Influence of growing environment on potato tubers quality

O A Starovoitova¹, A N Mute², A A Manoquina³, V I Starovoitov¹, D A Makarenkoff², V I Nazarov² and H N O Nasibov⁴

¹ Department of Technology and Innovative Projects, All-Russian Research Institute of Potato Industry named after A.G. Lorch, Lyubertsy, Russia
² SIC Kurchatov Institute, Moscow, Russia
³ Department of Agricultural Machinery, Russian State Agrarian University – K.A. Timiryazev Moscow Agricultural Academy, Moscow, Russia
⁴ The Ministry of Agriculture of Azerbaijan, Baku, Azerbaijan

E-mail: agronir2@mail.ru, mr.irea@bk.ru, alexman80@list.ru, agronir1@mail.ru, russiamr.irea@bk.ru, nazarov_vi41@mail.ru, khikmet@mail.ru

Abstract. The purpose of the study was to assess the impact of innovative drugs: sulfur-containing and microelements in chelated form: iron, zinc, manganese, copper, molybdenum, cobalt, boron, on the yield and quality of potato tubers of medium ripe variety Kolobok. The research was carried out in 2016–2017 on sod-podzolic sandy loamy soil. The field experience, records and observations were made in accordance with the requirements of the field experience methodology and the Potato Culture Research Methodology. On average, over two years, the use of the preparation with S content in chelate form increased the yield by 3.7 t/ha (14.2 %). Application of the preparation with the content of trace elements Fe, Zn, Mn, Cu, Mo, Ko, B in chelate form – by 3.5 t/ha (13.5 %). The content of nitrates on the variants with the use of sulfur-containing preparation was 201 mg/kg; the content of the preparation with trace elements was 230 at 245 mg/kg on the control variants. The lowest darkening of raw pulp on a scale of nine points was found on variants with S – 6.83 points (+1.83 or +36.6 %). On variants with the use of the preparation containing microelements, the average value of darkening of raw pulp of tubers was 6.75 points (+1.75 or +35.0 %). Tubers of the variant with the use of the preparation with S – 6.25 points turned out to be tastier. The data obtained may be of interest to specialists growing potatoes for industrial processing, for example, for mashed potatoes, vacuuming of peeled raw potatoes.

1. Introduction

Potatoes are an important foodstuff for the population. In the structure of potato consumption, over 50 % of the total potato production is used for food purposes to prepare a variety of potato dishes directly at home and in the modern catering industry. In Russia, the yield potential of varieties has not been realized even by half, so it is necessary to continue searching for elements of cultivation technologies that increase the yield and quality of potato tubers [1]. It is necessary to consider options for foliar cultivation [2]. Application of foliar fertilizers with microelements in the form of chelate fertilizer can give a significant increase in yield, saturation of tubers with the studied macroelements [3–5], improve the quality of yield [6–10].

Carrying out researches on development of potato growing technology with elements of using preparations containing microelements in the chelate form to increase the yield and quality of potato tubers is an important task.
2. Methods and materials
The purpose of the research is to assess the impact of innovative preparations containing microelements in chelated form on the yield and quality of Kolobok potato tubers. Laying of field experience, accounting and observations were carried out in accordance with the requirements of the field experience [11] and "Methods of research on potato culture" [12].

The research was carried out on the experimental base of Korenevo Luberetsky district of Moscow region in 2016-2017. The objective of the research was to establish the dependence of the change in yield and quality of tubers on the use of innovative drugs containing sulfur and a drug containing microelements in chelated form: iron, zinc, manganese, copper, molybdenum, cobalt, boron, etc. [13].

The soil of the experimental plot is soddy-podzolic, medium cultivated and sandy loamy in terms of its granulometric composition. At the depth of the arable horizon it is characterized by the following agrochemical parameters of Apache: The sum of exchange bases – 1.5...2.4 mg-equiv/100 g; humus content according to the Tjurin method (GOST 26213-91) – 1.99 %; mobile phosphorus according to Kirsanov (GOST 26207-91) – 380–653 mg/kg; potassium metabolism according to Kirsanov (GOST 26207-91) – 134–193 mg/kg; pH KSI, according to Alamovsky (GOST 26483-85) – 5.04; hydrolytic acidity (GOST 26412-91) – 3.46 mg-equiv.

The exploratory experiment was laid down according to the scheme by the method of systematic placement of plots. The predecessor of potatoes is grain-beans. Repetition of experience is fourfold. The area of the registration plot was (0.75×7.5 m) 5.6 m². The planting density is 44.4 thousand pieces/ha with row spacing of 75 cm.

