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STUDY ON THE PRODUCTIVITY OF IRRIGATION WATER ON COTTON CROP

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Abstract

The analysis of the climate change in the country shows that during the summer months there is a decrease in soil moisture, as a result of the increase in temperature and less precipitation during the period. Agriculture affects both the quantity and quality of available water resources for other uses. The purpose of this study was to investigate the effect of irrigation and productivity of irrigation water in certain varieties of cotton grown in irrigated and non-irrigated conditions. Established productivity of three varieties of cotton. The estimated climate indices and coefficients and analyzes the productivity of irrigation water and the effect of 100 m3 irrigation water to produce a kg of cotton per hectare can be used in the design and operation of irrigation systems and in determining the economic impact of drip irrigation, taking into account security of rainfall for periods of committed research. When two waterings are made, the productivity ranges from 4.99-7.40 kg/mm. Productivity of the water, after the completion of four irrigations ranges of 2.66 to 3.26 kg/mm.

Key words*: cotton, irrigation, varieties, yield, productivity.*

INTRODUCTION

Global climate change towards warming and drought raises the question of more economical ways of using irrigation water. One area where new or updated technologies and policies can have a significant impact on more efficient use of water resources is crop irrigation (Ziad et al., 2010; Moteva et al., 2016; Kireva et al., 2018). Demand for water saving technologies in agriculture is a priority for many countries in the European Union and the world. Increasing the efficiency of irrigation water is related to water supply and absorption of water through the vegetation of the crops. Drip irrigation has proved its advantages and effectiveness in a number of crops. In this way localized on which the irrigation water can lead to a 30 ÷ 50% saving of irrigation water and 20 ÷ 40% increase in yield, considered Ravender et al. (2010). Efficiency of irrigation is studied in a wide range of crops (Saldzhiev et al., 2011; Stoyanova et al., 2018; Mahan et al., 2018; Stoyanova et al., 2019).

When cultivated agricultural crops, including and cotton in a market economy and private economy growing emphasis on agrotechnics of crops, productivity and quality, the optimal mineral nutrition and soil fertility in general, the specific economic and environmental conditions.

In drip irrigation the irrigation rates may be regulated, restricted wetted surface and reduces evaporation from the soil surface. Possibility of applying fertilizers together with the irrigation water makes it possible to provide an appropriate diet of the plants in various stages of development and a better distribution of nutrients, reducing labor costs and reducing the amount of fertilizers (Petkov et al., 2013). Investigation of the influence of the feeding of nitrogen fertilizer deposited with irrigation water, has established that the reduction of the emission of 18.75% does not reduce the quality and quantity of the yields and increases the efficiency of utilization of the water supplied for irrigation (Zugui et al., 2003; Aujla et al., 2005; Li et al., 2017).

Yan et al. (2008) found that there was a significant correlation between root length density and cotton yield in the flowering stage and opening the box. There are a significant correlation between root length density and yields of cotton at flowering and boll opening stage.

The regression between irrigation amounts and yields of cotton are $y = -0.0026x^2+18.015x-24845(R^2 = 0.959)$. The regression showed that the irrigation amounts of 3464.4 m^3/hm^2 can access to appropriate root length density and yields of 6360.8 kg/hm^2.

Study efficient use of irrigation water, in three varieties of cotton, it is the basis of this field study.

MATERIALS AND METHODS

The agricultural study was taken in the field trials of the Department of Plant Production at the Thracian University - Stara Zagora. During the period 2018-2019 on a soil type of typical meadow-cinnamon soil, in a fertilizer experiment under irrigation and non-irrigation conditions a field experiment with three varieties of cotton was laid. The subject of the study are cotton varieties and their productivity under the influence of different levels of fertilization and moisture supply. Agricultural experience has been set by the method of fractional plots in four replicates at the size of the harvest plot 15 m^2 (1.80 x 8.34 m). The varieties studied are Helius, Darmi and Isabell. Fertilization is carried out at four norms of nitrogen fertilizer ($N_{O; 8; 16; 24}$).

