Stimulation of growth processes and productivity of grain crops in the forest-steppe of Western Siberia

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Abstract. The results of three years of research (2021-2023) are presented to study the effectiveness of pre-sowing treatment of seeds of grain crops (spring wheat, spring barley and oats) to regulate growth and development, increase yields and improve product quality. The research was carried out on leached chernozem of the Novosibirsk Ob region (JSC Irmen breeding plant, Ordynsky district, Novosibirsk region) and on gray forest soil (TPP "Michurintsev Garden"). The varieties of grain crops (spring wheat Licamero, spring barley Paustian and oats – Max) were studied. An increase in leaf area parameters was established against the background of the use of preparations for treating seeds with subsequent spraying of plants in the tillering phase with the following growth regulators Siliplant 0.01% (based on chelate forms), Epin-Extra 0.005%, Zircon 0.005%, Toro Combi 0.02% solution and Turmax 0.025% (chelate forms of macro and microelements). It was shown that the use of growth regulators increased the rate of growth and development, productivity and product quality. It was statistically established that the yield of grain crops depended on the elements - 38%, the crop under study - 31%, growth regulators and year conditions by 24%.

1 Introduction

Grain crops are the leading element of crop production in Western Siberia. Advanced production technologies are based on the use of high-yielding intensive varieties, placement of crops to optimize predecessors, providing plants with nutrients for a programmed harvest in various soil and climatic conditions, differentiated soil treatment and fertilization, the use of integrated protection of plants and pests, intensive implementation of a complex of agrotechnical works [1-5]. When cultivating grain crops, one should take into account the biological characteristics of the crop, as well as the requirements for growing conditions [6-8]. Of particular importance is the stabilization of grain production depending on weather conditions in different years [9-11]. The use and implementation of new innovative technologies makes it possible to increase the yield and quality of grain crops in terms of obtaining high guaranteed yields [12,13].

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In this regard, the use of growth regulators makes it possible to optimize growth processes and contribute to the formation of high-quality grain crops [14-16]. These drugs can increase productivity and reduce the consequences of soil pollution with heavy metals [17].

The purpose of the study is to study the influence of innovative growth regulators on the characteristics of growth and development, yield and quality of grain crops in the northern forest-steppe of the Ob region.

2 Materials and methods

The studies were carried out in different zones of the forest-steppe of the Novosibirsk Ob region on the experimental fields of the Irmen breeding plant CJSC in the Ordynsky district of the Novosibirsk region and on the gray forest soil of the Michurintsev Garden TPP. Meteorological conditions in the year of the research differed both in temperature and in the amount of precipitation. The soil of the experimental fields at the Irmen breeding plant CJSC is leached chernozem with a humus content of 6.43%, gross nitrogen 0.30, phosphorus 0.25 and potassium 1.22%. The soil had a content of easily hydrolyzable nitrogen of 12.4 mg/100g, mobile phosphorus of 21.9 and exchangeable potassium of 17.6 mg/100g, pH 6.35. The gray forest soil of the UAH " Michurintsev" was medium loamy, had a humus content of 4.59%, available phosphorus – 12.6 mg/100g and exchangeable potassium 13.1 mg/100g at pH 5.68. During the research, phenological observations were carried out according to the methodology of the State Variety Testing of Agricultural Crops [18]. The photosynthetic potential of crops was determined according to A.A. Nichiporovich [19]. The leaf area was determined according to the method of N.F. Konyaev. [20]. Statistical processing was carried out according to the method of B.A. Dospehova using the Snedecor application package modified by O.D. Sorokina [21]. The recording area of the plot is 16.4 m^2, replication is 4-fold, location is randomized.