Autumn preparation of the soil consisted of autumn ploughing at a depth of 18–22 cm with a reversible plough. Spring preplanting preparation of the soil included loosening to a depth of 12–15 cm with a disk heavy harrow. Experience was carried out on the background of mineral fertilizer (16:16:16 %), applied fractional-local before planting at cutting of ridges – N40P40K40 and at care of plantings – N100P100K100 with a cultivator.

Before planting, the tubers were treated according to the following variants: water (second control), sulfur-containing preparations, preparation containing microelements in chelate form for stimulation and improvement of kidney germination growth. Consumption of the working solution of 10 l/t tubers (dilution of 30 ml of the preparation with 10 l of water).

Pilot plants were planted in pre-cut combs with a manual potato planting unit with tubers, sparse tubers of elite medium ripe potatoes of medium ripeness Koloboks of medium fraction (30...53 mm in size) in 2016 – June 9, 2017. – May 15.

During the vegetation period according to the scheme, spraying was carried out on sprouts and in the budding phase – the beginning of flowering on variants: water and water-soluble innovative preparations containing sulfur-containing and microelements in chelate form. Flow rate of the working solution is 300 l/ha (dilution of 15 ml of the preparation for 10 l of water).

To control weeds, herbicides were used: system pesticide (selective herbicide, active substance: Rimsulfuron, DV content 250 g/kg) and system pesticide (selective herbicide, active substance – Metribuzine, DV content – 700 g/kg) for sprouts in the recommended dose. A single spraying with an insecticide – intestinal pesticide (active ingredient – Imidaclopride, DV content – 700 g/kg) in the recommended dose was performed against the Colorado beetle. During the vegetation period chemical treatments were performed against phytofluorosis and alternative diseases: 1–3 times (depending on the conditions of the year) with fungicide – contact pesticide (active ingredients: Famoxadon (250 g/l) and Tsimoksanil (250 g/l) in the recommended dose, the first – in the flowering period, the following – every 10–14 days. Water consumption is 300 l/ha. Potato tubers were harvested in the second decade of August.

The average air temperature during the growing season 2016 was 18.6 ºC, with the norm of 16.5 ºC. Total precipitation during the growing season 2016 was 470.2 mm or 180.5 % of the norm (260.5 mm). SCC 2016 amounted to 2.16 (very wet) with the climate norm of 1.3...1.4. The average air temperature during the growing season 2017 was 16.2 ºC, and precipitation during the growing season 2017 was 378.4 mm or 145.3 % of the norm. The 2017 SCC amounted to 2.06 (humid)) [14].
3. Results
Given the importance, Figure 1 presents the yield data depending on the application of micronutrient formulations in chelated form.

![Figure 1. Yield of marketable Kolobok potato fraction, t/ha](image)

The structure of tuber yield (total yield) is shown in Table 1. The size of the tubers with the largest transverse diameter according to the standard should be not less than 30 mm – for rounded-oval tubers. In the rainy season of 2016, the number of marketable tubers averaged 97 %, while in 2017 it was 98 %.

Potato nitrate content in potato tubers changed significantly depending on the meteorological conditions of the growing season and the preparations used (table 2).

| Year | Name                          | Fractional composition, mm | Yield, t/ha |
|------|-------------------------------|----------------------------|-------------|
|      |                               | <30 | 30–44 | 45–52 | 53–59 | 60 and more | 2016 | 2017 | Average |
| 2016 | 1 Control                     | 2   | 20    | 28    | 39    | 11           |
|      | 2 Water                       | 4   | 34    | 26    | 32    | 4            |
|      | 3 Preparations with S in chelate form | 3   | 35    | 27    | 30    | 5            |
|      | 4 Preparations with Fe, Zn, Mn, Cu, Mo, Ko, B in chelate form | 4   | 36    | 28    | 22    | 10           |
|      | Average                       | 3   | 31    | 27    | 31    | 8            |
|      | 1 Control                     | 4   | 29    | 16    | 29    | 22           |
|      | 2 Water                       | 2   | 27    | 31    | 29    | 11           |
| 2017 | 3 Preparations with S in chelate form | 2   | 22    | 22    | 23    | 31           |
|      | 4 Preparations with Fe, Zn, Mn, Cu, Mo, Ko, B in chelate form | 1   | 12    | 17    | 31    | 39           |
|      | Average                       | 2   | 22    | 22    | 29    | 25           |

According to our experience, Kolobok medium ripe tubers were on average kept in 2016 – 247 mg/kg, in 2017 – 214 mg/kg of nitrates.

