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Efficiency of Foliar Feeding with Zinc and Copper Chelates of Spring Soft Wheat in the Conditions of the Southern Forest-Steppe of the Omsk Irtysh Region

Igor Bobrenko
Department of Agrochemistry and Soil Science
Omsk State Agrarian University named after P.A. Stolypin
Omsk, Russia
ia.bobrenko@omgau.org

Valentina Popova
Department of Environmental Engineering, Water Use and Water Resources Protection
Omsk State Agrarian University named after P.A. Stolypin
Omsk, Russia
vv.popova@omgau.org

Natalia Goman
Department of Agrochemistry and Soil Science
Omsk State Agrarian University named after P.A. Stolypin
Omsk, Russia
nv.goman@omgau.org

Alexander Gaidar
Laboratory of primary seed breeding
Omsk Agrarian Scientific Center
Omsk, Russia
aa.gaydar@bk.ru

***Abstract*— The results of experiments on the use of zinc and copper chelates in the cultivation of spring wheat in the conditions of the southern forest-steppe of the Omsk Irtysh region by the method of foliar feeding are presented. The best doses of zinc and copper in foliar feeding in the tillering phase is 20 (yield increase of 0.25 t/ha, in the control of 2.09 t/ha) and 10 g/ha (0.26 t/ha), respectively. Protein collection thus increased from 273 in the control to 297-327 kg/ha with the use of chelates, the germination energy of the obtained seeds increased from 95 in the control to 96.3-98.0 % fromthe foliar feeding in the tillering phase. The best in weight of 1000 grains (33.5 g) was Zn20 variant, and in grain unit (735 g/l) - Cu10, which exceeds the control parameters (30.05 g and 711 g/l, respectively). The gluten content was 26.70-27.85 % (with GDI 57.5-62.5 units), in the best yield variants (Zn10 and Cu10) it was at the maximum level of 27.30 and 27.85 %, respectively. The amount of amino acids in the protein increases from 7,580 % without fertilizers to the highest 7,660 % with foliar feeding with chelated forms of Zn10 and 7,645 % - at Cu30. The positive effect of micronutrients on the protein content in the grain, laboratory germination of the seeds obtained was established.**

Keywords—zinc, copper, fertilizer, chelate, spring wheat, yield, grain and seed quality.

I. INTRODUCTION

Soils of Omsk region mostly have insufficient content of available zinc and copper for plants [1, 2]. At the same time, a number of researchers have shown the positive effect of these fertilizers in the cultivation of various crops in the region, including their application by the method of foliar feeding [3-5].

Zinc plays a versatile role in the functioning of plant and animal organisms, being part of a large number of enzymes, in particular carbonic anhydrase (it contains 0.33-0.34 % zinc). This enzyme catalyzes the reversible carbonic acid cleavage reaction, its role in the respiration process is crucial. Zinc is directly involved in the synthesis of chlorophyll and affects photosynthesis and carbohydrate metabolism in plants. The role of this element in phosphorus exchange is important. Vlue of zinc in the formation of auxins is very specific, its lack reduces their number, which slows down the growth of plants. The importance of copper in plant life is due to the fact that it is a part of various proteins and enzymes: nitrite- and hyponitrite reductases, ascorbic oxidases, etc.; affects nitrogen metabolism, plays an essential role in photosynthesis, in the formation of chlorophyll, contributes to the growth of plant resistance to adverse environmental conditions: high and low temperatures, drought, as well as affect of a variety of fungal and bacterial diseases [6-9].

Chelate is an organic complex, a chemical compound of a trace element with a chelating agent that reliably holds trace elements in a soluble state before entering the plant, then transfers it to an available form, and then breaks down into compounds that are freely absorbed by plants. Chelates have advantages for crops over other forms of trace elements, because these compounds are entirely supplied by foliar feeding - in the leaf or in case of pre-sowing treatment - in the seeds, and do not remain on the surface.

Spring wheat is the main grain crop of Russia and Omsk region, to increase the production of which it is necessary to use macro-and micro-fertilizers. Foliar feeding of wheat with minor nutrition elements is an effective method [4, 10, 11], but the use of chelated forms for this purpose is insufficiently studied in the Omsk region.

