

Effect of irrigation on maize (*Zea mays*) productivity and agrochemical indicators of leached chernozem in the forest-steppe in the Novosibirsk region

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ABSTRACT

The research aimed to improve the technology of corn cultivation in intensive farming to increase the yield and quality of the crop. Therefore, this study was conducted in 2018-2020 at a large agricultural enterprise Plemzavod Irmen, located in the village of Verkh-Irmen in the Ordynsky district of the Novosibirsk region (Russia) to investigate the main indicators of the condition of leached chernozem of the forest-steppe in the Novosibirsk Ob region (field moisture, humus content, and *pH* of soil solution) under maize crops grown for silage and grain. The results of the effect of irrigation on the yield are reflected: Kubansky 101 by 53.8% and Katerina by 33.2%, and the photosynthetic parameters of corn by 19.6% and 18.3%, respectively. A high quality, and increased nutritional and feed value of maize grain with a high content of fat (5.1-5.7%), protein (10.3-12.5%), starch (59.4-61.4%), and sugars (3.0-3.5%). The effectiveness of the use of irrigation in the cultivation of corn was established.

Key words : Chernozem, corn, grain, irrigation, product quality, soil indicators, yield

INTRODUCTION

Increasing the yield of grain maize (*Zea mays* L.) in combination with improving its biochemical composition is an urgent problem of today's crop production (Sebrina *et al.*, 2020; Panda *et al.*, 2021). Maize is the most important grain crop in the economy of many countries since it is not only excellent feed, but also the raw material for several industries, as well as a food product widely consumed by the population, and a medicinal plant (Ermokhin and Sklyarova, 2007). A sustainable increase in grain production is the primary task of the agro-industrial complex of Russia.

In the successful solution of this problem, an important role belongs to maize as one of the main grain-forage crops of multidimensional use (Akinchin and Fedorov, 2015). The biological potential of this crop reaches 12-14 t/ha (Galeev and Kiryakov, 2003). Maize is of great agronomic and ecological importance. Corn, grown for grain

is a good precursor for many crops, including winter wheat. Maize is highly productive insurance crop for restoring the grain area in the event of winter crops failure from unfavorable weather conditions (Zubenko, 1963; Shrestha *et al.*, 2018). However, grain yield in Western Siberia has a low level, which is due to unfavorable weather conditions (Pimenov, 2004; Dmitriev and Kvasha, 2011). The existing technologies of maize cultivation need to be improved in terms of energy conservation and environmental safety (Trutneva, 2004; Bhattarai *et al.*, 2018; Ajibola and Kolawole, 2019).

The purpose of the present research is to assess the effect of irrigation on the productivity and agrochemical indicators of the soil. The obtained data can be used to improve maize cultivation technology and increase crop yield. Agrochemical indicators of leached chernozem can be used to assess the cropping power and condition of the soil cover under maize crops.

MATERIALS AND METHODS

The research was carried out in 2018–2020 in the forest-steppe zone of Western Siberia, in both field and laboratory conditions. The forest-steppe zone of Western Siberia (54.5802°N, 82.2327°E) is located in the northern forest-steppe of the Ob region. The soil of the experimental site consists of leached chernozem.

The research objects were leached chernozem of the forest-steppe of the Novosibirsk Ob region, as well as crops of Kuban 101 hybrids for grain, and Katerina SV for silage. The applied irrigation mode was 2 per 400 m³/ha. Trial establishment included four-fold repetition, randomized placement of variants, the total area of the experiment was one hectare, the plot area was 100 m², the accounting area was 80 m².

The growing season of 2018 was characterized by an average of insufficient precipitation. The growing season of 2019–2020 was also unfavorable in terms of heat and moisture for grain and leguminous crops.

Soil samples, taken for laboratory studies, were prepared for analysis for determining field soil moisture by weight method, as well as for determining organic carbon by the method of I.V. Tyurin modified by V.N. Simakov and measuring water pH by the potentiometric method (GOST 26423-85).

Besides, photosynthetic parameters were also determined, the yield of maize and its structure were estimated, and the biochemical composition of the grain was analyzed.

We also determined the photosynthetic parameters (the leaf area was determined using the formulas of the regression equation according to the method of N. F. Konyaev and the photosynthetic potential of crops – according to A. A. Nichiporovich). We determined the yield of corn and its structure according to E. N. Panfilov. The biochemical composition of grain was also investigated: dry matter using the thermostat-weight method, sugar using the method of N. N. Sivakov, fat according to the method of N. A. Mikhailov, and starch, protein, and dextrans based on Evers polarography.

A comparison of the indicators, obtained with and without irrigation was carried out. Statistical processing of crop data

by the dispersion method was carried out according to the method of B. A. Dospekhov using SNEDECOR applications (Dospekhov, 2016).

