

Formation of planned potato yield in the conditions of the Souther Urals

Alexander Vasilyev*, Nikolai Glaz, Denis Nokhrin, Larisa Ufimtseva, and Oleg Gordeev

Federal state budgetary scientific institution " Ural Federal Agrarian Scientific Research centre, Ural Branch of the Russian Academy of Sciences» Yekaterinburg, Russia

Abstract. The most important factor for obtaining planned potato yields in rainfed farming in the forest-steppe zone of Chelyabinsk region is the availability of moisture. The yield of tubers depends on the weather conditions of the growing season by 18.7%, the density of crops - by 17.3%, varieties - by 8.4% and the use of microfertilizer Forsage by 5.1%. The level of balanced nutrition determines 46.2% of total potato yield variation and is the main factor. The yields of the studied varieties under the conditions of 2019 (HTC = 0.91) was 1.15-1.23 times higher than in 2020 (HTC = 0.85) and 1.25-1.67 times more than in the drought conditions of 2021 (HTC = 0.39). Dense planting of potatoes ensured an increase in the yield of tubers and did not affect the content of starch in the tubers. The microfertilizer Forsage increased the yield of the variety Zakhar by an average of 2.5 t/ha, Rosara - by 2.1 t/ha, Kashtak - by 2.5 t/ha compared to the control. The influence of Forsage on the starch content of tubers depended on the variety and density. The best result is provided by a combination of a dense planting, the use of varieties Zakhar and Kashtak and the use of microfertilizer Forsage.

1 Introduction

The optimal combination of plant life factors, including balanced mineral nutrition, ensures the formation of planned yield of potato (*Solanum tuberosum* L.) [1-2]. First of all, this is the optimization of provision of potatoes with macronutrients (nitrogen, phosphorus, potassium and calcium) [3-5]. This requirement is also true for trace elements [6-7]. Optimization of growing conditions ensures the harmonious growth of plants, increases their resistance to environmental stresses and contributes to the formation of the planned harvest [8-9].

The purpose of the research is to establish the optimal parameters for the formation of planned yield of tubers, depending on the balance of mineral nutrition, the microfertilizer Forsage and the potato planting variant at the Southern Urals.

* Corresponding author: kartofel_chel@mail.ru

2 Materials and methods

The studies were carried out in the forest-steppe zone of the Chelyabinsk region on the basis of Southern Urals Research Institute of Horticulture and Potato, a branch of Ural Federal Agrarian Scientific Research centre, Ural Branch of the Russian Academy of Sciences in 2019-2021.

There were three varieties in the experiment (Rozara - early season, Zakhar – mid-early season, Kashtak – mid season), two planting densities variant (75x27 and 75x19 cm) and three levels of nutrition (without fertilizers, mineral fertilizers per tuber yield of 30 and 40 t/ha). The use of microfertilizer Forsage for the treatment of seed tubers (1 l/t) was compared with the control (without treatment). The experiments were made in four replicates. Allocation was randomized. The plot area is 27 m². Experimental data were processed by multivariate analysis of variance [10].

The soil of the experimental field is medium-loamy leached chernozem with a humus content (according to Tyurin) - 5,3±0,2%, easily hydrolyzed nitrogen (according to Tyurin and Kononova) - 17,2±1,5 mg/100 g, mobile phosphorus (according to Chirikov) - 7,5±2,5 mg/100 g, mobile potassium (according to Chirikov) - 19,2±6,9 mg/100 g of soil, pH - 4,75±0,19. The predecessor is pure steam. For planting tubers 45-50 mm in diameter were used. Planting was carried out on May 16 (2019), May 6 (2020), and May 15 (2021), with simultaneous dressing of seed material with fungicide Benorad, SP (0.5 kg/t) and insecticide Imidor Pro, KS (0.2 l/t). Planting depth - 6-8 cm. Norms of mineral fertilizers based on the yield of tubers 30 t/ha (average for 3 years - N₈₀P₉₀K₁₀₀) and 40 t/ha (N₁₅₁P₁₇₀K₂₀₇) were introduced fractionally: the starting dose (N₃₀P₃₀K₃₀) - locally during planting potatoes, and the main part - for preplant tillage. Potato cultivation was carried out according to the generally accepted technology. The study period had a deficit of precipitation. The most favorable for potatoes was the growing season of 2019 (HTC = 0.91). Extreme conditions were in 2020 (HTC = 0.85), when 77% of precipitation fell over the last 40 days of the growing season, and the first part of the growing season was dry. The growing season of 2021 was dry (HTC = 0.39) and extremely unfavorable for potato cultivation.

