Economic efficiency of the use of microelement chelates in cultivation of spring wheat on quasigleyic blac soil

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Abstract. The purpose of the paper is to study the effect of foliar feeding with Zn and Cu chelates in the tillering period on the size and quality of the grain yield of spring common wheat during the cultivation on quasi-gleyic medium-thick, highly humus-rich, heavy loamy black soil in Omsk region. The field experiment scheme included the following options: without trace elements (control group); Zn10; Zn20; Zn30; Cu10; Cu20; Cu30. The use of Zn and Cu chelates for foliar feeding of plants during the tillering period had a positive effect on the yield, quality, germination energy, seed germination, the mass of 1000 grains and the unit of wheat grain. The increase in grain yield was 0.10-0.23 t / ha (4.5-10.5%) in average. In this experiment, the best dose of Zn and Cu chelates was 20 g / ha. The highest protein content was in the options with seed treatment with Zn20 - 14.35% and Cu30 - 13.95%, the yield of protein increased from 295 in the control group to 322-344 kg / ha when chelates were applied. The energy of seed germination significantly increased from 93.3 in the control group to 94.8-98.0%, with foliar feeding. When Zn chelate was used, the largest mass of 1000 grains (32.33 g) and grain nature (709 g / l) were formed in the Zn20 option, and when Cu chelate was used, the Cu10 option (32.45 g) was characterized by the highest value of the 1000-grain mass, which amounted to 717 g / l. D

1. Introduction
Timely foliar feeding improves the assimilation and work of macronutrients, stimulates metabolism and helps to increase yield and product quality, overcome stress, activate and implement protective systems of plants. A number of researchers noted that during the cultivation of various grain crops in the region, products with microelements in a chelated form are most effective. In contrast to sulfate, oxide, and other compounds, it is maximally available for plants and provides maximum assimilation of elements. It is in the form of chelates that all living things use metals [1-4]. The determination of the phase for the application of crop feeding is one of the main techniques to get the maximum effect from receiving and obtaining high qualitative crop.
2. Problem Statement
Spring wheat is the main grain crop of the region. It occupies over 70% of the area. The grain grown in the conditions of the steppe and forest-steppe zones of Omsk region, in terms of technological properties, is equal to world standards and is used to improve the baking qualities of flour in many regions of the Russian Federation and abroad. In order to increase wheat yield, it is necessary to use micronutrients [5-9], but the use of chelated forms for this purpose is not sufficiently studied in Omsk region.

3. Research Methods
The field studies were carried out in 2017–2019 in the fields of Federal State Budgetary Scientific Institution “Omsk Agrarian Scientific Center”. The scheme of the experiment was based on the method of organized repetitions, the repetition was 4-fold, the placement of the plots in the experiment was three-level and the options within the repetition were systematic with a shift. The area of plot was 16 m2. The doses of microelements were in grams of active ingredient per hectare in the form of chelates. The soil was black, quasi-gleyic, medium-thick, highly humified and heavy loamy.

Before the experiment, the content of nitrate nitrogen in the 0-40 cm soil layer (according to Grandval-Lyazh) was 15.5 ± 1.9 mg / kg, mobile phosphorus and potassium was 228 ± 17 and 338 ± 12 mg / kg, respectively (according to Chirikov), the content of mobile Zn and Cu in the soil was 0.54 ± 0.08 and 0.11 ± 0.03 (layer 0-20 cm). The studies were carried out on wheat in a three-field seed-growing crop rotation of fallow - wheat - wheat. Agrotechnics, generally accepted for the area: in autumn, the main processing was autumn plowing with a PN-4-35 plow to a depth of 20-22 cm; early spring harrowing with tooth harrows in two tracks when the soil reached the state of physical ripeness and pre-sowing cultivation of KPS-4 to the seeding depth. Sowing was carried out on May 25-27 with an SSFK-7 seeder; the seeding rate was 5.5 million germinating seeds per hectare, after sowing the soil was rolled with ZKK-6A ring rollers. Wheat was harvested in the first ten days of September by Hege-125 direct combining.

Chemical analyzes were carried out at the Department of Agrochemistry and Soil Science of Omsk State Agrarian University and in the laboratory of primary seed production of Omsk Agrarian Scientific Center according to standard methods.