The purpose of the research is to study the effect of foliar feeding with zinc and copper chelates in the tillering phase on the yield and quality of spring wheat harvest in the southern forest-steppe of the Omsk Irtysh region.

II. METHODS

Field studies were conducted in 2017-2018 in the fields of Omsk agricultural research center, laboratory research - at the Department of agrochemistry and soil science of Omsk SAU. Cultivar - In Memory of Aziyev. The location of plots on the experimental site is systematic. Plots area - 16 m^2. Duplication of options in the experiment is three-fold, arrangement of duplications is in three layers. The scheme is given in table 1, doses of trace elements (zinc and copper) - in grams of active substance per 1 ha in the form of chelates. Content in the soil layer 0-20 cm of $N\text{-}NO_3$, P_2O_5 and K_2O - high, of mobile Zn and Cu - low. Predecessor - coulisse fallow, agricultural equipment - common for the zone: main treatment in autumn - fall plowing with ПН-4-35 to a depth of 20-22 cm. Pre-sowing tillage consisted in early spring harrowing with tooth harrows in two tracks when the soil reaches tilth state and pre-sowing cultivation of КПС-4 to the depth of seed planting.

Sowing was carried out on May 25-27, the seeding rate - 5.5 million fertile seeds, seeder - СКФК-7. After sowing, the soil was rammed with ribbed rollers ЗКК-3А. Harvesting of spring wheat was carried out in the first decade of September by direct combining "Hege-125". Laboratory analyses on determination of the sowing and technological qualities of grain were carried out in the Department of seed production and grain quality laboratory of the Omsk agricultural research center

III. Results

Comparing the yield of grain in the years of research, significant differences should be noted: in 2017, the yield of spring wheat was 1.4 times higher than in 2018 (in the control, respectively, 2.45 and 1.73 t/ha). This is due to adverse weather conditions. Precipitation amount significantly exceeding the annual average at the beginning of the 2018 growing season (May-June) and low temperatures negatively affected the development of spring wheat, which further affected the formation of grain, and as a consequence – the yield. At the same time, the level of yield growth in 2018 during pre-sowing treatment of seeds with chelated micronutrients also decreased.

In studies on the optimal macronutrient background of meadow-chernozem soil improvement of nutrition of spring wheat using foliar feeding in the tillering phase with zinc and copper chelates (table 1) provided an increase in yield from 0.14 to 0.36 t/ha of grain (6.70-17.22%).

TABLE I. Grain yield of spring soft wheat in case of foliar feeding with chelated micronutrients in tillering phase (g ai/ha) on meadow-chernozem soil of Omsk region (2017-2018)

Variant	Grain yield, t/ha			Increase	
	2017	*2018*	*average*	*t/ha*	*%*
Control	2.45	1.73	2.09	-	-
Zn_{10}	2.59	1.86	2.23	0.14	6.70
Zn_{20}	2.75	1.93	2.34	0.25	11.96
Zn_{30}	2.80	1.97	2.39	0.30	14.35
Cu_{10}	2.60	2.08	2.34	0.23	11.00
Cu_{20}	2.62	2.00	2.31	0.22	10.52
Cu_{30}	2.65	2.04	2.35	0.26	12.44
LSD_{05} t/ha	0.11	0.08			

Experiments have revealed a positive effect of foliar feeding of spring wheat in the tillering phase with zinc chelates on grain yield. The use of 20 and 30 g/100 kg allowed to form a yield increase at the same level of 0.25 and 0.30 t/ha, respectively (in the control of 2.09 t/ha), while Zn_{10} increased the yield by a smaller amount - 0.14 t/ha. The use of copper fertilizers at a dose of 30 g/100 kg allowed to create a yield increase of 0.26 t/ha, and the treatment with Cu_{10} and Cu_{20} formed almost identical yield increases of 0.22 and 0.23 t/ha, respectively. But in general, increasing the dose of copper in the form of chelate to 20 and 30 g is ineffective compared to the use of 10 g/ha.

Thus, the use of foliar feeding of spring wheat at cultivation on meadow-chernozem soil with zinc and copper chelates in the tillering phase is effective. The best dose of zinc and copper in foliar feeding in the tillering phase is 20 and 10 g/ha, respectively.

