CROP PRODUCTION

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WATER REGIME OF SOIL UNDER DRIP IRRIGATION OF COTTON IN THE LOWE VOLGA REGION

Research article

Abstract

The article presents the results of the research of 4 drip irrigation regimes with the maintenance of the Soil Pre-Irrigation Moisture (SPIM) 65–65–60, 70–70–65, 75–75–70 and 80–80–75 % of Full Moisture Capacity (FMC) in the Lower Volga region, which, in combination with the introduction of mineral fertilizers with the doses of N140P60K45 kg / ha allowed to obtain an average yield of raw cotton 3.06 ... 4.51 t / ha. The highest yield of raw cotton of 4.51 t / ha was obtained while maintaining SPIM 75–75–70 % FMC. Analysis of the water regime of the soil showed that in the structure of the Total water consumption, irrigation water was 43.3 ... 51.9, moisture input from rainfall – 27.1 ... 28.5 and from the soil – 21.3 ... 28.2 %. On the control plot, with furrow irrigation with SPIM 75–75–70 % FMC the amount of moisture in the soil decreased to an average of 3.5 %, moisture input from rain – to 17.0 %, while the irrigation water increased to 79.5 %. At the same time, the value of Total water consumption, in comparison with drip irrigation, increased by 154.3 mm / ha or by 62.2 %, and the value of the Volume of irrigation water – by 198.5 mm/ha or by 2.6 times. As a result, with furrow irrigation it was obtained the yield of 3.08 t / ha, which was on 1.37 t / ha or 30.8 % less than with drip irrigation.

Keywords: total water consumption, drip irrigation, yield of raw cotton.

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ВОДНЫЙ РЕЖИМ ПОЧВЫ ПРИ КАПЕЛЬНОМ ОРОШЕНИИ ХЛОПЧАТНИКА В НИЖНЕМ ПОВОЛЖЬЕ

Научная статья

Аннотация

В статье представлены результаты исследования 4 режимов капельного орошения с поддержанием предполивного порога влажности почвы 65–65–60, 70–70–65, 75–75–70 и 80–80–75 % НВ в Нижнем Поволжье, которые в сочетании с внесением минеральных удобрений дозами N140P60K45 кг д. в./га позволили получить среднюю биологическую урожайность хлопка–сырца 3,06…4,51 т/га. Самая высокая урожайность хлопка–сырца 4,39…4,51 т/га была получена при поддержании предполивного порога влажности 75–75–70 % НВ. Анализ водного режима почвы показал, что в структуре суммарного водопотребления оросительная вода составляла 43,3…51,9, приход влаги от осадков – 27,1…28,5, а почвенные влагозапасы – 21,3…28,2 %. На контрольном участке, при поливе по бороздам с поддержанием предполивного порога влажности 75–75–70 % НВ доля почвенных влагозапасов снизилась в среднем до 3,5 %, осадков – до 17,0 %, в то время как, доля оросительной воды возросла до 79,5 %. При этом величина суммарного водопотребления, по сравнению с капельным поливом, увеличилась на 1543,0 м^3/га или на 62,2 %, а величина оросительной нормы – на 1840…2130 м^3/га или в 2,5…2,9 раз. В результате, была получена урожайность 4,15…4,20 т/га, которая была на 0,24…0,30 т/га ниже, чем при капельном поливе.

Ключевые слова: суммарное водопотреребление, капелное орошение, урожайность хлопка–сырца.

1. Introduction

About 100 countries in the world are involved in cotton growing. The leaders in cotton cultivation are India, the USA and China. In the Soviet Union it is actively engaged in the republics of Central Asia: Kazakhstan, Kyrgyzstan, Turkmenistan and Uzbekistan [1]. These republics were the main providers of cotton fiber to Russia after the crash of the Soviet Union. Duo to

the danger of introduction US sanctions, the main supplier, the Republic of Uzbekistan stopped to supply us these products. In this regard, in Russia there is an urgent need to develop its own, domestic cotton growing.

Taking into account the current situation, after 3 years of preliminary research [2], in 2019 a multifactorial field experiment with various irrigation methods, irrigation regimes, doses of mineral fertilizers and planting density to obtain a yield of 3 to 5 t / ha of cotton raw was started in Volgograd State Agrarian University.

