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Effect of Bio-Organic-Mineral Fertilizers on Quality, Yield, and Safety Indicators of Potatoes under Conditions of Akmola Region

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Abstract: This article shows the results of determining the effect of bio-organic-mineral fertilizers on the accumulation of Pb, Cd, As, and Hg and on the quality, and yield indicators of potatoes treated by plant development stages. According to the results of laboratory analysis, the qualitative and quantitative content of dry matter, starch, nitrates, vitamin C, lead, cadmium, arsenic, and mercury isolated from extracts treated with bio-organic-mineral fertilizers was determined. The effect of two bio-organic-mineral fertilizers and the stage treatment by these fertilizers on the content of dry matter, starch, nitrates, vitamin C, Pb, Cd, As, and Hg in potatoes of Nevsky variety was studied. It was shown that the bio-organic-mineral fertilizers have a slight impact on the content of toxic elements in potato tubers and, therefore, on the quality of the product based o-n them. When treating potatoes at the stages of full sprouts + flowering + budding with Bio ZZ solution and at the stages of full sprouts + flowering + budding with WORMic solution, in which an increase of quality indicators of potato tubers was observed, a favorable effect of bio-organic-mineral fertilizers on potato productivity was observed. The data of this study reflect a specific pattern that bio-organic-mineral fertilizers can increase marketability, improve the quality and productivity of potato seeds, and have a positive effect on potato safety.

Keywords: Potato, Bio-Organic-Mineral Fertilizers, Quality Indicators, Marketability, Toxic Elements

Introduction

As a result of the scientific and technological revolution, the pressure of anthropogenic factors on humans, living organisms, and the natural environment is continually increasing, thus about 6 thousand chemical compounds enter the environment annually, and 500 thousand new drugs are introduced through the commercial market per year. These chemical compounds include not only substances that directly impact the environment, but also their metabolites formed as a result of biotic and abiotic factors (Dubinin, 1977; Melnikov, 1990).

Potatoes are one of the most common crops in agriculture in the Republic of Kazakhstan, intended for use as a raw material in the production and nutritional, fodder properties. Today the cultivated area in Kazakhstan is 160-180 thousand hectares. It can be said that weather and soil conditions in our country are ideal for the cultivation of potato seeds. The data accumulated over many years shows that the potato yield depends on the quality of seeds (Toqbergenova, 2008).

Potatoes use many chemical elements for growth and development-nitrogen, phosphorus, potassium, calcium, magnesium, sulfur, boron, iron, and copper, these elements come through the root system from the soil. The need for nutrients increases as the top grows and reaches its maximum during the flowering stage. Potatoes consume potassium and phosphorus a lot, especially in July, during tuber formation (Zykin, 2005).

Potatoes are one of the most important products of the daily human diet. The food, fodder, and technical and medical importance of potatoes are determined by the

chemical composition of their tubers (Babayev *et al*., 2010). Today, many types of research are carried out on increasing the yield and quality of agricultural products by developing new and improving existing cultivation technologies, obtaining highly productive original potato seeds by microtonal propagation (Sharipova *et al*., 2016; Tokbergenova *et al*., 2017; Suraganov *et al*., 2018a, 2018b), studying the effect of different fertilizer systems on the content of toxic elements (Shlyk *et al*., 2014; Litsukov, 2011; Tsarenko and Ovsyanko, 2016; Durnov, 2009).

The constant exploitation of the soil decreases its fertility. The soil cannot provide the plants with all the nutrients they need on their own. Mineral fertilizers are good for the plants, but they pollute the soil. As a consequence, the soil becomes polluted, its acidity increases, and the development of microorganisms slows down, which negatively affects the quality of the grown crop. Organic additives keep the soil healthy, but they can't provide the plants with all the nutrients they need to grow well. Human-created organic-mineral fertilizers helped to solve the double problem: To keep the soil in good condition and create the most comfortable conditions for plant growth. The name "organic-mineral" suggests that it is a fertilizer made from a mixture of organic and mineral substances. They are obtained by enriching organic materials with macro-and micronutrients. The basis is an organic substance, which can be up to 40% of the total volume.

