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Dependence of Yield and Quality of Ripe Varieties of Potato on the Level of Mineral Nutrition in Conditions of North-West Russia

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DEPENDENCE OF YIELD AND QUALITY OF RIPE VARIETIES OF POTATO ON THE LEVEL OF MINERAL NUTRITION IN CONDITIONS OF NORTH-WEST RUSSIA

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Abstract. The main task of the research was to study the influence of different norms of mineral nutrition on such indicators as yield, marketability and quality of potato varieties of different ripening periods, taking into account the changing environmental conditions of North-West Russia and the Republic of Karelia in particular. The introduction of various norms of mineral fertilizers significantly increased the yield of potato tubers on average by varieties by 26-35%. The results of evaluating the effectiveness of different norms of mineral fertilizers when growing various varieties of potatoes (the average return of 1 kg of fertilizers per crop) showed that the best payback of mineral fertilizers in the NPK 1 rate was noted when they were applied under an early ripe potato variety 'Udacha' (an average of 34 kg). It has been established that an important role among biotic factors is played by the variety itself, the level of its genetic potential and responsiveness to the conditions of cultivation. Weather conditions and the use of fertilizers affect not only the yield of potatoes, but also their quality indicators. The use of different norms of mineral fertilizers, as a factor in controlling the production process of potatoes to be expected had a significant effect in all studied varieties on an increase in the average weight of tubers (in the Udacha variety by 66.7%, Red Scarlett -38.7%, Aurora - 24%), as well as on the quality of potato tubers, in terms of increasing the nitrogen content in them (by 8.8-15.4%), potassium (by 23.2-37.8%) and reducing starch content by 5 , 2-12.3%.

Keywords: potatoes, varieties, mineral fertilizers, yield, quality of tubers

1 Introduction

In solving the problem of information support for the domestic production of crop products, an important place is given to agricultural systems as a tool for managing agricultural production and which is a complex of interconnected agricultural technical, land reclamation and organizational events aimed at the effective use of agricultural landscapes and obtaining high crop yields [1-2]. The use of information technol-

ogies and the capabilities of robotic agricultural equipment led to the emergence at the end of the 20th century of a fundamentally new direction of agricultural science, called precision agriculture. One of the founders of the meto-dology of precision agriculture, Dr. P. Robert (USA), defined this concept, based on information and technologies, as an agricultural management system for identifying, analyzing and managing production, taking into account differentiated spatial and temporal soil variations on a single field in order to optimize costs, increase the sustainability of agrocenoses and achieve its environmental stability [3].

Currently, precision farming, as an element of information and digital technologies, is one of the main innovative directions in agriculture and is based on the observation, measurement of inter-field and intra-field variability in the cultivation of various crops [4-6]. Although the relevance of digital precision farming technologies to crop production has been increasing in recent years, in most cases agro-technologies have been applied without taking into account spatial variability in the characteristics of sowing and plant habitat, which ultimately leads to disequilibrium and reduced productivity of agroecosystems. The introduction of precision farming technologies is also constrained by the lack of a perfect methodological and instrumental framework for information support of new technologies in the market for intelligent systems [7-9].

Currently, the priority task of modern precision agriculture is to optimize accurate systems for the use of fertilizers for various crops and, in particular, for potatoes for the conditions of the North-West region of Russia [10].

In the North-West of Russia, potatoes are among the most important and widespread agricultural crops for food, fodder and technical purposes [11-14] and ranked third in Russia after grain and leguminous crops and sugar beet in terms of the required production volumes to ensure the country's domestic consumption [15].

Potatoes, possessing high potential productivity, are able to form, under favorable conditions, productivity up to 100 t / ha [16]. However, it is practically impossible to obtain it in production conditions due to a number of limiting factors, such as climatic, soil, ecological, agrotechnical, biological and especially varietal qualities. One of the important and indispensable factors for the effective and sustainable functioning of potato agrocoenosis is the rational use of mineral fertilizers, which makes it possible to obtain at least 30-50% of an additional yield increase with good quality [17-21]. The leading role of fertilizers in achieving these goals will continue for the foreseeable future [22, 23].

