Features of the use of growth regulators in the cultivation of corn for grain in Western Siberia

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Abstract. The results of three-year studies (2020-2022) on the effectiveness of the use of various growth regulators in the cultivation of corn hybrids for grain in the forest-steppe zone of Western Siberia are presented. The studies were carried out on leached chernozem of the Novosibirsk region of the Novosibirsk region and on gray forest soil of the forest-steppe zone of the Novosibirsk Ob region. It is shown that in the forest-steppe of Western Siberia it is effective to use modern innovative growth regulators and chelate fertilizers in the process of corn grain production. It has been shown that on soil types it is effective to apply growth regulators Ecofus 0.001%, Epin-Extra 0.04% l/ha and chelated organosilicon fertilizer Siliplant 0.01% with a working solution flow rate of 300 l/ha in the phase of four to six maize leaves on six hybrids. It was statistically determined that the yield of corn grain depended on the element of technology by 33, genotype - 27 and the conditions of the year 23% and green mass, respectively, 35, 29 and 25%. It was shown that growth regulators and chelate fertilizers improved the parameters of the yield structure of corn hybrids.

1 Introduction

Corn is one of the most important agricultural crops [1,2]. Its significance lies in the fact that it has a high potential yield and versatility of use [3,4]. Corn grain has a multi-purpose use for food, feed and technical purposes [5,6]. The significance of corn lies in the fact that during its production soil fertility increases due to the fact that more than 12 tons of organic substances are left on an area of one hectare, during the mineralization of which up to 63 kg of nitrogen, 14 kg of phosphorus and 64 kg of potassium accumulate in the soil [7, 8]. In addition, root secretions during the metabolism of corn plants suppress the development of pathogenic microflora in the soil when nitrogen-fixing bacteria are activated, and this significantly increases soil fertility [9, 10]. According to a number of scientists, it is effective to use growth regulators and modern chelated forms of microfertilizers on corn plants [10–13]. It has been shown that corn plants intensively absorb nitrogen, starting from the phase of 7-9 leaves. With the advent of the eighth leaf, up to 78% of nitrogen is absorbed. In this regard, it is very effective to carry out treatments with regulators and microfertilizers in different phases of growth and development of corn [14–16]. The use of modern intensive-

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type corn hybrids to obtain high grain productivity of good quality is of particular importance [17,18].

In this regard, the goal of our research in 2020-2022 was an assessment of the effectiveness of the use of various growth regulators and chelated microfertilizers in order to increase the productivity of corn grain and improve its quality on different soils of Western Siberia.

2 Materials and methods

The studies were carried out in 2020-2022 on leached chernozem of Praktik educational and experimental farm of the Novosibirsk region, "Irmen" breeding farm and gray forest soil of the Michurintsev Garden of the Novosibirsk region.

Under the conditions of the Praktik, the experimental plots had a humus content of 6.62% (average humus leached chernozems) had a total nitrogen of 0.19-0.25%, phosphorus 0.16-0.21 and potassium 1.12-1.28%. Easily hydrolysable nitrogen was 11.9 mg/100 g, mobile phosphorus 23.9, and exchangeable potassium 11.8 mg/100 g at pH 6.23.

The leached medium-thick chernozems of CJSC Irmen breeding farm had a content of easily hydrolysable nitrogen 12.8 mg/100g, mobile phosphorus 17.8 and exchangeable potassium 14.9 mg/100g at pH 6.09. The gray forest medium loamy soil of the Michurintsev Garden educational and production farm contained 4.19% humus, the content of mobile phosphorus 10.6 mg/100 g, exchangeable potassium 11.2 mg per 100 g of soil, pH 5.68.

During the years of the study, the sum of temperatures in the zones ranged from 1686 to 2140 °C with an excess of precipitation during the growing season of 268 mm at a rate of 239 mm.