The above shows the relevance of research on the use of organic-mineral fertilizers in agricultural technology to improve the productivity of potato crops.

For the first time, taking into account the positive and negative biological characteristics, a perennial herb from the Solanaceae family-potato (Solanum tuberosum) –has been considered. Effective innovative approaches to the economic use of the potential of a crop in specific climatic conditions have been created.

The purpose of the research work is to study the effect of bio-organic-mineral fertilizers on yield, marketability, quality indicators, and accumulation of toxic elements in potatoes under conditions of Akmola Oblast. In the hill-lowland zone of the Akmola region, meteorological conditions play a decisive role in the growth and development of potato plants. The main feature of the climate is its sharp continentality, which is manifested in the significant amplitude of fluctuations in air temperature, dry air, and an insignificant amount of atmospheric precipitation.

Research Objectives

- Study the effect of bio-organic-mineral fertilizers on quality indicators of potatoes
- Study the effect of bio-organic-mineral fertilizers on the accumulation of toxic elements in potato tubers
- Determine the effect of bio-organic-mineral fertilizers on potato productivity

Materials and Methods

The object of the study is Nevsky released a variety of potatoes in the Akmola Region; this variety is bred by crossing Veselovsky and Katahdin varieties. The plant is well foliated; the stem is green; the leaves are dark green, penetrating, venation pattern is coarse. Lobes have long stalks; the terminal lobe is rounded with a heart-shaped base; lobes are mostly angular. Lobing is average; flowering is significant but short. Buds are large; bells are dark green; flowers are white, large with long pointed tips, sometimes forming berries. Tubers are white, rounded, and round-oval; eyes are medium-deep and numerous; the flesh is white, slightly darker on the cut. The variety is good for early potatoes in fallow land and under irrigated conditions. In the field, potatoes are affected by blight, viral diseases, and scabs. The storability of tubers is good, however, their dormant period is short, an early awakening of tuber eyes (Abdullaev *et al*., 2010). The advantage of the variety: Stable yield and relatively weak damage. The variety is resistant to cancer, relatively resistant to viruses, and stem rot, and moderately resistant to blight and scab. Very poorly tolerates breaking of sprouts before planting (Zykin, 2005, p. 10; Abdullaev *et al*., 2010, p. 30).

Field experiments were conducted in 2020 at "Kokshetau experimental-production farm" LLP, in the Republic of Kazakhstan, Akmola Region, Zerenda district.

Laboratory analysis of the biochemical composition and quality indicators of potato tubers was conducted in the research laboratory of the "National Center of Expertise and Certification" JSC Akmola branch, Kokshetau.

Meteorological conditions, in the hill-plain zone of the Akmola Region, play a decisive role in the growth and development of potato plants. The main feature of the climate is its sharp continentality, which is manifested by a large amplitude of fluctuations in air temperature, air dryness, and a small amount of precipitation.

The main indicators-precipitation and temperature regime show that the conditions for growth and development of potato plants are satisfactory. The average monthly temperature in May was +16,5°C, which is 5,0°C higher than the level of long-time average annual data, while precipitation in May was 13,5 mm, which is 23,9 mm lower than the level of long-time average annual data (Table 1).

During the growing season (May-August) precipitation was 168,5 mm, which is 59,1 mm lower than the long-time average annual level (Table 1). The temperature in August exceeded the long-term average by 2,4 degrees, resulting in a shorter growing season and faster maturation of potatoes.

The temperature in June was 1,1 and 1,0°C higher than the long-time average annual indicator. Precipitation in June was at the long-time average annual level and amounted to 54,9 mm (Table 1). The temperature in July (20,4°C) was 2,2°C higher than the long-time average

annual level and in August (18,8°C) 2,4°C higher than the long-time average annual level. Low precipitation was observed in June (15,0 mm) and August (11,9 mm). Precipitation during the critical periods of plant development in July in the amount of 98,4 mm, allowed us to form an average level of potato yield for our zone.