Starch content in tubers averaged 11.9...12.9 % in 2016; 12.9...13.2 % in 2017.

The quality of potato tubers was assessed by the darkening of raw and boiled pulp, brewability and the taste of boiled potatoes (Figure 2). Analysis of data on darkening of raw tubers' pulp showed that the use of the studied preparations allowed influencing the values of this indicator.
Table 2. Nitrate content in potato tubers depending on the preparations used, mg/k

| No. of the variant | Drug                                      | 2016 | 2017 | Average | ± to control % to control |
|-------------------|-------------------------------------------|------|------|---------|---------------------------|
| 1                 | Control                                   | 252  | 277  | 265     | –                         | –                          |
| 2                 | Water                                     | 221  | 230  | 226     | –39                       | 85                         |
| 3                 | Preparations with S in chelate form        | 241  | 160  | 201     | –64                       | 76                         |
| 4                 | Preparations with Fe, Zn, Mn, Cu, Mo, Ko, B in chelate form | 273  | 187  | 230     | –35                       | 87                         |
| Average           |                                           | 247  | 214  |         | –                         | –                          |
| HCP<sub>05</sub>  |                                           | 18.8 | 44.4 |         |                           |                            |

Typically, cleaning is performed at least 90 days after planting [15]. However, in 2016, the cleaning operations were carried out on September 1, i.e. 83 days after landing. The haulm was still green and was just beginning to fade, which means that tuber formation had not reached its final stage.

When analyzing the data of marketable yield (Fig. 1), it was obtained that the use of the preparation with S in chelated form allowed to increase the yield by 1.4 ... 5.9 t/ha than in the control variant, the preparation with Fe, Zn, Mn, Cu, Mo, Ko, B in chelated form – by 0.6 ... 6.3 t/ha. The average yield in

Table 2. Potato tuber quality depending on the preparation used, point where:
Darkening of pulp: 1 – darkening very strongly; 3 – darkening strongly on all surface; 5 – darkening moderately; 7 – darkening slightly; 9 – not darkening. Digestibility: 1 – not boiled; 3 – poorly boiled; 5 – moderately boiled; 7 – strongly boiled; 9 – very strongly boiled. Taste: 1 – bad (unpleasant, bitter); 3 – fresh; 5 – satisfactory (including sweet); 7 – good; 9 – excellent

4. Discussion
Yield is the main criterion for evaluating crop cultivation measures [15, 16]. On average, over two years the mass of tubers in the flowering phase turned out to be approximately the same in all variants – 0.151...0.157 g/cust, and during harvesting a significant difference between the control variants and variants with the use of investigational drugs is already visible (Fig. 1).

Typically, cleaning is performed at least 90 days after planting [15]. However, in 2016, the cleaning operations were carried out on September 1, i.e. 83 days after landing. The haulm was still green and was just beginning to fade, which means that tuber formation had not reached its final stage.

When analyzing the data of marketable yield (Fig. 1), it was obtained that the use of the preparation with S in chelated form allowed to increase the yield by 1.4 ... 5.9 t/ha than in the control variant, the preparation with Fe, Zn, Mn, Cu, Mo, Ko, B in chelated form – by 0.6 ... 6.3 t/ha. The average yield in
2016 was 25.7 t/ha, while the average yield of NSR05 was 0.68 t/ha. In 2017, as in 2016, the yield of water options was lower than that of control due to high rainfall. The meteorological conditions of both years of research turned out to be very wet during the growing season. The average yield for 2017 was 28.9 t/ha, while the average yield for NCR05 was 3.18 t/ha.

On average, over two years the use of the preparation with S in chelated form increased the yield by 3.7 t/ha (14.2 %), the preparation with Fe, Zn, Mn, Cu, Mo, Ko, B in chelated form – by 3.5 t/ha (13.5 %). This suggests the expediency of using these drugs in potato growing.

The fractional composition of the tubers differed depending on the growing conditions (Table 1). Meteorological conditions in combination with cultivation techniques had a great influence. In the rainy season of 2016, the average market share was 97 %. A higher percentage of marketability was found in the control variant at 98 %. This can also be explained by the early harvest time. Especially when we look at the number of tubers formed in all the variants studied. That is, if we give time to continue the increase in the weight of the tubers under the bush, the greatest potential will be on the options with the use of investigational drugs, where the number of tubers during harvesting was by 2.9 tubers (1 bush) more.