Sowing of corn was carried out in the third decade of May and harvesting for grain in late September and early October. For weed control, Remus herbicides 0.05 kg/ha mixed with Diamat 0.5 l/ha were used. In some years (2021), the herbicide Meister (VDG) was used for post-emergence treatment at the rate of 0.125 l/ha with a working fluid flow rate of 300 l/ha.

The total area of the plots is 29.2 m^2, the accounting area is 25.6 m^2, the location is randomized, the repetition is four times. The row spacing in the experiments was 70 cm. The seeding rate was 85,000 germinating plants per 1 hectare.

During the growing season, in the phase of the fourth-sixth leaf, growth regulators Ecofus 0.001% solution, Epin-Extra 0.04 l/ha and Zircon 0.04 l/ha, as well as chelated silica-containing microfertilizer Siliplant 0.01% with a working fluid consumption of 300 l/ha were used. During the growing season, phenological observations were carried out according to the method of the State variety testing of agricultural crops, as well as the methodological guidelines of the Russian Academy of Agricultural Sciences (2011). Statistical data processing was performed according to the method of B.A. Dospekhov using the SNEDECOR application package [19].

3 Results and discussion

In 2020-2022 the authors carried out research on two soil varieties (leached chernozem and gray forest soil) of the forest-steppe zone of the Ob region to study the effectiveness of using innovative growth regulators on different hybrids of intensive corn: Ecofus, Epin-Extra and Zircon, as well as chelated silicic organic microfertilizer Siliplant. Spraying of plants in phase 4-6 of this leaf with water was used as a control. Our studies have shown that, on average, over three years of experiments, the height of plants of different corn hybrids was 13-19% higher in the conditions of the leached chernozem of the Praktik against the background of the use of growth regulators relative to the control. The average number of cobs in the control

(water) in the studied maize hybrids was 1 and increased to 1.3 against the background of Ecofus and Epin-Extra. It is shown that the average weight of the cob against the background of the use of growth regulators and chelated organosilicon microfertilizer Seliplant increased by an average of 18%. On the leached chernozem of "Irmen" on corn hybrids Kubansky 101 and Kubansky 102, an increase in plant height was also noted against the background of the use of growth regulators by 21%. The average number of cobs against the background of Epin-Extra reached 1.3 while 1.0 in the control. The average weight of the cob in the control was at the level of 0.130-1.138 kg and increased to 0.165 kg against the background of growth regulators. On gray forest soil in the experiment with corn hybrids Kuban 101 and Kuban 102, the plant height is also higher in variants with growth regulators. The weight of the cob increased from 0.132 in the control to 0.151 kg against the background of growth regulators Ecofus and chelated fertilizer Seliplant (Table 1).

Table 1. Biometric indicators of corn hybrids depending on growth regulators, average for 2020-2022.

F1 Hybrid	Growth regulator	Plant height	Average number of cobs per 1 plant, pcs	Average weight of the cob, kg
Praktik				
Ross 199 MV	Control(water)	289	1.0	0.141
	Ecofus 0.001%	296	1.2	0.179
	Siliplant 0.01%	303	1.1	0.181
	Epin-Extra 0.04 l/ha	301	1.3	0.167
	Zircon 0.04 l/ha	300	1.2	0.168
Krasnodar 194 MV	Control(water)	276	1.1	0.132
	Ecofus 0.001%	289	1.3	0.168
	Siliplant 0.01%	294	1.2	0.176
	Epin-Extra 0.04 l/ha	298	1.3	0.180
	Zircon 0.04 l/ha	290	1.2	0.181
KS 178 SV	Control(water)	268	1.0	0.129
	Ecofus 0.001%	276	1.1	0.158
	Siliplant 0.01%	283	1.2	0.167
	Epin-Extra 0.04 l/ha	280	1.0	0.172
	Zircon 0.04 l/ha	291	1.0	0.165
Irmen				
Kuban 101	Control(water)	276	1.0	0.136
	Ecofus 0.001%	293	1.1	0.158
	Siliplant 0.01%	288	1.2	0.163
	Epin-Extra 0.04 l/ha	294	1.1	0.159
	Zircon 0.04 l/ha	285	1.2	0.160
Kuban 102	Control(water)	280	1.0	0.138
	Ecofus 0.001%	293	1.3	0.149
	Siliplant 0.01%	295	1.2	0.156
	Epin-Extra 0.04 l/ha	297	1.1	0.153
	Zircon 0.04 l/ha	289	1.2	0.165
Katerina	Control(water)	270	1.0	0.130
	Ecofus 0.001%	283	1.2	0.156
	Siliplant 0.01%	292	1.2	0.162
	Epin-Extra 0.04 l/ha	281	1.2	0.153
	Zircon 0.04 l/ha	280	1.1	0.149
Michurintsev Garden				
	Control(water)	268	1.0	0.138
	Ecofus 0.001%	287	1.1	0.149