Technological measures were carried out per the recommendations and methods of the experimentation (Dospekhov, 1985; Andryushina and Batsanov, 1967). Field experiments were carried out in a 3-fold replication. Farming techniques in the experiments are zonal. The experimental plot area is 100 m2, and the placement of plots is randomized. Forecrop is black fallow. Soil-ordinary chernozem, mechanical composition-heavy loam. The potatoes were planted on May 11, 2020.

Two bio-organic-mineral fertilizers, BioZZ and WORMic, were used to treat potato plants. Seed treatment with bio-organic-mineral fertilizers was carried out during stages of plant development according to the experimental design. bio-organic-mineral fertilizers were used in the doses recommended by the manufacturing institutions (Green Service, 2021).

The experimental design included the following options.

Experiment 1 Effect of treatment with bio-organic-mineral fertilizer BioZZ on yield, marketability, quality indicators, and accumulation of toxic elements in potatoes depending on the stage of plant development:

1- Control (water)
2- Treatment in the stage of full sprouts
3- Treatment in the stage of flowering
4- Treatment in the stage of budding
5- Treatment in the stage of full sprouts + flowering + budding

Experiment 2 Effect of treatment with bio-organic-mineral fertilizer WORMic on yield, marketability, quality indicators, and accumulation of toxic elements in potatoes depending on the stage of plant development:

1- Control (water)
2- 2-Treatment in the stage of full sprouts
3- Treatment in the stage of flowering
4- Treatment in the stage of budding
5- Treatment in the stage of full sprouts + flowering + budding

BioZZ and WORMic are complex microbiological organic-mineral liquid fertilizers. Produced with commercial worms and a complex symbiosis of insects, fungi, bacteria, and microorganisms that revive the yield and fertility of tired degraded soils and closed greenhouse soils. They contain Amino acids, phytohormones, auxins, peptides, humins, and fulvates. BioZZ: N, P, K, Ca, Na, Mg, B, Fe, ZamZam...pH 6-8. WORMic: N, P, K, Ca, Na, Zn, Cu, Mn, Zam Zam…pH 6-8

These fertilizers have a powerful agrochemical effect. These fertilizers improve plant cellular respiration, photosynthesis, flowering, and growth. These fertilizers increase the Immunity of plants, resistance to diseases, stresses, and pests, seed germination, quantity, quality of the crop, and storage time. These fertilizers stimulate a gas exchange in the root system. Replenish the balance of micro and macronutrients. Shorten the maturation period. Increase the oil, sugar, protein, vitamins, and gluten content of the fruit. Applicable for all types of plants. Not dangerous for people and animals. Not harmful to microflora and microfauna. Allow getting the delicious healthy organic products suitable for the production of baby food.

The fertilizers significantly suppress the causative agents of snow mold, Septoria blight of grain legumes and cereals, and Fusarium head and root blight. Eliminate chlorosis. Suppress spot disease, Rhizoctonia blight, late blight, powdery mildew, smut, fungus, and scab. Preventing bacterial blight, thrips, aphids, mites, and psyllas. Soil antibiotics, bactericides, and fungicides are produced in the gut walls and tissues of the earthworm itself. The protection effect is enhanced by bacteria, sodium, iron, copper, manganese, calcium, magnesium, zinc, and boron. The fertilizers wake up and revive plants after exposure to pesticides. Enhance the effect of mineral fertilizers, allow to reduce doses of fertilizers up to 50%, while maintaining high yields and great economic effect. Compost organic residues in the soil, and improve the humus structure (Green Service, 2021).