One of the main tasks of our research is to study the water regime of the soil during drip irrigation (DI) of cotton. Such studies are carried out in the Lower Volga region for the first time.

Drip irrigation of cotton is practiced in many countries of the world. The cotton irrigation regimes, sowing patterns and installation of drip irrigation systems are researching in China [3], India [4], Syria [5] and the United States [6] today. A comparative analysis of cotton cultivation under surface and subsurface drip irrigation is carried out in India [7], the USA [8] and Turkey [9]. In Indonesia, the cultivation of cotton with drip irrigation 2 times a year with sowing in May and August is being investigated [10], [11].

In China, as well as in the Republic of Uzbekistan, the problem of raising the level of groundwater is very acute, so they are investigating the possibility of irrigating cotton with salt water by drip irrigation in arid regions of the country [12], [14].

2. Materials and methods of research

The experimental site is located on the right coast of the Volga River. The climate here is sharply continental with cold little snow winters and hot dry summer. It is characterized by an almost complete absence of rains in July and August, high temperatures of air in combination with a large number of hot strong dry winds during the period of the most intensive development of cotton.

The soils of the site are light brown, with a humus content of no more than 1–2 %, medium and heavy loamy. These are typical soils for the main territory of the Lower Volga.

Ground waters did not affect to the water regime of the soil, because they were at a depth much deeper than 3 m.

In relation to the amount of precipitation in the form of rainfall to the sum of the average daily air temperatures, the weather conditions in 2019 and 2020 characterized as severely arid.

The research was carried out with the cotton variety "PGSSH–1". This ultra–fast sort was created by breeders from the Volgograd State Agrarian University and the Republic of Uzbekistan especially for the soil and climatic conditions of the Volgograd region [2].

One of the main components of the soil water regime is the irrigation regime for agricultural crops, therefore, in our field experiments with drip irrigation of cotton, we studied 4 options for the irrigation regime: DI–1, DI–2, DI–3, DI–4 with maintaining SPIM respectively, 65–65–60, 70–70–65, 75–75–70 and 80–80–75 % FMC.

Three levels of water availability in each irrigation regime were observed sequentially in the interphase periods "sowing – flowering" (I), "flowering – fruit formation" (II) and "end of fruit formation – ripening"(III). Irrigations were carried out with calculated irrigation rates when soil moisture reached SPIM for each variant of drip irrigation.

The presented article shows the results of studies of 4 drip irrigation regimes for cotton in 2019 and 2020 on variants with the introduction of mineral fertilizers in doses of N140P60K45 kg/ha.

The control in these field experiments was the option with the traditional for Central Asia furrow irrigation (FI), which maintained the same level of mineral nutrition and SPIM 75–75–70% FMC, the same as in the site with DI–3.

3. The research results

The results of irrigation regimes studying on average for 2019–2020 are presented in Table 1. They showed that annually for all variants of the drip irrigation experiment it was necessary to carry out 1 irrigation after sowing with a rate of 13.0, and for irrigation along furrows – with a rate of 30.0 mm / ha.

Subsequently, the number of drip irrigations and the value of irrigation rates primarily depended on SPIM for each variant.

Table 1 – The Irrigation regime for cotton with drip irrigation and furrow irrigation on average for 2019 – 2020

SPIM, % FMC	Interphase periods			Total number of irrigations pieces	Volume of irrigation water (mm/ha)
	I	II	III		
	number of irrigations, pieces * irrigation rates, mm/ha				
Drip irrigation					
DI–1	1*13,0+ 1…2*22,0	1…2*22,0	1*25,0	4…6	104,0
DI–2	1*13,0+ 1…2*19,0	2…3*19,0	1*22,0	5…7	111,0
DI–3	1*13,0+ 2…3*16,0	2...3*16,0	1…2*19,0	6…9	121,5
DI–4	1*13,0+ 2…3*13,0	3…4*13,0	2…3*16,0	8…11	131,0
Furrow irrigation					
FI	1*30,0+1*80,0	1...2*80,0	1*90,0	4…5	320,0

On the DI–1 option with the lowest pre–irrigation soil moisture of 65–65–60 % FMC in the interphase periods "sowing – flowering" and "flowering – fruit formation" in 2019 –2020 carried out 1 ... 2 vegetation irrigations with a rate of 22.0 mm / ha and else 1 irrigation with a rate of 25.0 mm / ha during the period "end of fruit formation–ripening". In general, during the growing season of cotton 4 ... 6 irrigations were carried out with an average volume of irrigation water of 114.0 mm / ha.