Soil and climatic conditions, agrotechnics, type and variety of crops affect the quality of grain, as also micronutrients do [3]. The maximum protein content was obtained by foliar feeding in the tillering phase with Zn_{10}-13.31 % and Cu_{30}-13.53 % (table 2). In general, trace elements significantly increased this indicator, which was previously noted by other scientists [6, 7, 9, 12, 13]. This can probably be explained by the participation of zinc and copper in the reactions that provide nitrogen metabolism in plants. Protein collection thus increased from 273 kg/ha in the control to 297-327 kg/ha with the use of trace elements chelates, this is influenced by the increase in yield under the influence of fertilizers, and changes in the chemical composition of plants (grains) for the same reason.

TABLE II. Indicators of grain quality of spring soft wheat during application of chelate micronutrients in the tillering phase (g ai/ha) on meadow-chernozem soil of the Omsk region (average 2017-2018)

Variant	Vitreousness, %	Protein, %	Protein collection, kg/ha	Gluten, %	GDI, unit
Control	51.0	13.08	273	26.70	60.5
Zn_{10}	51.5	13.31	327	27.30	62.5
Zn_{20}	52.5	13.25	317	27.00	61.0
Zn_{30}	51.0	13.26	297	27.35	57.5
Cu_{10}	49.5	13.30	307	27.85	59.5
Cu_{20}	50.0	13.23	303	27.60	57.5
Cu_{30}	51.0	13.53	306	27.75	58.0
LSD_{05}	2.0	0.51	25.2	0.55	3.50

The main indicator of grain quality is the quantity and quality of gluten. The gluten content was 26.70-27.85 % (with GDI 57.5-62.5 units), in the best yield variants (Zn_{10} and Cu_{10}) it was at the maximum level of 27.30 and 27.85 %, respectively (GDI 62.5 and 59.5).

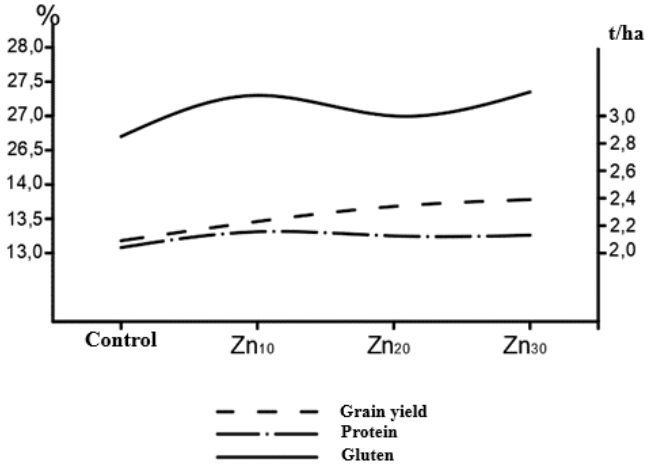

Fig. 1. Yield and quality of spring wheat grain during application of chelated zinc fertilizers in tillering phase (g ai/ha) on meadow-chernozem soil (average 2017-2018)

When analyzing the trend lines of zinc chelate action on the yield and grain quality of spring wheat, it can be noted (Fig. 1) that the protein content was maximum at a minimum dose of 10 g/ha, as well as gluten (the increase in its content with increasing doses is unreliable). However, the yield increased to the highest value with the use of Zn20 and Zn30.

When analyzing the same trend lines of copper chelate action on the same indicators of the studied culture, it can be noted (Fig. 2) that the protein content increased as the dose increased to 30 g/ha, and the gluten content and yield were maximum at the initial dose of 10 g/ha.

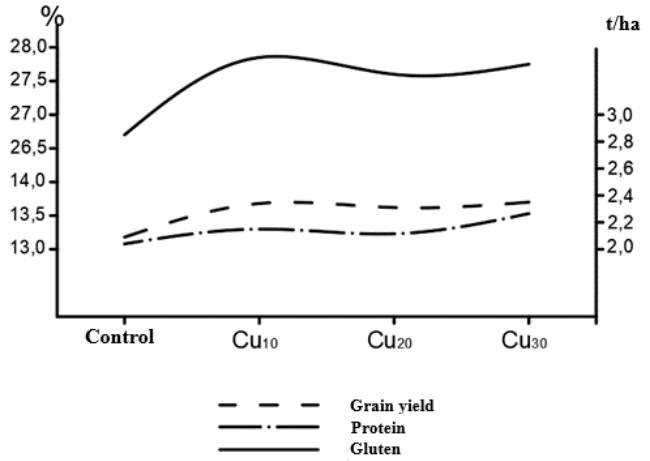

Fig. 2. Yield and quality of spring wheat grain during application of chelated copper fertilizers in tillering phase (g ai/ha) on meadow-chernozem soil (average 2017-2018)