Table 1: Comparative characteristics of meteorological conditions, 2020

	Precipitation, mm		Air temperature, °C	
Month	Long-time average annual	2020	Long-time average annual	2020
April	20,7	29,7	4,2	8,8
May	37,4	13,5	11,5	16,5
June	52,5	15,0	17,3	16,3
July	75,2	98,4	18,2	20,4
August	41,8	11,9	16,4	18,8
The growing season (May-August)	227,6	168,5	13,5	16,2

Table 2: Quality of potatoes depending on the stages of fertilizer application (2020)

No.	Treatment stages	Replication	BioZZ				WORMic			
			Mass fraction of dry matter, %	Mass fraction of starch, %	Nitrates: mg/kg, max	Vitamin C, %	Mass fraction of dry matter, %	Mass fraction of starch, %	Nitrates: mg/kg, max	Vitamin C, %
1	Control without treatment	I	23,8	16,9	148	14,2	23,4	17,1	141	14,3
		II	23,6	16,8	158	15,1	22,8	15,9	155	14,6
		III	24,6	17,2	142	13,0	22,6	16,2	153	12,8
		$\sum$	72	50,9	448	42,3	68,8	49,2	449	41,7
		$\sum_{ave.}$	24	16,97	149,3	14,1	22,93	16,4	149,67	13,9
2	full sprouts	I	23,6	18,2	151	15,1	23,5	17,85	165	15,6
		II	23,5	18,9	149	17,0	23,4	17,6	168	16,9
		III	24,7	19,3	151	16,2	23,9	18,1	162	14,3
		$\sum$	71,8	56,4	451	48,3	70,8	53,55	495	46,8
		$\sum_{ave.}$	23,93	18,8	150,3	16,1	23,6	17,85	165	15,6
3	flowering	I	23,9	17,7	150	14,7	24,0	17,9	155	15,2
		II	23,7	17,8	151	16,6	23,4	17,1	166	16,2
		III	23,9	17,9	148	15,3	23,9	17,6	158	13,7
		$\sum$	71,5	51,9	449	42,9	71,3	52,6	479	45,1
		$\sum_{ave.}$	23,83	17,3	149,7	14,3	23,77	17,53	159,67	15,03
4	budding	I	24,2	17,9	149	15,1	23,8	18,2	153	15,7
		II	23,5	18,0	148	16,2	23,2	16,9	162	16,2
		III	24,2	18,1	145	15,7	23,2	17,2	161	14,1
		$\sum$	71,9	54	442	47	70,2	52,3	476	46
		$\sum_{ave.}$	23,97	18	147,3	15,7	23,4	17,43	158,67	15,3
5	full sprouting + flowering + budding	I	24,2	20,1	158	18,1	24,2	20,5	170	18,6
		II	23,8	21,3	161	18,6	24,2	19,8	178	19,0
		III	24,6	22,6	162	18,2	24,1	19,7	168	15,9
		$\sum$	72,6	64	481	54,9	72,5	60	516	53,5
		$\sum_{ave.}$	24,2	21,3	160,3	18,3	24,12	20	172	17,83

Results

According to the results of the study of the biochemical composition of potatoes treated with complex bio-organic-mineral fertilizers depending on the stage of plant development, the content of the mass fraction of starch in the variant treated with BioZZ during the stages of full sprouts + flowering + budding showed the highest result and was 21,3%, exceeding the control sample by 4,33%. The content of the mass fraction of starch in the variant treated with BioZZ solution in the stages of full sprouts was 18,8%. A high result on the content of mass fraction of starch was observed in the variant treated with WORMic solution in the stages of full sprouts + flowering + budding and amounted to 20.0%, which indicates a positive effect on the starch content of the three-stage treatment of potato plants (Table 2).

The study of the composition of potato samples treated with complex bio-organic-mineral fertilizers BioZZ and WORMic showed that the dry matter content in all variants was at the level of the control sample.

In the variant treated at full sprouting + flowering + budding stages with BioZZ solution, the nitrate content was 160,3 mg/kg. The highest result for the content of nitrates was observed in the variant treated with WORMic solution in the stages of full sprouts + flowering + budding and was 172,0 mg/kg, which exceeds the control variant by 22,33 mg/kg. At the same time, the content of nitrates in potato tubers in all variants was at the level of MAC (Maximum Allowable Concentration).