3 Research results and discussion

The yield of potatoes during the years of research varied significantly depending on the weather conditions of the growing season (the contribution of the factor is 18.7%), planting density (17.3%), variety selection (8.4%) and the use of chelated microfertilizer Forsage (5.1%), however, the level of balanced nutrition, which determines 46.2% of the total variation in tuber yield, had a decisive influence on the yield.

The influence of the use of calculated doses of mineral fertilizers on the variation in the yield of tubers prevailed and by the years of research was: in 2019 - 64%, in 2020 - 46%, in 2021 - 54%. Planting density of potatoes gave 9.6%, 34.1 and 21.2% of the total yield variation, respectively. The genotype determined 12.8-14.9% of the potato yield variation. The use of microfertilizer Forsage had a significant impact on potato productivity and amounted to 9.2% in 2019, 3.1% in 2020, and 6.3% in 2021.

In the conditions of rainfed farming in the Southern Urals, moisture availability remains the most important factor in obtaining the planned potato crops. In our experience, programmable levels of potato productivity were achieved by varieties of the Chelyabinsk selection only in the conditions of 2019 in variants with the use of the microfertilizer Forsage. Fertilizer application (based on a yield of 30 t/ha) the specified level of productivity was obtained for all planting options: for the Zakhar - 30.5 and 33.0 t/ha, Kashtak - 33.2 and 34.7 t/ha (the best results fixed at maximum planting density). The

planned yield of 40 t/ha was formed with a dense planting variant in the conditions of 2019: in the mid-early season variety Zakhara - 39.8 t/ha, in the mid season Kashtak - 41.2 t/ha. The Rosara did not provide the indicated yield levels in any of the options (table 1).

Table 1. Productivity of potato tubers in the forest-steppe zone of the Chelyabinsk region, depending on agrotechniques, t/ha.

Planting density (B)	Variety (C)	Nutrition level (D)	Forsage (A)							
			Control (without application)				Forsage (1 L/t)			
			Yield, t/ha							
			2019	2020	2021	Average	2019	2020	2021	Average
75x27 cm	Rosara	0	15.4	12.8	12.4	13.5	19.4	12.4	13.6	15.2
		1	21.3	18.4	16.8	18.8	23.5	18.2	16.4	19.4
		2	25.6	21.9	21.5	23.0	29.9	25.4	22.2	25.8
	Zakhara	0	19.4	16.9	12.5	16.3	23.7	17.3	16.4	19.1
		1	26.8	23.6	19.6	23.3	30.5	24.5	23.6	26.2
		2	33.4	28.7	22.9	28.4	35.4	28.0	30.0	31.1
	Kashtak	0	19.4	13.5	11.8	14.9	21.1	19.3	11.4	17.3
		1	26.8	19.2	19.4	21.8	33.2	23.0	17.1	24.4
		2	32.7	21.9	20.0	24.9	38.8	28.0	20.7	29.2
75x19 cm	Rosara	0	17.3	14.0	16.5	15.9	18.8	18.3	18.1	18.4
		1	26.0	20.8	19.4	22.1	26.9	23.3	25.3	25.2
		2	31.8	28.8	24.9	28.5	33.5	29.0	28.4	30.3
	Zakhara	0	24.6	22.3	16.3	21.1	25.3	23.5	20.0	22.9
		1	32.5	28.4	23.7	28.2	33.0	31.1	28.4	30.8
		2	36.8	36.3	31.3	34.8	39.8	37.1	33.9	36.9
	Kashtak	0	20.7	20.2	13.3	18.1	23.7	20.8	12.2	18.9
		1	29.7	27.8	18.5	25.4	34.7	28.9	19.7	27.8
		2	36.7	34.0	23.6	31.4	41.2	34.4	26.4	34.0
HCP ₀₅			3.6	3.9	2.9	2.0	3.6	3.9	2.9	2.0
LSD ₀₅ (A, B)			0.9	1.0	0.7	0.5	0.9	1.0	0.7	0.5
LSD ₀₅ (C, D)			1.1	1.2	0.9	0.6	1.1	1.2	0.9	0.6

Note: 0 - without fertilizers; 1 - fertilizers based on a yield of 30 t/ha; 2 - fertilizers based on a yield of 40 t/ha.