Meteorological conditions during the years of the research developed in different ways. In 2017, the sum of effective temperatures in the period from May to September reached 79.1 °C, which was 1.8 °C higher than the average annual indicators (77.3 °C), and the amount of precipitation for this period was 170.7 mm, which was 72.3 mm below the long-term average indicators (243 mm). In 2018, the amount of precipitation during the growing season significantly exceeded the average annual indicators and amounted to 258.3 mm. The sum of effective temperatures was lower than the average annual indicators (64.5 °C). The growing season in 2019 was more favorable for the growth and development of wheat, the sum of effective temperatures (76.9 °C), as well as the sum of precipitation (239 mm) reached the average annual indicator.

4. Findings
The improvement of the nutrition of spring wheat using Zn and Cu chelates as foliar feeding of plants in the tillering period provided the increase in grain yield on average 0.10-0.23 t / ha, or 4.5-10.5% in relation to the control group (Table 1).

The experiments revealed a positive effect of foliar feeding of spring wheat in the tillering phase with Zn chelate on grain yield. The use of 20 and 30 g / ha allowed the increase in yield of 0.20 and 0.23 t / ha, respectively (10.5 and 9.1% to control group), while Zn10 increased the yield by a smaller amount - 0.10 t / ha. The best dose of Zn chelate for foliar feeding of spring wheat in the tillering phase was 20 g / ha.

The use of Cu fertilizers at a dose of 10 and 30 g / ha formed the increase in yield at the same level of 0.20 t / ha (in control group it was 2.30 t / ha), and treatment with Cu20 formed the increase in yield of 0.23 t / ha. In general, the application of a dose of Cu 10.20, 30 g gave almost the same increase.
The most effective feeding was Cu10, as it was less expensive in terms of the amount of the introduced element.

**Table 1.** Wheat grain yield with foliar feeding with chelated micronutrient fertilizers in the tillering period

| Option | Grain yield, t/ha | Yield gain | % |
|--------|-------------------|------------|---|
|        | 2017 | 2018 | 2019 | average | t/ha |  |
| Control group | 2.45 | 1.73 | 2.41 | 2.20 | - | - |
| Zn10 | 2.59 | 1.86 | 2.46 | 2.30 | 0.10 | 4.5 |
| Zn20 | 2.75 | 1.93 | 2.51 | 2.40 | 0.20 | 9.1 |
| Zn30 | 2.80 | 1.97 | 2.52 | 2.43 | 0.23 | 10.5 |
| Cu10 | 2.60 | 2.08 | 2.52 | 2.40 | 0.20 | 9.1 |
| Cu20 | 2.62 | 2.00 | 2.50 | 2.37 | 0.17 | 7.7 |
| Cu30 | 2.65 | 2.04 | 2.52 | 2.40 | 0.20 | 9.1 |
| HCP05 | 0.11 | 0.08 | 0.10 |  |  |  |

The quality of the crop is a complex indicator, forming in the process of growing crops for food and feed purposes [10, 11]. Varietal hereditary properties, soil and climatic conditions, agricultural technology affect the quality of grain, as micronutrient fertilizers [4, 8]. The highest protein content in our experiments was obtained in options with seed treatment with Zn20 - 14.35% and Cu10 - 13.95% (Table 2)

**Table 2.** Indicators of the quality of wheat grain with foliar feeding with chelated micronutrient fertilizers in the tillering phase (average for 2017–2019)

| Option | Hardness, % | Protein, % | Protein yield, kg/ha | Gluten, % | Gluten deformation index (GDI), unit |
|--------|-------------|------------|----------------------|----------|-------------------------------------|
| Control group | 50,0 | 13,39 | 295 | 26,50 | 59,0 |
| Zn10 | 51,0 | 13,99 | 322 | 27,40 | 61,0 |
| Zn20 | 51,7 | 14,35 | 344 | 27,66 | 58,3 |
| Zn30 | 50,3 | 13,68 | 332 | 27,03 | 56,0 |
| Cu10 | 49,0 | 13,79 | 331 | 27,60 | 57,7 |
| Cu20 | 49,7 | 13,67 | 324 | 27,30 | 57,3 |
| Cu30 | 50,3 | 13,95 | 335 | 28,03 | 57,0 |
| HCP05 | 2,0 | 0,52 | 25,2 | 0,55 | 3,50 |

The hardness of grain in our experiments was 49.0-51.7% (Table 2), therefore Memory of Aziev variety belongs to the medium-hard one and its grain has a sufficiently high content of protein, gluten and good baking qualities.