3 Results and discussion

In experiments 2021-2023. on leached chernozem and gray forest soil, pre-sowing treatment of seeds was carried out with stimulants with a biofertilizer effect: Siliplant 0.01%, Epin Extra 0.005%, Zircon 0.005%, Toro Combi 0.02%, as well as these preparations for the growing season in the tillering phase. The consumption rate of the aqueous solution before sowing is 10 l/t and during the growing season 300 l/ha. Experiments were carried out with spring soft wheat Licamero, spring barley of the Paustian variety and oats of the Max variety (JSC Irmen breeding plant, leached chernozem) and on varieties of wheat - Omskaya 36, barley - Biom, oats - Rovestnik (TPP "Michurintsev Garden").

It was noted that the indicators of the largest leaf area were higher with double (before sowing with seed treatment and during the growing season in the tillering phase) use of growth stimulants. In the spring wheat variety Licamero, the maximum leaf area in the variant with the use of the drug Turmax was 19% higher than the control data (water). In terms of average leaf area and FSP, variants with growth regulators Turmax, Toro Combi and Zircon were distinguished, exceeding the control by 16-24%. In spring barley variety Paustian, also with the use of growth stimulants, an increase in the parameters of leaf area and FSP was observed, especially in variants with growth regulators Turmax, Toro Combi and Zircon: by 18-23%. In experiments with oats, the parameters were exceeded by 14-20% against the background of the use of the studied growth stimulants (Table 1).

Table 1. Photosynthetic parameters of grain crops when treated with growth regulators before sowing seeds and during the tillering phase. Average data for 2021-2023.

Variant	Spring wheat			Spring barley			Oats		
	leaf area, thousand m^2/ha		FSP thous. m^2 day/ha	leaf area, thousand m^2/ha		FSP thous. m^2 day/ha	leaf area, thousand m^2/ha		FSP thous. m^2 day/ha
	max	aver		max	aver		max	aver	
1. Control	22.3	14.8	1423	21.2	13.2	1186	22.0	13.8	1170
2. Siliplant 0.01%	23.0	15.3	1476	20.9	13.8	1242	22.5	14.0	1148
3. Epin-Extra 0.005%	23.4	15.0	1440	21.6	14.3	1289	22.8	13.8	1136
4. Zircon 0.005%	22.8	15.4	1478	22.4	15.8	1423	23.1	14.1	1238
5. ToroCombi 0.02%	22.6	15.3	1469	23.5	14.8	1332	23.2	14.6	1415
6. Turmax 0.02%	24.1	15.5	1490	22.7	15.9	1431	23.4	14.5	1360
HCP_{05}	0.11	0.16	15.8	0.19	0.20	27.5	0.19	0.15	30.6

We determined the yield of grain crops depending on the double application of growth regulators. It was shown that in experiments with spring wheat of the Licamero variety on leached chernozem, the maximum yield was found in the variant of using the drug Turmax 0.02% - 3.74 t / ha with an increase of 31% to the control. Increased yield was also observed when applying Toro Combi 0.02%. Siliplant provided a 19% increase in control. In experiments with spring barley of the Paustian variety, the preparations Toro Combi and Turmax also showed greater effectiveness - 21 and 15%, respectively, relative to the control (water). The remaining drugs did not have a significant effect on the grain yield of spring wheat of the Licamero variety. In experiments with oats of the Max variety, the greatest effect was found in the following preparations: Toro Combi 22%, Turmax and Siliplant each with a 20% increase over the control (Table 2).

Table 2. The yield of grain crops using growth regulators. Leached black soil. CJSC breeding plant "Irmen", 2021-2023.

