EVAPOTRANSPIRATION AND BIOPHYSICAL COEFFICIENTS OF RASPBERRIES GROWN IN DRIP IRRIGATION

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Abstract: *In order to establish the aggregate and average daily values of raspberry evapotranspiration in an experimental site in the village of Chelopechene - Sofia, drip irrigation studies were carried out on a replanting variety "Liulin" under different irrigation regimes - from full satisfaction of the daily needs of the culture from water to irrigation with 20% and 40% irrigation norms. The meteorological conditions during the study period showed an influence on the sum of the sum and day-to-day values of the culture evapotranspiration.*
On average, during the research period, the total evapotranspiration rate for the raspberry vegetation period is 4730 m3 / ha, with the main part being formed by the irrigation rate - 60% and by rainfall - 40%
For the needs of practice and design, the ten-day values of the biophysical coefficients Z and Kp were calculated over a five-year period.
KEYWORDS: *EVAPOTRANSPIRATION, BIOPHYSICAL COEFFICIENTS, RASPBERRIES, IRRIGATION RATE, DRIP IRRIGATION*

The necessity of irrigation to maintain optimal soil moisture in the active soil layer is mainly determined by the quantity and distribution of rainfall during the vegetation period of the culture and the evapotranspiration. Evapotranspiration of any agricultural crop is a major cost element in the water balance of the active soil layer and is one of the main factors determining the parameters of the irrigation regime. For raspberries variety " Lyulin " cultivated in plains in the region of Plovdiv (Kornov, 2014), it varies from 480 to 698 mm, and for Newburg variety grown in the region of Kostinbrod - from 600-660 mm (Ivanov Al., 1980)

Drip irrigation is widely used to irrigate berry crops because of the ability to effectively control irrigation processes, irrigated planting and even the individual plant (Bucks, 1982) (Kireva, R., V. Petrova, 2014). fully meeting the requirements for sustainable agriculture and organic fruit production, ensures high yields, quality of production and reduces unwanted side effects. (Branson et al., 1981), (Kireva, R., V. Petrova, 2014)

The purpose of the study is to determine the values of the evapotranspiration and the biophysical coefficients of raspberries cultivated in drip irrigation in the Sofia field.

Materials and method

In order to establish the evapotranspiration of Raspberry from the “Lyulin” variety, an experiment was conducted in the test field in Chelopechene, Sofia. The soil is leached leptosols, slightly sandy loam in the ploughing layer, formed on the base of an old deluvial cone of sediment materials. It is poorly stocked with nitrogen, on average with phosphorus and well stocked with potassium. On average, for the layer 0 - 60 cm, the soil has the following water-physical properties: WHC = 22.1%, humidity till wilting rate - 12.3% to the weight of absolute dry soil, bulk weight with WHC - 1.47 g / cm3. For the soil layer 0 - 100 cm, the same indicators have the following values: WHC - 21.8%, frosting humidity - 12.3% and bulk density - 1.50 cm3.
Plants are planted in a scheme: row length 53 m, row spacing 2.20 m and plant spacing 0.50 m
The following irrigation options have been tested:
1. Option without irrigation;
2. Option irrigation with 100% irrigation rate;
3. Irrigation option with 80% irrigation rate;
4. Irrigation option with 60% irrigation rate;
The size of the irrigated rate is calculated using the formula (Frecman and Garzoli, 1980). To monitor the soil moisture change, sample 2 (100% i.r.) at a depth of 0-60 cm over 10 cm was sampled, which was processed by the weight-thermostatic method. Based on the data on soil moisture dynamics during the vegetation period, the irrigation water and the precipitated precipitations using the water balance method, ten day evapotranspiration (ET) of the raspberry was established and for the vegetation period in total. The calculation of the biophysical coefficients z and kb (Delibaltov, Hristov, Tsonev, 1969) and (Blanney, Criddle, 1962) was made to determine the evapotranspiration theoretically. The limit values of the individual elements of the raspberry irrigation regime have been established experimentally.

