

Potato productivity against different variants of mineral nutrition and density of planting on irrigated soils in the forest-steppe of the middle Volga region

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Abstract. The article studies the reaction of new Bellarosa potato variety on the introduction of calculated doses of mineral fertilizers and the density of planting in the forest-steppe soil of the Middle Volga region. The research shows that increased nutrition appropriately raises the yield of Bellarosa potato variety. The introduction of calculated fertilizer doses aimed at obtaining 30 tons of potato per hectare has increased the yield by 8.17–10.96 t/hectare depending on the planting density. Over 4 years of research the highest yield of 31.18 t/hectare was obtained when the planting density was 66.6 thousand tubers per hectare. It's worth noting that higher planting density increased the effectiveness of the fertilizer introduced in calculated doses for this level of yield. The increase in potato harvest, in this case, was 4.22 and 5.81 t/hectare. The following increase in planting density with further enhancement of nutrition didn't show such high effectiveness. For example, in the case of fertilizer dose calculated for the yield of 35 t/hectare the increase of density to 60.6 and 66.6 thousand tubers per hectare (in comparison with 55.5 thousand) gave the rise of 1.62 and 2.62 t/hectare in yield. Over 4 years of research the introduction of the fertilizer dose calculated for the yield of 40 t/hectare gave an additional 1.60 and 2.90 tons of potato per hectare.

1 Introduction

Potato is a widely spread agricultural crop that is ranked fifth in the world according to importance after wheat, corn, rice, and barley. The nutritive value of potatoes is determined by the optimal ratio of organic and mineral substances necessary for a human. Tubers contain high-quality protein. In Russia, people call the potato “the second bread”.

The forest-steppe of the Volga region, including the Republic of Tatarstan, belongs to those areas of Russia that are favorable for potato growing due to natural and climatic reasons. This makes potato an important crop in this region. At the same time the potato growing industry of Russia and, in particular, the Republic of Tatarstan has seen major changes in recent years. Almost everywhere potato production moved to the private sector, mainly subsistence farms, which became the main producers. As a result of a constant decrease in acreage, the share of potato output of big agricultural enterprises in the Republic of Tatarstan has decreased, while the share of subsistence farms has increased.

The development of potato growing industry and related sectors is not possible without large-scale investment, both state and private. It is also necessary to use modern equipment and agricultural practices as well as to reproduce adapted national and foreign varieties early.

The acreage decreases because of the high labor intensity needed to grow the crop, weak mechanization, especially harvesting and sorting operations, and, primarily, the lack of broad organizational and scientifically grounded technology for harvesting this crop.

When developing modern technologies for potato harvesting, it is necessary to consider the right balance of nutrition which will fully satisfy the need of nutrition elements for plants. Potato varieties should be placed in a crop sequence based on the best preceding crops and scientific approach. It is also necessary to use modern methods for tubers preparation and determination of optimal depth and means of planting, as well as the feeding area of plants.

The changes in economic mechanism and reorganization of public production have negatively influenced the system of previously established connections between potato growing industry partners. Now the chain “production – gathering – storing – delivery – processing – selling” lacks integrity. The logistics services and the economic mechanism of relationships in production and delivery of the final product represent a weak link in the potato production industry.

The transition to the market economy system has led to the degradation of some potato growing industry elements in the regions of the Russian Federation. The lack of an adequate consumer market infrastructure, a

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difficult financial situation which agricultural producers got into and the dismantling of state regulation mechanisms in the potato market have sharpened the contradictions in this area. The marketing of potato has become a serious problem. The current pricing mechanisms don't allow regions that grow potatoes to get enough profit from sales, which is necessary for extended crop reproduction.

In the face of emerging state food safety system and the necessity to follow WTO regulations, officials, managers, and scientists must develop an effective organizational mechanism for potato growing industry functioning and harmonization of relationships between all links based on economic methods and creation of progressive, integrated structures, including agricultural firms and trading and purchasing enterprises. This is an important task the solution of which will ensure the increased effectiveness of the potato growing industry.

