The effectiveness of a new organomineral fertilizer in potato cultivation in the Middle Urals

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Abstract. Purpose of research. To study the effectiveness of a complex multicomponent organomineral fertilizer of prolonged action on potato productivity. Method. The object of research is potato. The subject of research is to study the effect of a new combined organomineral fertilizer on the growth, development, and yield of potato. The studies were conducted in the field experiment in accordance with the basic requirements for their conduct according to B.A. Dospekhov. The experimental work is based on the following methodological recommendations: Methods of state variety testing of agricultural crops; Methods of field and vegetation experiments with fertilizers and herbicides. Results: An innovative product has been developed – a mixed combined organomineral fertilizer based on natural extracted mineral raw materials, bird droppings, and waste from the coke industry. The chemical composition of the fertilizer contains 6 macronutrients of plant nutrition: nitrogen (N) 12%, phosphorus (P_2O_5) – 12%, potassium (K_2O) – 2%, sulfur (S) – 10%, calcium (Ca) - 36%, and silicon (Si) – 25%. The positive effect of fertilizers on the growth, development, yield, and quality of potato has been established. Potato yield at a dose of NP(90) and NP(120) is 5.5; 5.9 t/ha or 30; 32.2% higher compared to the control. It has been established that it is economically feasible to use NP(90) for potato, which ensures low cost and increases the profitability of the production of this crop with high product quality. Scientific novelty. For the first time in the Middle Urals, a new innovative product was created and tested – a combined mixed multicomponent fertilizer for growing potatoes, application for RF patent No. 2023100288 (incoming number 0005490) dated 09.01.2023.

1 Introduction

Fertilizers are substances used to improve the conditions for the growth and development of crops and increase their productivity. On average, in the Russian Federation, each hundredweight of nutrients included in mineral fertilizers gives an increase of 23.7 hundredweight per hectare of potato tubers. The scientifically-based use of fertilizers increases the starch content in potato, as well as sugars and vitamins. Increasing yields and improving crop quality becomes more effective with the right combination of mineral, organic, and bacterial fertilizers.

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Increasing their efficiency will reduce consumption rates, and, consequently, reduce environmental pollution, material costs and increase their payback.

With a constant annual decline in soil fertility and the high cost of mineral fertilizers in recent years, close attention has been paid to new non-traditional sources of mineral nutrition of plants located and mined in the area of cultivation of agricultural plants.

The use of local non-metallic minerals is a more economically feasible alternative to expensive mineral fertilizers. The value of these materials is also due to the fact that they improve the physico-chemical properties of soils and improve the quality of the products obtained [1-3].

Local non-metallic minerals are valuable components when used in complex multicomponent fertilizer mixtures for growing agricultural plants.

In conditions of increasing the cost of mineral fertilizers and reducing the amount of their application, organomineral fertilizers, which include local non-traditional organic-raw materials in crop cultivation technologies, are of great importance.

It should be noted that in the literature there is a large amount of data on the positive effect of silicon compounds on the yield of various crops, including the study of the diatomite effect on the yield and quality of crops. There are results of studies on the introduction of diatomite, both in pure form and mixed with bird droppings [4,5].

The development of a fertilizer system should be carried out considering the requirements of technical support and environmental restrictions, the production and resource potential of the commodity producer and the level of his qualifications [6,7]. Nevertheless, the highest effect from the use of organomineral fertilizers can be achieved when they are applied considering the soil and climatic conditions of the region and the biological characteristics of the cultivated crops. The work is devoted to the study of the action mechanisms of a new compound multicomponent granular fertilizer on the growth, development and productivity of potato, as well as on its agronomic efficiency in the conditions of the Middle Urals [8].

The complex organomineral fertilizer of prolonged action contains in its composition 6 nutrients for plants: nitrogen, phosphorus, potassium, calcium, silicon, and sulfur. The fertilizer is granular, has good flowability, and is convenient for use in agricultural production. It can be used on any type of soil and for all agricultural crops. The production of fertilizer, an innovative product, contributes to the preservation and improvement of soil fertility, increasing the yield of cultivated crops [9-10].

