The effect of innovative copper-zinc chelate fertilizer on rice-plant growth and development in vegetation experience

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Abstract. The work studied the effect of various concentrations of an innovative zinc-copper chelate compound on rice plants as a microfertilizer, which was invented at the Kuban State Agrarian University named after I.T. Trubilin. The effect of foliar feeding of plants and presowing treatment of seeds with the studied microfertilizer on the growth and development of rice plants in laboratory and vegetation experiments was studied. The toxic effect of copper-zinc chelated fertilizer was revealed at its concentration above 0.05%. It was found that when processing rice seeds with 0.001%, 0.005% and 0.01% solutions of microelements, their germination energy increased by 6.8%, 8.2% and 6.8%, respectively, laboratory germination under these conditions reached 97.0%, 96.0% and 98.8%, respectively, which exceeded the control option by 3.2%, 2.1% and 5.1%.

1. Introduction
Kuban is traditionally the largest rice producer in the Russian Federation, where more than 80% of the sown area of this crop is concentrated. According to the Ministry of Agriculture and Processing Industry of the Krasnodar Territory, a record harvest of rice was harvested in the Kuban in 2016. The gross grain harvest amounted to over 1,026.5 thousand tons with an average yield of more than 75.3 centners/ha. The soils of the rice fields in the delta zone of the Kuban River have an acute shortage of mobile forms of zinc and copper, which, in turn, leads to a loss of rice yield and a decrease in grain quality. Therefore, it is necessary to look for innovative methods for realizing the potential productivity of rice bioagroecoses. One of them can be the use of innovative forms of micronutrient fertilizers [3-5]. Within the framework of laboratory and vegetation experiments, the effect of the proposed and innovative chelate complexes of copper and zinc on rice plants was studied.

2. Materials and methods
The research was based on laboratory and vegetation experiments. The germination energy, laboratory germination of seeds and the strength of initial growth were determined according to GOST 10968-88 and GOST 12038-84, linear parameters of plants - by measurements [8]. In the laboratory experiment, the following options were studied: control (water), copper-zinc chelated fertilizer (MU) (%) - 0.001; 0.005; 0.01; 0.05; 0.1; 0.5. The data were evaluated by the method of analysis of variance [2]. The
laboratory experiment used distilled water, rice seeds (variety Khazar) Petri dishes, filter paper; the seeds were disinfected with an antibiotic and antymycotic.

Prepared rice seeds were treated with streptocide and nystatin solutions. In Petri dishes, on filter paper, 100 rice seeds were counted to determine their sowing qualities.

To study the effect of microelements on the sowing qualities of seeds, 6 different concentrations of copper and zinc chelate were prepared, 7 control variant, where only distilled water was used. The exact concentrations of the chelating salts were calculated and a stock solution was prepared with the exact concentration of copper and zinc. In each Petri dish, 20 ml of the corresponding solution of micronutrient fertilizer in relation to water was poured; in the control variant, only distilled water was used. Then the cups were placed in a thermostat, the temperature in which was maintained at 28 degrees. Every day, 20 ml of distilled water was added to each dish. On day 4, the germination energy was measured. On the 10th day the number of germinated rice seeds was counted and the laboratory seed germination was determined.

Whilst laboratory studies, it was found that the most favorable concentration of micronutrient fertilizers was 0.01%. This made it possible in the future to lay the growing experience in which both the effect of foliar dressing and pre-sowing seed treatment were studied. Rice seeds were sown in pots. There were 6 variants with a solution of micronutrient fertilizers of different concentrations, and a variant with distilled water.

Plastic jars with a capacity of 8-10 liters of air-dry soil were used; a batch of identical jars was selected, a stock solution of zinc-copper micronutrient fertilizer for foliar feeding of rice plants in the tillering phase was prepared, from which working solutions were then prepared.

When packing the jars, the uniformity of soil compaction in the jar was achieved. The first stage of the packing work was to determine the amount of soil in the jar, for which a trial packing was done. A sample of soil was placed in an enamel basin, the necessary fertilizers were applied (background nutrition), mixed and poured into previously prepared jars with periodic uniform compaction by hands.

The jars were filled in such a way that a free space was left from the soil level to the edges of the jar to create a 10 cm layer of water on the soil surface.

Before sowing, the rice seeds were germinated. About twice the required number of plants was sown. Before sowing, water was stirred up on the surface of the jar, and rice seeds of the same size, selected with tweezers, were sown into each jar. The stirring of water in the jar was carried out to cover the seeds with settling silty soil particles. In the early days after rice seedling emergence, when the plants were sufficiently strong, the spare samples were removed and 10 plants were left in each jar.

