Efficiency of multifunctional chelate complexes used during spring wheat cultivation

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Abstract. Field experiments conducted in 2015-2017 on gray forest soils of Bryansk region (Russia) substantiated the effectiveness of multifunctional chelate mixtures for producing wheat grain. It was revealed that at the tillering and earing stages, double foliar fertilizing of crops using multifunctional chelate mixtures based on succinic acid (3.0 l/ha) instead of nitrogen N\textsubscript{30} (at the tillering stage) increase the yield by 1.5-2.0%, decreases production costs by 30% and increases profitability of grain production by 100%.

1. Introduction
Russia remains one of the main grain-producing countries in the world after the USA, India and the EU countries. Its share in world production is approximately 5.5%. In recent years, there has been an increase in grain production. In 2006-2010, the gross yield averaged 91.3 million tons which is 15.9% more than in 2001-2005, and the yield increased by 13.3% from 1.88 to 2.13 t/ha. According to the forecast of the Ministry of Economic Development and Trade, by 2020 the gross grain harvest will reach 125 million tons, the yield will increase to 2.6 t/ha [1].

Spring wheat occupies a significant share in the grain field of Russia. Over the past 5 years, the area of spring wheat increased to 14–15 million hectares, including 1.5 million hectares in the Nonchernozem belt of Russia. At the same time, the average yield of spring wheat in the Nonchernozem belt did not exceed 2.0 t/ha [2].

New varieties of spring wheat have the yield of 6–8 t/ha. They can adapt to natural and climatic conditions of the region and respond to the increasing intensity of the technology. At the same time, it is important to get a full economic return from agricultural activities and follow the environmental anthropogenic threshold [3].

Domestic and foreign experts believe that 50% of the yield potential of grain crops is achieved through the introduction of new varieties and hybrids, and 50% - through the improvement of the cultivation technology [2, 3].

Therefore, it is necessary to improve technological methods of cultivation of modern varieties of spring wheat, ensuring high grain yields with a simultaneous increase in economic efficiency.

The article aims to study effect of the multifunctional chelate complex on productivity and economic efficiency of spring wheat.
2. Materials and methods
The studies were conducted in 2015-2017 at the experimental field of Bryansk State Agrarian University on gray forest soils.

The object is a spring soft wheat variety Zlata. Variety originators are FITS Nemchinovka and FGBNU Verkhnevolzhsky FARC, Russia.

The predecessor is potato. The seeding rate is 5.0 million seeds per hectare. The repetition of the experiment is threefold. The placement of plots is systematic / The plot area is 50 m², the accounting area is 25 m².

The experiment scheme included the following options:
1. N₀₀P₆₀K₆₀ (background, control);
2. Background + N₃₀;
3. Background + 2 Terraflex treatment (17:17:17);
4. Background + 2 chelate treatment.

Terraflex 17 + 17 + 17 (manufactured by Nu3 N.V., Belgium) is a complex water-soluble fertilizer. It contains the following macro and micronutrients: N₉₃ – 17, P₂O₅ – 17, K₂O – 17, MgO – 3, SO₃ – 13.8, Fe – 0.1, Mn – 0.1, Zn – 0.035, Cu – 0.05, B – 0.03, Mo – 0.01 %. Fe is in the form of DTPA, Mn, Zn and Cu – in the form of EDTA. Nitrogen is in nitrate, ammonium and amide forms.

The chelate complex is a liquid complex microfertilizer developed by Bryansk State Agrarian University. The composition was developed taking into account data analysis for similar domestic and foreign drugs, as well as the need of spring wheat in trace elements. Succinic acid is used as a chelating component which contributes to the energy metabolism, active growth and development of the root system. The chelate complex contains the following macro and micronutrients: N₉₃ – 82, P₂O₅ – 82, K₂O – 28, SO₃ – 30, MgO – 19, Mn – 0.5, Cu – 0.24, Zn – 0.17, B – 0.13, Co – 0.03, Mo – 0.06 g/l. Nitrogen is in the amide form.

In all the variants, N₀₀P₆₀K₆₀ was applied as a background fertilizer. The nitrogen phosphorous potassium fertilizer was the main fertilizer (16:16:16). The background was a control option.

In the second variant of the experiment, spring wheat crops were fertilized with ammonium salt at a dose of N₃₀.

In the third variant, wheat was treated with microfertilizer Terraflex (17:17:17) at the tillering and earing stages at a dose of 2.5 kg/ha.

In the 4th variant, wheat was treated with the Chelate complex at the tillering and earing stages at a dose of 3.0 l/ha.

Terraflex and Chelate (3 and 4 variants) was used as part of a tank mixture of pesticides. The plant protection products used in the experiment are permitted for use in the Russian Federation [4].

The tillage system, the plant protection system, the choice of a precursor and the seeding rate were in compliance with regional recommendations for grain crop cultivation [3]. Harvesting was carried out in the phase of full ripeness of the weevil by the direct combining method. The crop moisture was 14%, and purity – 100%. Field studies and statistical processing of the results were carried out according to the method of the field experiment [5]. Laboratory and analytical studies were carried out by the researchers of Bryansk State Agrarian University. The economic efficiency of mineral fertilizers was calculated by the method developed by the Institute of Soil Science and Agrochemistry, Minsk [6].

3. Results and discussion
The analysis of the crop structure (Table 1) showed that the use of root nitrogen fertilizer (N₃₀) and Terraflex (2.5 kg/ha) and Chelate (3.0 l/ha) increase the weight of 1000 seeds by 0.8-3.5%, grain weight by 2.1-4.2%, productive tillering by 2.7-4.5% and mass of grain by 6.4-8.3%.