Chemical composition of the fertilizer: Nitrogen (N) – 12%, phosphorus (P_2O_5) -12%, potassium (K_2O) -2%, sulfur (S) – 10%, calcium (Ca) – 36%, and silicon (Si) – 25%.[11].

Potato has high requirements for nutrients in the soil. This is due to a large accumulation of dry matter in the crop and an underdeveloped root system. On average, for every 100 kilograms of tubers, potato takes out about 5 kilograms of nitrogen, 2 kg – phosphorus, and 9 kg - potassium from the soil. The relatively weak root system of plants and a large amount of nutrients consumed necessitate the introduction of increased doses of fertilizers for potato, which ensures the formation of a high yield. Under potato, first of all, organic fertilizers are applied, as well as mineral fertilizers. The need for them increases significantly in the tuber formation phase. Insufficient supply of individual nutrients causes changes in various organs and a decrease in yield. The use of organomineral fertilizers combining both organic and mineral substances with prolonged action in their composition can fully contribute to the optimization of crop nutrition and ensure high productivity and crop quality [12-15].

2 Materials and methods

The purpose of the research: To study the effectiveness of a complex multicomponent organomineral fertilizer of prolonged action on potato productivity.

The one-factor stationary experiment was laid in 2022 at the site of the educational and experimental farm on the other side of the river (FSBEI HE Ural State Agrarian University, Studenchesky village, Beloyarsky CD, Sverdlovsk region).

The type of soil on which the research was carried out is podzolized, heavy-loamy, medium-sized chernozem with a humus content of 4.6% (according to I. Tyurin), salt pH – 5.18 (according to Kappen), hydrolytic acidity - 13 mg-eq/100g of soil, the amount of absorbed bases is 32.1 mg-eq/100 g of soil, the content of easily hydrolyzable nitrogen is 208.7 mg/kg (according to Cornfield), mobile phosphorus – 243.7 mg/kg and exchangeable potassium – 252.6 mg/kg of soil (according to Kirsanov).

In 2022, spring was protracted, a complete snowfall was recorded on April 13, and the transition through 5 degrees occurred on April 9, 13 days earlier than the average long-term date. As a result, almost all winter precipitation seeped into the soil, there was no water runoff in the fields. The average monthly air temperature in April exceeded the long-term average by 2.1^0C. During the month, the amount of precipitation was at the level of 28 mm, while a significant part of them fell in the first decade.

In May, the average daily air temperature for all decades was almost at the level of the average long-term indicators. The transition of air temperature through 10^0 occurred on May 8, which is 5 days earlier than the multi-year date. The total amount of precipitation in May was 67.4 mm, which is 46% higher than normal, which favorably affected the appearance of friendly seedlings of crops.

The average daily air temperature for June was 14.6^O, which is slightly above the norm by 0.5 degrees. Precipitation fell in the second decade of the month at the level of 60% of the total. In general, in June, the total amount of precipitation was 100.6 mm, which exceeded the norm by 48%.

In the first half of July, moderately warm weather was observed, in the second part – hot with an excess of the average daily temperature by 2.4-5.0^0C. The air temperature for the month exceeded the average annual norm by 1.7^0. A small amount of precipitation fell in the first and second decades of the month, in general for the month - only 17.1 mm or 20.3% of the norm.

For the period from May to the first decade of August, the hydrothermal coefficient (HTC) was 1.22 units[11].

In August, hot weather was still observed, the average daily temperature for the month exceeded the norm by 3.9 degrees. The total amount of precipitation for the month was 13 mm or 17.5% of the norm. In August, there was hot weather with a lack of soil moisture. The HTC for August was 0.22, which corresponds to the acutely arid humidification conditions.

Thus, the weather conditions of 2022 turned out to be satisfactory for vegetable crops and potato.

The agricultural technique of potato cultivation in the experiment was generally accepted for the Middle Urals.