Results and discussions

Meteorological conditions of the experiments

The instability of the meteorological factor - rainfall - determines the irrigation as a major event of the agro-technical complex, with a significant contribution to the obtaining of high and sustainable yields from the cultivated crops.

Regarding the amount and the distribution of rainfall during the vegetative season April to September, the conditions in the individual years are characterized by variety and presence of extremes. According to the provision of rainfall, determined in a 50 year series (1956-2005) (Table 1 and Fig.1, three of the years - 2001, 2002 and 2005 are wet, one - 2003 - average and one - 2004 - very dry. Droughts lasting more than ten days are observed throughout the years of the surveyed period.

The sum of precipitation in 2001, which is characterized as moderately humid, in April - September period it was close to the average for the 50-year period - 358 mm, and in July - August it was 75 mm (Table 1). The dry season (2004) is the sum of rainfall for the April-September period is 258 mm, which is 30% less than the average to the multiannual values, and in July and August the rainfall was 73 mm, almost the same as in the averagely humid year (2001). These rainfall was insufficient for the development of raspberries, which also predetermined a larger number of irrigations. The annual sum of precipitation in 2002 , characterized as very humid, with a 15.3% guarantee, due to the unusual rainfall in July, August and September, and the wettest year with 1.4% the provision of rainfall factor during both sub periods is 2005, which differs from the others in the series with extremely high rainfall for the period April - September 765 mm, which are 1.7 to 5.7 times higher than the average for a 104 year series.
The temperature sums, both for the April-September potential and the July-August period, show that without exception the years are warm (Table 1 and Fig. 2).

Table 1 *Rainfall during raspberries vegetation period (2001– 2005 years.)*

Periods	Total rainfall, mm					Rainfall factor security, %				
Years	2001	2002	2003	2004	2005	2001	2002	2003	2004	2005
м. IV – IX	358	418	329	258	765	37,1	17,3	59	94,6	1,4
Aaverage multi-annual	365	365	365	365	365	-	-	-	-	-
м. VII – VIII	75	158	104	73	400	76,8	9,3	47	74,8	1,4
Average multi-annual	110	110	110	110	110	-	-	-	-	-

