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Efficiency of Cultivating Corn for Grain under Irrigation in the Prialeyskaya Steppe

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Abstract

To assess the effectiveness of irrigation when cultivating corn for grain in the conditions of the arid Prialeyskaya steppe of the Altai Territory, an irrigation regime was developed to maintain pre-irrigation moisture at 60 and 70 % minimum moisture-holding capacity in the soil layer -- 0.5 m. Water with irrigation was used mineralization of 0.3 g/l, it lacked toxic salts. In 2015, the irrigation norm with an irrigation regime of 60 % minimum moisture-holding capacity was 2650 m^3/ha, with a regime of 70 % minimum moisture-holding capacity -- 2850 m3/ha. In 2016, irrigation norms for irrigation regimes were 60 and 70 % minimum moisture-holding capacity of 2250 and 2450 m^3/ha, respectively. In 2017, at the 60 % minimum moisture-holding capacity option, 7 irrigations were carried out, the irrigation rate was 2700 m^3/ha. On the irrigation variant of 70 % of the minimum moisture-holding capacity, 8 irrigations were carried out, the irrigation rate was 2900 m^3/ha. The highest yield of corn grain was obtained while maintaining a humidity level of at least 70 % minimum moisture-holding capacity. The maximum yield in 2015 was 6.7 t/ha, in the control -- 3.8 t/ha. The yield increases on this option were significant in comparison not only with the control without irrigation, but also in comparison with the 60 % minimum moisture-holding capacity. To identify the economic efficiency of cultivating corn with irrigation, the costs of irrigation and the cost of the resulting crop were considered. The highest net income and profitability were obtained in 2016 with an irrigation regime of 70 % minimum moisture-holding capacity. Net income was 63.31 thousand rubles/ha, profitability level 370.45 %. In all years of research, the economic indicators for irrigation options were significantly superior to those for the non-irrigation option.

Keywords: irrigation, rainfall, corn, productivity profitability.

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1. Introduction

Low moisture supply in the territory of the main agricultural regions of the Altai Territory, often repeated droughts are one of the main reasons for the low level of crop productivity. [1, 2] As a result, the degree of intensity of agricultural production in the regions of the region becomes lower. For the steppe regions of the region, artificial irrigation is relevant, which contributes to a significant increase in land productivity and productivity. Reclamation assessment of irrigated land is good. Soils are characterized by high

moisture capacity, good water permeability, they are not compacted [3]. Irrigation of lands changes their water and salt regimes, increases productivity and quality of crops, which is directly related to the economic efficiency of cultivating crops. [4, 5].

In some periods, with a lack of moisture, crop yields decrease especially sharply. They are called critical. The critical period for plants falls on the formation of organs that determine the size of the crop. It does not always coincide with the period of maximum water consumption by plants and is determined not only by biological characteristics, but also by meteorological factors, lack of moisture in the soil during pollination and grain loading, etc. Observations have shown that the yield of fruits and seeds is significantly reduced if plants lack water. When determining the timing and number of irrigations, it is necessary to know the phases of growth and development in which the plant is most sensitive to lack of moisture [6--10].

The aim of the study is to determine the effectiveness of cultivating corn for grain during irrigation.

Research objectives: 1) development of irrigation regimes, 2) identification of patterns in the dynamics of crop yields under various irrigation regimes, 3) determination of total water consumption; 4) the calculation of the economic efficiency of cultivating crops.

Objects of research: culture -- corn for grain, irrigation water.

2. Research Methods

The studies were conducted in 2015--2017. Field experiments were conducted on the lands of the Agroros peasant farm in the Rubtsovsky district of the Altai Territory on the territory of the Aleiskaya irrigation system (AIS). All studies on the development of an irrigation regime were carried out on crops of corn for grain.

The crop irrigation mode was developed to maintain pre-irrigation humidity at the level of 60 and 70 % of the minimum moisture-holding capacity in the soil layer -- 0.5 m. For irrigation, water with a salinity of 0.3 g/l was used, there were no toxic salts [11].

Minimum moisture-holding capacity of the soil was determined in the field by the method of flooding the sites. Water permeability of soils was determined in the field using metal cylinders.