RESULTS AND DISCUSSION

The pre-sowing field moisture of leached chernozem for maize crops cultivated for grain in areas with irrigation, and without irrigation is approximately at the same level and equated to moderate soil moisture, favorable for the cultivation of crops, including maize (Figs. 1 and 2) (Albert *et al.*, 2019). In the areas where maize is grown for silage, soil moisture tends to decrease along the profile (Fig. 2). This may be due to insufficient water permeability of the arable horizon, or compaction of the sub-arable horizon due to soil treatment.

The content of humus in the soil is an important indicator that determines, and often limits the soil fertility and the yield of cultivated crops (Dmitriev *et al.*, 2004). Degradation and loss of organic matter significantly worsen the agricultural production properties of soils, which creates conditions for obtaining low unstable crop yields and reducing their quality (Fedotov and Shalaev, 2012).

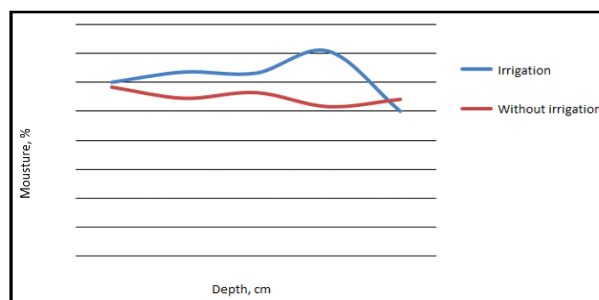


Fig. 1. Field moisture content of chernozem soil with irrigation for maize crops for grain.

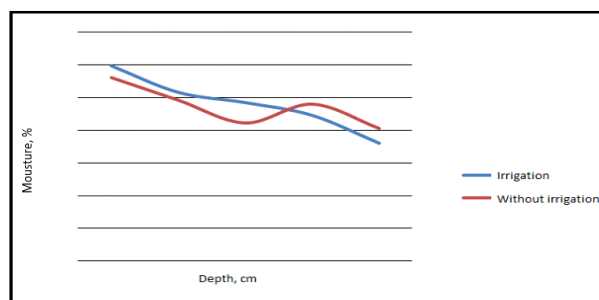


Fig. 2. Field moisture content of chernozem soil without irrigation for maize crops for silage.

The humus content in the leached chernozems under maize crops and for silage and grain varies in the arable layer from a low and average content (2.81-4.67%), and from a very low 0.23% to a low 2.82% (Tables 1 and 2). Given that maize has specific requirements for the soil on which it is grown, it can be stated that the level of humus content is sufficient to obtain high yields.

To create optimal conditions for maize growing and developing, it is necessary to control the level of soil acidity. The yield of maize at a pH of less than 5.5 is significantly reduced (Dmitriev and Kvasha, 2011). The studied samples in the arable layer have a neutral 6.68-6.98 and a slightly alkaline 7.0 to 7.49 medium. In the sub-arable horizon, the pH ranges from slightly alkaline to alkaline. Thus, the acidity of the soil is within the permissible range of pH and thus does not limit the yield of the cultivated crop.

The high productivity of crops is determined by the dynamically optimal ratio of individual elements of photosynthesis. The main ones include the assimilation capacity, photosynthetic potential, as well as intensity, and productivity of photosynthesis (Anderson and Melis, 1983). One way to increase the

efficiency of agriculture is to create crops with a good structure of the spatial arrangement of leaves. The leaf surface is the main working organ of green plants, and the amount of the crop is almost completely determined by its size (Vong and Yoshio, 1978). The results of the assessment of photosynthetic activity are presented in Table 3.

The indicators of the average leaf area of the studied Kuban 101 hybrid in the fields with irrigation are 26.1 thousand m²/ha, while without irrigation, the leaf area is 21.3 thousand m²/ha. A maize hybrid, used for growing as a feed crop, showed similar results, with a tendency to increase the leaf area, equal to 25.4 and 19.9 thousand m²/ha, respectively. As for the indicators of photosynthetic activity of plants, the Kuban 101 hybrid has a high indicator on irrigated chernozem, equal to 2,962 m² day/ha. The photosynthetic parameters increase with the use of irrigation both in the Kuban 101 hybrid and the Katerina hybrid.