	Siliplant 0.01%	282	1.2	0.151
	Epin-Extra 0.04 l/ha	273	1.0	0.145
	Zircon 0.04 l/ha	278	1.1	0.139
	Control(water)	271	1.1	0.133
	Ecofus 0.001%	282	1.3	0.151
	Siliplant 0.01%	279	1.2	0.144
	Epin-Extra 0.04 l/ha	280	1.1	0.146
	Zircon 0.04 l/ha	279	1.3	0.148
HCP$_{05}$		**5.12**	**0.11**	**0.034**

We determined the yield of grain and green mass of corn against the background of the use of growth regulators and chelate fertilizer. It was found that in the Ross 199 MV hybrid, the use of Ecofus increased grain yield by 26%, green mass by 32%, Siliplant - by 24% and Epin-Extra by 13 and 14%, respectively, and Zircon by 17 and 11% relative to control (water). In the Krasnodarsky 194 MV hybrid, the introduction of Ecofus increased grain yield by 28% and green mass by 31%, and the use of Siliplant by 24 and 27%, Epina-Extra 20 and 18, Zircon by 18 and 16, respectively, in comparison with the control. Similar results were obtained for the hybrid KS 178 SV.

In CJSC breeding farm "Irmen" in the hybrid Kubansky 101, the use of a growth regulator increased the yield of corn grain by 27% and green mass by 21%. Against the background of Siliplant, the yield was higher than the control by 20 and 22%. Epin-Extra increased the yield by 13 and 19%. A significant increase in yield in the variant with Zircon was not observed. Similar results were obtained for the Kubansky 102 hybrid. On the gray forest medium loamy soil of the agricultural farm "Garden Michurintsev", in the Kubansky 101 hybrid against the background of Ecofus, the yield of corn increased by 25%, Siliplant - 19% and Epin-Extra - 15%. However, the use of Zircon did not increase the yield of grain and green mass of corn. A similar trend was revealed in the F1 hybrid Kuban 102 with an increase in the yield of green mass against the background of growth regulators up to 22-35% (Table 2).

Table 2. Maize yield when using growth regulators and microfertilizers, average for 2020-2022

F1 Hybrid	Growth regulator	Yield					
		Corn			Green mass		
		t/ha	increase to control		t/ha	increase to control	
			t/ha	%		t/ha	%
Praktik							
Ross 199 MV	Control (water)	6.5	—	—	42	—	—
	Ecofus 0.001%	8.2	1.7	26	56	14	32
	Siliplant 0.01%	8.1	1.6	24	52	10	24
	Epin-Extra 0.04 l/ha	7.4	0.9	13	48	6	14
	Zircon 0.04 l/ha	7.6	1.1	17	47	5	11
Krasnodar 194 MV	Control (water)	6.1	—	—	48	—	—
	Ecofus 0.001%	7.8	1.7	28	63	15	31
	Siliplant 0.01%	7.6	1.5	24	61	13	27
	Epin-Extra 0.04 l/ha	7.3	1.2	20	57	9	18
	Zircon 0.04 l/ha	7.2	1.1	18	56	8	16
KS 178 SV	Control (water)	5.4	—	—	43	—	—
	Ecofus 0.001%	6.8	1.4	26	56	13	30
	Siliplant 0.01%	6.4	1.0	19	54	11	25
	Epin-Extra 0.04 l/ha	6.1	0.7	13	51	8	18
	Zircon 0.04 l/ha	6.0	0.6	11	47	4	9
Irmen							
Kuban 101	Control (water)	7.0	—	—	53	—	—

