Action of innovative forms of copper and zinc on photosynthetic activity of rice plants under conditions of delta zone of Kuban

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Abstract. The influence of various concentrations of innovative zinc-copper micronutrient fertilizer on rice plants as micronutrient, which was invented by a group of scientists from Kuban State Agrarian University named after I.T. Trubilin (patent RU 2546193 “Method for obtaining complex micronutrient fertilizer”) was considered [6]. Under the conditions of field experiments, the effect of foliage spraying of plants with the considered micronutrient fertilizer on the assimilation surface of leaves and the content of photosynthetic pigments was studied. Foliage spraying of rice plants with an innovative composition provided a more intensive accumulation of photosynthetic pigments, as well as an increase in the assimilation surface. Treatment of plants in the tillering phase with a solution of trace elements containing copper and zinc chelates at a dose of 2.0 l/ha creates favorable conditions for the growth and development of rice plants.

1. Introduction

Rice is one of the most valuable cereal crops widely used for dietary and medical nutrition, as well as for pharmaceutical purposes, brewing, perfumery industry, etc. The cultivation of rice in the world is of strategic importance. At present, the population of Russia is almost completely provided with domestic rice cereals. Moreover, Russia is both an importer and an exporter of this valuable cereal crop. The growth of grain production of this crop will significantly increase its export. For this, it is to increase the productivity of rice bioagrocenose and the quality of grain. Nevertheless, it is extremely difficult to solve this problem, since the peculiarities of the rice crop rotation lead to a negative balance of nitrogen, phosphorus and potassium and a decrease in the coefficients of their use from the soil. A partial solution to this problem can be proposed through the use of trace elements [5]. The use of trace elements such as zinc and copper for foliage spraying of rice is proposed. Moreover, the deficit of their mobile forms in rice soils has been established. However, at high concentrations, zinc and copper can manifest themselves as heavy metals, so their content must be strictly differentiated [1]. Therefore, the scientifically grounded use of these essential trace elements by introducing micronutrients against the background of their deficiency should lead to an increase in the yield and quality of rice grain, which is extremely important for the development of agriculture [5, 6, 7]. An important indicator of plant growth and development is photosynthetic activity, which activity is presented in this work under the conditions of the use of innovative copper-zinc micronutrient fertilizer.
2. Materials and methods
The data were experimentally obtained under the conditions of a field experiment, laid down in the conditions of the right bank of the Kuban River. The main fertilizer was applied at a dose of N\textsubscript{120} P\textsubscript{80} K\textsubscript{60}. Zinc-copper chelated micronutrient fertilizer was used as foliage spraying and pre-sowing treatment of seeds with concentrations calculated from the results of laboratory and vegetation experiments. The volume of the working solution is 300 l/ha. Control plants were treated with water. The total area of the plot was 15.0 m\textsuperscript{2}, and the accounting area was 10 m\textsuperscript{2}. The number of replicates was 4. The plots were arranged in a randomized way. The phases of tillering, casting out and milky-wax ripeness were studied.

Experience scheme:
- Control - NPK (background)
- Background + foliage spraying 0.5 l/ha
- Background + foliage spraying 1 l/ha
- Background + foliage spraying 1.5 l/ha
- Background + foliage spraying 2 l/ha
- Background + foliage spraying 2.5 l/ha
- Background + foliage spraying 3 l/ha

Foliar treatment of plants was carried out in the tillering phase by spraying the plants with a hand sprayer with chelate complexes of solutions of trace elements at the rate of 0.5 l/ha, 1.0; 1.5; 2.0; 2.5 and 3.0 l/ha. Control plants were treated with water.

The agricultural technology in the experiments corresponded to the recommendations of the All-Russian Research and Development Institute of Rice [8].

3. Results and discussion
In the field test, 7 options were provided, including the control option. Options of foliage spraying of plants with micronutrient fertilization at doses of 0.5 l/ha; 1.0; 1.5; 2.0; 2.5; 3.0 l/ha were studied (table 1).

Analysis of the data obtained shows that a solution of copper and zinc chelates in the studied concentrations has a positive effect on the assimilation surface of rice (figure 1).

Table 1. Leaf area of plants against the background of foliage spraying with copper-zinc chelated fertilizer, cm\textsuperscript{2}/plant.

| Experimental option | Rice vegetative phase |     |     |
|---------------------|-----------------------|-----|-----|
|                     | tillering             | casting out | milky-wax ripeness |
| Control (water)     | 53.8                  | 82.0   | 59.8 |
| FS 0.5 l/ha         | 54.0                  | 84.3   | 61.8 |
| FS 1.0 l/ha         | 55.9                  | 84.8   | 65.6 |
| FS 1.5 l/ha         | 56.2                  | 87.2   | 66.9 |
| FS 2.0 l/ha         | 58.9                  | 88.3   | 68.4 |
| FS 2.5 l/ha         | 57.1                  | 84.2   | 64.7 |
| FS 3.0 l/ha         | 56.3                  | 84.9   | 65.3 |
| LSD\textsubscript{05} | 2.9                   | 3.2    | 4.4  |

FS – foliage spraying
HCP\textsubscript{05} – least significant difference at 95% confidence level
Figure 1. Leaf area of plants in conditions of foliage spraying with copper-zinc chelated fertilizer, cm²/plant.