With an increase of SPIM from 65–65–60 to 80–80–75 % FMC the irrigation rates for vegetation drip irrigations in the interphase periods "sowing – flowering" and "flowering – fruit formation" gradually decreased from 22.0 to 13.0, and during the "end fruit formation–ripening "– from 25.0 to 16.0 mm / ha.

At the same time, the Total number of drip irrigations during the growing season of cotton increased from 4 ... 6 to 8 ... 11 pcs, and the volume of irrigation water – on averaged from 114.0 to 131.0 mm/ ha.

On the control variant, when irrigating along the furrows, while maintaining SPIM 75–75–70 % FMC 1 irrigation with a rate of 80.0 mm/ ha was performed in the interphase period "sowing – flowering", 1 ... 2 irrigations of 80.0 mm/ha – during the period of "flowering–fruit formation" and 1 irrigation with a rate of 90.0 mm / ha – during the "end of fruit formation–ripening" period.

In this regard, on the control plot the total number of irrigations for the season was 4 ... 5 pcs and the average volume of irrigation water was 320.0 mm / ha.

Comparison of irrigation regimes for cotton with two methods of irrigation showed that in the variant with drip irrigation the value of post–sowing irrigation rate decreased by 17.0 mm / ha and vegetation irrigation rates – by 71.0 ... 74.0 mm / ha. The Total number of irrigations decreased from 6 ... 9 to 4 ... 5 pcs simultaneously with a decrease of the Volume of irrigation water – from 121.5 to 320.0 mm / ha, that is in 2.6 times.

Weather conditions were another factor influencing to the drip irrigation regime of cotton. Due to the fact that in the second year of research the amount of precipitation decreased from 87.0 to 49.7 mm/ha, in 2020, in comparison with 2019, on the options for drip irrigation of cotton DI–1 and DI –2, the Total number of irrigations per season increased by 2, and on options DI –3 and DI –4 – by 3 units.

The main indicator characterizing the water regime of the soil was the Total Water Consumption. Its value on average for the variants of the experiment is shown in Table 2.

Table 2 – The Total water consumption of cotton with drip irrigation and furrow irrigation on average for 2019–2020

Experience Option	Volume of irrigation water (M) mm/ha	Rainfall (P) mm/ha	Soil moisture reserves (ΔW) mm/ha	Total water consumption (E) mm/ha	Share of E, %		
					M	P	ΔW
Drip irrigation							
DI–1	104,0	68,4	67,8	240,2	43,3	28,5	28,2
DI–2	111,0	68,4	63,7	243,0	45,7	28,1	26,2
DI–3	121,5	68,4	58,4	248,2	48,9	27,5	23,5
DI–4	131,0	68,4	53,2	252,5	51,9	27,1	21,0
Furrow irrigation							
FI	320,0	68,4	14,2	402,6	79,5	17,0	3,5

The Total Water Consumption was formed from the Total volume of irrigation water and water, coming from Rainfall and Soil moisture reserves.

The Volume of irrigation water for DI, on average for 2019 – 2020 equal to 104.0 ... 131.0 mm / ha accounted for 43.3 ... 51.9 % of the Total water consumption. However, due to a significant decrease of Rainfall in the second year of research, in 2020, in comparison with 2019, the share of irrigation water in the Total water consumption increased from 34.9 ... 44.6 to 51.3 ... 58.9 %.

The arrival of moisture from Rainfall (on average over 2 years 27.1 ... 28.5 %) and Soil moisture reserves (21.3 ... 28.2 %) also constituted a significant share in the Total water consumption.

At the same time, it was found that with an increase of SPIM on the options DI–1 ... DI–4 from 65–65–60 to 80–80–75 % FMC the Total water consumption, as well as the Volume of irrigation water per season on average for 2019 – 2020 increased from 240.2 to 252.5 mm / ha, while Soil moisture reserves decreased from 67.8 to 53.2 mm / ha.

In the structure of Total water consumption for furrow irrigation, the share of Soil moisture reserves decreased on average to 3.5 % and Rainfall– to 17.0 %, while the share of irrigation water increased to 79.5 %. At the same time, the value of Total water consumption, in comparison with drip irrigation, increased by 154.3 mm / ha or 62.2 %.