When laying and conducting the field experiment, the basic laws of agriculture were guided: the irreplaceability, equivalence, and interaction of all factors of plant growth and development for the study of the technological element optimization of organomineral fertilizer dose during potato cultivation.

Experiment options:

1. Without fertilizers (control)

2. OMF ($N_{30}P_{30}$)
3. OMF ($N_{60}P_{60}$)
4. OMF ($N_{90}P_{90}$)
5. OMF ($N_{120}P_{120}$)

The potato variety of the Ural selection – Alaska.

Potato. Alaska variety. Medium-ripened variety of table potato Alaska, bred by Ural breeders. The tuber is oval with small eyeholes. The peel is red. The flesh is creamy. The mass of the commercial tuber is 98-149 g. Starch content - 14.0-18.5%. The taste is good and excellent. Marketability - 86-87%. The shelf life is 95%. Alaska potato is resistant to the causative agent of potato cancer, the golden potato cyst-forming nematode. According to the Institute of Phytopathology, it is moderately susceptible to the causative agent of late blight on tops and tubers. According to the originator, it is resistant to wrinkled, striped mosaic, medium resistant to leaf twisting.

The studies were conducted in the field experiment in accordance with the basic requirements for their conduct according to B.A. Dospekhov.

3 Results of the study and their discussion

According to the results of observations on the development of potato plants (Table 1) it was found that the phase of the beginning of shoots on all studied variants occurred almost simultaneously on 18.06.

Table 1. Results of phenological observations of potato plants depending on the dose of organomineral fertilizer application, date (2022).

No.	Options	Calendar periods							
		sowing	seedlings		budding		flowering phase		Harvesting
			beginning	complete	beginning	complete	beginning	complete	
1	Control (no fertilizers)	01.06	18.06	24.06	14.07	20.07	25.07	27.07	14.09
2	NP (30)	01.06	18.06	24.06	14.07	19.07	24.07	26.07	14.09
3	NP (60)	01.06	18.06	23.06	13.07	18.07	23.07	26.07	14.09
4	NP (90)	01.06	17.06	22.06	13.07	18.07	23.07	25.07	14.09
5	NP (120)	01.06	18.06	23.06	13.07	18.07	23.07	25.07	14.09

The phase of full shoots occurred 1-2 days earlier on the variants NP (60), NP (90), NP (120), but the difference was insignificant. The budding phase began on 13.07-14.07 and practically did not depend on the doses of fertilizer application. In the future, the development took place with a slight advance of 1-2 days on experimental variants when applying various doses of fertilizer. Nevertheless, in general, it should be noted that the difference was insignificant. Cleaning of all options was carried out in one period on 14.09.

Thus, the use of a new organomineral fertilizer slightly accelerated the development of potato plants for 1-2 days.

The duration of the growing season of a particular variety depends on the speed of passage of interphase periods of plant development, which is an important condition for growing plants in northern regions. The study of the duration of interphase periods in potato plants, depending on the doses of a new organomineral fertilizer, showed (Table 2) that

with an increase in the dose of nutrients, there was a slight acceleration in the development of potato plants.

Table 2. Duration of interphase periods in potato plants, depending on the doses of organomineral fertilizer, day (2022).

No.	Options	Number of days from sowing to			
		seedlings	budding	flowering phase	harvesting
1	Control (no fertilizers)	24	50	57	106
2	NP (30)	24	49	56	106
3	NP (60)	23	48	56	106
4	NP (90)	22	48	55	106
5	NP (120)	23	48	55	106

Seedlings appeared on the 22-24 day after sowing, and on variants with the introduction of NP (60) or more, seedlings appeared 1-2 days earlier. The same pattern manifested itself in the budding phase, which occurred 48-50 days after planting. During the flowering phase, the trend persisted, and the filling of tubers went faster on experimental versions. Potato harvesting was carried out on all variants of the experiment on 106 days after planting.

Thus, the use of organomineral fertilizer has a positive effect on the development of potato plants.

