflow radiation for 3 years of research on all irrigated variants (Tab.3, Fig.3)

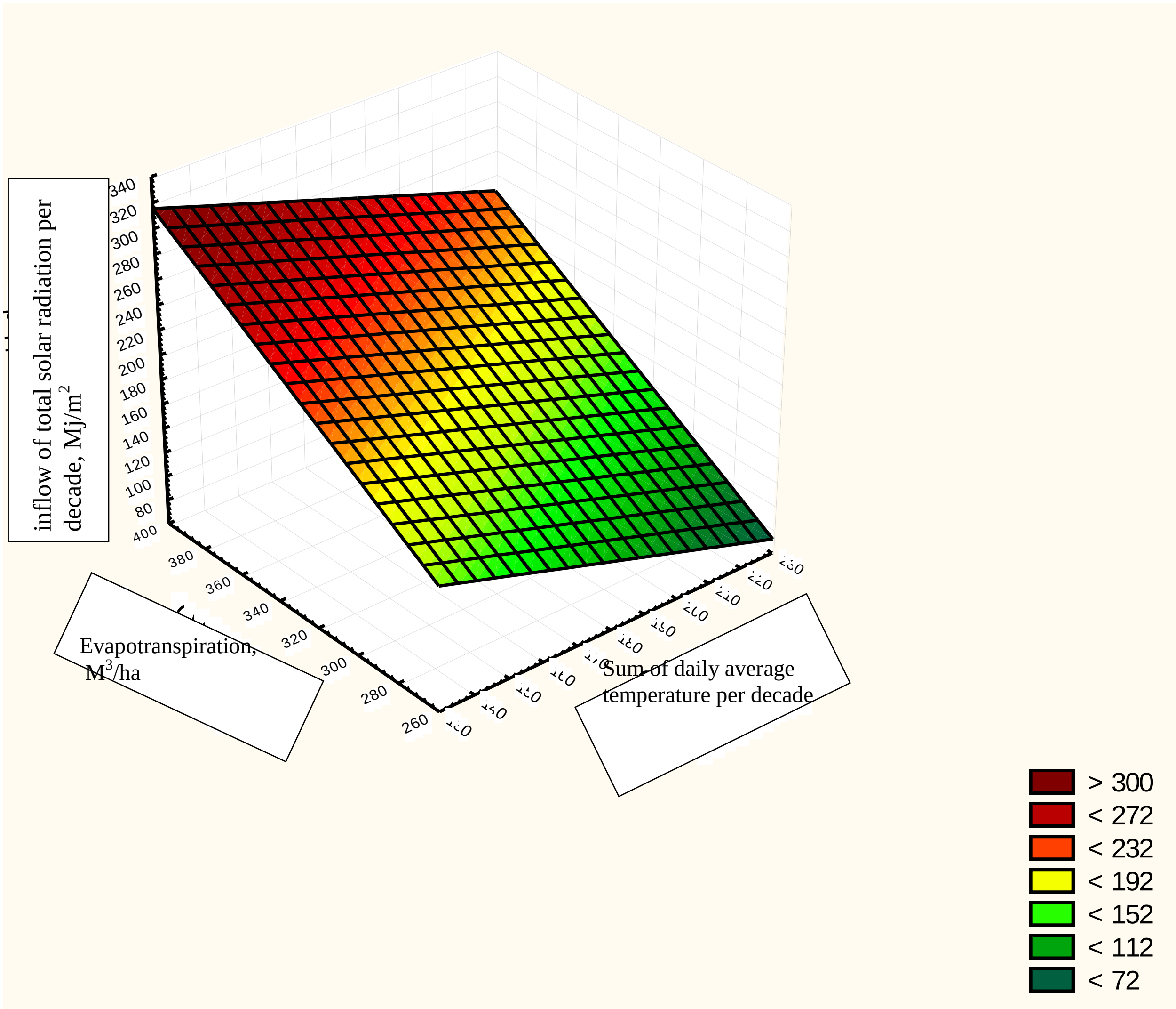

Figure 2: *Three-dimensional graph of the dependence of evapotranspiration on climatic factors for 1 variant of three-year seedlings*

Table 3: *Dependence of evapotranspiration (E) on the total solar radiation inflow (Q)*

Experience option/Year	2011	2012	2013
I	E=1,21Q+23,9 R^2=0,91	E=1,97Q – 81,7 R^2=0,87	E=1,68Q+14,49 R^2=0,94
II	E=1,00Q+37,9 R^2=0,91	E=1,48Q-48,3 R^2=0,91	E=1,31Q+26,1 R^2=0,95
III	E=1,21Q+23,9 R^2=0,91	E=1,21Q+23,9 R^2=0,91	E=1,31Q+25,3 R^2=0,94