In our studies, the vitreousness of grain of cultivar In Memory of Aziyev was in the range of 49.5-52.5 % (table 2), therefore, this variety of spring wheat belongs to the medium-glassy.

When studying the effect of micronutrients on the qualitative characteristics of wheat protein, it was revealed that the amount of amino acids increases from 7,580 % without fertilizers to the highest 7,660 % with foliar feeding with chelated forms Zn10 and 7,645 % - at Cu30. Especially significantly micronutrients influenced the increase of arginine, methionine content. But in general, this influence is multidirectional. When these doses of micronutrients were applied, the greatest accumulation of essential amino acids was observed (table 3).

TABLE III. EFFECT OF CHELATE MICRONUTRIENTS ON THE AMINO ACID COMPOSITION OF SPRING WHEAT PROTEIN, WHEN CULTIVATED ON MEADOW-CHERNOZEM SOIL, % (AVERAGE 2017-2018)

Amino acid	Variant						
	Control	Zn_{10}	Zn_{20}	Zn_{30}	Cu_{10}	Cu_{20}	Cu_{30}
Protein content, %	13.08	13.31	13.25	13.26	13.30	13.23	13.53
Arginine	0.740	0.840	0.795	0.820	0.830	0.740	0.785
Lysine	0.360	0.330	0.300	0.320	0.305	0.320	0.345
Tyrosine	0.255	0.250	0.240	0.255	0.230	0.240	0.265
Phenylalanine	0.525	0.530	0.505	0.525	0.515	0.520	0.555
Histidine	0.320	0.290	0.275	0.275	0.290	0.280	0.280
Leucine+isoleucine	1.260	1.275	1.205	1.240	1.245	1.220	1.290
Methionine	0.200	0.225	0.245	0.245	0.215	0.220	0.205
Valine	0.540	0.570	0.530	0.550	0.535	0.535	0.570
Proline	1.305	1.345	1.285	1.335	1.290	1.300	1.290
Threonine	0.410	0.385	0.365	0.375	0.365	0.370	0.385
Serine	0.725	0.690	0.655	0.670	0.675	0.660	0.700
Alanine	0.450	0.430	0.400	0.420	0.410	0.410	0.460
Glycine	0.490	0.500	0.465	0.480	0.460	0.475	0.515
Sum of amino acids	7.580	7.660	7.265	7.510	7.365	7.290	7.645
Sum of indispensable amino acids	3.295	3.315	3.150	3.255	3.180	3.185	3.350
Sum of limiting amino acids	0.97	0.94	0.91	0.94	0.885	0.91	0.935

Germination energy is an important parameter of sowing qualities of seeds, contributing to simultaneous growth and development of plants, grain ripening and filling, which improves its quality and facilitates harvesting (table 3). It significantly increased with foliar feeding in the tillering phase from 95.0 in the control to 96.3-98.0 % with the use of chelates trace elements. The greatest seed germination energy was at foliar feeding with chelated forms in doses of Zn_{10}, Cu_{10}, Cu_{20}, respectively, 97.3; 97.3 and 98.0 %, laboratory seed germination - Zn_{30} (99.5 %).

In general, reliable influence of chelates of trace elements on the energy of germination of spring wheat seeds can be noted according to the results of studies. Seed germination increased only in the Zn_{30} variant, but slightly and amounted to 99.5% (in the control 99.0 %).