The application of mineral fertilizers based on a tuber yield of 30 t/ha (N₈₀P₉₀K₁₀₀) on average over the years of research provided an increase in the yield of potato varieties Rosara 5.6 t/ha (35.6%), Zakhara - 7.3 t/ha (36, 8%), Kashtak - 7.6 t/ha (or 43.7% in relation to the control). For an increased level of nutrition (N₁₅₁P₁₇₀K₂₀₇), designed to obtain a tuber yield of 40 t/ha, the increase in the yield of the studied varieties increased almost to a widow, reaching 11.1 t/ha for the Rosara, 13.0 t/ha for Zakhara, and 12.6 for Kashtak. t/ha In relation to the level of the control variant, this amounted to 70.7%, 65.4 and 72.8%.

Liquid microfertilizer Forsage contains: nitrogen (N) - 38 g/L, phosphorus (P₂O₅) - 30g/L, potassium (K₂O) - 30 g/L, sulfur (SO₃) - 30 g/L, magnesium (MgO) - 1 g/L, copper (Cu) - 0.5 g/L, zinc (Zn) - 0.5 g/L, boron (B) - 0.6 g/L, iron (Fe) - 0.2 g/L, manganese (Mn) - 0.5g/L, molybdenum (Mo) - 0.5 g/L, cobalt (Co) - 0.3 g/L, chromium (Cr) - 0.3 g/L, lithium (Li) - 0.2 g/L, vanadium (V) - 0.2 g/l, nickel (Ni) - 0.1 g/l, selenium (Se) - 0.1 g/l, and also a complex of amino acids (including aminoacetic acid - 150 g / l) and humic acid - 10 g / l. The use of microfertilizer Forsage for the processing of planting material contributed to an increase in potato productivity by 2.1-2.5 t/ha or by 10-11% in relation to the control. There were no significant differences between the varieties in terms of responsiveness to this fertilizer.

An increase in the planting density of potatoes from 49 to 70 thousand tubers/ha was accompanied by an increase in the yield of the Zakhara by an average of 5.1 t/ha, Rosara - 4.1 t/ha, Kashtak - by 3.8 t/g or 21, 0%, 21.3 and 17.4% respectively.

The described regularities are shown in fig. 1. The profiles of the results of the experiment averaged over three years are presented. In particular, there is an increase in yield with an increase in the dose of mineral fertilizer, a higher yield of Kashtak and Zakhar, as well as a stable effect from the use of the microfertilizer Forsage. The maximum yield of tubers was formed in the dense planting variant with the application of mineral fertilizer at the rate of 40 t/ha for the Zakhar.