Photosynthesis is a process of absorbing and converting light energy into the chemical energy of organic compounds represented by carbohydrates, fats, and proteins. The productivity of potato mainly depends on photosynthesis. It is determined by a big number of values and the dynamic ratio of foliage surface, its life period, and the intensity of photosynthesis itself. The most important factor influencing the growth and development of plants is solar radiation that is an energy basis for plants' life. This factor is the most difficult to regulate, unlike mineral nutrition, water and temperature regimes, the content of carbon dioxide.

To further increase the productivity of potato growing it is necessary to develop new agricultural

methods of cultivation. One of the tasks in modern agriculture is to develop and implement new methods that increase the productivity of potato. One such method used currently is growing planned potato harvests which includes the development of interrelated cultivation technology elements. Their implementation will ensure reaching the planned level of yield.

Based on obtained data, some researchers indicate that the optimal foliage surface is 30–40 thousand m²/hectare. In this case, the amount of absorbed energy significantly increases [1, 2]. However, the excessive foliage surface leads to a decreased yield in harvest per foliage surface unit [3–5].

Using fertilizers is a necessary condition for getting high yields of potato. In this respect, organic fertilizers have a special value for increased yield and edibility of potato. However, organic fertilizers are decomposed slowly, and plants use them weakly during the initial period of growth. To provide potato with enough nutrition substances during the initial period of growth it is necessary to use both organic and mineral fertilizers. The latter contains nutritional substances in a form that is readily available for plants [6].

The effectiveness of introduced fertilizers mainly depends on the needs in nutrition which cultivated crop has. This is most fully satisfied by calculating the fertilizer doses based on the balance method when nutritional substances are in optimal ratio taking into consideration the biological properties of a crop [7–11].

Our research aims to find the influence of planting density and type of nutrition on the yield and quality of Bellarosa potato variety.

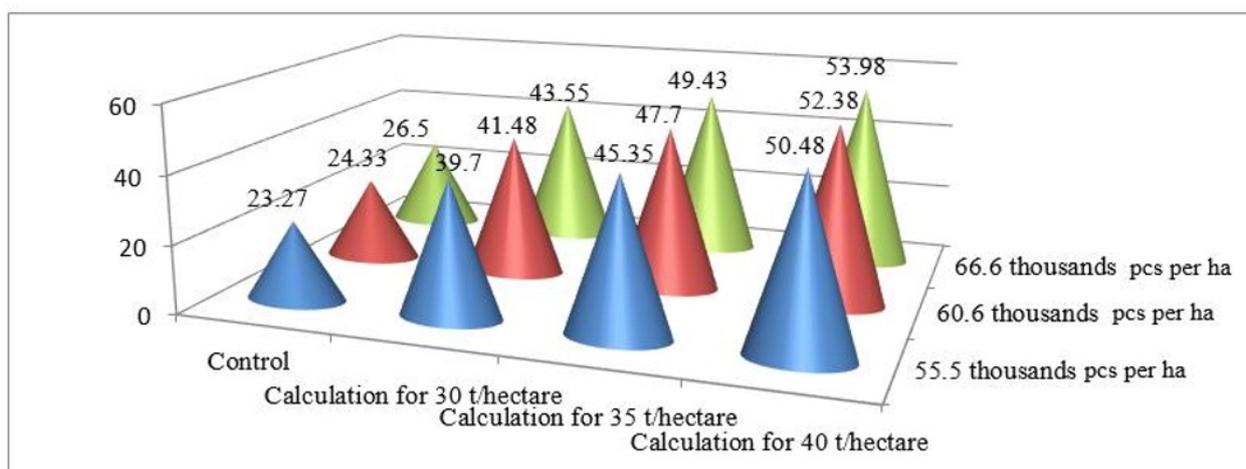


Fig. 1. The maximum foliage surface of Bellarosa potato variety plants depending on the planting area and nutrition type, thousand m²/hectare, 2012–2015.

2 Conditions, materials and methods of research

We carried out research on grey forest soil of the Republic of Tatarstan which has the following agrochemical characteristics of the topsoil: alkali-

hydrolyzable N – 129–134; P₂O₅ – 114–125; K₂O – 141–170 mg/kg.