In 2017, the average market share of Kolobok variants was high at 98 %. A higher percentage of marketability was found in the variant with Fe, Zn, Mn, Cu, Mo, Ko, B in chelated form – 99 %.

Nitrate inflow and accumulation in tubers may be affected by variety characteristics, stressful situations, current conditions of vegetation (water availability, temperature, illumination, etc.) [17]. The high content of nitrates in 2016 (Table 2) can be explained by the fact that the tubers did not have time to reach physiological maturity and the impact of too hot weather with increased moisture (average daily temperature in August exceeded the average long-term values by 1.0 ... 3.5 °C). Often the values of nitrate content exceeded the maximum permissible concentration (MPC) of 250 mg/kg [17, 18]. In 2017, the average nitrate content was 206 mg/kg. At the same time, the control variant had the highest content of nitrates – 277 mg/kg, which is explained by the smaller mass of the obtained tubers in this variant. On average, for two years the lowest content of nitrates was found on variants with S in chelated form – 201 mg/kg and with Fe, Zn, Mn, Cu, Mo, Ko, B in chelated form – 230 mg/kg. On average, the content of nitrates in the control variants was 245 mg/kg. The use of the preparations had a positive effect on the content of nitrates in tubers, as the yield of these variants of tubers was higher.

The main quality indicators of potato tubers are their starch content, which is primarily a biological feature of the variety. High content of starch provides an increased yield of finished products [19]. It is important to obtain not only a large yield of potatoes, but also to achieve a high content of starch in the tubers, especially when assigning the yield to certain types of processing. In 2016, a higher starch content in tubers was obtained in variants with Fe, Zn, Mn, Cu, Mo, Ko, B in chelated form – 12.9 %. In 2017, the higher values of starch in the tubers were obtained in the control variant, which can be explained by the size of the tubers (the tubers were smaller). The average starch content over two years was between 12.6 and 12.9 %.

One of the important technological (physical) indicators of potatoes is the darkening of the tubers' pulp. This parameter is important for the comprehensive assessment of the quality of different types of potato products. Potato pulp darkening determines one of the main special requirements for raw materials, production and processing technologies. The darkening resistance of potato tubers to darkening, regardless of their nature, is primarily determined by their variety. Soil-climatic conditions, agrotechnical methods, storage and processing regimes significantly influence the intensity of darkening. [19].

In 2016, the lowest darkening of raw pulp by a nine-point system (Figure 2) was noted in variants with S in chelated form, variant 3 – 6.83 points (+2.33 or +51.9 %). On variants with Fe, Zn, Mn, Cu, Mo, Ko, B in chelated form, variant 4, the average value of darkening of raw tubers pulp was 6.67 points (+2.17 or +48.1 %). In contrast, the water variants had a score of 5.0 (+0.50 or 11.1 %). The greatest darkening of the raw pulp of the tubers turned out to be on the control variants – 4.5 points.
In 2017, the lowest darkening of raw pulp was observed in variants with S in chelated form and Fe, Zn, Mn, Cu, Mo, Ko, B in chelated form, variants 3 and 4 – 6.83 points. In the variants with water, the average value of darkening of raw pulp of tubers was 6.17 points. The greatest darkening of the raw pulp of the tubers turned out to be on the control variants – 5.5 points.

On average, the lowest darkening of raw pulp by a nine-point system for two years turned out to be on variants with S in chelated form, variant 3 – 6.83 points (+1.83 or +36.6 %). On variants with Fe, Zn, Mn, Cu, Mo, Ko, B in chelated form, variant 4, the average value of darkening of raw tubers pulp was 6.75 points (+1.75 or +35.0 %). On water variants – 5.59 points (+0.59 or 11.8 %). The greatest darkening of raw pulp of tubers appeared on control variants – 5.0 points.

In 2016, there were no significant differences in darkening of cooked pulp, boiling capacity and taste when using the studied preparations (Fig. 2). However, the taste of the tubers of these variants was higher – 5.67 points. According to the average estimate with a slight difference, the best variant was the one with S in chelate form – 7.78 points. However, since the tubers did not have time to reach full physiological maturity due to early harvesting, the taste was slightly lower than in accordance with the catalogue of varieties.

In 2017, the results were similar to those of 2016, namely, there was no difference in darkening boiled pulp and digestibility, but the version with the use of the drug with S in chelate form – 6.25 points – was also slightly different in taste. Therefore, according to the average assessment, the best variant was the one with S in chelate form – 7.08 points.

