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THE YIELD OF POTATO DEPENDING ON THE BACKGROUND OF MINERAL NUTRITION IN THE CONDITIONS OF IRRIGATION OF FOREST-STEPPE OF THE MIDDLE VOLGA REGION

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Abstract

The purpose of the research is to study the effectiveness of application of fertilizers with increasing doses of nitrogen in the cultivation of potato. The variety of potato Gala of the middle-early maturity group was used on the background of application of phosphorus-potassium fertilizers and sulfur in the dose of $P_{120}K_{120}S_{30}$. Field experiments were conducted in 2014-2016 at the experimental field of the Department of Horticulture of Kazan State Agricultural University, in gray forest soil with middle loamy granulometric composition. According to Tyurin, the content of humus in the arable layer of soil was 3.25... 3.31%, easily hydrolyzed nitrogen – 140... 152 mg/kg of soil, labile phosphorus – 142... 145 mg/kg, exchangeable potassium – 151-156 mg/kg of soil, pH – 5.6... 5.7. The influence of the studied doses of fertilizers on the productivity of crop, content of dry matter, starch, nitrates and taste was determined. The optimal dose of nitrogen fertilizers for potato of variety Gala on the background of mineral fertilizers $P_{120}K_{120}S_{30}$ and chelated forms of microelements: copper, boron and molybdenum in the composition of liquid mixed fertilizers (LMF-1 and LMF -2) was established. Nitrogen fertilizers were applied, depending on the variant, in increasing doses — N_{30}, N_{60}, N_{90}, N_{120} kg of the active ingredient. In the process of research, it was found that the application of fertilizers in a dose of $P_{120}K_{120}S_{30}$ (background) increased the crop of potato on average over 3 years by 9.54 t/ha. Nitrogen fertilizers, applied in addition to the background ($P_{120}K_{120}S_{30}$), due to the raising of their dose from 30 to 120 kg of active ingredient per ha, increased the yield by 1.27... 6.34 t/ha. Raising doses of nitrogen fertilizers contributed to a decrease in the content of dry matter, starch and taste of potato. The amount of nitrates was also increased, but it was significantly lower than the MPC.

Key words : microelements, nitrogen, mineral fertilizers, yield, potato (*Solanum tuberosum*), vitamin C, starch, protein, nitrates.

Introduction

One of the main factors of normal growth and development of plants, the formation of high yields of potato is the use of fertilizers (Vladimirov *et al.,* 2012; Vladimirov, 2013; Gareev *et al.,* 2016; Morier *et al.,* 2015; Vladimirov *et al.,* 2015; Flis, 2019). The relevant task of modern potato farming is to reduce the cost of nutrient fertilizers, using to form a unit of potato yield.

This problem can be solved due to the differentiated application of nitrogen against the background of using the phosphorus-potassium fertilizers.

This crop has weakly developed root system, and during the growing season it accumulates a significant amount of dry matter, therefore good fertilizer elements are required for it. The seedlings of potato plants appear only after the rooting of sprout in the soil, and receiving of mineral nutrients through the roots (Vecher & Goncharik, 1973).

In the process of development of fertilization system for potato, it is necessary to take into account the middle-early group of maturity of potato variety. Early varieties are more responsive to mineral fertilizers, especially in higher doses, than late varieties. On the contrary, later varieties better use the nutrients of organic fertilizers and soil. The doses of nitrogen fertilizers for early, middle-

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early and middle-ripening varieties amount to 90... 100 kg, and for late ones - 60... 90 kg of AI per ha (Simakov *et al.,* 2005).

Among the elements of mineral nutrition, potato uses nitrogen, phosphorus and potassium most of all (Shpaar *et al.,* 2016).

Nitrogen fertilizer plays a pivotal role in the formation of high yields of potato. With a lack of nitrogen nutrition, there is a significant decrease in the yield of potato tubers. It is associated with a low growth of tubers during their formation and premature extinction of the above-ground mass (Butov, 1980; Kosarev & Ganzin, 1981; Kukresh, 1980). However, single high nutrition with nitrogen leads to the excessive increase in the above-ground mass of potato plant, the inhibition of growth and development of tubers, as well as to the decrease in their quality indicators (Nitsch & KLEIN, 1992; Votoupal, 1976).