The positive influence of the conducted agrotechnical methods on the leaf area of rice has been established. A significant increase in the indicator with foliage spraying of crops at doses of 1.5 and 2.0 l/ha in the casting out phase was shown, where the leaf surface area reaches 87.2 and 88.3 cm²/plant. From the above data, it follows that the leaf area with foliage spraying of plants with a solution of microelements in the tillering phase at all studied concentrations of the working solution was 0.4 - 9.5\% more than in the control, which is 0.2 - 5.1 cm²/plant. In the stage of casting out, the greatest difference from the control group reached 7.7\% (6.3 cm²/plant) against the background of processing with microelements at the rate of 2.0 l/ha. In the phase of milky-wax ripeness of grain, foliage spraying with copper-zinc chelated fertilizer provided an increase in leaf area by 2.0 - 8.6 cm²/plant, which is 3.3 - 14.4\% in relation to the control. With foliage spraying of plants at the rate of 2.0 l/ha, the leaf area reached 8.6 cm²/plant in comparison with the control, which is an increase of this indicator by more than 14\%.

The leaf area reached its maximum size during the casting out phase, which corresponds to the nature of the dynamics of leaf surface formation for all rice varieties, regardless of weather and mineral nutrition conditions.

Thus, foliage spraying of rice with copper-zinc chelated fertilizer contributes not only to the intensive formation of the assimilation surface, but also to its preservation in an active state. This indicator reached its maximum value, as noted above, at a micronutrient dose of 2.0 l/ha. The effect of other studied doses of micronutrient fertilization on the assimilation surface of leaves was weaker.

Foliage spraying with a solution of trace elements also had a positive effect on the content of photosynthetic pigments in the leaves (Table 2). In all options of the experiment, an increase in the content of chlorophylls is noted in the range of the investigated concentrations of copper-zinc micronutrient fertilizers. Foliage spraying with zinc-copper micronutrient fertilizer most intensively increased the content of chlorophylls of group a. Thus, foliage spraying of plants at doses of 1.5 l/ha; 2.0 and 2.5 l/ha contributed to an increase in the content of chlorophyll of group a on the 10th day after treatment of plants in the tillering phase by 34.2 mg/100 g of wet weight of plants; 39.0 and 37.1, respectively. A similar trend is observed at further stages of plant development.
Table 2. The content of photosynthetic pigments in the leaves after foliage spraying with copper-zinc chelated fertilizer, mg/100 g of wet weight of plants.

| Experimental option | tillering | casting out | milky-wax ripeness |
|----------------------|-----------|-------------|--------------------|
|                       | Ch. a     | Ch. b       | Ch. a       | Ch. b       | Ch. a     | Ch. b       | Car.     |
| Control (water)       | 115.2     | 49.5        | 68.3        | 105.4       | 44.6      | 63.3        | 97.4  |
| FS 0.5 l/ha           | 140.7     | 65.7        | 71.7        | 118.3       | 43.6      | 67.7        | 110.7 |
| FS 1.0 l/ha           | 147.7     | 66.0        | 72.7        | 125.3       | 46.0      | 68.3        | 120.5 |
| FS 1.5 l/ha           | 149.4     | 67.2        | 73.8        | 129.7       | 49.5      | 70.7        | 122.4 |
| FS 2.0 l/ha           | 154.2     | 68.8        | 77.2        | 132.2       | 51.8      | 73.7        | 127.0 |
| FS 2.5 l/ha           | 152.3     | 68.0        | 76.7        | 123.7       | 45.8      | 69.3        | 116.7 |
| FS 3.0 l/ha           | 150.2     | 67.6        | 75.4        | 127.3       | 47.3      | 70.5        | 120.0 |

FS – foliage spraying  
Ch. a – chlorophyll of group a  
Ch. b - chlorophyll of group b  
Car. - carotinoids

So, in the tillering phase, the total content of chlorophyll (a+b) exceeded the control option on average in the experiment by 41.7-58.3 mg/100 g of wet weight, which amounted to 25.3-35.4%. In the phase of casting out and milky-wax ripeness, their amount exceeded the control by 11.9-34.0 and 12.7-39.4 mg/100 g of wet weight, respectively.

Experimental data indicate that no significant quantitative changes in the dynamics of the content of carotenoids in rice leaves were revealed throughout the growing season.

4. Conclusion
In the process of research, it was found that foliage spraying of rice with copper-zinc chelated fertilizer has a positive effect on the photosynthetic activity of plants in the entire range of the studied concentrations. However, the studies carried out made it possible to identify the most effective concentrations of the considered microfertilizer. Thus, foliage spraying of plants at doses of 1.5 l/ha; 2.0 and 2.5 l/ha contributed to an increase in chlorophyll content, and on the 10th day after treatment of plants in the tillering phase by 34.2 mg/100 g of wet weight of plants; 39.0 and 37.1, respectively. Thus, foliage spraying of rice can be used as an effective agricultural technique against the background of a deficiency of mobile forms of copper and zinc in the soil.

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