Garden strawberry: the effect of micronutrients foliage spraying on winter hardiness in the Krasnoyarsk forest-steppe

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Abstract. The work highlights the results of studies on the application of foliar treatments with micronutrient solutions N-1.6% + 8 minor-nutrient elements (Fe-0.4%, Cu-0.12%, B-0.028%, Mn-0.36%, Zn-0.09%, Mg-0.05%, Mo-0.08%, Co-0.016%); Cu 1% + 7 trace elements (Mn-0.018%, Fe-0.02%, Mo-0.004%, Co-0.00018%, B-0.0014%, Zn-0.0045%, Mg-0.0025%); Fe 2% + 7 minor-nutrient elements (Mn-0.018%, Cu-0.006%, Co-0.0008%, B-0.0014%, Mo-0.004%, Zn-0.0045%, Mg-0.0025%) in plantings of strawberry varieties Elista, Pervoklassnitsa, Zephyr, Solnechnaya Polyanka. Agrochemical parameters of the soil before planting bushes of garden strawberries showed its high fertility by a set of indicators. At the same time, there was a deficiency of minor-nutrient elements: low content - Cd, Cu, Zn, Co, Cr. The availability of manganese and lead is average. The foliage spraying of plants with micronutrient solutions did not provide a statistically significant confirmation of the effect on the winter hardiness of plants; these indicators depend solely on the varietal characteristics of the sample.

1. Introduction
In modern conditions the production of fruit and berry crops is an important and a key indicator in achieving targets of food security in the regions [1]. In the Russian Federation recommended medicine level of rational consumption of fruit and berry products is 90-100 kg per person per year [2]. The actual consumption figure is only half this level. In the Siberian Federal District, only 15.6% of the recommended level of fruit and berries consumption per year is provided by its own production [3].

Strawberry is immensely popular among the population of Krasnoyarsk region, it is valued for rapid entry into fruiting, high yield, unique taste of the fruit that are the richest source of the antioxidant complex, mainly vitamins C and P [4].

Mineral nutrition refers to factors through which the development of plants can be directionally influenced. Even on powerful black soils characterized by high fertility, fertilizers with normal water supply give a large production effect [5]. The problem of stabilizing the productivity of berry plantations, managing their stability and quality of the berries is relevant and requires the development of new biological and agricultural techniques. An important physiological role in solving this problem belongs to major- and minor nutrient elements [6].

One of the ways to satisfy plants in the elements of mineral nutrition is exogenous feeding [7]. Foliar nutrition occurs by the absorption by leaves and other organs of nutrients in a different form, while nutrients are immediately included in the plant’s metabolism [8]. T G Prichko, L A Khilko, M G Germanova [9] note that foliage spraying increases growth activity, normalizes metabolic processes and, as a result, has a positive effect on the development and growth of plants, and also allows short terms to carry out high-quality additional nutrition through the leaves. At the same time, all the nutrients are
fully assimilated within a few hours and bring the most positive effect to the most important stages of plant development.

The purpose of the research is to study the effect of foliage spraying on the winter hardiness of garden strawberries in the conditions of the Krasnoyarsk forest-steppe.

2. Materials and methods

The experiment was conducted in 2018-2019. The experimental sites are located in the Emelyanovo district in the forest-steppe zone of the Krasnoyarsk Territory. Objects of research: 4 varieties of garden strawberry - Elista, Pervoklassnitsa, Zephyr, Solnechnaya polyanka. Landing pattern 70 × 30 cm. Landing date - June 15, 2018. The area of the experimental plot is 44.1 m². The experimental options included exogenous treatment (spraying) with water solutions of nutrient elements in chelate form (manufacturer LLC RIC BashInkom, Ufa): 1) control (spraying with water); 2) N-1.6% + 8 minor nutrient element (Fe-0.4%, Cu-0.12%, B-0.028%, Mn-0.36%, Zn-0.09%, Mg-0.05%, Mo-0.08%, Co-0.016%); 3) Cu 1% + 7 minor nutrient element (Mn-0.018%, Fe-0.02%, Mo-0.004%, Co-0.00018%, B-0.0014%, Zn-0.0045%, Mg-0.0025%); 4) Fe 2% + 7 minor nutrient elements (Mn-0.018%, Cu-0.006%, Co-0.0008%, B-0.0014%, Mo-0.004%, Zn-0.0045%, Mg-0.0025%). Spraying was carried out with a frequency of one time in two weeks in the early morning hours. During the growing season of 2018, seven treatments were carried out, and eleven treatments were carried out in 2019. The observed element is winter hardness. The degree of freezing was taken into account in the 2nd year of research after the end of the winter period (2019) in accordance with the Program and methodology of variety studies of fruit, berry, and nut-bearing crops [10]. Laboratory analysis of soil samples was carried out according to GOSTs (State Standards) at the Research and Testing Center of Krasnoyarsk State Agrarian University. The following types of analyses were performed in soil samples: determination of the pH of an aqueous suspension according to GOST 26423-85; determination of nitrate nitrogen according to the Central Research Institute of Agrochemical Services for Agriculture (CRIASA) method according to GOST 26488-85; determination of exchange ammonium according to the CRIASA method according to GOST 26489-85; determination of labile phosphorus and exchangeable potassium according to the Chirikov method in the modification of CRIASA according to GOST 26204-91. The soil of the experiment is black soil, characterized by a high humus content of 8.3% and a neutral soil reaction (pH of water 7.5). The content of macro- and micronutrients in the soil was determined by the generally accepted method [11]. Mathematical processing of the research results was performed by analysis of variance [12] using the MSEexcel computer program.