At the same time, the yield of protein increased from 295 kg / ha in the control group to 322-344 kg/ha with the use of chelates of microelements. This was influenced by the increase in yield under the influence of fertilizers and a change in the chemical composition of plants (grain) for the same reason.

The gluten content was 27.03-28.03% (with GDI of 57.0-61.0 units), in the best yield options (Zn30 and Cu10, Cu30) it was at the level of 27.03 and 27.6, 28, 03% respectively (GDI 56 and 57.7, 57).

During the analysis of the graph data of the effect of Zn chelate on the yield and grain quality of spring wheat, it is possible to note (Figure 1) that the protein concentration was maximum at a dose of
10 g / ha, as well as gluten. At the same time, the yield increased to the highest value during the use of Zn30.

![Graph showing yield and grain quality of spring wheat with foliar feeding with chelated Zn fertilizers in the tillering phase (g.r.a./ha) on quasi-gleyic black soil (average for 2017-2019)](image)

**Figure 1.** Yield and grain quality of spring wheat with foliar feeding with chelated Zn fertilizers in the tillering phase (g.r.a./ha) on quasi-gleyic black soil (average for 2017-2019)

During the analysis of the graph data of the effect of Cu chelate on the same indicators of the studied crop, we can note (Figure 2) that the protein content increased with the increase of a dose to 30 g / ha, the gluten content and yield were also maximal at a dose of 30 g / ha.

![Graph showing yield and grain quality of spring wheat with foliar feeding with chelated Cu fertilizers in the tillering phase (g.r.a./ha) on quasi-gleyic black soil (average for 2017-2019)](image)

**Figure 2.** Yield and grain quality of spring wheat with foliar feeding with chelated Cu fertilizers in the tillering phase (g.r.a./ha) on quasi-gleyic black soil (average for 2017-2019)
The full value of proteins is determined by the quality of protein, i.e., amino acid composition. In total, proteins contain 20 amino acids. Among them, the determination of essential amino acids, which cannot be synthesized in humans and animals, is of great importance. These are tryptophan, phenylalanine, methionine, lysine, valine, threonine, isoleucine, leucine, cystine. There are 4 critical or limiting among them, they most often limit the growth and development of animals, they include: threonine, methionine, cystine and lysine. Conditionally essential acids include arginine and histidine.

During the study of the effect of microfertilizers on the qualitative characteristics of wheat protein, it was found that the amount of amino acids increased from 7.40% without fertilizers to the highest 7.71% with foliar feeding in the tillering period with chelated forms of Zn at a dose of 10 g and 8.10% with Cu20. In general, the influence of chelated forms of microelements is multidirectional (Table 3).

**Table 3.** Amino acid composition of spring wheat protein with foliar feeding with chelated micronutrient fertilizers (g/ha) in the tillering phase, % (average for 2017-2019)

| Amino acid                  | Option          | Control | Zn10 | Zn20 | Zn30 | Cu10 | Cu20 | Cu30 |
|-----------------------------|-----------------|---------|------|------|------|------|------|------|
| Protein content, %           |                 | 13,39   | 13,99| 14,35| 13,68| 13,79| 13,67| 13,95|
| Arginine                    |                 | 0,72    | 0,82 | 0,74 | 0,81 | 0,81 | 0,767| 0,77 |
| Lysine                      |                 | 0,35    | 0,35 | 0,31 | 0,33 | 0,32 | 0,35 | 0,34 |
| Tyrosine                    |                 | 0,26    | 0,26 | 0,24 | 0,26 | 0,25 | 0,29 | 0,29 |
| Phenylalanine               |                 | 0,52    | 0,55 | 0,5  | 0,52 | 0,56 | 0,6  | 0,57 |
| Histidine                   |                 | 0,28    | 0,27 | 0,25 | 0,28 | 0,28 | 0,29 | 0,28 |
| Leucine + Isoleucine        |                 | 1,23    | 1,29 | 1,18 | 1,3  | 1,3  | 1,37 | 1,34 |
| Methionine                  |                 | 0,22    | 0,2  | 0,22 | 0,22 | 0,18 | 0,2  | 0,18 |
| Valine                      |                 | 0,53    | 0,6  | 0,51 | 0,56 | 0,53 | 0,6  | 0,58 |
| Proline                     |                 | 1,30    | 1,35 | 1,27 | 1,35 | 1,35 | 1,51 | 1,32 |
| Threonine                   |                 | 0,40    | 0,5  | 0,36 | 0,45 | 0,43 | 0,43 | 0,5  |
| Serine                      |                 | 0,70    | 0,66 | 0,62 | 0,64 | 0,65 | 0,74 | 0,68 |
| Alanine                     |                 | 0,45    | 0,52 | 0,42 | 0,51 | 0,54 | 0,61 | 0,54 |
| Glycine                     |                 | 0,48    | 0,49 | 0,45 | 0,48 | 0,47 | 0,51 | 0,51 |
| The amount of amino acids   |                 | 7,40    | 7,71 | 7,06 | 7,6  | 7,51 | 8,1  | 7,76 |
| The amount of essential amino acids |       | 3,24    | 3,41 | 3,08 | 3,33 | 3,26 | 3,53 | 3,43 |
| The sum of critical amino acids |             | 0,97    | 0,97 | 0,89 | 0,95 | 0,88 | 0,96 | 0,93 |