The varieties are Bulgarian selection approved by Executive Agency for Variety Testing, Testing and Seed Control. Helius was obtained by the method of experimental mutagenesis - irradiation with gamma rays (150 Gy) of seeds. Helius and Darmi were established and introduced into production as early as 2007-2008. Isabell variety is an achievement in the selection of cotton in our country and marks the beginning of a new generation of naturally colored fibers with high environmental and economic effect. The variety was obtained by intraspecific hybridization by crossing the breeding lines with brown and white fibers. The variety was recognized in 2009. High biological potential and high fiber quality are at the heart of the selection of varieties.

Due to the change of the climate elements and their influence on the growth, development and fruitfulness of the crops, the humidity coefficient and the hydrothermal coefficient (HC) have been determined. The active temperature sums were used to determine climatic indicators and coefficients. The active temperature sums are determined by the equation:

$$\Sigma T^oC > 10^o = (t_1 + t_2 + t_3 + \dots + t_n),$$

where: $\Sigma\ T^oC > 10^o$ - sum of effective temperatures (for the period with average daytime temperature > 10º) in ºC; $t_1, t_2, t_3, \dots t_n$ - consecutive observations of daily average air temperatures in ºC; 1, 2,… n - index for the daily number of days during the established period.

The wetting coefficient of Ivanov (1941) is determined by the following dependence:

$$E = 0.0018 * (t + 25) 2 * (100\text{-}a),$$

where: t is the average monthly (decade) air temperature, °C; a - average relative humidity, %. The values of the hydrothermal coefficient (by Selyaninov) are calculated by the formula:

$$K = P * 10 / \sum T^o$$

where P is the sum of precipitation (mm) over a period of time, $\sum$- this is the sum of average daily air temperatures (°C) for the same period.

RESULTS AND DISCUSSIONS

Climatic conditions and coefficients

The elements of the climate that mainly influence the development, productivity and quality of cotton are temperature and rainfall. The air temperature in the ground of the test field is characterized by values close to the temperature norm (Figure 1). The fluctuations in the first trial year are larger. The sowing and the beginning of the growing season takes place at temperatures higher than normal. The average monthly values for April 2018 exceed by +3.68ºC in April compared to the annual norm set for a period of 89 years. Deviations were reported in May (+1.94ºC) and August (+2.43ºC). In the second year of the experiment, the measured temperature values show an excess in June (+2.27°C), August (+1.83°C) and September (+1.53°C). The total temperature is 10.8°C higher in 2018 compared to the multiannual norm.

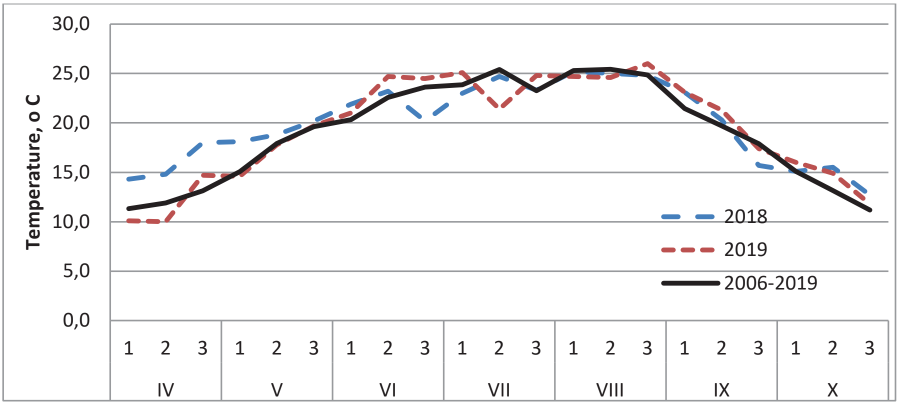

Figure 1. Dynamics of average air temperatures for the period growing season for cotton in the Stara Zagora region, 2018-2019

The data in Figure 2 show the amount and distribution of precipitation over ten days. The total rainfall over the entire growing season varies within a narrow range by year. At 346.0 mm (April-October), we can see how close the values are to the perennials. With regard to the moisture supply of cotton during the growing season, it is important to distribute the rainfall by ten days. The first year of the Field study is characterized by a distribution that guarantees the availability of easily accessible moisture for the plants. Tensions are reported in July and the second and third ten days of August.