5. Conclusion
1. Application of the preparation with S in chelate form increased the yield by 3.7 t/ha (14.2 %). Application of the preparation with Fe, Zn, Mn, Cu, Mo, Ko, B in chelate form – by 3.5 t/ha (13.5 %). Which makes it advisable to use these drugs in potato growing.

2. On average, the lowest darkening of raw pulp on a scale of nine points for two years turned out to be on the variants with S in chelate form – 6.83 points (+1.83 or +36.6 %). On variants with Fe, Zn, Mn, Cu, Mo, Ko, B in chelated form, the average value of darkening of raw tubers was 6.75 points (+1.75 or +35.0 %). On variants with water – 5.59 points (+0.59 or 11.8 %). The greatest darkening of raw pulp of tubers appeared on control variants – 5.0 points. Tubers of the variant with the use of the preparation with S in chelate form turned out to be more tasty – 6.25 points.

3. The data obtained may be of interest to potato growers for industrial processing, e.g. for mashed potatoes, vacuuming of peeled raw potatoes.

References
[1] Starovoitov V I, Pavlova O A and Voronov N V 2007 Prospects of potato growing techniques in wide rows In: *Potato production and innovative technologies* ed A J Haverkort and B V Anisimov (Wageningen) pp 246–51
[2] Korshunov A V 2001 *Crop and potato quality management* (Moscow) 369 p
[3] Gaj R, Murawska B, Fabisiak-Spychaj E et al December 2018 The impact of cover crops and foliar application of micronutrients on accumulation of macronutrients in potato tubers at technological maturity stage *Europ. J. of Horticult. Sci.* 83(6) 345–55
[4] Zhevora S V, Fedotova L S, Timoshina N A and Knyazeva E V 2018 Efficiency of growth regulators in potato cultivation *Potatoes and vegetables* 12 21–4
[5] Usanova Z I and Bulyukina O A 2017 Influence of microelement complexonates on the formation of topinambour yield *Increase of managerial, economic, social, innovation-technological and technical potential of enterprises and branches of agro-industrial complex* Coll. of sci. papers based on the mat. of the Int. sci.-pract. Conf. pp 8–11
[6] Novikov N N 2014 *Biochemical basis for the formation of the quality of crop production* (Moscow: RGAU_ISHA named after K.A. Timiryazev) 194 p
[7] Kabata-Pendias A and Pendias H 1989 *Microelements in soils and plants* (Moscow: Mir) 439 p
[8] Ansok P I 1990 *Microfertilizers* (Leningrad: Agropromizdat) 272 p
[9] Sheudzhen A H 2003 *Biogeochemistry* (Maikop: Adygeya GURIPPE) 1028 p
[10] Wulkow A, Pawelzik E and Heckl B 2008 Effect of calcium and boron in potato tubers (Solanum tuberosum) of various cultivars differing in blackspot susceptibility *Potato for a changing world* Mater. 17th triennial Conf. of the Europ. Associat. for potato res. pp 228–9 (Brasov)
[11] Dospekhov B A 1985 *Field experience methodology (with the basics of statistical processing of research results, 5th ed., additional and rework)* (Moscow: Agropromizdat) 351 p
[12] Methodology of research on potato culture 1967 (Moscow: NIIKH) 263 p
[13] Makarenkov D A, Nazarov V I, Shelakov M N and Popov A P 2018 Application of chelate forms of microelements in the technology of production of the granulated fertilizers NPK Coll. *Topical issues of chemical technology and environmental protection* VII All-Russ. Conf. with int. participat. pp 139–40
[14] Starovoitova O A, Starovoitov V I and Manokhina A A 2019 The study of physical and mechanical parameters of the soil in the cultivation of tubers *J. of Phys.: Conf. Ser. Int. Conf. on Appl. Phys., Power and Mater. Sci.* 012083
[15] Shpaar D, Ivanyuk V, Shuman P, Postnikov A et al 1999 Under ed of D D Shpaara (Monthly: FIAinform) 272 p
[16] Shabanov A E, Kiselev A I and Fedotova L S 2018 Potential yield parameters of the potato varieties of the VNIIKH breeding center *Farming* 5 34–6
[17] Korshunov A V 2001 *Yield and potato quality management* (Moscow) 369 p
[18] Teslyuk P S and Teslyuk L P 2009 *Tsikave potato growing. Naukovo-populyarnoe vidennie* (Lutsk: Nadstir'ya) 292 p
[19] Dzintra Zālīte Kartupelu grāmata 2006 (SIA "Jumava", Izdevums Latviešu valodā) 183 p