The soil and climatic conditions of the North-West of Russia provide the highest return in the Russian Federation from the use of almost all types of fertilizers on potato varieties of early, mid-early and mid-ripeness groups. The optimal and timely use of fertilizers also improves the general condition of potato plants, increasing their resistance to a wide range of pathogens [19, 24-26]. An important role among biotic factors is played by the variety itself and its responsiveness to cultivation conditions. The productivity of potatoes, like any agricultural crop, is determined by the level of its genetic potential - the primary and leading factor. Cultivation technology only contributes to a greater or lesser extent to the realization of this important property of the variety [27-31]. In this regard, the study of the influence of abiotic factors on such

indicators as early maturity of the variety, yield, marketability and quality of products, the responsiveness of the variety to mineral nutrition is of particular importance [32].

Taking into account the relevance of the problem under consideration, the task of our research was to study the influence of the above factors on increasing the productivity and quality of potato varieties of different ripening periods, taking into account the changing environmental conditions in the North-West of Russia, and in particular, the Republic of Karelia.

2 Materials and research methods

The methodological basis of the study was a two-factor microfield experiment. The experiment scheme included the following options: by factor A - potato varieties (*Solanum tuberosum L.*) zoned for the conditions of the North-West region of Russia with different ripening periods, early maturing (Udacha), mid-early (Red Scarlett) and mid-maturing (Aurora); by factor B- a fertilizer system in the form of a control variant - without fertilizers (NPK0) and experienced N80P60K120 (NPK 1), N120P90K180 (NPK 2).

The soil on the experimental plot is soddy-weakly podzolic, light loamy, cultivated with the following agrochemical characteristics: pHKCl —5.11, humus content - 3.92%, mobile phosphorus (GOST 26207-90) - 252 mg / kg; exchangeable potassium (GOST 26210-84) - 168 mg / kg.

The area of the experimental plot is 3 m2 (1.5x2 m), the replication in the experiment is 4-fold, the placement of variants is systematic. Mineral fertilizers (ammonium nitrate, ammoniated superphosphate, potassium sulfate) were introduced according to the experimental scheme for pre-planting soil cultivation. Planting at the rate of 5 tubers / m^2 was carried out in the second or third decades of May. Care for the potato plantings was carried out by pre-emergence harrowing and three inter-row treatments, including two hilling. The crop accounting was carried out using a continuous gravimetric method. The yield structure was evaluated for 5 plants. The quality of tubers was assessed according to generally accepted methods. Statistical processing of the experiment results was carried out using the Excel and Stat graphic programs.

3 Research results

The Northwestern region of the Russian Federation, to which the Republic of Karelia belongs, is part of the regions with the highest return on the use of most types of fertilizers and ameliorants [33-35]. However, this rule has an exception due to the impact of unfavorable weather and climatic conditions. On average, over two years, the temperature regime of the growing season was close to long-term values with insignificant deviations in heat supply in June and moisture supply, which in 2019, especially during tuberization, exceeded the norm by up to 3 times, while hydrothermal Selyaninov's coefficient (SCC) for the growing season reached 3.4 units. (Table 1).

The precipitation, many times higher than the average annual values, favorably influenced the obtaining of a high yield of tubers of all varieties compared to 2020, when the seed tubers were planted in dry soil and the planting-seedling period was distinguished by aridity - 30% lower from the mean annual values. In general, in 2020, precipitation was observed at the level of average long-term values, the GTC for the growing season was 1.1 units.

Table 1. Agrometeorological conditions of the growing seasons

Month	Average temperature, °C			Precipitation, mm		
	2019	2020	average long-term	2019	2020	average long-term
May	9,7	8,3	7,3	48,4	23	41
June	16,6	15,8	13,5	59,9	42,7	59
July	14,5	16,1	16	252,1	58,1	85
August	13,5	14,6	14	118,3	56,8	70

The studies have shown that the yield of potato tubers varied from year to year and depended both on weather conditions and on the reaction of varieties to the application of different fertilizer rates (Table 2).