A number of mathematical and statistical methods are used in the analyzes of climatic factors to calculate different climatic indicators and indices. Rainfall values and average monthly air temperature are the main parameters in calculating "evaporation".

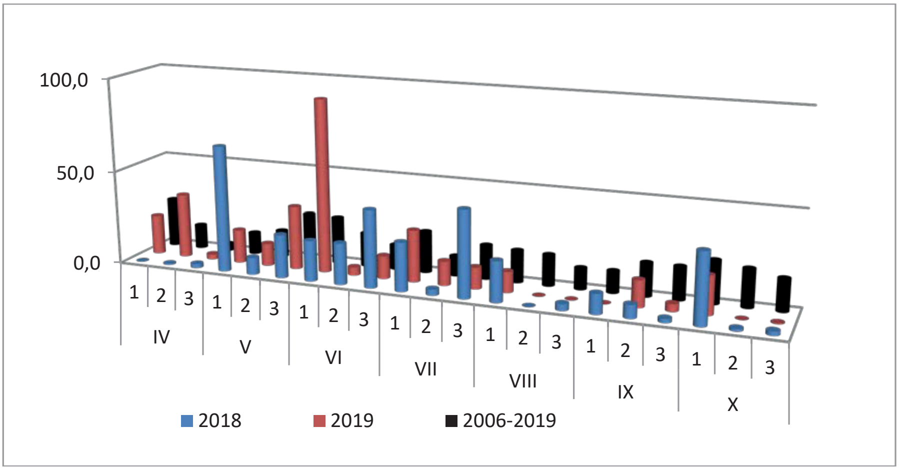

Figure 2. Dynamics of rainfalls during the growing season for cotton in the region of Stara Zagora, 2018-2019

The humidity coefficient and the moisture balance factor reflect the warmth and humidity of the area. The empirical formula for calculating the evaporation of Ivanov shows the degree of humidity over ten days for the period during which the plants need sufficient moisture in the soil. In the last ten days of July, the humidity in the first year was 70% lower than the second. The water deficit during these periods necessitates watering to increase the water supply in the soil.

Table 1. Humidification and hydrothermal coefficients

Year	Humidity coefficient of Ivanov																	
	IV			V			VI			VII			VIII			IX		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
2018	1,14	0,91	1,36	1,00	1,07	1,40	1,23	1,59	1,14	1,37	1,87	1,01	1,86	2,21	2,01	1,79	1,33	1,25
2019	0,69	0,64	1,19	1,02	0,99	1,26	1,10	1,73	1,72	1,94	1,43	1,74	1,87	2,30	2,57	2,00	2,08	1,10
Hydrothermal coefficient																		
2018	0,01	0,04	0,12	3,71	0,48	1,14	0,99	0,95	2,03	1,13	0,13	1,97	0,86	0,00	0,14	0,46	0,35	0,13
2019	2,09	3,41	0,18	1,22	0,67	1,71	4,39	0,17	0,50	1,10	0,60	0,46	0,45	0,00	0,00	0,00	0,67	0,23

The humidity differs by a coefficient of variation, VC = 27.42%. The values of the hydrothermal coefficient range from 0.00 to 4.39 for 2019, which shows the nature of the year. High variability is characterized by CTC in the period VI-VII. The coefficient of variation of the moisture balance for the whole period at CTC is very high VC = 36.68%.

Irrigation water productivity

The productivity results of cotton grown under natural moisture conditions show a great variety over the two experimental years. Helios N16 fertilization reported an increase of 70.3% compared to zero fertilization in the first year, characterized by a more favorable rainfall distribution. In the second year, the increase was 114.6%. The water deficit during the period from flowering to fruiting influenced the flowering and retention of the boxes on the fruiting twigs. This has reduced the yield of raw cotton. The results show that Darmi and Isabelle have the highest yields recorded in nitrogen fertilization with N24 under conditions of periodic water deficit in 2018. The excess ranges from 29.9% (Darmi) to 36.8% (Isabell) .