Potato forms high yields of tubers and above-ground mass, with which a large amount of nutrients are carried out. Sulfur is one of these elements, which presents in the composition of proteins and participates in their synthesis. This element is represented in soils mainly by organic compounds, which are the part of humus. Sulfur plays significant role in metabolism; it has an impact on the formation of chlorophyll, and enhances the development of the root system of plants (Davlyatshyn *et al.,* 2013). Some authors note, that the application of silicon reduces the water-deficient stress of a potato plant (Pilon *et al.,* 2014).

Vlasenko et al, points out, that high statuses of mineral nutrition, especially nitrogen ones, cause not only the accumulation of nitrates, but also the decrease in the content of dry matter and starch in tubers, and also cause the deterioration in culinary and taste qualities of potatoes (Vlasenko *et al.,* 1979).

The purpose of the research is to study the features of formation of yields of variety Gala potato, belonging to the middle-early maturity group, in the conditions of the forest-steppe of the Middle Volga region; to determine the most effective dose of mineral fertilizers when using chelated micronutrient fertilizers (LMF-1 for the treatment of tubers and LMF-2 for foliar application during the growing season).

Materials and Methods

The investigations were carried out in 2014-2016. The soil of the experimental field was gray forest with middle loamy granulometric composition. It had the following agrochemical characteristics: pH of salt extract - 5.6... 5.7; content of humus - 3.25... 3.31%; easily hydrolyzed nitrogen - 140... 152 mg/kg; labile phosphorus - 142... 145, exchangeable potassium - 151... 156 mg/kg of soil.

Seed tubers of the first reproduction with a mass of 60... 65 g were used for planting. During all the years of research, the preceding crop was winter wheat, and 40 t/ha of organic fertilizers were applied for its growth. Row width was 75 cm, planting density – 53.2 thousand tubers per hectare (25 × 75 cm). The depth of planting was 10... 12 cm, the total plot area was 72 m^2, the discount area – 60 m^2. Autumn soil preparation consisted in a stubble ploughing with disk plough-harrows to a depth of 6... 8 cm after harvesting the preceding crop, and after 10… 12 days ploughing with a reversible plough EuroDiamant to a depth of 22... 24 cm. Rototilling was performed by power harrow Zirkon - 7/300 in spring. A four-row potato planter HassiaSL 4 BZS was used for planting.

The object of research was the middle-early variety Gala. The scheme of the experiment included the study of the following options: without fertilizers (control); $P_{90}K_{120}S_{30}$ – background; background + N_{30}; background + N_{60}; background + N_{90}; background + $N_{120.}$ Macrofertilizers were applied during planting. In all variants, except for the control (without fertilizers), microelements were applied in easy digestible, chelated form as part of the liquid mixed fertilizers LMF-1 (for the treatment of tubers before planting with 0.5% solution, at the rate of 10 l/t) and LMF-2 (for double treatment of the plant during the growing season with 0.2% solution, at the rate of 500 l/ha during the phase of flower-bud formation and in two weeks). Planting was carried out in 2014 on May 10, in 2015 - on May 12, in 2016 - on May 10.

Irrigation was performed by sprinkling (400 m^3/ha) 3 times during the growing season. The first watering was in the phase of flower-bud formation, the second and the third – during the intensive growth of tubers.

The yield was defined by weighing of tubers from each plot.

Results and Discussion

The analysis of data on the number of seedlings showed, that the applied fertilizers did not have a significant impact on their number, which, depending on the variant, ranged from 52.69 in the control to 52.86 thousand pcs/ha. On average, during the years of research, in the control variant, the linear dimensions of stems of potato plants of the studied variety were 52 cm, and when fertilizers were applied in a dose of $N_{90}P_{120}K_{120}S_{30}$ their dimensions were 17 cm higher Table 1.

Table 1: The number and height of potato stems, depending on the mineral nutrition of plants, 2014-2016.