**Table 4.** Sowing qualities of wheat seeds with foliar feeding with chelated micronutrient fertilizers in the tillering phase (average for 2017–2019)

| Option          | germination energy, % | germination ability, % |
|-----------------|------------------------|------------------------|
|                 | 2017  | 2018  | 2019  | Average | 2017  | 2018  | 2019  | Average |
| Control group   |       |       |       |         |       |       |       |         |
| Zn10            | 95,5  | 97,0  | 95,0  | 93,3    | 98,0  | 98,0  | 96,0  | 97,3    |
| Zn20            | 97,0  | 95,5  | 97,0  | 95,8    | 99,5  | 99,0  | 98,0  | 98,8    |
| Zn30            | 96,5  | 98,0  | 96,0  | 96,8    | 100   | 99,0  | 97,0  | 98,7    |
| Cu10            | 98,0  | 96,5  | 96,0  | 96,8    | 98,5  | 99,5  | 98,0  | 98,7    |
| Cu20            | 99,5  | 96,5  | 98,0  | 98,0    | 99,5  | 98,5  | 98,0  | 98,7    |
| Cu30            | 94,0  | 95,9  | 95,0  | 94,8    | 99,5  | 96,0  | 96,0  | 97,2    |
| HCP05           | 4,9   | 4,8   | 4,3   | 4,4     | 4,3   | 4,3   | 3,30  | 3,30    |
Germination energy is an important indicator of the sowing qualities of seeds. Its high values contribute to the simultaneous growth and development of plants, ripening and grain filling, which improves the quality of grain and facilitates harvesting. In our studies, the seed germination energy varied from 93.3 to 98.0% (Table 4, Figure 3-4).

With foliar feeding with Zn chelates, the maximum germination energy was observed when using 30 g / ha and amounted to 96.8%. During crop treatment with Cu chelates, the maximum value in the experiment was obtained from the use of 20 g / ha, the germination energy was 98.0%.

In laboratory studies, the germination of the obtained seeds significantly increased with foliar feeding in the tillering phase from 97.3% in the control group to 98.2-98.8% when using chelates of microelements.

![Figure 3. Laboratory germination of spring wheat seeds depending on the use of Zn in the tillering phase (average for 2017-2019)](image-url)
**Figure 4.** Laboratory germination of spring wheat seeds depending on the use of Cu in the tillering phase (average for 2017-2019)

The best germination rate was revealed with foliar feeding with chelated forms at doses of Zn10 (98.8%), with foliar feeding with doses of Zn30, Cu10, Cu20, laboratory germination was the same and amounted to 98.75%.

The mass of 1000 grains as an element of the structure of the yield determines the size and grain size. A high 1000 grain weight indicates a large supply of nutrients in grains. One of the features that determine the milling advantages of wheat is the nature of grains. This indicator is closely related to the value and density of grains, its size and shape. There is a positive correlation between the nature of grain and the yield of flour [10, 11].

The use of chelated micronutrient fertilizers using the method of foliar feeding in the tillering phase showed high results of the physical properties of grains (Table 5).