The height of cotton plants and the yield of raw cotton are shown in Table 3.

Table 3 – The height of cotton plants and the yield of raw cotton with drip irrigation and furrow irrigation on average for 2019–2020

Experience Option	Height of cotton plants, cm	Number of opened cotton bolls on one bush, pcs.	Yield of raw cotton t/ha
Drip irrigation			
DI–1	55	5,4	3,17
DI–2	60	6,5	3,89
DI–3	69	7,5	4,45
DI–4	81	6,8	4,18
Furrow irrigation			
FI	74	5,1	3,08

The research results showed that the height of the plants increased simultaneously with the increase in the level of water supply to the plants. By increasing SPIM for drip irrigation from 65–65–60 to 80–80–75 % FMC plant height gradually increased on average up to 2 years of research from 55 to 81 cm. With furrow irrigation, compared with drip irrigation plants were 4 cm higher.

Further analysis showed that the developed irrigation regimes for drip irrigation in combination with the application of mineral fertilizers with doses of N140P60K45 kg/ha allowed to obtain the yield of raw cotton on average for 2 years of research 3.17 ... 4.45 t / ha.

The lowest yield of 3.17 t / ha was obtained while maintaining SPIM 65–65–60 % FMC. An increase in the level of water supply to 70–70–65 % FMC contributed to an increase in yield up to 3.89 t / ha.

The highest average yield of 4.45 t / ha was obtained while maintaining SPIM 75–75–70 % FMC. It was observed on the variant that the largest number of bolls opened for harvesting (7.5 pcs. on one cotton plant).

With a further increase in the level of water supply to 80–80–75 % FMC the yield decreased to 4.18 t /ha. This was due to the fact that in this variant plant growth continued, reaching the highest average values of 81 cm.

However, all the growth energy went only to the development of the leaf area, which led to a decrease in the opened bolls to 6.8 pcs. on one plant.

A similar situation was in the control variant. Despite the fact that when irrigated along the furrows, the plants were on average 5 cm higher, the decrease in the number of bolls to 5.1 pcs. on one plant led to the decrease in yield to 3.08 t / ha or 44.5 %.

Thus, the researches carried out in 2019 – 2020 showed that the developed irrigation regimes for drip irrigation in combination with the application of mineral fertilizers with doses of N140P60K45 kg / ha allowed to obtain a yield of raw cotton equal to 3.17 ... 4.45 t / ha.

The highest yield of raw cotton of 4.45 t / ha was obtained while maintaining SPIM 75–75–70 % FMC. In this variant, the height of the plants was 69 cm, and for harvesting 7.5 opened cotton bolls were on one plant.

This mode of drip irrigation was provided by 1 post–sowing irrigation with a rate of 13.0 mm / ha, 2 ... 3 irrigations with a rate of 16.0 mm / ha in the interphase periods "sowing – flowering" and "flowering – fruit formation", as well as 1 ... 2 irrigations of 19.0 mm/ha during the period "end of fruiting–ripening".

Analysis of the water regime of the soil showed that the Total water consumption increased on average from 210.2 to 252.5 mm / ha simultaneously with an increase in the Volume of irrigation water from 104.0 to 131.0 mm / ha with an increase in SPIM from 65–65–60 to 80–80 –75 % FMC.

In the structure of the Total water consumption during drip irrigation of cotton, irrigation water was 43.3 ... 51.9, moisture input from rainfall – 27.1 ... 28.5 and Soil moisture reserves – 21.3 ... 28.2 %.

In the structure of total water consumption for furrow irrigation, the share of Soil moisture reserves decreased to an average of 3.5 %, rainfall – to 17.0 %, while the share of irrigation water increased to 79.5 %. At the same time, the value of the Total water consumption, in comparison with drip irrigation, increased by 154.3 mm / ha or 62.2 %.

At the same time, on the control plot, the value of irrigation rates increased by 4.7… 5.0 times, the number of irrigations decreased by 2… 4 units, and the Volume of irrigation water increased by 198.5 mm / ha or 2.6 times. As a result, on this plot with furrow irrigation it was obtained the yield of 3.08 t / ha, which was on 1.37 t / ha or 30.8 % less than with drip irrigation.

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Conflict of Interest

None declared.

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