Variant	Spring wheat			Spring barley			Oats		
	Yield, t/ha	Increased control		Yield, t/ha	Increased control		Yield, t/ha	Increased control	
		t/ha	%		t/ha	%		t/ha	%
1. Control	2.85	—	—	3.16	—	—	2.70	—	—
2. Siliplant 0.01%	3.42	0.55	19	3.39	0.23	6	3.24	0.54	20
3. Epin-Extra 0.005%	3.06	0.21	8	3.30	0.14	4	2.95	0.25	9
4. Zircon 0.005%	3.10	0.25	9	3.25	0.09	2	3.08	0.38	14
5. ToroCombi 0.02%	3.63	0.76	27	3.85	0.69	21	3.29	0.59	22
6. Turmax 0.02%	3.74	0.89	31	3.64	0.48	15	3.24	0.54	20

Note. Results of variance analysis of a three-factor experiment (3x6x3) = factor A (culture), B (growth regulator), C (year conditions). NSR05 for private – 0.21, NSR05 for A – 0.38, NSR05 B and AB – 0.30; Main effects and their interactions. Factor A – 37.6, B – 31.2, C – 24.6%, AB – 2.76, BC – 1.25, AC – 0.96; ABC – 0.53%

Analysis of variance of a three-factor experiment determined that grain yield depended on the crop by 38%, growth regulator 31, and year conditions by 25%, with the greatest interaction between crop and growth regulator being about 3%.

In an experiment on gray forest heavy loamy soil of the "Michurintsev Garden" TPP it was shown that against the background of double application of growth regulators during the pre-sowing seed treatment and during the growing season in the tillering phase, an increase in yield was observed relative to the control (water). In the spring soft wheat variety Licamero, the maximum yield was in the variant with the application of Turmax 0.02% - 2.77 with an increase to the control up to 28%, then in the Toro Combi preparation 2.72 and 2.5%, respectively. In the variant with Siliplant, the increase in control was 12%. Other growth regulators did not provide a significant increase in yield. In spring barley varieties Max, Epin Extra and Zircon also did not have significant yield increases compared to the control. The largest increases were noted against the background of Siliplant - 20%, Toro Combi - 18% and Turmax - 16% above the control (Table 3).

Table 3. The influence of growth regulators on the yield of grain crops. Gray forest soil. UPH "Sad Michurintsev" Average for 2021-2023.

Variant	Spring wheat			Spring barley			Oats		
	Yield, t/ha	Increased control		Yield, t/ha	Increased control		Yield, t/ha	Increased control	
		t/ha	%		t/ha	%		t/ha	%
1. Control	2.16	—	—	2.25	—	—	2.20	—	—
2. Siliplant 0.01%	2.42	0.26	12	2.72	0.47	20	2.67	0.47	21
3. Epin-Extra 0.005%	2.27	0.11	5	2.30	0.05	2	2.18	-0.02	9
4. Zircon 0.005%	2.35	0.19	9	2.34	0.09	4	2.25	0.05	10
5. ToroCombi 0.02%	2.72	0.55	25	2.67	0.42	18	2.68	0.48	22
6. Turmax 0.02%	2.77	0.61	28	2.60	0.35	16	2.78	0.58	26

Note. Results of variance analysis of a three-factor experiment (3x6x3) - factor A - culture, B - growth regulator, C - year conditions. NSR05 – for partial differences – 0.21, NSR05 for A – 0.29, NSR05 for B and AB – 0.26; Main effects and their interactions: Factor A – 34.8, B – 29.6, C – 23.8, AB – 2.93, BC – 1.90, AC – 0.92, ABC – 0.79%

We studied the economically valuable characteristics of grain crops on two types of soils (leached chernozem and gray forest soil). It was noted that on the leached chernozem of the Irmen breeding plant CJSC, the number of grains, the weight of grains in an ear, the weight of 1000 grains and the number of ears in an ear exceeded the indicators on gray forest soil by an average of 1.3 times.

On both types of soils, an increase in the number of grains per ear in the spring soft wheat variety Licamero was established against the background of the preparations Siliplant, Toro Combi, and Turmax. The drugs Epin Extra and Zircon were less effective and did not provide a significant increase. The weight of grain in an ear of spring wheat was maximum in the variant with the use of Turmax. The number of spikelets per ear was higher against the background of Toro Combi and Turmax. The protein content in spring wheat grain on both types of soil is higher in the variants using Tora Combi and Turmax, as well as against the background of Siliplant. Similar trends were noted in experiments on two types of soil when growing spring barley of the Paustian variety. On leached chernozem, the largest number of grains was against the background of Toro Combi and Turmax, and also in these variants there were more ears per ear and a higher weight of grain per ear. In terms of protein content,

the leached chernozem contained more protein in the variants with Turmax and Siliplant. The gray forest soil contained less protein than the leached chernozem and its content was higher against the background of Epin-Extra and Turmax (Table 4).

