

Sulfur Role and Trace Elements in a Chelated form in the Potato Cultivation

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Abstract— The use of foliar application with trace elements in the form of chelated fertilizer may positively affect the plants and give a significant increase in crop productivity. The goal of research was to evaluate the impact of innovative drugs: sulfur-containing and trace elements containing in chelated form: Fe, Zn, Mn, Cu, Mo, Co, B, on the yield and quality of potato tubers of the middle-ripening Kolobok variety. Researches were carried out in moisture-supplied 2016-2017 years on soddy podzolic loamy soil. In the experiment, the treatment of planting tubers and two nonroot treatments for seedlings and in the budding phase - the beginning of flowering were performed. To evaluate the drugs effects in addition to pure control, there was also an option with water treatment. The experiment was carried out according to the requirements of the field experience methodology and research Methodology concerning potato culture. The use of the tested drugs increased the value of commercial yield by 3.5...3.7 t / ha (13.5...14.2%). In a rainy 2016 the mass of commercial tubers averaged 97%, in 2017 – 98%. The lowest nitrate content was found in the variants with the use of sulfur-containing drug - 201 mg / kg and the drug with trace elements - 230 mg/kg at 245 mg/kg in the control variants. On average, during the two storage periods, the lowest total losses were in potato cultivation variants with the use of sulfur-containing drug, the total losses amounted to 4.76% with 5.20-5.38% in control variants. The data obtained substantiate the feasibility of using trace elements in chelated form in potato growing.

Keywords—*trace elements in a chelated form, biometry, crop productivity, potato tuber storability.*

I. INTRODUCTION

Potatoes are an important food of the population. More than 50% from the total consumption production is directed to the concoction of diversified dishes from potatoes, primarily at home, as well as in the catering industry. The potential yield of potato varieties in Russia is not realized even in ½. That is why, in order to increase the yield and quality of potato tubers, it is important to continue the search for the new elements of cultivation technology [1]. It is necessary to consider options for foliar treatments [2]. The use of foliar application with trace elements in the form of chelated fertilizer can give a significant increase in a crop productivity, tubers saturation with the studied macro-and trace elements [3-6].

It is a matter of common knowledge, that sulfur on its physiological significance in a metabolism of plants among elements of food takes the important place after nitrogen, phosphorus and potassium; the sulfur content in plants makes 0,005-1,0% of dry weight [7,8]. The growth and morphogenesis of potato organs depend on the reserve of plants with manganese [9], while high concentrations of manganese in the nutrient medium reduce the absorption of other trace elements [10]. The activity and nature of nutrients metabolism consumed by the plant is significantly affected by iron, which accelerates the metabolism in the plant body [11, 12]. Zinc has a positive effect on the formation of growth regulating substance (auxins) and chlorophyll [12,13]. In order to increase the nitrogen, potassium, manganese and molybdenum supply to the potato plants, zinc is introduced into the nutrient solution, which accelerates the development of potatoes, shortening the growing season, and increases resistance to buck eye rot [13]. The use of copper can increase the resistance of plants to lodging and adverse environmental conditions [12]. In order to increase the plants resistance buck eye rot, reduce the affection of damping-out, scab and the rust spot, copper is added to the nutrient solution, which also accelerates tuber formation [13]. The main signs of boron deficiency are anthoptosis of flowers and sets, low seeds and fruits yield with normal development of vegetative mass [10, 12]. With the optimal development of potato plants in tubers, the ratio of calcium to boron (Ca: B) ranges from 15 to 100, if the ratio of Ca: B is higher than 100 – there is a boron deficiency [14]. Molybdenum enters plants in the form of the molybdate acid ion or chelate compounds. With increasing pH, molybdenum becomes easily mobile. [9]. The cobalt content in plants depends on the species and averages 0.2 mg / kg (0.01...0.85 mg/kg) of the dry basis. [12]. Cobalt deficiency in plant tissues is 0.02 mg / kg of a dry matter; optimum-0.03-1.00; excess-1.01-50.00 mg / kg of a dry matter [10].

In order to increase the crop productivity and the quality of potato tubers, research for the development of potato cultivation technology with elements of the use of trace elements in chelated form is relevant.