Table 2. The influence of mineral fertilizers on the yield of different kinds of potatoes, t / ha of tubers

Variety	2019	2020	Average over 2 years	Increase in yield		Payback, kg / kg of active ingredient
				t / ha	%	
No fertilizer (control) (NPK0)						
Udacha	32,99	27,79	30,39	-	-	-
Red Scarlett	27,14	23,84	25,49	-	-	-
Aurora	33,06	29,8	31,43	-	-	-
$N_{80}P_{60}K_{120}$ (NPK 1)						
Udacha	42,14	36,34	39,24	8,85	29	34
Red Scarlett	36,67	29,20	32,94	7,45	29	29
Aurora	35,02	40,05	37,54	6,11	19	24
$N_{120}P_{90}K_{180}$ (NPK 2)						
Udacha	44,36	34,45	39,41	9,02	30	23
Red Scarlett	37,27	34,76	36,02	10,53	41	27
Aurora	36,59	49,22	42,91	11,48	37	29
HCP_{05} variety	1,2	2,1				
HCP_{05} fertilizers	2,0	4,7				
HCP_{05} interaction of variety and fertilizer	3,4	2,0				

On average, the two-year research showed that without mineral fertilizing, the mid-season Aurora variety turned out to be the most productive, with the mid-early Red Scarlett variety the least productive.

The introduction of various norms of mineral fertilizers significantly increased the yield of potato tubers an average of 26-35%. The average yield of potatoes without fertilizing in the experiment was 29.1 t / ha, with the introduction of both NPK 1 - 36.57 t / ha and NPK 2 -39.4 t / ha.

In the conditions of the waterlogged 2019, the early ripening Udacha variety was the most responsive to mineral fertilizing, the yield increase of which compared to the unfertilized one was 9.15 t / ha or 28% with NPK 1, and 11.37 t / ha, with NPK 2, or 34%, respectively. The smallest changes in productivity from mineral fertilizing were in the mid-season Aurora variety - with NPK 1 - 1.96 t / ha or 6%, and with NPK 2 - 3.53 t / ha or 11%, respectively.

The mid-season Aurora variety reacted least of all to the dry planting period (2020). Mineral fertilizing in a dose of NPK 1 increased the yield of this variety compared to the control by 10.25 t / ha or 34%, respectively. The NPK 2 dose application made it possible to obtain an increase in the crop yield of 19.42 t / ha or 65%, respectively. The medium-early Red Scarlett variety proved to be less responsive during this period to mineral fertilizing with NPK 1; the yield increase in comparison with the control was 5.36 t / ha or 22%, respectively. The lowest yield indicators with an increase in the rate of application of mineral fertilizers (NPK 2) were obtained for the early-ripe Udacha variety - 6.66 t / ha or 24%, respectively.

The results of evaluating the effectiveness of various doses of mineral fertilizers when growing varieties of potatoes (the average return of 1 kg of fertilizers per crop) showed that the best return of mineral fertilizers in the NPK 1 rate is observed when they are applied under an early ripe potato Udacha variety (an average of 34 kg). The lowest return with NPK 1 is noted for the mid-season Aurora variety (Table 2). However, with NPK 2, the early-maturing potato Udacha variety (23 kg) had the lowest return from the use of an increased rate of mineral fertilizers and the Aurora variety (29 kg) reached the highest return. The findings should be considered with respect to the biological characteristics of the studied varieties. The early ripening Udacha variety completes the growing cycle of development with NPK 1 in a shorter time period, and in this case, an increase in the rate of fertilization does not contribute to an increase in crop yield. The Aurora variety, belonging to the mid-ripening group, used the nutrients for a longer period to complete the tuberization process.

When analyzing the structure of the yield for an average of two years, it was found that the use of mineral fertilizers significantly affects the number and weight of tubers per plant and the average weight of tubers. Based on the experimental data given in Table 3, a larger number of tubers per plant was formed in the medium-ripe Aurora potato variety when applying an increased dose of fertilizers (10 pieces of tubers and their largest weight per plant – 865.3 g), smaller analogous indicators were noted in the Red Scarlett potato variety, which at a dose of NPK 1 fertilizers formed only 5.4 tubers per plant, which is probably due to the biological feature of the variety.

Table 3. Yield structure and marketability of potatoes of various kinds depending on the dose of fertilizers (on average for 2019-2020)

Variety	Mineral fertilizers	The number of tubers per plant, pieces	Mass of tubers from 1 plant, g	Average mass of tubers, g	Marketability of tubers, %
Udacha	No fertilizers - NPK0	9,6	606,0	64,1	94,0
	$N_{80}P_{60}K_{120}$ - NPK1	7,3	782,9	107,7	96,0
	$N_{120}P_{90}K_{180}$ - NPK2	7,8	784,2	106,9	93,7
Red Scarlett	No fertilizers - NPK0	5,7	508,8	93,2	95,3
	$N_{80}P_{60}K_{120}$ - NPK1	5,4	655,8	124,6	94,9
	$N_{120}P_{90}K_{180}$ - NPK2	6,0	719,9	129,3	94,5
Aurora	No fertilizers - NPK0	9,4	627,8	68,0	90,6