Table 4. Economically valuable traits of grain crops depending on the use of growth regulators. Average data for 2021-2023.

Variant	Leached black soil					Gray forest soil				
	number of grains in an ear	weight of grain in an ear, g	weight of 1000 grains, g	number of spikelets in an ear	protein in grain,%	number of grains in an ear	weight of grain in an ear, g	weight of 1000 grains, g	number of spikelets in an ear	protein in grain,%
Spring wheat "Likamero"										
Control	25	1.24	34	28	13.05	22	1.15	26	24	12.25
Siliplant 0.01%	29	1.36	39	34	13.08	25	1.19	29	27	12.20
Epin-Extra 0.005%	26	1.22	35	30	12.96	23	1.14	38	24	12.18
Zircon 0.005%	25	1.26	35	28	13.0	22	1.15	24	25	12.12
ToroCombi 0.02%	28	1.34	38	35	13.6	26	1.23	28	26	12.32
Turmax 0.02%	28	1.40	41	33	13.4	25	1.25	30	28	12.36
Spring barley "Paustian"										
Control	22	1.18	37	23	11.20	19	1.06	26	19	11.15
Siliplant 0.01%	27	1.26	46	26	11.26	23	1.15	28	23	11.10
Epin-Extra 0.005%	23	1.19	40	23	11.16	20	1.09	26	20	11.20
Zircon 0.005%	21	1.17	38	24	11.12	18	1.12	25	20	10.92
ToroCombi 0.02%	29	1.28	48	28	11.23	26	1.18	30	26	11.06
Turmax 0.02%	28	1.27	46	30	11.28	25	1.16	31	24	11.12
HCP_{05}	0.84	0.07	1.25	2.14	0.08	2.4	0.02	1.26	1.05	0.04

4 Conclusion

In the forest-steppe of Western Siberia, when growing spring soft wheat of the Paustian variety and oats of the Max variety on leached chernozem and gray forest soil, it is effective to use growth regulators with a fertilizer effect as a pre-sowing treatment and their subsequent use in the tillering phase: Turmax 0.02%, Tora Combi 0.02% and Siliplant 0.01%. The consumption rate of preparations when treating seeds is 10 l/t and in the tillering phase – 300 l/ha.

Growth regulators based on chelated forms of macro and microelements: Turmax, Toro Combi and Siliplant ensured the formation of a developed leaf surface in spring wheat of the Licamero variety, spring barley Paustian and oats of the Max variety, exceeding the control parameters (water) by 16-24%.

The studied preparations provided higher yields of grain products relative to the control. On leached chernozem, using the Turmax preparation, a yield of 3.74 t/ha was achieved, which is 31% higher than the control. Spring barley Paustian and oats variety Max have higher parameters in the variant with Toro Combi, 3.85 and 3.29 t/ha, respectively. On gray forest soil, wheat and oats had higher indicators with the use of Turmax 0.02% and barley with the use of Toro Combi.

Analysis of variance determined that the yield of grain crops on leached chernozem depends on the crop by 38%, the growth regulator by 31% and the conditions of the year by 25%. Double treatment with chelated macro and microfertilizers with the effect of growth regulators: Siliplant 0.01%, Toro Combi 0.02% and Turmax 0.02% on both types of soils increased the yield structure indicators: the number of grains in an ear, the weight of grains in an ear, the weight of 1000 grains, the number of spikelets in an ear, and also contributed to an increase in grain protein content.

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