	Ecofus 0.001%	8.9	1.9	27	67	14	26
	Siliplant 0.01%	8.4	1.4	20	65	12	22
	Epin-Extra 0.04 l/ha	7.9	0.9	13	63	10	19
	Zircon 0.04 l/ha	7.5	0.5	7	58	5	9
Kuban 102	Control (water)	6.7	—	—	50	—	—
	Ecofus 0.001%	8.5	1.8	27	65	15	28
	Siliplant 0.01%	8.3	1.6	23	62	12	22
	Epin-Extra 0.04 l/ha	7.8	1.1	16	55	5	10
	Zircon 0.04 l/ha	7.0	0.3	4	54	4	8
Michurintsev Garden							
Kuban 101	Control (water)	4.7	—	—	38	—	—
	Ecofus 0.001%	5.9	1.2	25	47	9	24
	Siliplant 0.01%	5.6	0.9	19	45	7	18
	Epin-Extra 0.04 l/ha	5.4	0.7	15	41	3	9
	Zircon 0.04 l/ha	5.0	0.3	6	39	1	2
Kuban 102	Control (water)	4.9	—	—	35	—	—
	Ecofus 0.001%	5.8	0.9	18	48	13	35
	Siliplant 0.01%	5.5	0.6	12	43	8	22
	Epin-Extra 0.04 l/ha	5.4	0.5	10	36	1	3
	Zircon 0.04 l/ha	5.3	0.4	8	36	1	3

Note 1. The results of the analysis of variance of the three-factor experiment (6x5x3) - A (genotype), B (growth regulator), C (year). Grain yield software HCP05 for partial differences is 0.28t, HCP05 for A is 0.35t, NCP05 for B and interaction AB is 0.31t. Main effects and interactions A, 27%; B, 33; C, 23; AB, 4.2; AC, 1.3; BC, 1.8; and ABC, 0.9%.

2. According to the yield of corn green mass: HCP05 for partial differences 0.87, HCP05 for A - 0.99t, HCP05 for B and interaction AB 0.95t. Main effects and interactions A, 29%; B, 35; C, 25; AB, 2.2; AC, 0.87; BC, 1.2; and ABC, 1.1%.

According to the analysis of variance of a three-factor experiment (6x5x3), the grain yield was determined by the genotype by 27%, growth regulators and chelate fertilizer by 33%, and the conditions of the year by 23%. The yield of green mass depended on the genotype by 29%, growth regulators and fertilizers - 35% and the year - 25%.

When determining the structure of the yield of corn hybrids, depending on growth regulators and chelate fertilizer, their positive effect on the number of cobs, the number of rows per cob, the number of grains per cob, the number of grains in a row and the weight of 1000 grains was noted. The maximum number of cobs was found in all studied corn hybrids against the background of the use of growth regulator Ecofus and chelate fertilizer Siliplant: up to 7.2 pcs against the background of Ecofus and 6.9 pcs. - Siliplant. The number of rows per cob also increased with the use of chemicals, with the exception of the Zircon growth regulator. The number of grains in the cob was not equal to Ecofus and Siliplant preparations: up to 532. Epin-Extra and Zircon preparations had lower values, but higher than control (water). The mass of 1000 corn on leached chernozem of UOH "Praktik" and CJSC stud farm "Irmen", as well as on gray forest soil of UF "Garden Michurintsev" was observed with higher values against the background of Ecofus and Siliplant preparations up to 369 g at 328-342 g in control (Table 3).