The preceding crop is winter wheat. The planting density was: 55.5 (75 × 24 cm); 60.6 (75 × 22 cm); 66.6 (75 × 20 cm) thousand tubers per 1 hectare. The crests were formed with the inter-row spacing of 75 cm. For planting, we used tubers of average weight (60–65 g). The treatment was done with Maxim fungicide in 2012

and Prestige in 2013–2015. Potato tubers were planted to the depth of 8–10 cm. After soil contracted, we introduced Zenor herbicide (1.0 kg/hectare). We used Ridomil Gold MC and cupric substances to fight with foot rot and Aktaru against potato beetles in 2012. While planting we used four variants of nutrition: 1. Without fertilizers (control sample). 2. Manure 20 t/hectare + N_{62...77}P_{45...80}K_{80...136}. 3. Manure 30 t/hectare + N_{85...107}P_{55...95}K_{94...139}. 4. Manure 40 t/hectare + N_{110...134}P_{80...115}K_{109...156}. The planting was done on the 12 of May in 2012 and 2015 and on the 10 of May in 2013 and 2014. The area of the plot was 72 m², while the accounting area was 60 m².

3 Results and discussion

Phenological observations showed that the starting and ending time of development periods for plants in the experiment depended on the fertilizer doses introduced and the density of planting. The research shows that increased nutrition appropriately raises the yield of Bellarosa potato variety.

The biggest foliage surface in our experiments was during the flowering period. The increase in foliage surface was stimulated by a denser planting and introduction of calculated fertilizer doses. In general, over four years the foliage surface of the control sample reached 23.27–26.50 thousand m²/hectare (fig. 1) depending on the planting density.

This value increased with more fertilizer being introduced. In the variant where the amount of fertilizer was calculated for the yield of 30 t/hectare, it varied

between 39.70 and 43.55 thousand m²/hectare depending on the number of planted tubers. In the variant with the estimated yield of 40 t/hectare, it varied between 50.48 and 53.98 thousand m²/hectare.

The increase in the number of planted tubers from 55.0 to 60.60 thousand/hectare has increased the foliage surface by the values between 1.06 and 2.35 thousand m²/hectare depending on the nutrition type in the variant calculated for 35 t/hectare. The further increase in the introduced amount of fertilizer didn't enhance the foliage surface by increasing the number of plants.

The rise in planting density to 66.60 thousand tubes/hectare increased the foliage surface from 3.23 thousand m²/hectare in the control variant to 4.08 thousand m²/hectare in the variant where 35 tons of the fertilizer were introduced per hectare. The same result was in the variant with 45 tons of fertilizer per hectare where the increase in foliage surface was 3.50 thousand m²/hectare which is lower in comparison to the variants with 30 and 35 tons/hectare.

The introduction of calculated fertilizer doses aimed at obtaining 30 tons of potato per hectare has increased the yield by 8.17–10.96 t/hectare depending on the planting density. Over 4 years of research the highest yield of 31.18 t/hectare was obtained when the planting density was 66.6 thousand tubers per hectare. It's worth noting that higher planting density increased the effectiveness of the fertilizer introduced in calculated doses for this level of yield. The increase in potato harvest, in this case, was 4.22 and 5.81 t/hectare (table 1).

Table 1. The yield of potato depending on the fertilizer doses and the planting density, 2012–2015.

The amount of fertilizer	Planting density, thousand tubers/hectare	Yield, tons per hectare					± from the amount of nutrition	± from the planting density
		2012	2013	2014	2015	average		
Without fertilizer	55.5	19.62	16.60	15.52	17.05	17.20	–	–
	60.6	22.50	18.32	16.44	19.04	19.08	–	+ 1.88
	66.6	22.83	19.71	18.10	20.23	20.22	–	+ 3.02
Calculation for 30 t/hectare	55.5	29.51	26.81	23.48	29.65	25.37	8.17	–
	60.6	31.22	28.58	26.10	32.45	29.59	10.51	+ 4.22
	66.6	31.80	30.42	28.84	33.65	31.18	10.96	+ 5.81
Calculation for 35 t/hectare	55.5	35.63	33.47	31.64	34.87	33.90	16.70	–
	60.6	37.91	34.81	32.85	36.48	35.52	16.44	+ 1.62
	66.6	38.30	36.10	34.10	37.56	36.52	16.30	+ 2.62
Calculation for 40 t/hectare	55.5	39.94	38.06	36.41	38.65	38.27	21.07	–
	60.6	41.32	40.34	37.95	39.87	39.87	20.79	+ 1.60
	66.6	41.50	42.10	38.75	42.33	41.17	20.95	+ 2.90