In the second year, which is characterized by a higher humidity coefficient, the increase is in the narrower range from 1.4% to 3.3% for fertilization with N24. With better soil moisture, the results show higher yields of N16 fertilizer application. For all three varieties, productivity gains were measured within 6.8% to 14.6%. The distribution of moisture provided by rainfall creates the conditions for the development of more powerful stems, with larger boxes. On average for the study period, yields with nitrogen fertilizer at a dose of N16, under non-irrigation conditions, were highest for Helius (42.5%).

Table 2. Water productivity in three varieties of cotton grown at four levels of fertilization

Cotton varieties	Variants	2018		2019		Water produktivity kg/mm		Average		
		Yield, kg/ha	M	Yield, kg/ha	M	2018	2019	Yield, kg/ha	M	Water produktivity kg/mm
Helios	N_0	1541,8	300	1668,7	600	5,14	2,78	1605,25	450	3,57
	N_8	1496,7	300	1870,0	600	4,99	3,12	1683,35	450	3,74
	N_{16}	1745,0	300	1817,0	600	5,82	3,03	1781,00	450	3,96
	N_{24}	1533,4	300	1758,9	600	5,11	2,93	1646,15	450	3,66
	Average	***1579,2***	***300***	***1778,6***	***600***	***5,26***	***2,96***	***1678,90***	***450***	***3,73***
Darmi	N_0	1891,8	300	1793,0	600	6,31	2,99	1842,40	450	4,09
	N_8	1996,7	300	1840,4	600	6,66	3,07	1918,55	450	4,26
	N_{16}	2220,1	300	1954,6	600	7,40	3,26	2087,35	450	4,64
	N_{24}	1965,0	300	1808,9	600	6,55	3,01	1886,95	450	4,19
	Average	***2018,4***	***300***	***1849,2***	***600***	***6,73***	***3,08***	***1933,80***	***450***	***4,30***
Isabell	N_0	1790,1	300	1597,6	600	5,97	2,66	1693,85	450	3,76
	N_8	2171,7	300	1892,6	600	7,24	3,15	2032,15	450	4,52
	N_{16}	1901,7	300	1869,4	600	6,34	3,12	1885,55	450	4,19
	N_{24}	1795,0	300	1765,2	600	5,98	2,94	1780,10	450	3,96
	Average	***1914,6***	***300***	***1781,2***	***600***	***6,38***	***2,97***	***1847,90***	***450***	***4,11***

The productivity of irrigation water is an important point in modern conditions when water resources are scarce and of high value. This study calculated the water productivity of the different fertilization and irrigation options (Table 2). The productivity of irrigation water is defined as the ratio between the yield and the irrigation rate. An analysis of the productivity of irrigation water shows that the submission of a lower irrigation rate in 2018 leads to an increase in water productivity. When two waterings are made, the productivity ranges from 4.99 - 7.40 kg/mm. The highest productivity was found at Darmi (6.73 kg mm) and at all four fertilization levels. For Helius the values range from 4.99 to 5.82 kg/mm. For the Isabella colored natural fiber variety, the average for the four fertilizer variants is 6.38 kg/mm. The tendency to decrease in productivity values after the realization of four waterings in the second year is observed in the three varieties. The variation is very narrow, from 2.66 to 3.26 kg/mm. During the study average, irrigation water productivity was estimated to be lowest for Helius (3.57 kg/mm), zero fertilization, and 3.66 kg/mm for high nitrogen (N_{24}). The highest water productivity is Darmi. The calculated average period average is 4.64 kg/mm for the N_{16} fertilizer variant. Darmi exceeds water productivity by 15.3% compared to Helius. In terms of Isabell, data show 10.2% higher productivity.

The effect of irrigation is expressed by the resulting yield of raw cotton (Table 3). The higher yields resulting from the irrigation were the result of the second year. Increasing the water supply of soil moisture guarantees better plant development, more vegetative mass and fruit twigs. Helius has the largest vegetative mass, many boxes that cannot be opened and this reduces the yield. The rapid growth rate and the betting on more boxes, many of which remain open after irrigation, account for the lower first-year results. Four waterings were conducted in the second year. The irrigation effect is the reported additional yield for all varieties and variants of fertilization.