Table 3. Yield structure of corn hybrids depending on growth regulators, average data for 2020-2022

F1 Hybrid	Growth regulator	Number of cobs, pcs/m^2	Number of rows on the cob	Number of grains on the cob	Number of grains in a row	Weight of 1000 grains, g
Praktik						
Ross 199 MV	Control (water)	6.5	11.8	486	28	342
	Ecofus	7.2	15.2	498	36	368
	Siliplant	6.8	14.6	510	42	370
	Epin-Extra	6.6	12.3	495	32	353
	Zircon	6.5	11.6	483	30	348
Krasnodar 194 MV	Control (water)	6.6	12.8	503	34	328
	Ecofus	7.3	13.9	532	38	369
	Siliplant	6.9	14.2	524	39	362
	Epin-Extra	6.7	13.3	514	43	343
	Zircon	6.4	12.6	508	32	330
KS 178 SV	Control (water)	6.8	10.8	486	48	338
	Ecofus	7.2	13.5	514	56	372
	Siliplant	6.9	12.9	505	62	364
	Epin-Extra	6.8	13.2	493	50	345
	Zircon	6.8	12.9	485	42	335
Irmen						
Kuban 101	Control (water)	5.9	12.6	457	24	328
	Ecofus	7.4	15.3	486	28	345
	Siliplant	7.1	14.6	493	29	332
	Epin-Extra	6.8	13.8	462	27	329
	Zircon	6.0	12.8	46.3	22	324
Katerina	Control (water)	6.2	11.8	43.8	21	312
	Ecofus	6.8	13.8	46.5	26	356
	Siliplant	6.5	12.7	45.8	24	351
	Epin-Extra	6.4	12.3	44.2	23	348
	Zircon	6.1	11.9	43.9	21	328
Michurintsev Garden						
Kuban 101	Control (water)	5.1	8.9	43.2	19	338
	Ecofus	5.6	9.8	45.8	22	345
	Siliplant	5.5	9.9	46.2	23	353
	Epin-Extra	5.4	9.5	46.2	20	342
	Zircon	5.2	9.0	44.3	20	340
Kuban 102	Control (water)	5.1	8.2	41.8	17	328
	Ecofus	5.4	9.3	43.8	19	358
	Siliplant	5.3	8.8	44.2	21	361
	Epin-Extra	5.6	8.5	42.6	22	349
	Zircon	5.2	8.1	41.9	17	345
HCP$_{05}$		**0.13**	**0.23**	**0.48**	**1.86**	**4.25**

4 Conclusion

In the conditions of the forest-steppe of Western Siberia, when growing six hybrids of corn for grain and green mass, it is effective to use in the phase of four to six true leaves spraying plants with growth regulators Ecofus 0.001%, Epin-Extra 0.04 l/ha and Zircon 0.04 l/ha, as well as chelated organosilicon fertilizer Siliplant 0.01%.

The maximum plant heights of corn hybrids both on leached chernozem and gray forest soil were revealed against the background of Ecofus, Siliplant and Epin-Extra preparations up to 303 cm, an increase in the number of ears per plant up to 1.3 and the average weight of an ear up to 181 g was noted. Hybrids maize Ross 199 MV, Krasnodar 194 MV, KS 178 SV, Kuban 101, Kuban 102 and Katerina showed responsiveness to the use of these drugs.

On two types of soils, the growth regulator Ecofus and the chelated fertilizer Siliplant increased the yield of grain and green mass of corn hybrids to 28 and 32% and 24 and 27, respectively. Preparations Epin-Extra and especially Zircon increased the yield of corn hybrids to a lesser extent.

According to the analysis of variance of a three-factor experiment, the yield of corn grain depended on the technology element by 33% and the green mass, respectively, 35; 29 and 25%.

The use of regulators Ecofus 0.001%, Epin-Extra 0.04 l/ha and Siliplant 0.01% fertilizer in the phase of four to six true corn leaves with a working fluid flow rate of 300 l/ha increased the parameters of the number of cobs per square meter, the number of rows in the cob, the number of grains on the cob, the number of grains in a row and the weight of 1000 grains by an average of 12-21%, ensuring high parameters of nutritional and fodder qualities of the product.

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