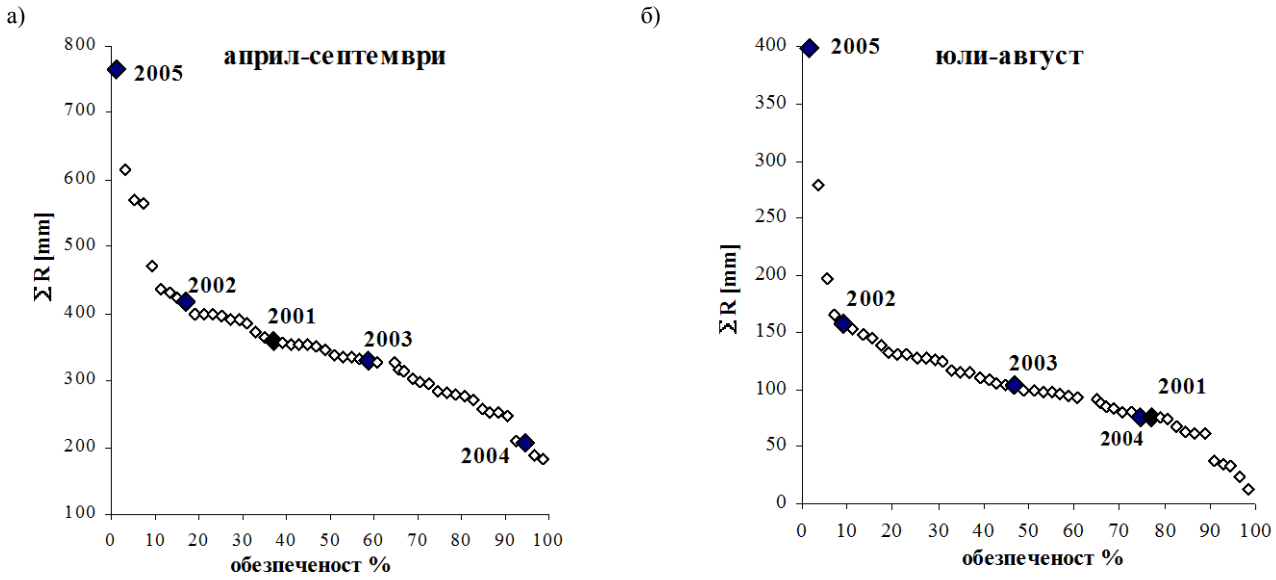

Fig. 1 *Coverage curves for the fifty-year series (1956-2005) for the periods: (a) April to September; b) July-August*

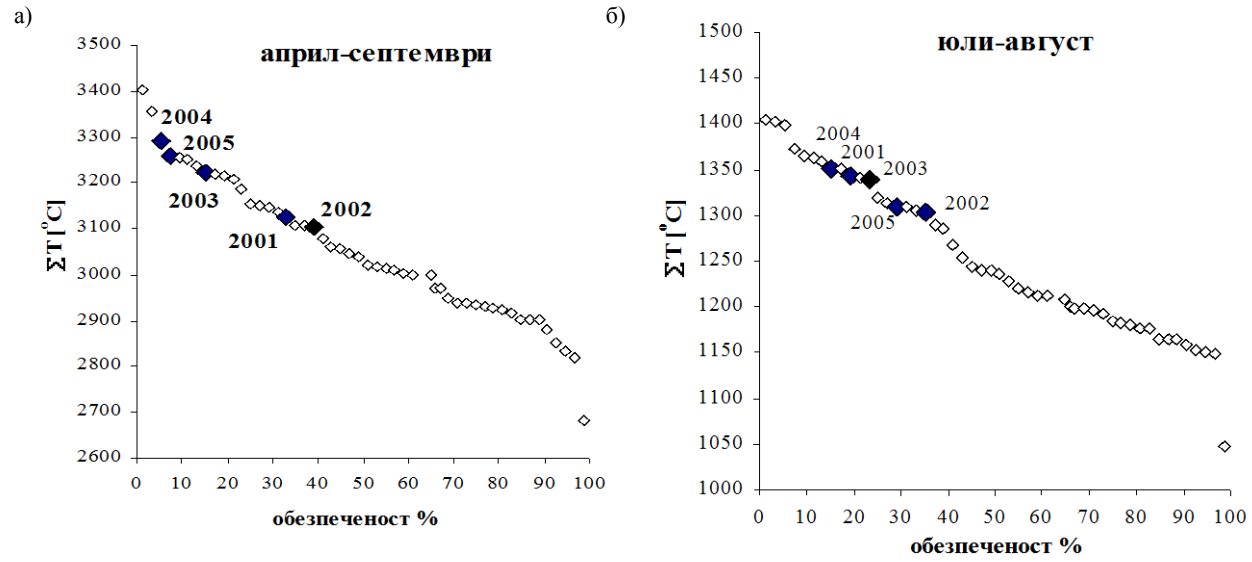

Fig. 2. *Coverage of the temperature sums for the fifty-year series (1956-2005) for the periods: a) April-September; b) July-August*

The need for irrigation of raspberries to maintain optimal soil moisture in the 0-60 cm layer is mainly due to the amount and distribution of rainfall during the vegetation period of the crop. The irrigation norms are implemented for the period from the beginning of May to the end of September. Inter irrigation periods during the vegetation of the crop are different and depend on the quantity and distribution of precipitation, as well as the phases of the development of the culture. It has been established that the requirements of raspberries for soil moisture are higher in the periods of flowering, ripening and harvesting of the fruits where the highest number of irrigations have been realized (Table 2), and therefore the moisture in the soil during this period is it is necessary to maintain 80-85% of WHC in the 0-60 cm layer.