Table 3. Additional yield, effect of 100 m^3 irrigated water and effect of 100 m^3 irrigated water in kg in three varieties of cotton, Stara Zagora

Cotton varieties	Variants	Yield without irrigation, kg/ha		Yield under irrigation, kg/ha		Additional yield, kg/ha		Irrigation norm, mm		Effect of 100 m^3 irrigated water in kg cotton	
		2018	2019	2018	2019	2018	2019	2018	2019	2018	2019
Helios	N_0	1408,3	1400,8	1541,8	1668,7	133,5	267,9	300,0	600,0	44,5	44,7
	N_8	2121,7	1469,2	1496,7	1870,0	-	400,8	300,0	600,0	-	66,8
	N_{16}	2398,4	1604,7	1745,0	1817,0	-	212,3	300,0	600,0	-	35,4
	N_{24}	1991,7	1438,5	1533,4	1758,9	-	320,4	300,0	600,0	-	53,4
Darmi	N_0	1758,4	1515,7	1891,8	1793,0	133,4	277,3	300,0	600,0	44,5	46,2
	N_8	2061,7	1639,5	1996,7	1840,4	-	200,9	300,0	600,0	-	33,5
	N_{16}	2108,4	1678,5	2220,1	1954,6	111,7	276,1	300,0	600,0	37,2	46,0
	N_{24}	2283,4	1536,7	1965,0	1808,9	-	272,2	300,0	600,0	-	45,4
Isabell	N_0	1476,7	1450,8	1790,1	1597,6	313,4	146,8	300,0	600,0	104,5	24,5
	N_8	1906,7	1544,9	2171,7	1892,6	265,0	347,7	300,0	600,0	88,3	58,0
	N_{16}	1845,0	1549,0	1901,7	1869,4	56,7	320,4	300,0	600,0	18,9	53,4
	N_{24}	2019,8	1499,0	1795,0	1765,2	-	266,2	300,0	600,0	-	44,4

When calculating the effect of 100 m^3 of irrigation water, the amount of additional yield and irrigation rate shall be taken into account. The effect ranges from 18.9 to 104.5 kilograms of cotton per hectare. Better humidity in 2018 forms a high yield in non-irrigation options. The additional yield obtained by Isabel shows the susceptibility of the variety to irrigation. The artificial irrigation water contributed to the realization of additional yields from 265.0 to 313.4 kg/ha at low fertilizer rates and at zero fertilization. The irrigation effect is higher in the second year of the field experience, which is characterized by lower values of the CTC. The four waterings provided contribute to an additional yield of 15.2% to 28.6% for Helius, 13.3% to 18.2% for Darmi, and for Isabell it is in the range of 18.3% to 24.0 %. As a result of this additional yield, an increase in the effect of 100 m3 of irrigation water is also observed. The effect of 100 m^3 of irrigation water in 2019 is highest in Helius, with an average of 50.1 kg of cotton per hectare for fertilizing options. For Isabell, the average for 2019 is 45.0 kg of cotton per hectare, and for Darmi it is 42.8 kg. Over the two years, it is estimated that Darmi and Isabell produce more than 100 m3 of irrigation water.

The calculated climate indicators and coefficients and analyzes of irrigation water productivity and the effect of 100 m^3 of irrigation water for the production of kilograms of cotton per hectare can be used in the design and operation of irrigation systems and in determining the economic effect of drip irrigation, taking into account rainfall coverage for the periods for which the respective surveys were carried out.

CONCLUSIONS

Analysis of the irrigation water productivity data shows that the submission of a smaller irrigation rate leads to an increase in water productivity.

When two waterings are made, the productivity ranges from 4.99 - 7.40 kg/mm. Water productivity after the implementation of four irrigation ranges from 2.66 to 3.26 kg/mm.

The effect of 100 m^3 of irrigation water varies by year, depending on the additional yield and the irrigation rate achieved. The study ranged from zero to 66.8 kg of cotton per hectare.

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