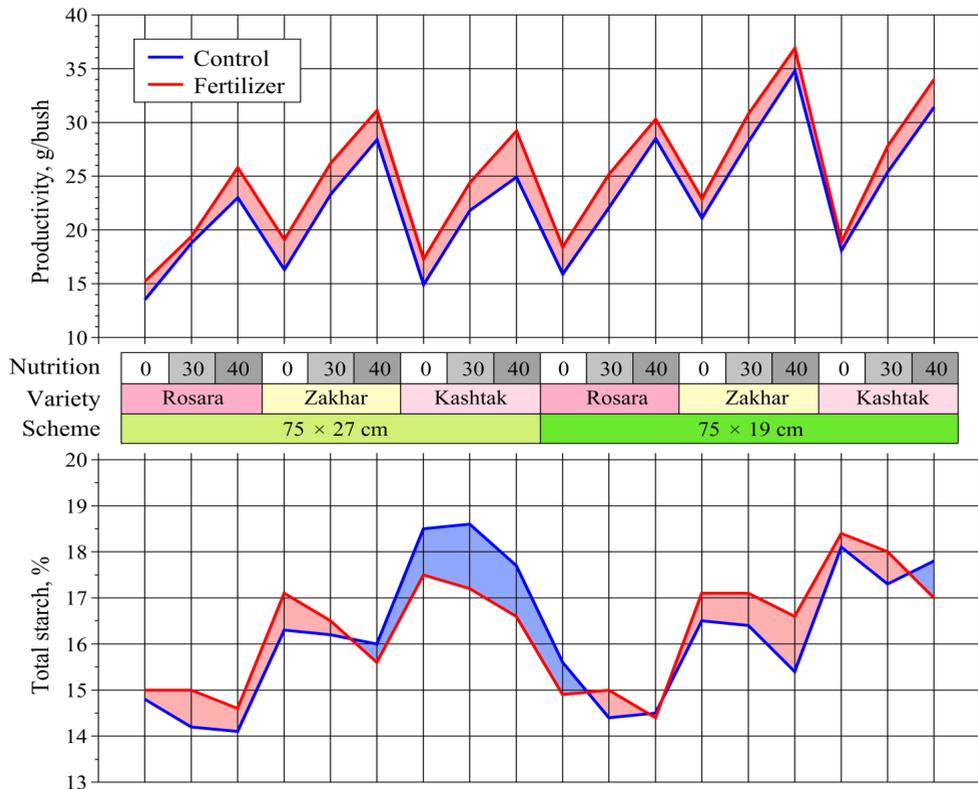


Fig 1. Yield and starch content in potato tubers depending on agrotechniques.

The starch content in tubers varied in different degrees (Table 2, Fig. 1). In general, with an increase in mineral nutrition, the starch content of tubers decreased. The maximum starch content was noted in the control variants of the experiment with a sparse planting in tubers of the variety Kashtak (blue area in Fig. 1). For dense planting the highest starch content was found for the Kashtak and Zakhar in the variants using the fertilizer Forsage (pink area in Fig. 1).

In general, the starchy content of potato tubers depended mainly on the genotype (factor contribution - 85.9%), less - on the level of mineral nutrition (5.4%) and the interaction of factors AC (Forsage and variety - 2.4%) and ABC (Forsage , planting density, variety - 1.7%). The starch content in tubers varied significantly over the years of research. So, for the Kashtak, the starch content in tubers at 2019 averaged 19.6%, at 2020 - 13.6%, at 2021 - 19.9%, for Zakhar - 18.4%, 12.6 and 18.2%, and for Rosara - 16.8%, 12.4 and 15.0%, respectively (Table 2).

Table 2. Starch content of potato tubers in the forest-steppe zone of the Chelyabinsk region, depending on agrotechniques, %.

Planting density (B)	Variety (C)	Nutrition level (D)	Forsage (A)							
			Control (without application)				Forsage (1 l/t)			
			Yield, t/ha							
			2019	2020	2021	Average	2019	2020	2021	Average
75x27 cm	Rosara	0	16.0	13.9	14.3	14.8	16.1	12.1	16.8	15.0
		1	15.9	12.5	14.2	14.2	16.6	11.6	16.7	15.0
		2	16.7	11.8	13.9	14.1	16.9	12.1	14.9	14.6
	Zakhar	0	18.3	13.4	17.4	16.3	18.5	13.4	19.4	17.1
		1	17.8	13.3	17.6	16.2	17.9	12.6	19.2	16.5
		2	18.0	12.7	17.5	16.0	17.6	12.0	17.1	15.6
	Kashtak	0	19.9	16.0	19.5	18.5	18.8	14.1	19.6	17.5
		1	19.9	14.5	21.5	18.6	19.3	13.9	18.3	17.2
		2	19.6	13.3	20.3	17.7	19.4	11.8	18.5	16.6
75x19 cm	Rosara	0	18.0	13.7	15.0	15.6	18.1	12.1	14.6	14.9
		1	16.3	12.4	14.5	14.4	16.4	12.5	16.1	15.0
		2	16.6	12.8	14.3	14.5	17.7	11.2	14.2	14.4
	Zakhar	0	18.5	12.5	18.5	16.5	20.0	11.9	19.4	17.1
		1	18.2	12.8	18.2	16.4	20.0	12.0	19.3	17.1
		2	17.4	12.4	16.5	15.4	19.2	11.8	18.7	16.6
	Kashtak	0	19.9	14.2	20.3	18.1	20.8	13.7	20.7	18.4
		1	18.9	12.4	20.4	17.3	20.8	14.0	19.3	18.0
		2	18.5	12.5	22.4	17.8	19.4	13.0	18.4	17.0
LSD ₀₅			1.76	1.21	2.07	1.67	1.76	1.21	2.07	1.67
LSD ₀₅ (A, B)			0.41	0.29	0.49	0.40	0.41	0.29	0.49	0.40
LSD ₀₅ (C, D)			0.51	0.35	0.60	0.49	0.51	0.35	0.60	0.49