On average, during the vegetative period of the raspberry, 16 irrigations with an average irrigation rate of 180 m3 / ha and an irrigation norm of 2880 m3 / ha were submitted, with the highest number of irrigation being carried out during the dry year 2004, at least during the wet 2005 -8 pieces.

Highest values evapotranspiration reached 5260 m3 / ha in dry 2004 and in the remaining years it ranged from 4360 to 4850 m3 / ha (Table 3). On average, during the research period, the total evapotranspiration rate for the raspberry vegetation period is 4730 m3 / ha, with the main part being formed by the irrigation rate - 60% and the rest of the rainfall - 40% (Table 3). Percentage participation of ET forming elements varies between years and is dependent on meteorological factors (rainfall). The largest share in the formation of ET is the irrigation rate in 2004 (dry), its percentage contribution to 75% and the remaining 25% are precipitations, and in 2005 (wet), the percentage contribution of fallen rainfall in the vegetation of raspberries reaches 68%.

Table 2 *Number of irrigation rates in the rape season at 100% irrigation rate averaged over the survey period*

Development phases	Number irrigation rates	Irrigation periods
Strong growth	1	3-та decade may 2-ра decade June
Flowering	2-3	3-ра decade June 2-ра decade July
3. Ripening and harvesting of fruits	10-11	3-ра decade July, August, September

Table 3 *Total amount of evapotranspiration and forming elements of raspberries*

Years	Total amount of evapotranspiration,m^3/ha	Forming elements of evapotranspiration	
		Irrigation rate,%	Rainfall, %
2001	4650	66	34
2002	4360	60	40
2003	4850	68	32
2004	5260	75	25
2005	4550	32	68
Average 2001-2005	4550	61	39

It is of great importance to determine not only the wateruse throughout the growing season, but also the one during the different periods of raspberry development expressed in its average daily round. On average, experimental years with evapotranspiration values range from 0.9 to 6.3 mm per day with two minimums - at the beginning and end of the vegetation and a maximum - in July and August, reaching 5.8 - 6.3 mm , (Table 4).

In the initial phase of culture development, the average daily values of the evapotranspiration are lower, due to the smaller size of the plants, which consume small amounts of water and the low stress of the meteorological factors (low sunlight, low soil temperatures and open air) . Optimizing soil moisture increases the water consumption of raspberries, the degree of growth depends on the climate and the number of water courses.

With raspberries entering the intensive growth phase, starting in the second ten-month period of June, a more intense increase in ET was observed, reaching an average of 4.3 mm during the month of the survey. The maximum values of the average daily values of the evapotranspiration are related to the ripening period, the fruit harvest, which coincides with the period of the highest tension of the meteorological factors. This period covers July, August. The maximum ET is in the first ten days of August - 6.3 mm. At the end of the rape vegetation with decreasing the pressure of the meteorological factors, the medium-density ET decreases and in the first and second decade of September it reaches -2,4-3,1 mm (Table 4).

The values of day-to-day evapotranspiration in option 2 (100% irrigation rate) vary from 0.8 to 6.8 mm in the different years, the highest being in the dry 2004. The course of its variations during the vegetation period follows the development of culture and changes in meteorological factors. (Table 4).

For the needs of the meliorative practice it is necessary to calculate the evapotranspiration by methods requiring experimentally determined biophysical coefficients. They reflect the specifics of water consumption depending on the biological requirements of the culture, the stage of development, the manifestations of the meteorological factors.

The calculated ten-day values of the biophysical coefficients based on the experimental definition of the evapotranspiration and the daily sums of the average daily air temperature (for the coefficient Z calculated by the formula Delebaltov, Hristov, Tsonev) and the air temperature and the daily hours for every ten days in% during the year. (for the Kb coefficient according to the Blanney, Criddle formula) are presented in (Table 5). Changes in the values of these coefficients follow changes in the evapotranspiration during the growing period of the culture. The set values of the biophysical coefficients represent an objective basis for determining the design irrigation regime and predicting the irrigation time of the crop.