The goal of the research – is to evaluate the influence of innovative drugs: sulfur-containing and containing trace elements in chelated form: Fe, Zn, Mn, Cu, Mo, Co, B, on the parameters of crop productivity and quality of potato tubers of medium-ripening Kolobok variety.

II. RESEARCH METHODS

The experiment was performed according to the requirements of the field technique [15] and the potato culture research Methodology [16].

In the period of 2016-2017 years the research was carried out on soddy podzolic medium-cultured soil, according to the grain-size distribution of sandy loam soil of the experimental base Korenevo (Nizhny Novgorod) of the Moscow region. The objectives of the research were to establish the dependence of changes in crop productivity and tubers maturation on the use of innovative drugs: containing sulfur (S); containing trace elements in chelated form: iron (Fe), zinc (Zn), manganese (Mn), copper (Cu), molybdenum (Mo), cobalt (Co), boron (B) [17].

The soil at the plough-layer depth is characterized by agrochemical indicators A_{plough} : total exchangeable bases – 1,5...2,4 mg-EQ/100 g; the content of humus by the Tyurin’s method (GOST 26213-91) – 1,99%; labile phosphorus according to Kirsanov (GOST 26207-91) – 380-653 mg/kg; exchangeable potassium according to Kirsanov (GOST 26207-91) – 134-193 mg/kg; pH_{KCl} , according to Alyamovsky (GOST 26483-85) – 5,04; combined acidity (GOST 26412-91) – 3,46 mg-EQ.

The search experience was laid according to the scheme by the method of systematic placement of plots in four-fold repetition with a density of planting 44.4 thousand bushes / ha. The planting width was 75 cm. The previous green manure was leguminous. The registration plot area was 5,6 m².

In the autumn, the under-winter ploughing (depth-18 ... 22 cm) by the one-way plough unit was performed. In the spring, for pre – planting soil preparation, loosening (depth-12...15 cm) was performed by a machine-tractor aggregate with a heavy disk harrow. At cutting of ridges before planting and at care of plantings fractional-locally mineral fertilizer is brought (16%:16%:16%) in a dose of N40P40K40 (before planting) and N100P100K100 (when caring for planting) by a machine-tractor aggregate with an inter-row cultivator (background).

Before planting, the tubers were treated according to the options: water (second control), sulfur-containing drugs, a drug containing trace elements in a chelated form in order to stimulate and improve the growth of bourgeons germination at the rate of 10 l / t tubers. Concentration was 3.0 ml of the drug per 1.0 liter of water.

The experimental variants planting with elite material of non-chitted seed tubers of a middle fraction (tubers size on the greatest cross – section – 30...53 mm) of a medium-ripe potato of Kolobok variety was carried out in the cut ridges by the unit with a potato-planter with manual feeding of seed tubers, with tubers in 2016-on June 09, in 2017-on May 15.

According to the scheme complied with the two-time spraying in the full seedlings stage and in the budding phase – beginning of flowering on the second control - water and water-soluble options experienced subjects are the sulfa drugs containing microelements in chelate form. Consumption of the working solution was 300 l / ha (concentration-1.5 ml of the drug / 1.0 l of water).

In the full seedlings stage herbicides to control weeds: systemic pesticide (selective herbicide, primary plant nutrient: Rimsulfuron, primary plant nutrient content –250 g/kg) and systemic pesticide selective herbicide, primary plant nutrient – Metribuzine, primary plant nutrient content –700 g/kg) were used. One-time insecticide spraying (primary plant nutrient – Imidacloprid, primary plant nutrient content–700 g/kg) was performed against pests (Colorado potato beetle). Two chemical treatments with a fungicide – contact pesticide (primary plant nutrients: Famoxadone (250 g/l) and Cymoxanil (250 g/l) were performed against major diseases (buck eye rot and Alternaria leaf mold). The first one was carried out in blossom time, the next one – in two weeks. All drugs are made in the recommended dose by the manufacturer. Consumption of the working solution was 300 l / ha. The harvesting of potato tubers was carried out in the second half of August.

Meteorological conditions in the years of research were wet: hydrothermal index of the year 2016 was 2.16 (very wet), 2017-2.06 (wet) with a climatic norm of 1.3...1.4. The average air temperature for the growing season of 2016 was 18.6 °C, for the period of 2017-16.2 °C, with a norm of 16.5 °C. In 2016 total precipitation for the growing season fell 470.2 mm or 180.5% of the norm (260.5 mm); for the period of 2017-378.4 mm or 145.3% of the normal range. Hydrothermal Index [18].