The determination of biometric indicators when using a new fertilizer has shown (Table 3) that the height of plants increased with an increase in the dose of application.

Thus, on the control version (without the use of fertilizers) it was lower than the other variants by 0.18-9.96 cm and amounted to 50.34 cm. The number of stems varied according to the variants from 3.96 to 4.33 pcs with a slight increase in their number on the experimental variants. The number of leaves in plants ranged from 8.76 to 10.52 pcs per plant and was highest in the NP (90) and NP (120) variants, with the difference with the control being 1.44-1.76 pcs. This eventually affected the area of the assimilation surface.

Table 3. Biometric indicators of potato plants in the rosette phase depending on the dose of organomineral fertilizer, (2022).

No.	Options	Height, cm	Number of stems, pcs	Number of leaves, pcs	Leaf area of one plant, cm^2	Leaf area, thousand m^2 per 1 ha
1	Control (no fertilizers)	50.34	3.96	8.76	3786	17.04
2	NP (30)	50.52	4.06	8.81	3792	17.06
3	NP (60)	53.2	4.23	9.47	4007	18.03
4	NP (90)	60.00	4.33	10.20	4138	18.62
5	NP (120)	60.3	4.27	10.52	4201	18.90

Thus, the leaf area of one potato plant was higher in the variants with doses of fertilizers compared to the control by 6-215 cm^2, and the highest indicator was achieved in the variants with doses of 60 kg of nitrogen and phosphorus and higher. The area of leaves per 1 ha varied depending on the dose of fertilizer application from 17.4 to 18.9 thousand m^2/ ha, and a significant increase in this indicator was noted in 3.4 and 5 variants.

Thus, the introduction of a new organomineral fertilizer in doses of NP (60), NP (90), and NP (120) contributes to a better development of the vegetative part of potato plants, thereby increasing the assimilation surface of plants.

Our research has established that (Table 4) the use of organomineral fertilizer in doses of NP (90) and NP (120) reduced the dry matter content in tubers by 0.79-1.08%. The starch content increased by 0.3-1.3% when applying the fertilizer, and the starch yield was highest in the variants with doses of NP (90) and NP (120). The sugar content ranged from 1.9 to 2.1% in the variants, and its content in the variants with high doses was lower compared to the control by 0.16-0.18%.

Table 4. Biochemical parameters of potato tubers depending on the doses of organomineral fertilizer, 2022.

No.	Option	Dry matter, %	Starch, %	Sugars, %	Vitamin C, mg%	Nitrates, mg/kg
1	Control (no fertilizers)	24,41	15,60	2,08	14,87	68
2	NP (30)	24,43	15,90	2,06	14,43	71
3	NP (60)	24,83	16,07	2,10	13,85	94
4	NP (90)	23,62	16,80	1,92	14,48	118
5	NP (120)	23,33	16,90	1,90	14,38	153
	MPC	-	-	-	-	250

The vitamin C content varied from 13.85 to 14.87 mg% and practically did not depend on the use of fertilizer. The content of nitrates increased with an increase in the dose of fertilizer application, but in all variants it was lower than the MPC.