The indices of the weight of tubers per plant increased with the use of fertilizing of all studied varieties. The use of different norms of mineral fertilizers, as a factor in controlling the production process of potatoes, quite expectedly, had a significant effect on all studied varieties and on an increase in the average mass of tubers (the Udacha variety -66.7%, Red Scarlett -38.7%, Aurora - 24%). Udacha and Aurora varieties reached a maximum with NPK1 - 107.7 g and 84.3 g, respectively. However, with an increase in fertilizing from N80P60K120 to N120P90K180, there were no significant changes in the indices of these varieties, except for the Red Scarlett variety, which, with an increase in the rate of mineral fertilization, had the highest average tuber weight per plant. Marketability indicators for all the studied potato varieties did not differ significantly according to the variants and were in the range of 90.6% - 96.0%[19].

The variance analysis of the yield obtained with different combinations of the studied variants showed that the most significant factor was the use of mineral fertilizers – the increase in the total yield of variety tubers compared to the non-fertilized variant was 42% for an average of two years. The influence of the cultivated varieties was also significant and amounted to 25%. The interaction of the variety + fertilizer factors was 9 %. The influence of random factors, which should include the agrometeorological conditions of the growing season, was significant and amounted to 24% (Figure 1).

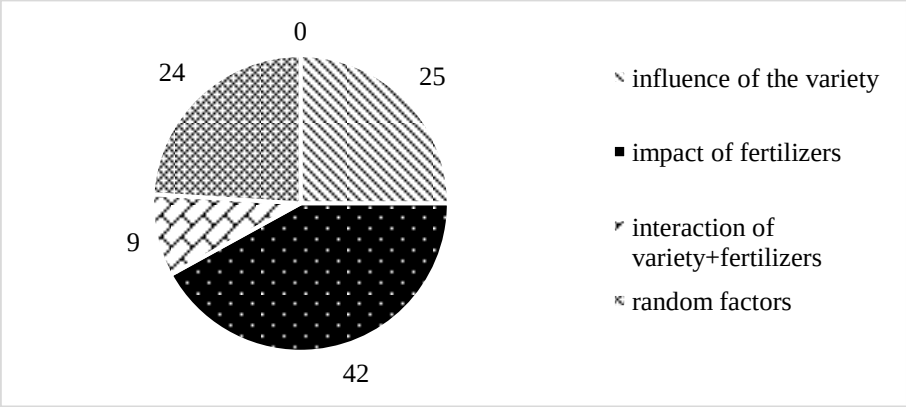

Fig. 1 Influence of individual factors on potato yield, on average over 2 years, (%)

Weather conditions and the use of fertilizers had an impact not only on the yield of potatoes, but also on their quality indicators (Table 4). In general, the highest content of dry matter and starch was observed in the varieties without the use of mineral fertilizers (in the Udacha variety-19.6% and 16%, in the Aurora variety-18.9 % and 15.4% , and in the Red Scarlett variety-17.4 % and 14.2%, respectively).

Mineral fertilizers added to the soil significantly increased the content of nitrates in the tubers of Red Scarlett and Aurora potato varieties compared to the control, but their amount was significantly less than the maximum permissible concentrations of nitrates (250 mg/kg). The potato tubers of the Red Scarlett variety contained more nitrates and a higher nitrogen content (2.05-2.23%) in comparison with the other varieties (Table 4).

Probably, the nitrogen of fertilizers entering the potato tubers was used more productively by plants of this variety and it was actively converted into an organic form [8]. Thus, the use of various norms of mineral fertilizers, as a factor in the management of the potato production process, had a significant and quite natural impact on the quality in terms of reducing starchiness by 5.2-12.3% and increasing the nitrate content by 23.9-68.0%.