During the research period, systematic observations of soil moisture were carried out; the method of determination was thermostatic-weighted. Water consumption of plants was calculated by the formula of water balance [12]. The essence of the method is to establish the dependence of water consumption on various climatic factors: the

sum of temperatures, solar radiation, air humidity deficit, volatility, etc. Due to the high reliability of the method, it is among the reference methods for establishing the total water demand of plants. This method is used in agronomy and land reclamation, both in science and in practice. The crop yield results were statistically processed by analysis of variance [13].

3. Experimental Part

Productivity of crops depends on moisture reserves in the soil, agrochemical and water-physical properties of soils, on the amount of precipitation, temperature and soil moisture deficit, etc. [14, 15]. We have established quantitative relationships between moisture consumption and crop yield, determined the relationship between crop yield and total water consumption.

The field experiment design included:

1. option without irrigation;
2. option with irrigation at 60 % of minimum moisture-holding capacity;
3. option with irrigation at 70 % of minimum moisture-holding capacity.

Research on the development of an irrigation regime was carried out on corn crops for seeds, the variety -- "Bylina". Early ripe variety of Altai selection. The cobs are large, the weight of the cob in milk-wax ripeness is 203 grams, size 14×4.2 cm. Grain of medium size, great taste. Sugar content reaches 2.2 %. For food grain is used in milk ripeness.

The growing season ranges from 80 to 150 days. Seeds germinate at a temperature of 8--10 ˚C, seedlings appear at a temperature not lower than 10--12 ˚C. Sowing on May 10--15. The emergence of seedlings 10--12 days after sowing. The most favorable temperature for plant growth and development is 20--27 ˚C. At temperatures above 30--35 ˚C, pollen loses its fertilizing ability during flowering. Freezing in spring at an air temperature of --2--3 ˚C damages seedlings, in autumn leaves. At --3 ˚C, unripe wet grain loses its germination capacity. Corn tolerates spring frosts better than autumn frosts [16]. Undoubtedly, meteorological factors have a significant impact on the growth and development of crops, but the most important factor in increasing yields is the correctly calculated irrigation regime under certain conditions (table 1).

4. Research Results

In 2015, the irrigation norm with an irrigation regime of 60 % of the minimum moisture-holding capacity was 2650 m^3/ha, with a regime of 70 % of the minimum moisture-holding capacity -- 2850 m^3/ha. In 2016, irrigation norms accounted for 60 and 70 % of the minimum moisture-holding capacity of 2,250 and 2,450 m^3/ha under irrigation regimes, respectively. In 2017, on the option of 60 % of the minimum moisture-holding capacity, 7 irrigation was carried out, the irrigation rate was 2700 m^3/ha. On the irrigation variant of 70 % of the minimum moisture-holding capacity, 8 irrigations were carried out, the irrigation rate was 2900 m^3/ha.

Irrigation contributes to a significant increase in the yield of corn grain. The data for this indicator is shown in table 2.

For all years of research on options with irrigation, the moisture content of the calculated soil layer was within the specified limits at 60 and 70 % minimum moisture-holding capacity. In 2015, the yield of maize without irrigation was 3.8 t/ha. The yield increase was 1.7 and 2.9 t/ha, with irrigation regimes of 60 % and 70 % minimum moisture-holding capacity, respectively. Since in 2016 more rain fell than in previous years, the crop yield without irrigation was 4.0 t/ha, with an irrigation mode of 60 and 70 % minimum moisture-holding capacity of 6.0 and 7.0 t/ha, respectively. In 2017, corn yields increased by 1.8 t/ha in the first irrigation regime. In the second regime, the yield increase was 2.7 t/ha. Analyzing the data of table 2, we note that the yield increase for each of the irrigation options is significant.

One of the most important indicators when cultivating crops under irrigation is the total water consumption of plants -- the value is variable and largely depends on soil and climatic conditions, the length of the growing season, plant species and variety, and other factors.

We determined the structure of total water consumption under irrigation regimes of 60 and 70 % of minimum moisture-holding capacity (tables 3, 4).

From the data of tables 2 and 3 it is seen that the total water consumption of crops has different values for irrigation options and without irrigation.

In 2015, in maize with an irrigation regime of 60 and 70 % of the minimum moisture-holding capacity, the total water consumption was 4,567 and 4,727 m^3/ha, respectively, without irrigation -- 1957 m^3/ha.

In 2016, a large amount of precipitation fell, so the total calculated indicator this year is maximum, relative to other years of the study. In the case with an irrigation regime of 60 % of the minimum moisture-holding capacity -- 5580 m^3/ha, and with

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Table 1: Crop irrigation regime in 2015--2017.