The obtained equations allow to maintain soil moisture in accordance with required irrigation regime (tab.4) and the period of development of seedlings, as each equation is valid for a specific period. This is especially true for drip irrigation, when frequent irrigation norms mainly correspond to evapotranspiration over the past period (2 – 7 days), i.e.

$$m = E, \quad m^3/ha$$

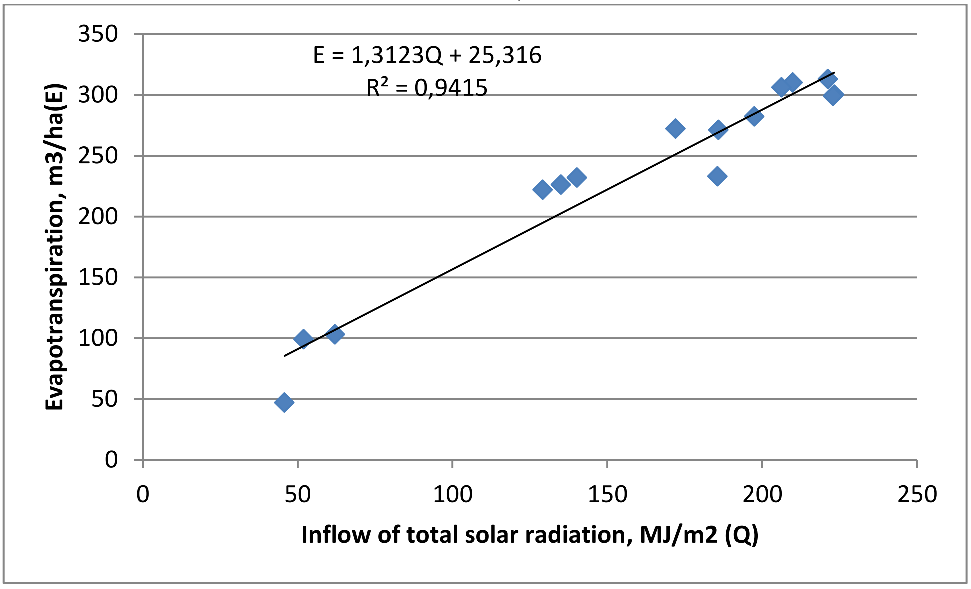

Figure 3: *Graph of the dependence of evapotranspiration (E) on the inflow of total solar radiation (Q)*

For maintenance the specified soil moisture ranges, the irrigation norm was: for 1 variant – 1665, 1481, 1463 m³/ha for years of research, for II variant 1362, 731,748 m³/ha, for III variant -1644, 725 and 741 m³/ha, respectively (Tab. 3). Irrigation water were regularly fed to the site with small norms, thus ensuring constant and uniform moisture of the active soil layer.

Table 4: *Comparative characteristics of different modes of irrigation of apple seedlings.*

Indicator	Experience options								
	I variant (70-90 % FC)			II variant (60-80 % FC)			III variant differentiated		
	Year of research								
	2011	2012	2013	2011	2012	2013	2011	2012	2013
M (irrigation norm, m^3/ha	1665	1481	1463	1362	731	748	1644	725	741
m (norm of watering,m^3/ha	41	49	59	41	46	58	40	45	57
Number of waters	41	30	25	33	16	13	41	16	13
T (The period between watering, day)	2	3	4	3	5	7	2	5	7

Irrigation norms increased annually in accordance with the increasing of roots zone from 30 to 50 cm and amounted to 40, 49, 58 m^3/ha years research respectively. The number of waterings depended on the experience and meteorological conditions of the year and varied from 16 to 30. The period between watering varied according to years of research and depending on soil moisture regime (experience options) from 2 to7 days, which ensured uniform moisture during drip irrigation.

V. Conclusions

1. Resource-saving technologies that contribute to reducing food security risks include the development of scientifically based §rational irrigation regime based on knowledge o plant evapotranspiration by development phases.

2. The maximum value of evapotranspiration during the vegetation period is typical for the most humid variant (1) – 3561,3828 and 4239 m^3/ha years of research, respectively, the minimum – for control (without irrigation) – 2301,2344 and 2777 m^3/ha. The highest values of evapotranspiration were recorded in the 2nd and 3rd decades of May (I variant - 355 -382 m^3/ha, II variant – 312 – 314 m^3/ha, control – 182- 244 m^3/ha)

3. Differentiated irrigation regime contributes to the saving of irrigation water, which in two years reached 777 m^3/ha, in three years - 1500 m^3/ha and decrease in evapotranspiration by 795 and 1519 m^3/ha, respectively.

4. Regression equations describing the dependence of evapotranspiration on the inflow of total solar radiation and the sum of average daily temperatures have been obtained, the use of which will allow to quickly manage the water regime of plants in accordance with changing climatic factors and resource saving requirements.

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