Note: 0 - without fertilizers; 1 - fertilizers based on a yield of 30 t/ha; 2 - fertilizers based on a yield of 40 t/ha.

The starch content in potato tubers depended on the growing season. This indicator was the highest in the mid-season variety Kashtak (average for the experiment - 17.7%), somewhat less in the medium-early variety Zakhar (16.4%), and the lowest starch content in the tubers was the early variety Rosara (14.7%).

The use of mineral fertilizers $N_{80}P_{90}K_{100}$ did not lead to a significant decrease in the starch content of tubers (for Rosara the decrease was 0.4%, for Zakhar - 0.2%, for Kashtak - 0.3%). When using fertilizers $N_{151}P_{170}K_{207}$, the decrease of the starch content in the tubers of the studied varieties was significant (for the Rosara - by 0.6%, Zakhar - by 0.8%, Kashtak - by 0.9%), but did not cause serious concern.

When plantings were compacted from 49 to 70 thousand tubers per 1 ha, the starch content of tubers during the study period changed within the experimental error (the increase in this indicator for varieties was 0.1-0.2%).

The effect of microfertilizer Forsage was not unambiguous. A significant change in the starch content of tubers was noted for the variety Zakhar with a dense planting (75x19 cm), where an increase in this indicator by 0.8% was noted, and for the Rosara and Kashtak with a sparse planting (75x27 cm): for early season variety the starch content increased by 0.5%, while for mid-season variety it decreased by 1.2%.

4 Conclusion

1. In the conditions of rainfed agriculture at the South Ural, the moisture supply of the growing season is most important factor in obtaining the planned potato yields. The studied

potato varieties formed the highest tuber yield under the conditions of 2019 (HTC = 0.91): Zakhar - 30.1 t/ha, Kashtak - 29.9 t/ha, Rosara - 24.1 t/ha. This indicator was less in 2020 (HTC = 0.85): for the variety Zakhar - 26.5 t/ha, Kashtak - 24.3 t/ha, Rosara - 20.3 t/ha. The lowest productivity of varieties was noted in the conditions of drought in 2021 (HTC = 0.39): Zakhar - 23.2 t/ha, Kashtak - 17.9 t/ha, Rosara - 19.6 t/ha.

2. Balanced mineral nutrition provided a significant increase of potato yield and high starch content in tubers. The use of fertilizers based on the yield of tubers 30 t/ha (N₈₀P₉₀K₁₀₀) and 40 t/ha (N₁₅₁P₁₇₀K₂₀₇) increased the yield of tubers of the Kashtak by an average of 7.6 and 12.6 t/ha, respectively, Zakhar - by 7.3 and 13 .0 t/ha, and Rosara - by 5.6 and 11.1 t/ha compared with the control.

3. The change in planting density from 75x27 to 75x19 cm caused an increase in the yield of tubers: Zakhar - by 5.1 t/ha, Rosara – by 4.1 t/ha, Kashtak - by 3.8 t/ha. The starch content of tubers did not change significantly.

4. The treatment of tubers with microfertilizer Forsage (1 l/t) contributed to an increase in potato yield by 2.1-2.5 t/ha compared to the control. The starch content in tubers was different depending on the variety and planting density. This indicator significantly increased for variety Zakhar with a dense planting variant (by 0.8%), and for variety Rosara with a sparse one (by 0.5%), for variety Kashtak the starch content in tubers with a planting density of 75x27 cm decreased by 1.2 %.

5. The combination of a dense planting, the use of varieties Zakhar and Kashtak, and the use of microfertilizer Forsage provided the best result. In this case, it is possible to achieve the planned yield (with optimal moisture supply during the growing season) and a relatively high starch content in the tubers.

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