Treatment of experimental variants with complex bio-organic-mineral fertilizers has a positive effect on the content of vitamin C, the indicators of which in all cases exceed the control variant. The study of the composition of potato samples treated with bio-organic-mineral fertilizers compared with the control sample showed that the content of vitamin C in the variant with BioZZ, treated in the stage of full sprouts exceeded by 2,0%, in the variant with WORMic treated in the stage of full sprouts, as well as in the stage of budding, vitamin C content was 15,6 and 15,3% respectively. When treated with WORMic solution in the stages of full sprouts + flowering + budding, this figure was 17,83%. The highest rate of vitamin C content was observed in the variant treated in the stages of full sprouts ± flowering ± budding with BioZZ solution, 18,3%, which was 4,2% higher than in the control variant.

Thus, the highest efficiency was shown in the variants where the potato was treated with BioZZ solution in the stage of full sprouts + flowering and with WORMic solution in the stage of full sprouts + flowering. The quality indicators of the treated potato tubers increased, that is, the content of dry matter, starch, and ascorbic acid. At the same time, the content of nitrates in potato tubers in all variants was at the level of MAC (Maximum Allowable Concentration).

The accumulation of heavy metals in products can harm humans and animals. Therefore, reducing the intake of toxic elements in crop products is one of the main objectives in the cultivation of crops (Litsukov, 2011).

Cadmium is a highly toxic substance, with a lethal dose to humans of 150 mg/kg body weight. Like many other heavy metals, cadmium has a clear tendency to accumulate in the body, its half-life is 10-35 years. By the age of 50, its total weight content can reach 30-50 mg.

Potatoes are the most common and popular root crop among Russians.

Consumption of potatoes with high cadmium content causes moderate to moderate toxic effects in humans. Cadmium can damage the kidneys and liver, disrupt blood pressure, and is a factor in the development of hypertension. It also leads to pulmonary dysfunction, skeletal deformities, and involuntary bone fractures because it can leach calcium out of the body. Cadmium excess can also cause malignant tumors (TIVL, 2019).

Our studies of the biochemical composition of potatoes on the content of toxic elements treated with bio-organic-mineral fertilizers WORMic and BioZZ depending on the stage of plant development showed the following results (Fig. 1).

In the control variant, the lead content was 0,081 mg/kg, which was lower than MAC by 0,419 mg/kg. In variants treated with bio-organic-mineral fertilizer WORMic in the stage of full sprouts and WORMic in the stage of full sprouts + flowering + budding, lead content was 0.08 mg/kg, which was 0,42 mg/kg lower than MAC.

Cadmium content in potato tubers was insignificant, its content ranged from 0,0063 mg/kg in WORMic variants during the full sprouts stage to 0,0067 in WORMic variants during the budding stage and WORMic during full sprouts + flowering + budding, which is 5 times lower than MAC.

When considering the results of the study of the composition of potatoes, treated with bio-organic-mineral fertilizer BioZZ, depending on the stage of plant development, the content of toxic elements in the control variant of lead was 0,081 mg/kg, which was lower than MAC by 0,419 mg/kg.

In variants treated with BioZZ solution in the stage of full sprouts, lead content was 0,077 mg/kg. The content of lead in the variant treated with BioZZ bio-organic-mineral fertilizer in the stage of budding was 0,08 mg/kg.

The intake of cadmium into potato tubers was insignificant, its content ranged from 0,0058 mg/kg in the BioZZ variant at the stage of budding to 0,0064 in the BioZZ variant at the stage of full sprouts (Fig. 1).

According to Fig. 2, the content of arsenic in all variants was less than 0,02 mg/kg with a maximum allowable concentration of 0,2 mg/kg. The content of mercury also did not exceed MAC and was less than 0,0025 mg/kg in all tested variants.

Consequently, treatment with bio-organic-mineral fertilizers WORMic and BioZZ depending on the stage of plant development has no negative impact on the accumulation of toxic elements in potato tubers.

Studies of potato productivity with the treatment of bio-organic-mineral fertilizers WORMic and BioZZ depending on the stage of plant development showed the following results (Table 3).