2015 year					2016 year					2017 year				
Corn (forgrain)														
Watering number	Watering minimum moisture-holding capacity from		Irrigation rate (minimum moisture-holding capacity 60 %) m^3/ha	Irrigation rate (minimum moisture-holding capacity 70 %) m^3/ha	Watering number	Watering minimum moisture-holding capacity from		Irrigation rate (minimum moisture-holding capacity 60 %) m^3/ha	Irrigation rate m^3/ha (minimum moisture-holding capacity 70 %)	Watering number	Watering minimum moisture-holding capacity from		Irrigation rate (minimum moisture-holding capacity 60 %) m^3/ha	Irrigation rate (minimum moisture-holding capacity 70 %) m^3/ha
											60 %	70 %		
	60 %	70 %				60 %	70 %							
1	12.05	12.05	250	200	1	12.05	12.05	200	200	1	13.05	13.05	250	200
2	20.05	19.05	300	250	2	27.05	20.05	250	250	2	22.05	20.05	300	250
3	02.06	31.05	350	300	3	06.06	02.06	300	250	3	01.06	31.05	350	300
4	14.06	10.06	400	400	4	18.06	13.06	350	350	4	17.06	14.06	400	350
5	27.06	21.06	400	400	5	03.07	25.06	350	350	5	30.06	28.06	450	450
6	09.07	01.07	450	400	6	14.07	10.07	400	350	6	11.07	07.07	450	450
7	24.07	14.07	500	450	7	27.07	21.07	400	350	7	25.07	16.07	500	450
8		24.07		450	8		03.08		350	8		05.08		450
Irrigation rate, m^3/ha			2650	2850				2250	2450				2700	2900

Table 2: Productivity of corn for grain, t/ha.

Year	Irrigation options					
	Noirrigation (control)	Yield increase to control	60 % minimum moisture-holding capacity	Yield increase to control	70 % minimum moisture-holding capacity	Yield increase to control
2015	3,8	0	5,5	1,7	6,7	2,9
2016	4,0	0	6,0	2,0	7,0	3,0
2017	3,5	0	5,3	1,8	6,2	2,7
HCP_{05}				0,4		0,4

Table 3: The structure of the total water consumption of corn at 60 % of the minimum moisture-holding capacity.

Crop	Years of observation	Total water consumption (E), m^3/ha	Irrigation rate		Moisture from precipitation		Use of soil moisture reserves	
			m^3/ha	% of E	m^3/ha	% of E	m^3/ha	% of E
Corn without irrigation	2015	1957	0	0	1757	89,78	200	10,22
Irrigation corn	2015	4567	2650	58,02	1757	38,47	160	3,51
Corn without irrigation	2016	3370	0	0	3170	94,07	200	5,93
Irrigation corn	2016	5580	2250	40,32	3170	56,81	160	2,87
Corn without irrigation	2017	1559	0	0	1359	87,17	200	12,83
Irrigation corn	2017	4219	2700	63,99	1359	32,21	160	3,80

Table 4: The structure of the total water consumption of corn at 70 % of the minimum moisture-holding capacity.

Crop	Years of observation	Total water consumption (E), m^3/ha	Irrigation rate		Moisture from precipitation		Use of soil moisture reserves	
			m^3/ha	% of E	m^3/ha	% of E	m^3/ha	% of E
Corn without irrigation	2015	1957	0	0	1757	89.78	200	10.22
Irrigation corn	2015	4727	2850	59.88	1757	37.57	120	2.55
Corn without irrigation	2016	3370	0	0	3170	94.07	200	5.93
Irrigation corn	2016	5690	2400	41.67	3170	56.20	120	2.13
Corn without irrigation	2017	1559	0	0	1359	87.17	200	12.83
Irrigation corn	2017	4379	2900	65.84	1359	31.39	120	2.77

an irrigation regime of 70 % of the minimum moisture-holding capacity -- 5690 m^3/ha, without irrigation -- 3370 m^3/ha.

In 2017, the total water consumption while maintaining a humidity level of 60 % of the minimum moisture-holding capacity was 4219 m^3/ha, with 70 % of the minimum moisture-holding capacity -- 4379 m^3/ha, without irrigation -- 1559 m^3/ha.