III. RESEARCH RESULTS

The biometric indicators data of the development of the aerial part of plants (tops) having significant impact on the crop formation is given in table 1.

TABLE I. BIOMETRIC INDICATORS OF POTATO PLANTS (FLOWERING PHASE) DEPENDING ON THE DRUGS USED

| № of the variant | Name of the variant | Development parameters of the aerial potatoe plants parts | | | |
|-------------------|--|---|-----------------|--------------------------|--|
| | | Stems, PCs / bush | Bush height, cm | Weight of tops, g / bush | Assimilation surface of leaves, m ² /bush |
| 2016 y | | | | | |
| 1 | Control | 3.4 | 64.8 | 612 | 1.43 |
| 2 | Water | 4.0 | 63.8 | 682 | 1.88 |
| 3 | Drug with S in a chelated form | 4.8 | 58.5 | 656 | 1.69 |
| 4 | Drug with Fe, Zn, Mn, Cu, Mo, Co, B in a chelated form | 6.4 | 55.3 | 552 | 1.33 |
| Average rate | | 4.7 | 60.6 | 626 | 1.8 |
| HCP ₀₅ | | 1.13 | 3.89 | 49.26 | 0.22 |
| 2017 y | | | | | |
| 1 | Control | 3.3 | 42.3 | 214 | 0.35 |
| 2 | Water | 3.6 | 41.5 | 236 | 0.35 |
| 3 | Drug with S in a chelated form | 3.9 | 43.3 | 244 | 0.41 |
| 4 | Drug with Fe, Zn, Mn, Cu, Mo, Co, B in a chelated form | 3.0 | 43.3 | 201 | 0.44 |
| Average rate | | 3.5 | 42.6 | 224 | 0.39 |
| HCP ₀₅ | | 0.34 | 0.75 | 17.12 | 0.04 |

| Average rate for 2016-2017 years | | | | | |
|----------------------------------|--|-----|------|-------|------|
| 1 | Control | 3.4 | 53.6 | 413.0 | 0.89 |
| 2 | Water | 3.8 | 52.7 | 459.0 | 1.12 |
| 3 | Drug with S in a chelated form | 4.4 | 50.9 | 450.0 | 1.05 |
| 4 | Drug with Fe, Zn, Mn, Cu, Mo, Co, B in a chelated form | 4.7 | 49.3 | 376.5 | 0.89 |
| Average rate | | 4.1 | 51.6 | 425 | 0.99 |

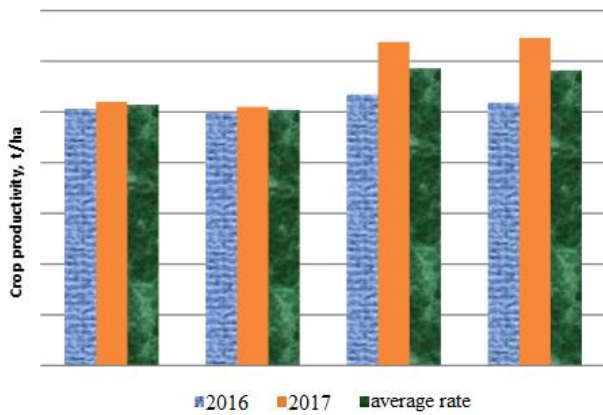


Fig. 1. Crop yield of commodity fraction of Kolobok variety potatoes, t / ha

According to our experiments, tubers of the middle-ripening Kolobok variety contained 247 mg/kg of nitrates on average in 2016. In 2017, tubers contained an average of 206 mg / kg of nitrates. The data obtained in the experiments show that the tubers of the Kolobok variety in 2016, the starch content on average fluctuated between 11.9...12.9%. In terms of 2017 it was 12.9...13.2%.

The use effect of the studied drugs on the potatoes preservation was studied during the two autumn-winter periods 2016-2017 and 2017-2018 (table 2).