Table 4. The quality of tubers of various potato varieties depending on the rate of application of mineral fertilizers (2019)

Variety	Mineral fertilizers	Content of main elements,% dry matter			Starch content, %	Dry matter, %	NO_3 mg/kg raw mass
		N	P_2O_5	K_2O			
Udacha	No fertilizers	1,62	0,28	1,94	16,0	19,6	75,8
	$N_{80}P_{60}K_{120}$	1,87	0,30	2,39	13,7	16,8	68,8
	$N_{120}P_{90}K_{180}$	1,71	0,26	2,45	15,8	19,4	67,5
Red	No fertilizers	2,05	0,31	2,17	14,2	17,4	115,8

Scarlett	$N_{80}P_{60}K_{120}$	2,23	0,29	2,40	13,8	16,9	206,0
	$N_{120}P_{90}K_{180}$	2,11	0,29	2,99	13,7	16,8	177,4
Aurora	No fertilizers	1,55	0,21	2,20	15,4	18,9	152,0
	$N_{80}P_{60}K_{120}$	1,73	0,22	2,68	14,2	17,4	156,2
	$N_{120}P_{90}K_{180}$	1,69	0,25	2,71	14,6	18,0	176,6

The phosphorus content in potato tubers, depending on the variety, was in the range of 0.21-0.31% of dry matter, with the Aurora variety having the smallest amount and the Red Scarlett variety having the largest one. According to the nitrogen content in potato tubers of the studied varieties, its increase depended on the norms of mineral nutrition, by 8.8% (Red Scarlett variety), 11.6% (Aurora variety) and 15.4% (Udacha variety). It should also be noted that the potassium content in potato tubers in all the studied varieties showed an increase in the norms of mineral fertilizers use and in the Udacha variety by 26%, Red Scarlett-37.8% and Aurora-23.2%, respectively. The potassium content in the tubers in the control variants varied in the range of 1.94-2.17%.

4 Conclusion

Potatoes, as a crop with a food, feed and technical purpose, are widespread in the North-West of Russia in agricultural organizations of various forms of ownership and their cultivation depends on the climatic, soil, environmental and agrotechnical conditions of the environment, as well as biological and especially varietal characteristics of the crop. As a result, the conducted studies made it possible to obtain information on the influence of various factors on the increase in productivity and quality of potato varieties of different ripening periods, such as early-ripe (Good Udacha) , mid-early (Red Scarlett) and mid-season (Aurora) for the conditions of the North-Western region of Russia and, in particular, the Republic of Karelia.

. It was found that the application of various norms of mineral fertilizers significantly increases the average potato tuber yield by 26-35%. The average potato yield without the use of fertilizers in the experiment was 29.1 t / ha, with the application of NPK 1-36.57 t/ha and NPK 2 -39.4 t / ha. At the same time, it was revealed that the resulting potato yield varies by year and significantly depends on both weather conditions and the reaction of varieties to the introduction of different fertilizer rates. On average, after a two-year study with and without the use of mineral fertilizers, the mid-season Aurora variety turned out to be the most productive, while the mid-early Red Scarlett variety was the least productive.

The most responsive to the use of mineral fertilizers in the conditions of wet 2019 was The early ripening Udacha variety, whose yield increase compared to the option without fertilizers was 9.15 t/ha using NPK 1 and NPK 2 -11.37 t / ha. In the dry year of 2020, the best crop yield indicators were for the Aurora variety, since the use of mineral fertilizers in the NPK 1 norm increased the yield of this variety compared to the control by 10.25 t/ha or 34%, and, respectively, by 19.42 t/ha when using NPK 2.

In terms of economic efficiency (the average return of 1 kg of fertilizers per crop), the best indicators were noted when applying NPK 1 for the early-ripening Udacha potato variety (an average of 34 kg), while at a dose of NPK 2, with the highest return of 29 kg for the Aurora variety.

The analysis of the crop structure over an average of two years showed that the use of mineral fertilizers on all potato varieties significantly affects the number and weight of tubers per plant and the average weight of tubers, which, in comparison with the control variants, increased in the Udacha variety by 66.7%, Red Scarlett - 38.7%, and Aurora-24%, respectively.

The use of fertilizers had a significant impact on the qualitative composition of tubers of the studied potato varieties, increasing the content of nitrogen (by 8.8-15.4%), potassium (by 23.2-37.8%), nitrates (by 23.9 - 68.0%) and reducing starchiness by 5.2-12.3

The variance analysis of experimental data on the the yield of potatoes obtained with different combinations of the studied variants showed that the most significant factor in the formation of the maximum productivity of the studied crop was the application of mineral fertilizers (42%), followed by such indicators as the variety (25%) and the interaction of the variety and fertilizers (9%).

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