The yield of maize consists of its elements (cob length, cob width, cob circumference, the number of grains in a row and around the circumference, as well as a mass of 1,000 grains). The assessment of the

Table 1. Agrochemical indicators of leached chernozem in the cultivation of maize for grain

No.	Indicators	Selection depth, cm	Unirrigated background	Irrigated background (2 per 400 m ³ /ha)
1	Humus (%)	0-10	4.36±0.43	4.48±0.67
2		10-20	3.89±0.77	4.09±0.61
3		20-30	3.62±0.54	3.84±0.58
4		30-40	2.53±0.50	2.82±0.56
5		40-50	0.89±0.18	1.41±0.28
6	pH	0-10	7.06±0.1	7.35±0.1
7		10-20	7.14±0.1	6.98±0.1
8		20-30	7.00±0.1	7.32±0.1
9		30-40	7.16±0.1	7.17±0.1
10		40-50	7.82±0.1	7.34±0.1

Table 2. Agrochemical indicators of leached chernozem during the cultivation of maize for silage

No.	Indicators	Selection depth, cm	Unirrigated background	Irrigated background (2 per 400 m ³ /ha)
1	Humus (%)	0-10	3.96±0.59	3.36±0.50
2		10-20	4.10±0.61	2.79±0.56
3		20-30	4.67±0.70	2.81±0.56
4		30-40	2.29±0.45	0.63±0.13
5		40-50	1.65±0.33	0.23±0.05
6	pH	0-10	6.68±0.1	7.20±0.1
7		10-20	6.74±0.1	7.33±0.1
8		20-30	6.84±0.1	7.49±0.1
9		30-40	7.85±0.1	8.07±0.1
10		40-50	8.26±0.1	8.34±0.1

Table 3. Photosynthetic parameters (PSP) of maize hybrids

Background	Hybrid	Leaf area (thousand. m ² /ha)		PSP (thousand, m ² day/ha)
		Maximal	average	
Irrigated	Kuban 101	36.4	26.1	2,962
	Katerina	35.2	25.4	2,612
Unirrigated	Kuban 101	27.8	21.3	2,476
	Katerina	26.1	19.9	2,208
HCP (P=0.05)		1.23	0.93	29.3

biological productivity of maize shows that using irrigation has allowed increasing the yield of Kuban 101 and Katerina hybrids. The yield of green mass of grain maize increased by 10 t/ha, while for silage – by 12 t/ha. The grain yield of the Kuban 101 hybrid with irrigation was 5.26 t/ha, which is almost 54% more than without irrigation. The yield of Katerina maize grain without irrigation was 3.04 t/ha, which is 1.01 t/ha less than that with irrigation. The weight of 1,000 grains increases by almost 12% in the Kuban 101 hybrid, and by 20% in the Katerina hybrid (Table 4). It is noted that the circumference of the cob in the Katerina hybrid in comparison with Kuban 101 is larger both in the case of using irrigation and without irrigation. Thus, irrigation contributes to forming larger cobs, as well as increasing yield.

The biochemical properties of maize make it a very useful food product. Maize grain is a source of protein for the human and animal bodies (Vong and Yoshio, 1978). The analysis of the biochemical composition of Kuban 101 grain maize showed that the

amount of dry matter in grain in non-irrigated fields is higher than that in irrigated fields, while all other indicators presented in Table 5 are higher when irrigating a field. The Katerina hybrid, grown for silage, also was characterized by a higher percentage of dry matter, without applying irrigation.

CONCLUSIONS

As a result of the conducted research, it was noted that using irrigation in the cultivation of maize for silage and grain in the forest-steppe zone of Western Siberia contributes to the improvement of the photosynthetic parameters of maize plants for both grain and silage. Increasing the level of moisture supply contributes to forming larger maize cobs, as well as increases significantly the yield and the quality indicators of the biochemical composition of maize grain. The data obtained will serve as the basis for improving the technology of corn cultivation and increasing its yield. Agrochemical indicators of leached chernozem can be used

Table 4. Maize yield and its structure when grown for grain and silage

Hybrid	Background	Crop yield (t/ha)		Weight of 1,000 grains (g)	Cob length (cm)	Cob width (cm)	Cob circumference (cm)	Number of grains kd	
		grain	herbage					In length	Circumferentially
Kuban 101	Without-watering	3.42	22.8	217.2	12.4	3.2	14.3	37.2	19.2
	Watering	5.26	33.6	276.1	19.6	4.7	15.8	39.8	20.3
Katerina	Without-watering	3.04	20.3	198.2	13.6	3.0	15.7	33.1	14.9
	Watering	4.05	32.4	247.9	18.3	4.4	16.1	34.9	19.8
HCP (P=0.05)		0.42	0.28	13.8	1.23	0.26	18.3	1.43	0.92

Table 5. Biochemical composition of maize grain depending on moisture availability

Hybrid	Background	Dry matter (%)	Starch (%)	Sugar (%)	Fat (%)	Protein (%)	Dextrins (%)
Kuban-101	Irrigated	85.2	61.4	3.2	5.7	12.5	1.8
	Unirrigated	86.7	60.2	3.0	5.2	10.3	1.5
Katerina	Irrigated	85.0	60.3	3.5	5.4	11.8	1.9
	Unirrigated	86.5	59.4	3.1	5.1	10.6	1.7
HCP (P=0.05)		0.12	0.65	0.13	0.18	0.74	0.12

to assess the fertility and condition of the soil cover under corn crops.

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