The values of the biophysical coefficient Z of the culture range from 0.06 to 0.29 and the Kb factor from 0.18 to 1.09 on average over the study period.

Table 4. *Medium-day Evapotranspiration of rraspberries*

Evapotranspiration, mm							
Months	Ten days	2001	2002	2003	2004	2005	Average
Май	III	0,8	0,8	0,8	1,2	0,8	0,9
June	I	1,33	1,0	2,88	3,14	1,39	1,95
	II	2,22	1,5	3,15	3,52	2,22	2,52
	III	3,25	3,05	3,74	4,08	3,24	3,48
July	I	4,07	4,03	4,32	4,72	4,30	4,29
	II	4,95	5,08	5,07	5,44	5,38	5,19
	III	6,02	6,13	5,95	6,28	5,24	5,92
August	I	6,48	6,30	6,40	6,80	5,47	6,26
	II	6,35	5,10	5,90	6,25	5,50	5,82
	III	4,54	4,00	4,15	4,38	4,81	4,38
September	I	3,20	3,05	2,92	3,10	3,48	3,15
	II	2,13	2,67	2,01	2,49	2,57	2,37
Total		3,8	3,6	4,0	4,3	3,7	3,8

Table 5. *Values of biophysical coefficients z and kb during the growing season*

Months	Ten days	2001		2002		2003		2004		2005		Average	
		Z	$K_б$	Z	$K_б$	Z	$K_б$	Z	$K_б$	Z	$K_б$	Z	$K_б$
May	III	0,05	0,16	0,05	0,16	0,06	0,18	0,07	0,23	0,05	0,15	0,06	0,18
June	I	0,08	0,26	0,06	0,18	0,14	0,49	0,18	0,58	0,09	0,26	0,11	0,35
	II	0,12	0,39	0,08	0,26	0,15	0,51	0,17	0,58	0,11	0,38	0,13	0,42
	III	0,17	0,56	0,14	0,49	0,18	0,63	0,21	0,70	0,14	0,64	0,17	0,60
July	I	0,20	0,68	0,17	0,62	0,20	0,71	0,19	0,70	0,21	0,73	0,19	0,69
	II	0,21	0,78	0,21	0,79	0,25	0,87	0,27	0,93	0,25	0,89	0,24	0,85
	III	0,29	1,03	0,29	1,05	0,24	0,92	0,28	1,04	0,22	0,84	0,26	0,98
August	I	0,26	1,03	0,29	1,08	0,30	1,12	0,33	1,21	0,28	1,0	0,29	1,09
	II	0,31	1,15	0,29	1,01	0,25	1,0	0,29	1,12	0,26	1,0	0,28	1,06
	III	0,24	0,93	0,21	0,78	0,18	0,75	0,21	0,82	0,23	0,9	0,21	0,84
September	I	0,19	0,70	0,17	0,65	0,18	0,65	0,16	0,64	0,18	0,7	0,18	0,67
	II	0,13	0,48	0,22	0,69	0,14	0,48	0,13	0,53	0,14	0,55	0,15	0,55
Total		0,19	0,48	0,22	0,79	0,21	0,74	0,21	0,76	0,18	0,67	0,19	0,69

Conclusions

1. The total amount of crop's evapotranspiration has been established, which varies between years and is dependent on weather conditions, with the highest values reaching 5260 m3 / h during the 2004 dry season, and in the remaining years ranging from 4360 to 4850 m3 / h

2. The total evapotranspiration rate for the raspberry vegetation period is determined - 4730 m3 / ha. 60% are formed by the irrigation rate and the remaining 40% are precipitated.

3. It has been reported that day-to-day evapotranspiration ranges from 0.9 to 6.3 mm with two minima, at the beginning and end of vegetation, and a maximum in July and August, which reaches 5.8 - 6.3 mm

4. For the needs of the practice and the design, the ten-day values of the biophysical coefficients Z and Kp were calculated for a five-year period and the average for that period.

5. An analysis of meteorological factors has been made during the years of experimentation and their effect on the size of the raspberry transplantation.

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