TABLE IV. SOWING QUALITIES OF SPRING WHEAT SEEDS DURING APPLICATION OF CHELATED MINOT NUTRITION ELEMENTS IN TILLERING PHASE (G AI/HA) ON MEADOW-CHERNOZEM SOIL OF THE OMSK REGION (2017-2018)

Variant	**Germination energy, %**			**Laboratory germination, %**		
	2017	***2018***	***average***	***2017***	***2018***	***average***
Control	94.5	95.5	95.0	99.0	99.0	99.0
Zn_{10}	95.5	97.0	96.3	99.5	99.0	99.3
Zn_{20}	97.0	95.5	96.3	98.5	98.0	98.3
Zn_{30}	96.5	98.0	97.3	100	99.0	99.5
Cu_{10}	98.0	96.5	97.3	98.5	99.5	99.0
Cu_{20}	99.5	96.5	98.0	99.5	98.5	99.0
Cu_{30}	94.0	95.9	95.0	99.5	96.0	97.8
LSD_{05}	4.90	4.80		4.40	4.30	

Physical properties of grains and seeds include: shape of the grains, their linear dimensions and size, volume, plumpness and shriveling, weight of 1000 grains, alignment, seed yield. weight of 1000 grains as an element of crop structure determines size and plumpness of grain. A high weight value of 1000 grains indicates a large supply of

nutrients in the grain. One of the features that determine the milling advantages of wheat is grain unit. This indicator is closely related to grain plumpness and density, its size and shape. There is a positive correlation between grain unit and yield of flour.

Evaluation of spring wheat seeds with the use of chelated micronutrients showed that the best by weight of 1000 grains was characterized by Zn_{20} (33.5 g) variant, and by grain unit (737 g/l) was Cu_{10} (table 4), and in control 30.05 g and 711 g/l respectively. When using zinc chelate, the largest mass of 1000 grains (33.5 g) and grain unit (730 g/l) were formed in the Zn_{20} variant. From copper chelate, the highest value of the mass of 1000 grains was characterized by the variant Cu_{10} (33.15 g), the best by grain unit was the Cu_{10} variant (737 g/l). At the same time, both by weight of 1000 grains, and by grain unit, and by energy of germination, the indicators of 2018 were inferior to those of 2017. Probably, the insufficient amount of heat in 2018 affected. As a result, the quality of seeds was reduced.

TABLE V. PHYSICAL QUALITIES OF SPRING WHEAT SEEDS DURING APPLICATION OF CHELATED MINOT NUTRITION ELEMENTS IN TILLERING PHASE (G AI/HA) ON MEADOW-CHERNOZEM SOIL OF THE OMSK REGION (2017-2018)

Variant	Weight of 1000 grains, g			Grain unit g/l		
	2017	*2018*	*average*	*2017*	*2018*	*average*
Control	31.40	28.70	30.05	732	690	711
Zn_{10}	35.20	31.50	33.35	742	714	728
Zn_{20}	35.50	31.50	33.50	748	712	730
Zn_{30}	34.90	30.00	32.45	747	709	728
Cu_{10}	35.70	30.60	33.15	754	719	737
Cu_{20}	32.80	29.70	31.25	723	701	712
Cu_{30}	33.20	30.10	31.65	732	697	715

IV. CONCLUSION

The use of zinc and copper chelates in tillering phase by foliar feeding of plants in the conditions of the southern forest-steppe of the Omsk region positively affected the yield and sowing qualities of seeds of soft spring wheat. The best doses of zinc and copper in meadow-chernozem soil with foliar feeding in the tillering phase is 20 (yield increase of 0.25 t/ha, in the control of 2.09 t/ha) and 10 g/ha (0.26 t/ha), respectively. Protein collection thus increased from 273 in the control to 297-327 kg/ha with the use of chelates, the germination energy of the obtained seeds increased from 95 in the control to 96.3-98.0 % from the foliar feeding in tillering phase. The gluten content was 26.70-27.85 % (with GDI 57.5-62.5 units), in the best yield variants (Zn10 and Cu10) it was at the maximum level of 27.30 and 27.85 %, respectively. The amount of amino acids in the protein increases from 7,580 % without fertilizers to the highest 7,660 % with foliar feeding with chelated forms of Zn10 and 7,645 % - at Cu30. Especially significantly micronutrients influenced the increase of arginine, methionine content. The best in weight of 1000 grains (33.5 g) was Zn20 variant, and in grain unit (735 g/l) - Cu10, which exceeds the control parameters (30.05 g and 711 g/l, respectively).

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