**Table 5.** Physical qualities of wheat seeds with foliar feeding with chelated micronutrient fertilizers in the tillering phase

| Option | Weight of 1000 grains, g | Grain unit g/l |
|--------|-------------------------|----------------|
|        | 2017  | 2018  | 2019  | Average | 2017  | 2018  | 2019  | Average |
| Control| 31.40 | 28.70 | 29.67 | 29.92   | 720   | 690   | 669   | 693     |
| Zn10   | 35.20 | 31.50 | 29.67 | 32.12   | 742   | 714   | 663   | 706     |
| Zn20   | 35.50 | 31.50 | 30.00 | 32.33   | 748   | 712   | 668   | 709     |
| Zn30   | 34.90 | 30.00 | 30.03 | 31.64   | 747   | 709   | 656   | 704     |
| Cu10   | 35.70 | 30.60 | 31.04 | 32.45   | 754   | 719   | 677   | 717     |
| Cu20   | 32.80 | 29.70 | 30.33 | 30.94   | 723   | 701   | 680   | 701     |
| Cu30   | 33.20 | 30.10 | 30.70 | 31.33   | 732   | 697   | 685   | 705     |
| НСР   | 0,91  |       |       |         |       |       |       | 18,2     |

In the experiment, the Cu10 option was characterized by the best in the mass of 1000 grains (32.45 g) and in grain unit (717 g / l), and with the use of Zn chelate the greatest mass of 1000 grains (32.33 g) and grain unit (709 g / l) was in Zn20 option. From Cu chelate, the largest value of the mass of 1000 grains was characteristic of Cu10 option (32.45 g), Cu10 option (709 g / l) was the best in grain unit.

During the course of the determination of the actual economic efficiency of the use of fertilizers for agricultural crops, the increase in yield is estimated at current prices (in this case, 2020). This allows identifying the feasibility of the investment in the resulting increase in yield from fertilizers [2, 4]. All the main costs associated with the cultivation of spring wheat, harvesting additional products from the use of mineral fertilizers, transportation, loading and unloading were calculated according to the cost standards used in Sosnovskoe enterprise in Omsk region.

In order to calculate the economic efficiency of spring wheat fertilization, we used yield data depending on the doses and the method of the application of chelates (Table 6).

**Table 6.** Economic efficiency of the use of chelated forms of Zn and Cu fertilizers by foliar feeding (g/ha) in the tillering phase during the cultivation of spring wheat (average for 2017-2019)

| Indicator                              | Zn  |             | Cu  |             |
|----------------------------------------|-----|-------------|-----|-------------|
|                                        | 10  | 20          | 30  | 10          | 20 | 30 |
| Increase in yield, t / ha              | 0,1 | 0,2         | 0,23| 0,2         | 0,17| 0,2 |
| Costs associated with the use of fertilizers, rubles / ha | 825,1 | 958,1 | 1048,6 | 890,2 | 953,8 | 1050,5 |
| Selling price, rub / t                 | 11000| 11000       | 11000| 11000       | 11000| 11000 |
| Cost of additional products, rub / ha  | 1100 | 2200        | 2530| 2200        | 1870| 2200 |
| Conditional net income, rubles / ha    | 274,9| 1241,9      | 1481,3| 1309,8      | 916,2| 1149,5|
| Profitability, %                       | 33,3| 129,6       | 141,3| 147,1       | 96,1| 109,4|
In our experiments, the net income received from the use of microfertilizers reached 274.9-1481.3 rubles / ha, depending on the option. The calculated profitability showed that the use of microfertilizers for spring wheat is economically profitable. The profitability level of the best yield options was 109.4-141.3%.

5. Conclusion
The use of foliar feeding of wheat with Zn and Cu chelates in the tillering phase in the southern forest-steppe area of Omsk Priirtysh region had a positive effect on the yield, food and sowing qualities of grain. The best doses of Zn and Cu on quasi-gleyic black soil with foliar feeding in the tillering period was 20 g / ha (yield increase 0.20 t/ha, control 2.20 t/ha) and 10 g/ha (0.20 t/ha) respectively.

At the same time, the yield of protein increased from 295 in the control group to 322-344 kg / ha with the use of chelates, the germination energy of the obtained seeds increased from 93.3 in the control group to 94.8-98.0% of foliar feeding in the tillering phase. The gluten content was 27.03-28.03% (with IDC 57.0-61.0 units), in the best yield options (Zn20 and Cu10) it was at the maximum level of 27.66 and 27.60%, respectively. The best one in terms of the weight of 1000 grains (32.45 g) and grain unit (717 g / l) was the Cu10 option, which exceeded the control indicators (29.92 g and 693 g / l, respectively).

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