Variant	Height of stems, cm	Quantity of stems	
		Pieces per one plant	Thousand pieces per hectare
Without fertilizers (control)	52	4.1	216
$P_{120}K_{120}S_{30}$ (background)	61	4.4	232
Background + N_{30}	62	4.5	237
Background + N_{60}	64	4.5	238
Background + N_{90}	67	4.6	243
Background + N_{120}	69	4.6	243
LSD_{05}	2.32	0.20	5.83

Although the quantity of stems per 1 plant is a varietal characteristic, which is determined by the number of sprouts, the mass of seed tubers, physiological state of the planting material, our research showed that the levels of mineral nutrition had some effect on the number of stems per 1 plant and per 1 ha. In case of fertilizers application, it increased by 0.3 per 1 plant and by 16 thousand pieces per 1 ha. The maximum values (4.6 pieces per 1 plant and 243 thousand pcs/ha) of these indicators were defined after application of fertilizers in the dose of $N_{90}P_{120}K_{120}S_{30}$.

Against the background of natural fertility, without the use of fertilizers, the yield of potato of the middle-early variety Gala was relatively high during all the years of research (24.70... 26.16 t/ha). This can be explained by the application of organic fertilizers for the preceding crop and the use of irrigation of potato plantations Table 2.

The analysis of research results showed that the increase in potato yield when applying background fertilizers ($P_{120}K_{120}S_{30}$) in relation to control in 2014 amounted to 5.33 t/ha, in 2015 – 3.76, in 2016 – 6.05 t/ha, and an average of three years – 5.01 t/ha. The influence of increasing doses of nitrogen fertilizers (on the background of phosphorus-potassium fertilizers) on the formation of potato tubers was manifested quite significantly, and the yield increased with increasing of dose.

With the application of even minimum dose of nitrogen fertilizers (30 kg of AI per ha) the yield of tubers was increased by 3.33 t/ha, compared to the background variant. In case of application N_{60}, the additional yield of tubers was 4.76 t/ha, while application N_{90} – 6.65 t/ha. The highest yield in the experiment (37.72 t/ha) was obtained when nitrogen was applied in a dose of N_{120} on the background of $P_{120}K_{120}S_{30}$, that was 12.26 t/ha higher than the yield level of the control, and 7.25 t/ha higher than in the background variant.

When fertilizers are applied, the most important indicator of their rational use in the cultivation of potato is the obtaining of additional yield per 1 kg of applied active ingredient. In our investigations it was defined that this indicator was the highest when the minimum dose of nitrogen fertilizers (N_{30}) kg/ha was applied (Fig. 1). In this variant it was 81... 129 kg of tubers per 1 kg of active ingredient of nitrogen, depending on the year of research. With an increase in the dose of nitrogen fertilizer to 60 kg/ha and more, its payback decreased. Depending on the year of research, with a dose of nitrogen N_{60} it was 72... 90 kg, with a dose of N_{90} – 72... 80 kg, and with a dose of N_{120} – 57... 63 kg of tubers per 1 kg of active ingredient of nitrogen.

The application of mineral fertilizers had the influence not only on the formation of potato yield, but also on the quality of tubers. Nitrogen fertilizers enhance the growth and development of plants, thereby extending the growing season. Therefore, the defining of the optimal dose of nitrogen fertilizers is important for obtaining good tubers. The content of dry matter in potato tubers in the control variant on average for 3 years was 23.0%, and the application of background fertilizers ($P_{120}K_{120}S_{30}$) increased it by 0.27% Table 3.

Table 2: The yield of potato variety Gala, depending on the dose of nitrogen fertilizer.

Variation	Yield, t/ha				Yield increase, ± in relation to	
	2014	2015	2016	average	control	background
Without fertilizers (control)	25.42	24.70	26.16	25.46	–	–
$P_{120}K_{120}S_{30}$ (background)	30.75	28.46	32.21	30.47	5.01	–
Background + N_{30}	34.62	32.16	34.63	33.80	8.34	3.33
Background + N_{60}	35.25	33.87	36.56	35.23	9.77	4.76
Background + N_{90}	37.25	35.65	38.45	37.12	11.66	6.65
Background + N_{120}	38.32	35.78	39.05	37.72	12.26	7.25
LSD_{05}	1.26	1.40	1.32			

When nitrogen was applied in a dose of N_{30} together with background fertilizers, the content of dry matter was at the level of the control variant. Further increase of nitrogen fertilizers led to a decrease in the synthesis of dry matter in potato tubers, especially with the application of higher doses (N_{90-120}).