As a result of the research, it was determined that treatment with bio-organic-mineral fertilizer WORMic has a positive effect on potato yields. In all studied variants, there was an increase in yield compared to the control variant.

In the variant treated with WORMic solution at the stages of full sprouts and with WORMic solution during the flowering stage, the yield was approximately at the same level of 14,1-14,3 t/ha, which exceeds the control sample by 2,2-2,4 t/ha. In the variant treated with WORMic solution in the stage of budding, the yield was 13,1 t/ha.

At the same time, the highest marketability of 96% is noted in the control variant. Compared to the control variant, the index of marketability in the variants treated with WORMic solution in the stage of full sprouts and with WORMic solution in the flowering stage was 10-11% lower, respectively.

When studying the productivity of potatoes treated with bio-organic-mineral fertilizer BioZZ depending on the stage of plant development, the following results were obtained.

The lowest yield of 1,09 t/ha was shown by the variant treated with BioZZ solution in the stage of budding, where the deviation from the control was 5,9 t/ha. Treatment with bio-organic-mineral fertilizer BioZZ in stages of full sprouts + flowering + budding showed a yield of 12,4 t/ha.

The fertility depended on tuber size and the number of tubers in the seedbed and averaged 71-92%. In the variant treated with bio-organic-mineral fertilizer BioZZ in the stages of full sprouts + flowering + budding, the marketability was 89%, higher than the control variant by 8%.

In comparison with the control variant, the marketability in variants treated with bio-organic-mineral fertilizer BioZZ in the stage of flowering and bio-organic-mineral fertilizer BioZZ in the stage of full sprouts was the lowest at 71-74% respectively.

Table 3: Productivity of potatoes depending on the stages of mineral fertilizer application (2020)

	BioZZ			WORMic		
Variant	Yield, t/ha	Yield, t/ha	Deviation from the control	Marketability, %	Deviation from the control	Marketability, %
Control (water)	16,8	11,9	-	96	-	81
Treatment in the stage of full sprouts	14,3	14,3	+2,4	86	-2,5	74
Treatment in the stage of flowering	14,0	14,1	+2,2	85	-2,8	71
Treatment in the stage of budding	10,9	13,1	+1,2	90	-5,9	92
Treatment by stages of full sprouting + flowering + budding	12,4	18,6	+6,7	91	-4,4	89