TABLE II. POTATO TUBERS STORABILITY DEPENDING ON THE USE OF DRUGS, %

| No. | Drug | The average for the 2016-2017 winter period | | | | The average for the 2017-2018 winter period | | | | Average over two storage periods | | | |
|-------------------|--|---|-----------|------|------|---|-----------|------|------|----------------------------------|-----------|------|------|
| | | Gross loss | Including | | | Gross loss | Including | | | Gross loss | Including | | |
| | | | NL | LS | SL | | NL | LS | SL | | NL | LS | SL |
| 1 | Control | 4.90 | 4.51 | 0.24 | 0.16 | 5.49 | 4.67 | 0.15 | 0.67 | 5.20 | 4.59 | 0.20 | 0.42 |
| 2 | Water | 4.66 | 4.16 | 0.30 | 0.20 | 6.10 | 5.14 | 0.29 | 0.67 | 5.38 | 4.65 | 0.30 | 0.44 |
| 3 | Drug with S in a chelated form | 4.31 | 3.98 | 0.16 | 0.18 | 5.20 | 4.39 | 0.19 | 0.62 | 4.76 | 4.19 | 0.18 | 0.40 |
| 4 | Drug with Fe, Zn, Mn, Cu, Mo, Co, B in a chelated form | 4.42 | 3.74 | 0.14 | 0.53 | 5.37 | 4.40 | 0.21 | 0.76 | 4.90 | 4.07 | 0.18 | 0.65 |
| Average range | | 4.6 | 4.1 | 0.2 | 0.3 | 5.5 | 4,7 | 0.2 | 0,7 | - | - | - | - |
| HCP ₀₅ | | 0.23 | 0.28 | 0.06 | 0.15 | 0.34 | 0.30 | 0.05 | 0.05 | - | - | - | - |

NL – natural loss; LS – sprout loss; SL – scrap loss (rot rose)

IV. RESULTS DISCUSSION

The size of the potatoe aerial parts is often a decisive factor affecting the intensity rate, the crop size and the tubers reproduction rate. The crop productivity of potato tubers under favorable conditions of growth and development depends on the power of the top mass. The more powerful and healthier the bush, the higher the crop productivity of tubers located under it. Although under unfavorable conditions powerfully developed tops do not give the highest yield [19].

In 2016, the use of the studied drugs positively affected the number of main stems, which, in turn, affected the number of tubers obtained (table 1). In the variants with the use of the drug with Fe, Zn, Mn, Cu, Mo, Co, B in the chelated form, the largest number of main stems was obtained-6.4 pcs. / bush, which is higher than in the control by 3.0 pcs./bush. When using the drug with S in the chelated form, the number of main stems was greater than in the control by 1.4 pcs. / bush.

All the plants, despite the late planting, quickly passed the stages of vegetation. In our experiment, when measuring the height three weeks after planting, the highest were plants on variants with the use of the drug with Fe, Zn, Mn, Cu, Mo, Co,

B in chelated form - up to 13-17 cm; on variants with the use of the drug with S in chelated form - up to 7-13 cm; with water - up to 11-13 cm; plants of control variants grew up to 6-12 cm.

In the blossom phase, the experimental variants had a larger number of main stems, but they were inferior in height and weight to the plants of the control variants (pure control and control with water). Conditions in 2016 were such that, for all the examples, the height, weight of aerial parts of the plant and the assimilatory surface of leaves (leaf area) was significantly greater than that seen in normal or dry conditions for years, with the plants height in the blossom phase of 35-50 cm, weight tops 200-400 g/tree, and the leaf area – 0,40...0,70 m²/bush [20].

In less humid and more favorable conditions in 2017, the number of main stems when introducing a sulfur-containing drug was also higher than in the control version. Unlike 2016, the plants of all variants have approximately the same height – 41.5... 44.8...sm. More high were the bushes variants with participant drugs containing S in aa chelated form and with Fe, Zn, Mn, Cu, Mo, Co, B in a chelated form-43.3 cm. The weight of the tops was the largest in the variants with the use

of the drug containing S in chelated form-244 g/bush. The use of the tested drugs increased the surface area of the leaves to 0.41...0.44 m²/ bush.

On average, for two years, the use of drugs with S in chelated form and with Fe, Zn, Mn, Cu, Mo, Co, B in chelated form increased the number of main stems to 4.4 and 4.7 pcs./bush, and plants of control variants were higher-53.6 and 52.7 cm.