3. Results and discussion

The agrochemical background of the soil during the planting of strawberry bushes in open ground indicates its high fertility by a set of indicators and meets the requirements for cultivating this crop. At the same time, there is a deficiency of minor nutrient elements in the soil in the experimental plot: low content - Cd (0.2 mg / kg), Cu (0.5 mg / kg), Zn (1.3 mg / kg), Co (0.6 mg / kg), Cr (0.3 mg / kg). The availability of manganese (65.4 mg / kg) and lead (2.0 mg / kg) is average (table 1).

| Index                        | The content in the samples, mg / kg | Degree of security |
|------------------------------|------------------------------------|--------------------|
| Nitrate-nitrogen             | 20.2                               | Very high          |
| Ammonium nitrate             | 20.1                               | Very high          |
| Potassium according to Chirikov | 399.5                            | Very high          |
| Phosphorus according to Chirikov | 526.4                           | Very high          |
| Lead                         | 2.0                                | Average            |
| Cadmium                      | 0.2                                | Low                |
| Copper                       | 0.5                                | Low                |
| Zinc                         | 1.3                                | Low                |
| Nickel                       | 0.4                                | Low                |
| Cobalt                       | 0.6                                | Low                |
| Chromium                     | 0.3                                | Low                |
| Manganese                    | 65.4                               | Average            |
Strawberries absorb nutrients throughout the growing season and have two critical periods in nutrition: the first period occurs in spring, after waking up, the second in summer and autumn, when the root system grows, flower buds and horns are laid. Strawberries consume the maximum amount of nutrients at the stage of flowering and fruiting. Not only good leaf development for the next year, but also flowering and fruiting of plants depends on the level of supply of plants with minerals (nitrogen and phosphorus in particular) [13; 14; 15; 16].

Winter hardiness of strawberry plants is one of the key parameters for growing this crop since it is the least winter hardy in comparison with other berry plants and can freeze at –15 ... –18 °С with insufficiently high snow cover. Climatic conditions during the dormant period of plants 2018-2019 in comparison with long-term average indicators, were characterized by lower temperatures and insufficient snow cover (table 2).

| Months       | Meteorological parameters | Average for 2018-2019 | Long-run annual indicators | Deviation from long-run annual indicators, ± |
|--------------|---------------------------|------------------------|-----------------------------|-------------------------------------------|
| October      | t° C                      | 4.7                    | 1.9                         | +2.8                                     |
|              | precipitation (mm)        | 11                     | 19.8                        | -8.8                                     |
|              | snow depth (cm)           | 0.5                    | 3.2                         | -2.7                                     |
| November     | t° C                      | -8.9                   | -7.8                        | +1.1                                     |
|              | precipitation (mm)        | 34                     | 25.8                        | +8.2                                     |
|              | snow depth (cm)           | 7.4                    | 10.1                        | -2.7                                     |
| December     | t° C                      | -20.3                  | -14.1                       | +6.2                                     |
|              | precipitation (mm)        | 12                     | 15.5                        | -3.5                                     |
|              | snow depth (cm)           | 10.6                   | 18.7                        | -8.1                                     |
| January      | t° C                      | -21.1                  | -18.3                       | +2.8                                     |
|              | precipitation (mm)        | 8.6                    | 7.3                         | +1.3                                     |
|              | snow depth (cm)           | 14.9                   | 23.1                        | -8.2                                     |
| February     | t° C                      | -15.3                  | -15.5                       | -0.2                                     |
|              | precipitation (mm)        | 3.8                    | 8.4                         | -4.6                                     |
|              | snow depth (cm)           | 19.3                   | 25.6                        | -6.3                                     |
| March        | t° C                      | -6.6                   | -5.2                        | +1.4                                     |
|              | precipitation (mm)        | 5.4                    | 11.7                        | -6.3                                     |
|              | snow depth (cm)           | 14.4                   | 21.5                        | -7.1                                     |

Winter hardiness depends not only on varietal characteristics, but also on a set of factors such as vegetation and hardening conditions in the autumn season, crop load in the previous season, plant age, level of agricultural technology, height, period of establishment and disappearance of snow cover, duration and intensity of frost [17].

The degree of freezing was determined in May on the whole plot and expressed in points. A weak freezing of plants (up to 10%) was observed in the cultivar Solnechnaya polyanika in all experimental variants (table 3). On the Fe 2% + 7 minor nutrient elements variant (IV variant), all studied varieties showed a weak degree of freezing, but the obtained results were not statistically confirmed (P> 0.05).

| Variety                 | The degree of freezing, points |
|-------------------------|--------------------------------|
|                         | I option | II option | III option | IV option |
| Elista                  | 2        | 2         | 2          | 1         |
| Pervoklassnitsa         | 2        | 1         | 2          | 1         |
| Zephyr                  | 2        | 1         | 2          | 1         |
| Solnechnaya polyanika   | 1        | 1         | 1          | 1         |
However, when counting dead and damaged plants, it was found that only plants of the First Grader variety showed the largest number of intact plants, therefore, this variety has the highest winter hardiness (figure 1).

![Graph showing strawberry plants freezing, %, 2019](image)

4. Conclusion

Thus, the non-root treatment of garden strawberries under conditions of high soil fertility and a deficiency of certain trace elements (Cd, Cu, Zn, Co, Cr) did not provide a statistically significant confirmation of the effect on the winter hardiness of plants. Winter hardiness depends, first of all, on the varietal characteristics of the culture, which is confirmed statistically (p < 0.01; the power of the influence of the variety SS = 30.1%).

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