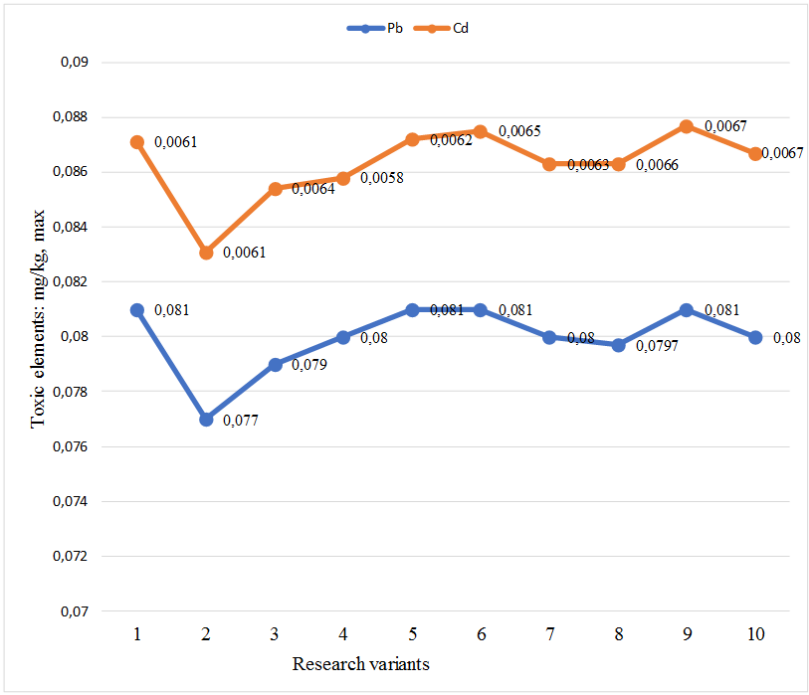

Fig. 1: The content of toxic elements in potato tubers depending on the stages of fertilizer treatment (2020) Names of the research variants: 1 -Control (no treatment); 2 -BioZZ in the stage of full sprouts; 3 -BioZZ in the stage of flowering; 4 -BioZZ in the stage of budding; 5 -BioZZ in the stage of full sprouts + flowering + budding; 6 -Control (no treatment); 7 -WORMic in the stage of full sprouts; 8 -WORMic in the stage of flowering; 9 - WORMic in the stage of budding; 10 -WORMic in the stage of full sprouts + flowering + budding

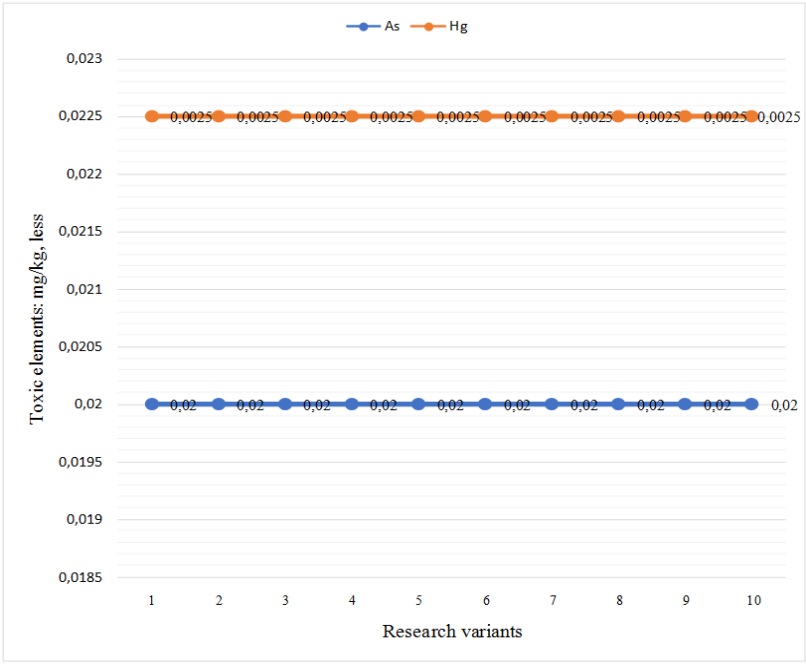

Fig. 2: The content of toxic elements in potato tubers depending on the stages of fertilizer treatment (2020) Names of the research variants: 1 -Control (no treatment); 2 - BioZZ in the stage of full sprouts; 3 - BioZZ in the stage of flowering; 4 -BioZZ in the stage of budding; 5 -BioZZ in the stage of full sprouts + flowering + budding; 6 -Control (no treatment); 7 -WORMic in the stage of full sprouts; 8 -WORMic in the stage of flowering; 9 -WORMic in the stage of budding; 10 -WORMic in the stage of full sprouts + flowering + budding

Discussion

The effectiveness of the use of organometal fertilizers is confirmed by the works of several scientists (Fedotova *et al*., 2002). Peat humic pelleted fertilizers were tested for many years and adopted for mass production in various organizations in scientific and industrial areas of Russia, Ukraine, and Belarus. Peat humic pelleted fertilizers were developed by specialists of St. Petersburg institutes. It was found that the use of pelleted fertilizers gives a reliable increase in yield by 15-20% on the background of the improvement of product quality and allows farmers to apply fewer mineral elements by 20-25%. In most experiments, the advantage of organomineral fertilizers compared to mineral fertilizers and organic fertilizers applied in equivalent doses has been proven (Lyubimskaya and Kuznetsov, 2018).