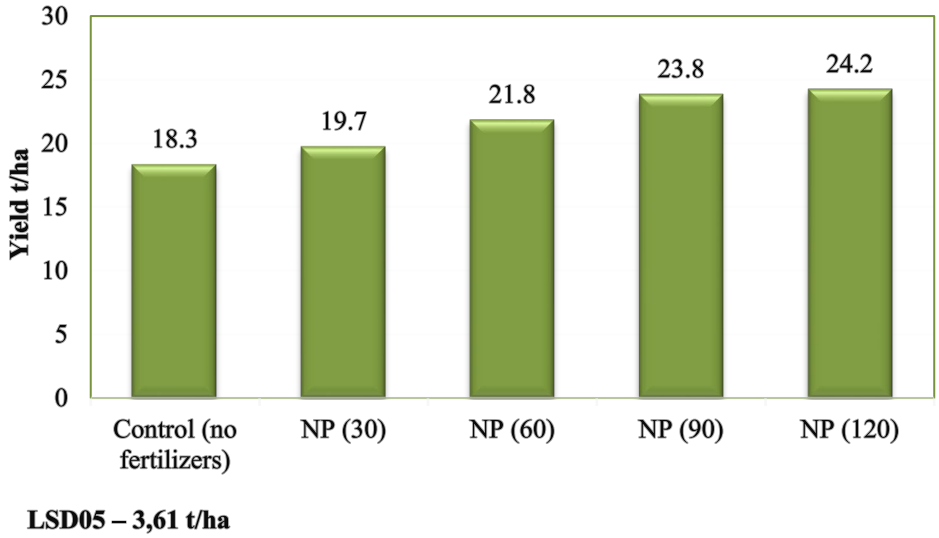

Fig. 1. Potato yield depending on the dose of fertilizer application, t/ha.

The determination of potato yield, depending on the doses of organomineral fertilizer application, showed (Fig.1) that this indicator varied from 18.3 to 24.2 t/ha, and in the variants with the introduction of NP (90) and NP (120), the difference compared to the control was mathematically significant at LSD_{05} = 3.61 t/ha.

In general, it should be noted that the introduction of mixed organomineral fertilizer, depending on the dose, gave an increase from 1.4 to 5.9 t/ha or from 7.6 to 32.2%, with the greatest effect provided by doses of NP (90) and NP (120).

Thus, the most optimal doses of organomineral fertilizer for potatoes are NP (90) and NP (120).

The efficiency of potato production, depending on the doses of fertilizers applied, is shown in Table 5.

Table 5. Potato production efficiency.

Indicators	Control	NP (30)	NP (60)	NP (90)	NP (120)
Yield, t/ha	18.3	19.7	21.8	23.8	24.2
Production cost of 1 t, rubles	11133.21	10615,15	9874.01	9299.00	9348.05
Commercial cost of 1 t, rubles	11912.53	11358,21	10565.19	9949.93	10002.42
Sale price of 1t, rubles	17470	17470	17470	17470	17470
Profit per 1t, rubles	5557.47	6111,79	6904.81	7520.07	7467.58
Profitability, %	46.7	53.8	65.4	75.6	74.7

Analyzing the data in Table 5, it can be concluded that the highest profitability was obtained when applying fertilizers at a dose of NP (90) – 75.6%, due to the low cost of production compared to other options (9299.00 rubles/ton), the lowest profitability was obtained in the control version of 46.7%.

4 Conclusion

Based on the results of the research work in 2022, the following conclusions can be drawn:

1. On the basis of advanced domestic experiment, an innovative product has been developed on the basis of the FSBEI HE Ural State Agrarian University – a mixed combined organomineral fertilizer based on natural extracted mineral raw materials, bird droppings and waste from the coke-chemical industry.

The chemical composition of the fertilizer contains 6 macronutrients of plant nutrition: nitrogen (N) 12%, phosphorus (P_2O_5) – 12%, potassium (K_2O) – 2%, sulfur (S) – 10%, calcium (Ca) - 36%, and silicon (Si) – 25%.

2. The use of organomineral fertilizer has a positive effect on the development of potato plants.
3. The introduction of organomineral fertilizer in doses of NP(60), NP(90), and NP (120) contributes to the better development of the vegetative part of potato plants.
4. The content of vitamin C in tubers practically did not depend on the dose of application, the content of nitrates increased with an increase in the dose of fertilizers, but did not exceed the MPC in all variants.
5. By means of conducting a field experiment with potato, the high efficiency of the developed fertilizer was established, the doses of its main application to the soil were optimized. The positive effect of fertilizers on the growth, development, yield, and quality of potato has been established. Thus, potato yield at a dose of NP (90) and NP (120) is 5.5; 5.9 t/ha or 30; 32.2% higher than the control variant without fertilizers.

6. Calculations of economic efficiency have established that it is economically feasible to use NP(90) for potato, which ensures low cost and increases the profitability of the production of this crop with high product quality.

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