	2012	2013	2014	2015
LSD ₀₅ A	0.69	1.36	0.65	1.09
LSD ₀₅ B	0.33	0.23	0.43	0.40
LSD ₀₅ AB	0.60	0.71	1.13	0.68

The following increase in planting density with further enhancement of nutrition didn't show such high effectiveness. For example, in the case of fertilizer dose calculated for the yield of 35 t/hectare the increase of

density to 60.6 and 66.6 thousand tubers per hectare (in comparison with 55.5 thousand) gave the rise of 1.62 and 2.63 t/hectare. Over 4 years of research the introduction of the fertilizer dose calculated for the yield

of 40 t/hectare gave an additional 1.60 and 2.90 tons of potato per hectare.

Selection plays a great role in increasing the quality of potato. However, to do selection successfully it is necessary to know inner factors that determine the tuber quality. Only objective evaluation of different quality attributes and their change depending on the potato

variety and growth conditions give the opportunity to increase requirements for the quality of potato.

In our experiments, the quality of tubers changed differently under the influence of studied agricultural techniques (table. 2).

Table 2. The quality indicators of potato tubers depending on the variety, fertilizer doses, and the planting density, 2012–2015.

Amount of fertilizer	Planting density, thousand tubers/hectare	Starch, %	Quality, %	Dry substance, %	Nitrates, mg/kg
Without fertilizers (control sample)	55.5	15.27	77.79	21.59	47.59
	60.6	15.39	74.96	21.80	47.14
	66.6	15.61	73.10	22.04	45.61
Calculation for 30 t/hectare	55.5	14.76	88.89	21.24	62.01
	60.6	14.97	86.77	21.39	60.15
	66.6	15.09	84.47	21.47	57.08
Calculation for 35 t/hectare	55.5	14.36	92.73	20.95	72.29
	60.6	14.60	90.59	21.04	70.66
	66.6	14.72	88.58	21.17	70.22
Calculation for 40 t/hectare	55.5	13.60	96.67	20.34	82.81
	60.6	13.67	94.24	20.49	81.67
	66.6	13.80	92.44	20.58	79.31

4 Conclusion

In the case of grey forest soils of the Republic of Tatarstan, the introduction of mineral fertilizers aimed at getting 30 tons of potato per hectare combined with organic fertilizer aimed at getting 35–40 tons of potato per hectare increases photosynthetic activity of plants and ensures a necessary yield of Bellarosa potato variety under the planting density of 66.6 thousand tubers per hectare. Those fertilizers calculated for 35–40 tons of potato yield per hectare decreased the content of the dry substance in tubers by 0.29–0.35 % (planting density – 60.6 thousand tubers per hectare) and 0.30–0.89 % (planting density – 66.6 thousand tubers per hectare).

The highest amount of starch (15.61 %) was in control variant tubers (without fertilizers) under the planting density of 66.6 thousand tubers per hectare. The lowest amount of starch was in the variant with 40 tons of fertilizer introduced per hectare. Here, the value varied between 13.60–13.80 % depending on the planting density.

The increase in the number of plants per square unit and the introduction of fertilizers in the planned amounts increased the share of saleable tubers in the yield. In the control variant, the number of saleable tubers was 73.10–77.79 % depending on the planting density. In the variant with 40 tons of fertilizer introduced per hectare, it was 92.44–96.67 %.

The use of fertilizers increased the content of nitrates in potato. However, their amount was lower than MPC in all the variants of the experiment.

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