The studied microfertilizer in the vegetation experiment was used as foliar feeding and pre-sowing treatment of seeds based on recalculating the concentration of the active substance, which was 4 ml/l for foliar treatment. For foliar feeding of plants, distilled water was used as a solvent; the treatment was carried out in the tillering phase. Observations were carried out by phases of vegetation.

3. Results and discussion
Analysis of the data obtained shows that the solution of trace elements has a positive effect on the seed germination energy and laboratory germination (table 1). The most effective concentrations were found to be from 0.001% to 0.01%. Under the action of higher concentrations (more than 0.05%), inhibition of seeds was noted, which was most likely due to the acidic reaction of the micronutrient fertilizer solution caused by the hydrolysis of chelating zinc and copper salts.
Table 1. Influence of pre-sowing treatment of rice seeds with copper-zinc chelate fertilizer on the sowing qualities of rice.

| Variant     | Seed germination energy, % | Laboratory germination, % |
|-------------|---------------------------|---------------------------|
|             | average ± to control      | average ± to control      |
| Control     | 73.0 - 94.0               | 94.0 -                     |
| MU 0.001 %  | 78.0 5.0                  | 97.0 3.0                  |
| MU 0.005 %  | 79.0 6.0                  | 96.0 2.0                  |
| MU 0.01 %   | 78.0 5.0                  | 98.8 4.8                  |
| MU 0.05 %   | 76.0 3.0                  | 95.0 1.0                  |
| MU 0.1 %    | 64.0 - 9.0                | 81.6 - 12.4               |
| MU 0.5 %    | 59.0 - 14.0               | 75.0 - 19.0               |
| НСР 05      | 3.6 -                     | 2.0 -                     |

MU – solution of zinc and copper chelates of appropriate concentration.
НСР 05 – smallest significant difference at 95% confidence level.

When treating rice seeds with a solution of micronutrient fertilizer, the germination energy and laboratory germination of seeds increased, respectively, by 4.1 - 8.2% and 1.2 - 5.1% as a whole in comparison with the control variant. The seed germination energy reaches the highest values when they are enriched with a solution of copper-zinc chelate fertilizer with a concentration of 0.005%. When processing rice seeds with 0.001%, 0.005% and 0.01% solutions of microelements their germination energy increases by 6.8%, 8.2% and 6.8%, respectively. Laboratory germination under these conditions reached 97.0%, 96.0% and 98.8%, respectively, which exceeds the control variant by 3.2%, 2.1% and 5.1%.

The positive effect of the established optimal concentrations - 0.001%; 0.01 and 0.05%, was also observed when measuring the height of rice sprouts, length and number of roots (table 2).

The established dependence can also be seen in table 2.

Table 2. The strength of the initial growth of rice seeds when treated with copper-zinc chelated fertilizer (on the 10th day).

| Variant     | Sprout height, cm | Root length, cm | Number of roots, pcs. |
|-------------|-------------------|-----------------|-----------------------|
| Control     | 3.8               | 6.2             | 3.5                   |
| MU 0.001 %  | 4.5               | 5.9             | 3.7                   |
| MU 0.005 %  | 4.8               | 6.1             | 3.7                   |
| MU 0.01 %   | 5.1               | 6.6             | 3.9                   |
| MU 0.05 %   | 4.9               | 6.2             | 3.6                   |
| MU 0.1 %    | 2.6               | 2.8             | 1.8                   |
| MU 0.5 %    | 1.1               | 1.5             | 1.7                   |
| НСР 05      | 0.3               | 0.6             | 0.5                   |

MU – solution of zinc and copper chelates of appropriate concentration.
НСР 05 – smallest significant difference at 95% confidence level.

On the tenth day of germination, the highest sprout height (5.1 cm) and root length (6.6 cm) were in seedlings from seeds treated with a 0.01% solution of microelements. In general, in the variants
with the use of copper-zinc chelate fertilizer, it increased by 0.7-1.3 cm, which is 18.4 - 34.2% in relation to the control variant. The use of a solution of trace elements in concentrations of 0.1% and 0.5% leads to inhibition of plant growth in the early stages of ontogenesis.

The positive effect of the established concentrations was also observed on the height of rice sprouts, length and number of roots. The concentration of the solution was most efficiently 0.01% at which the height of the sprout was 5.1 cm, root length - 6.6 cm with an average number of roots 3.9 pcs. by experience options. Treatment of seeds with a 0.01% solution of microelements stimulated an increase in root length by 0.4 cm (6.5%) compared to the control. On average, the number of roots according to variants increased by 2.9 - 11.4% in comparison with the control.