The use of phosphorus-potassium and sulfur fertilizers

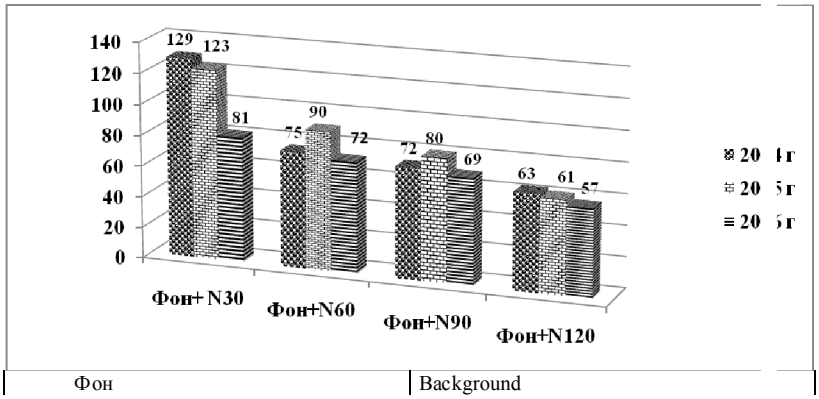

Fig. 1: Additional yield of potato per 1 kg of nitrogen, kg of tubers, 2014-2016.

Table 3: Indicators of quality of potato tubers of the variety Gala, depending on the doses of nitrogen fertilizers, 2014-2016.

Variant	Content in potato tubers		
	Dry matter, %	Dtarch, %	Nitrates, mg/kg
Without fertilizers (control)	23.0	12.7	44.3
$P_{120}K_{120}S_{30}$ (background)	23.3	12.8	42.7
Background + N_{30}	23.0	12.7	50.3
Background + N_{60}	22.8	12.5	60.9
Background + N_{90}	22.4	12.1	76.7
Background + N_{120}	22.3	12.0	86.0
LSD_{05}	0.21	0.15	1.95

($P_{120}K_{120}S_{30}$) caused an increase in the starch content in potato tubers by 0.13%. Nitrogen fertilizers in a dose of N_{30} together with background fertilizers did not reduce the starch content. The application of nitrogen fertilizers in higher doses (N_{60}…N_{120}) was accompanied by a decrease in the starch content in potato tubers, compared to the phosphorus-potassium background, by 0.3... 0.8%.

In the control variant, the content of nitrates in potato tubers was low and averaged to 44.3 mg/kg over three years. The use of nitrogen in moderate (N_{30} and N_{60}) and even high (N_{90} and N_{120}) doses together with phosphorus-potassium and sulfur fertilizers ($P_{120}K_{120}S_{30}$) did not lead to significant accumulation of nitrates in potato tubers, compared with the control. Even with the application of a maximum dose of nitrogen, accumulation of nitrates in potato tubers did not exceed the MPC.

Conclusions

Under the conditions of irrigation, the application of nitrogen fertilizers on the background of phosphorus-potassium and sulfur fertilizers in gray forest soils is an effective method for growing of the middle-early potato.

The use of nitrogen fertilizers for potato variety Gala in increasing doses from 30 to 120 kg/ha in the conditions of the experiment was appropriate, since it led to a significant increase in the yield, and was not dangerous for the use of the obtaining crop as food.

The application of moderate doses of nitrogen fertilizers (N_{30} and N_{60}) did not have a significant effect on the content of dry matter in potato tubers. The use of nitrogen fertilizers in increased and high doses (N_{90} and N_{120}) resulted in a noticeable decrease in the accumulation of dry matter.

The starch content in potato tubers was the highest in case of application of phosphorus-potassium and sulfur fertilizers (12.8%), and their combined use with N_{30} (12.7%). With the increase of doses of nitrogen fertilizers to 60, 90 and 120 kg of AI per ha, the content of starch decreased to 12.5, 12.1 and 12.0%.

Under the conditions of irrigation, the use of nitrogen fertilizers in high (N_{90} and N_{120}) doses on the background of phosphorus-potassium and sulfur fertilizers ($P_{120}K_{120}S_{30}$) did not lead to an excessive accumulation of nitrates, exceeding the MPC.

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