In the control variant, in variants with N₃₀ and Chelate, the number of grains did not change and was 24 pcs. In the variant with Terraflex, the number of grains increased by 4.2%. 
The use of foliar fertilizing with Terraflex and Chelate (variants 3 and 4) increased the productivity by 0.9–1.8%, grain mass - by 0.3–1.9%, mass of 1000 seeds - by 1.0–2.7% and mass of ear grain - by 2.1% in comparison with the variant with root nitrogen fertilizers (variant 2).

When comparing the variants of non-root application of micronutrients (3 and 4), we can note that the use of the Chelate complex increases productive indicators by 0.9%, the grain weight – by 1.6% and the weight of 1000 seeds - by 1.7%. The grain weight per ear did not change (1 gram), and in the variant with Terraflex, the number of grains in the ear increased by 4.2% compared to the variant with Chelate.

The average yield of spring wheat for 3 years of research was 4.16-4.48 t/ha (Table 2).

| Variant                      | Productivity t/ha | Yield increase to control, t/ha |
|------------------------------|-------------------|-------------------------------|
| 1. N_{60}P_{60}K_{60} (background, control) | 4.16              | -                             |
| 2. Background + N_{30}        | 4.41              | 0.25                          |
| 3. Background + Terraflex    | 4.42              | 0.26                          |
| 4. Background + Chelate       | 4.48              | 0.32                          |
| HCP_{0.05}                   |                   | 0.17                          |

The lowest yield was observed in the control variant (4.16 t/ha), and the highest one was observed in the variant with Chelate (4.48 t/ha). The use of fertilizers contributed to a significant increase in grain yield by 0.25-0.32 t/ha. Introduction of ammonium nitrate at a dose of N_{30} increased the yield by 0.25 t/ha, double treatment of crops with Terraflex and Chelate increased the yield by 0.26 and 0.32 t/ha, respectively.

Economic indicators were calculated by the method [6] based on the cost of a crop yield increase due to the application of fertilizers and additional costs of fertilizers, unloading, storage, preparation, loading, transportation, harvesting, refinement and sales of the yield increase. Costs of unloading, storage, preparation, loading, transportation, harvesting, refining and sales of the yield increase were calculated using average standards.

Analysis of economic efficiency (Table 3) showed that with an increase in the yield from the use of fertilizers at the level of 0.25-0.32 t/ha and the selling price of grain of 140 USD/t, costs of the yield increase reach 37.5-48.0 USD/ha. At the same time, costs of the yield increase grew by 1.5 USD/ha in the variant with non-root application of Terraflex, and by 8 USD/ha - in the variant with Chelate in comparison with the variant with Terraflex.

Additional costs associated with the use of fertilizers range from 20.63 to 29.07 USD/ha, the maximum value of this indicator was observed in the variant with ammonium nitrate (29.07 USD/ha), the minimum - in the variant with double treatment with the Chelate Complex (20.63 USD/ha ). The use of Terraflex and the Chelate complex instead of nitrates reduces costs by 7.11-8.44 USD/ha, and the use of the Chelate complex instead of Terraflex reduces costs by 1.33 USD/ha.

| Variant | Productive tillering | The number of grains in the ear, pcs | Grain mass from 1 spike, g | Mass of 1000 seeds, g | Grain mass from 1 m², g |
|---------|----------------------|--------------------------------------|-----------------------------|-----------------------|------------------------|
| 1. N_{60}P_{60}K_{60} (background) | 1.12 | 24 | 0.96 | 39.5 | 424.1 |
| 2. Background + N_{30} | 1.15 | 24 | 0.98 | 39.8 | 451.4 |
| 3. Background + Terraflex | 1.16 | 25 | 1.00 | 40.2 | 452.5 |
| 4. Background + Chelate | 1.17 | 24 | 1.00 | 40.9 | 459.3 |
Table 3. Cost-effectiveness of spring wheat fertilizers (average for 2015-2017)

| Indicator                          | N60P60K60 + N30 | N60P60K60 + Terraflex | N60P60K60 + Chelate |
|------------------------------------|-----------------|------------------------|---------------------|
| Productivity, t/ha                 | 4.41            | 4.42                   | 4.48                |
| Yield increase to control, t/ha    | 0.25            | 0.26                   | 0.32                |
| Cost of yield increase, USD/ha     | 37.5            | 39.0                   | 48.0                |
| Additional costs to control, USD/ha| 29.07           | 21.96                  | 20.63               |
| Conditional net income to control, USD/ha | 8.43 | 17.04                  | 27.37               |
| Profitability, %                   | 29.0            | 77.6                   | 132.7               |

Thus, the maximum conditional net income was derived using the variant with the Chelate complex (27.37 USD/ha). In the variant with Terraflex, this indicator was lower by 10.33 USD/ha, and the minimum value of net income (8.43 USD/ha) was observed in the variant with root nitric top fertilizers. The level of profitability is 77.6 and 29.0%.

4. Conclusion
Based on the research results, it can be concluded that double application of the Chelate complex at a dose of 3.0 l/ha (at tillering and earing stages) instead of nitrogen fertilizers at a dose of N30 (at the tillering stage) increases the yield by 1.5 - 2.0%, reduces production costs by 30% and increases profitability of grain production by 100%.

5. Approbation
The results of the work on the use of polyfunctional chelate complexes for developing stable yields of spring wheat with high grain quality indicators were tested at the AgroRuss 2017 exhibition in St. Petersburg and were awarded a gold medal of the Ministry of Agriculture of the Russian Federation. Currently, production tests are being conducted by agricultural enterprises of Bryansk and Rostov regions and Krasnodar Krai (Russia).

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