The main criterion for assessing the measures taken in the cultivation of culture is the crop productivity [19, 21, 22]. On average, in two years, despite the fact that the mass of commercial tubers in the blossom phase was approximately at the same level in all variants-0.151...0.157 g / bush, there was a significant difference between the experimental and control variants during harvesting (figure 1).

In 2016, harvesting was carried out less than 90 days after planting. The plants tops were just beginning to wilt, which meant that tuber formation might still continue.

During the data analysis of commodity yield (figure 1), it was found that the application the drug with S in the chelated form gave an increase in crop productivity of 1.4...5.9 t / ha, compared with the control version; the drug with Fe, Zn, Mn, Cu, Mo, Co, B in the chelated form-0.6...6.3 t / ha. The average crop productivity for 2016 was 25.7 t / ha, NSR05-0.68 t / ha.. The weather conditions of both years of research were very wet during the growing season. The average yield for 2017 was 28.9 t / ha, NSR05-3.18 t / ha.

On average, for two years, the use of the drug with S in the chelated form increased the crop productivity value by 3.7 t/ha (14.2%), the drug with Fe, Zn, Mn, Cu, Mo, Co, B in the chelated form-by 3.5 t / ha (13.5%). A significant increase in crop productivity confirms the feasibility of using drugs with trace elements in chelated form when growing potatoes.

In rainy 2016, the number of commercial tubers averaged 97%, in 2017 – 98%.

The entering and accumulation of nitrates in tubers are influenced, first of all, by varietal characteristics, as well as stressful situations and vegetation conditions (water availability, temperature, light, etc.) [23].

The high nitrate content in 2016 can be explained by the fact that the tubers did not have time to reach physiological ripeness and from the influence of too hot weather with increased humidity (the average daily temperature in August exceeded the average annual values by 1.0...3.5 °C). Often the nitrate content values exceeded the maximum permissible concentration (MPC) of 250 mg / kg [23, 24]. On average, for two years the lowest nitrate content was found on variants with the use of the drug with S in chelated form-201 mg / kg and the drug with Fe, Zn, Mn, Cu, Mo, Co, B in chelated form – 230 mg/kg. On average, the nitrate content in the control variants was 245 mg / kg. The use of drugs had a positive impact on the nitrate content in the tubers, as in the resulting crop of these variants; the tubers were bigger than others.

The main indicator of the potato tubers quality is the content of starch, which is primarily the biological characteristic of the variety. Many researches have shown that high starch content provides increased crop productivity of finished products [25]. It is important to obtain a large harvest of potatoes, it is also important to achieve high starch content

in tubers, especially when assigning the crop to certain consumption types.

In 2016, higher starch content in tubers was obtained in variants using the drug with Fe, Zn, Mn, Cu, Mo, Co, B in chelated form-12.9%. In 2017, higher values of starch content in tubers were obtained in the control version, which can be explained by the tubers size (tubers were smaller). On average, for two years, the starch content on average was in the range of 12.6...12.9%.

The gross losses during potatoes storage depend on storage conditions and on the quality of tubers stored, which is confirmed by the data obtained (table 2).

The tested drugs had a positive effect on the keeping quality of tubers during storage. On average, during the two storage periods, the lowest total losses were in potato cultivation variants with the use of S in chelated form, the total losses were 4.76% with 5.20-5.38% in control variants.

V. CONCLUSIONS

1. The use of drug with S in chelated form increased the crop productivity value by 3.7 t / ha (14.2%). The drug use with Fe, Zn, Mn, Cu, Mo, Co, B in chelated form increased the crop productivity value 3.5 t / ha (13.5%). A significant increase in crop productivity confirms the feasibility of using drugs with trace elements in chelated form when growing potatoes.

2. A higher percentage of marketability was found on variants with the drugs use with S in chelated form and with Fe, Zn, Mn, Cu, Mo, Co, B in chelated form-97.5%. In variants "Control" and "Water" – 97.0%.

3. On average, for two years, the lowest nitrate content was in the variants with the drugs use with S in chelated form-201 mg / kg and the drug with Fe, Zn, Mn, Cu, Mo, Co, B in chelated form-230 mg/kg at 245 mg/kg in the control

5. On average, during the two storage periods, the lowest total losses were in potato cultivation variants with the use of S in chelated form; the total losses were 4.76% with 5.20-5.38% in control variants.

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