To identify economic efficiency in the cultivation of crops with irrigation, it is necessary to consider the costs of irrigation and the cost of the crop.

The main indicators of economic efficiency are the cost of production, net income and profitability.

Net income is determined by the difference between the value of the crop with irrigation options and without irrigation minus the cost of irrigation.

Profitability -- the ratio of net income to the cost of irrigation.

To calculate economic efficiency, data were used on yield, irrigation water consumption, feed units in production, grain prices, irrigation costs. In the calculations, the price for 1 kg of corn (for grain) is accepted -- 20 rub/kg.

The tariff for irrigation water supply is 7.12 rub/m^3.

Calculations of economic efficiency indicators are given in table 5.

Analyzing the results presented in table 4, it can be argued that irrigation during the years of research has proven to be economically feasible. On all options with irrigation, the values of net income and level of profitability were higher in comparison with the option without irrigation. It should also be noted that it is economically feasible to maintain a pre-irrigation humidity level of 70 % of the minimum moisture-holding capacity in comparison with the option of 60 % of the minimum moisture-holding capacity.

5. Conclusion

1. The developed regimes for irrigation of corn suggest maintaining a pre-irrigation humidity of 60 and 70 % of the minimum moisture-holding capacity. To maintain a predetermined level of pre-irrigation soil moisture in 2015, the irrigation norm for the variant 60 % of the minimum moisture-holding capacity was 2650 m^3/ha, while 70 % of the minimum moisture-holding capacity was 2850 m^3/ha. In 2016, irrigation rates were at 60 and 70 % of the minimum moisture-holding capacity of 2250 and 2450 m^3/ha, respectively. In 2017, at 60 % of the minimum moisture-holding capacity, the irrigation rate was 2700 m^3/ha, at 70 % of the minimum moisture-holding capacity -- 2900 m^3/ha.

2. The highest yield of corn grain was obtained while maintaining a humidity level of at least 70 % minimum moisture-holding capacity. The maximum yield in 2015 was 6.7 t/ha. The yield increases on this option were significant in comparison not only with

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TABLE 5: Economic efficiency corn irrigation.

Crop	Year	Option	Irrigation rate, m^3/ha	Productivity, t/ha	The content of feed units in 1 kg of feed	The output of feed units, t/ha	The cost of production, thousand rub/ha	Watering costs, thousand rubles/ha	Net income (NI), thousand rub/ha	Profitability Level (PL), %
Corn (for grain)	2015	No irrigation	0	3.8	1.34	5.09	101.84	0	--	--
		60 % of minimum moisture-holding capacity	2650	5.5		7.37	147.4	18.87	26.69	141.44
		70 % of minimum moisture-holding capacity	2850	6.7		8.98	179.56	20.23	57.49	284.18
	2016	No irrigation	0	4.0		5.36	107.2	0	--	--
		60 % of minimum moisture-holding capacity	2250	6.0		8.04	160.8	16.02	37.58	234.58
		70 % of minimum moisture-holding capacity	2400	7.0		9.38	187.6	17.09	63.31	370.45
	2017	No irrigation	0	3.5		4.69	93.80	0	--	--
		60 % of minimum moisture-holding capacity	2700	5.3		7.10	142.04	19.22	29.02	150.99
		70 % of minimum moisture-holding capacity	2900	6.2		8.31	166.16	20.65	51.71	250.41

the control without irrigation, but also in comparison with the 60 % minimum moisture-holding capacity.

3. The total water consumption in 2015 for corn with an irrigation regime of 60 and 70 % of the minimum moisture-holding capacity is 4567 and 4727 m3/ha, respectively, without irrigation -- 1957 m^3/ha. In 2016, with 60 % of the minimum moisture-holding capacity, the total water consumption was 5580 m^3/ha, with 70 % of the minimum moisture-holding capacity -- 5690 m^3/ha, without irrigation -- 3370 m^3/ha. In 2017, the total water consumption at 60 % of the minimum moisture-holding capacity was 4219 m^3/ha, at 70 % of the minimum moisture-holding capacity -- 4379 m^3/ha without irrigation -- 1559 m^3/ha.

4. The highest net income and profitability level were obtained in 2016 with an irrigation regime of 70 % of minimum moisture-holding capacity. Net income was 63.31 thousand rubles/ha, profitability level 370.45 %. In all years of research, the economic indicators for irrigation options were significantly superior to those for the non-irrigation option.

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