Attention should be paid to the inhibitory effect of micronutrient concentrations of 0.1 and 0.5%. Under the action of such high doses, extremely low sprout heights of 2.6 and 1.1 cm, respectively, were noted, the root length was 2.8 and 1.5 cm, respectively, and the number of roots was 1.8 and 1.7 pcs., respectively.

On the basis of the laboratory experiments, the effective concentrations of the tested zinc-copper micronutrient fertilizer for pre-sowing treatment was determined, which required the establishment of vegetation experiments. When setting up the experiment, a research scheme was included with a control option, a background option, foliar treatment with an aqueous solution and the microfertilizer tested. Table 3 shows the obtained measurement results. The results obtained for plant height in the tillering, ear emergence, full ripeness phases show the effectiveness of foliar treatment of plants at the rate of 1 l/ha in the tillering phase and foliar treatment together with pre-sowing seed treatment at a dose of 0.001%. Thus, these agrochemical methods contributed to an increase in the height of plants in the ear emergence phase by 7.3 and 8.4 cm, respectively.

**Table 3.** Height of rice plants during pre-sowing treatment and foliar feeding of plants with micronutrient fertilization (vegetation experiment, 2020).

| Variant                  | Plant height, cm | ear emergence | full ripeness |
|--------------------------|------------------|---------------|---------------|
| Control (water)          | 46.5             | 89.1          | 90.5          |
| Control + PSST 0.001%    | 47.4             | 96.6          | 97.2          |
| Control + PSST 0.005%    | 48.4             | 94.5          | 95.4          |
| Control + PSST 0.01%     | 44.6             | 92.4          | 93.5          |
| Control + FS 1 l/ha      | 47.2             | 96.4          | 97.0          |
| FS 1 l/ha + PSST 0.001%  | 48.2             | 97.5          | 97.9          |
| FS 1 l/ha + PSST 0.005%  | 45.3             | 93.8          | 94.1          |
| FS 1 l/ha + PSST 0.01%   | 46.8             | 94.2          | 94.9          |
| HCP<sub>0.05</sub>       | 3.2              | 4.1           | 4.8           |

PSST – pre-sowing seed treatment.
FS – foliar spraying.
HCP<sub>0.05</sub> – smallest significant difference at 95% confidence level.

Of great interest are the results of studies on determining the dry mass of plants under the conditions of a vegetation experiment and grain harvesting (table 4).
Table 4. The dynamics of the dry matter production in the aboveground plant plants (vegetation experience, 2020).

| Variant                  | Dry weight, g/plant |                      |                      | grain harvest g/jar |
|--------------------------|---------------------|----------------------|----------------------|---------------------|
|                          | tillering           | ear emergence        | full ripeness        |                     |
| Control (water)          | 1.09                | 4.40                 | 9.9                  | 35.9                |
| Control + PSST 0.001%    | 1.15                | 4.52                 | 10.5                 | 38.8                |
| Control + PSST 0.005%    | 1.30                | 4.67                 | 11.2                 | 42.6                |
| Control + PSST 0.01%     | 1.14                | 4.61                 | 12.15                | 41.4                |
| Control + FS 1 l/ha      | 1.24                | 5.19                 | 14.00                | 46.8                |
| FS 1 l/ha + PSST 0.005%  | 1.26                | 4.80                 | 12.10                | 42.0                |
| FS 1 l/ha + PSST 0.005%  | 1.29                | 4.85                 | 11.90                | 41.5                |
| FS 1 l/ha + PSST 0.01%   | 1.26                | 4.84                 | 12.34                | 43.5                |
| HCP                      | 0.07                | 0.36                 | 0.59                 | 2.50                |

PSST – pre-sowing seed treatment
FS – foliar spraying

The most intensive accumulation of plant biomass was provided by options with pre-sowing treatment of seeds with a micronutrient fertilizer concentration of 0.01%, foliar treatment of plants at the rate of 1 l/ha, as well as together with pre-sowing treatment at concentrations of 0.001%; 0.005 and 0.01% against the background of foliar feeding of plants. Accounting for the mass of grain in vessels showed the most effective method - foliar processing of plants. Under these conditions, it was possible to obtain an average of 46.8 g of grain from a jar, which exceeded the control variant by 10.9 g.

Thus, the developed innovative zinc-copper chelated micronutrient fertilizer against the background of artificial deficiency of the same microelements is able to positively influence the main indicators of growth and development of rice plants. The most effective is the use of microfertilizers in the form of foliar treatment of plants in the tillering phase.

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