The results of our studies reflect a certain pattern of increasing quality indicators when using bio-organic-mineral fertilizers. The positive effect of organomineral fertilizers on the growth and development of potatoes is also observed by Russian scientists. For example, the work of (Burmistrova *et al*. 2012) discusses the effectiveness of the use of organomineral fertilizers when growing potatoes, yield increase by 12,20%, and an increase in starch content in tubers by 0,5...1,4% were observed.

According to Sharipova's research, with the improvement of mineral nutrition conditions, potato yield increased from 18,6 to 47,3% (Sharipova *et al*., 2016).

The use of effective fertilizer systems in various soil and climatic conditions is an important factor in increasing the potato yield, improving the tuber quality, increasing their starch content, and reducing nitrates. When combinations and rates of fertilizers in organo-mineral systems were optimized, potato yields significantly increased concerning the control on sod-podzolic soils to 31–38 t/ha in the Non-Chernozem zone in the Central region and the North-west region, to 20-22 t/ha in the north in the European parts, to 19 t/ha in marginal conditions on the permafrost taiga soils of Central Yakutia and 6–7 t/ha beyond the arctic circle. The parameters of environmentally safe fertilizer systems were established, ensuring that potatoes could be sustainably produced as the population's most important food product (Merzlaya *et al*., 2021).

The study of the effect of bio-organic-mineral fertilizers on potatoes showed that the yield, marketability, and quality indicators of potatoes, as well as the content of toxic elements in potatoes, differ from the control sample.

According to the results of laboratory analysis, the mass fraction of dry matter in the variants treated with bio-organic-mineral fertilizer BioZZ was at the same level as the control variant and varied from 23,7 to 24,2%. The indicators of the mass fraction of dry matter in the variants treated with bio-organic-mineral fertilizer WORMic exceeded the control variant by 1-2%.

The results of the study reflect a certain pattern of increasing the quality indicators when using bio-organic-mineral fertilizers, compared with the control variant, the use of bio-organic-mineral fertilizer BioZZ increases starch content in variants with the treatment in the stage of complete sprouts by 1,83%; with treatment during the flowering stage -0,33%; with treatment during the budding stage -1,03% and in the variant with treatment in stages of complete sprouts + flowering + budding-4,33%. In the control variant, where the effect of treatment with bio-organic-mineral fertilizer WORMic was determined, the average amount of starch mass fraction was 16.4%. In variants treated in the stage of full sprouts, the starch content was 17,85%. Mass fraction of starch was at the same level in the variants treated at the flowering stage 17,53 and 17,43% in the variant treated at the stage of budding. The highest indicator of the mass fraction of starch in the laboratory analysis equal to 20% was observed in the samples treated with bio-organic-mineral fertilizer WORMic in the stages of full sprouts + flowering + budding.

The content of nitrates in the variant treated with BioZZ in the stage of full sprouts was 150,3 mg/kg; in the variant treated with WORMic in the stage of full sprouts, it was 165,0 mg/kg.

Treatment of experimental variants with complex bio-organic-mineral fertilizers has a positive effect on the content of vitamin C, the indicators of which in all cases exceed the control variant. When treated with WORMic solution in the stages of full sprouts + flowering + budding, this figure was 17,83%. The highest rate of vitamin C content was observed in the variant treated in the stages of full sprouts + flowering + budding with BioZZ solution, 18,3%, which was 4,2% higher than in the control variant.

Studies of the biochemical composition of potatoes on the content of toxic elements with treatment by bio-organic-mineral fertilizers WORMic and BioZZ depending on the stage of plant development have shown that treatment of plants with WORMic solution during the flowering stage amounted to 0,0797 mg/kg of lead, which was 0,4203 mg/kg lower than MAC. The content of lead in the variant treated with bio-organic-mineral fertilizer WORMic in the stage of budding was at the level of the control variant. The variant treated with BioZZ solution in the stage of full sprouts + flowering + budding was at the control level. Treatment of plants with BioZZ solution during the flowering stage showed no more than 0,079 mg/kg of lead.

It should be noted a slight increase in cadmium content by 0,0001-0,0002 mg/kg during the treatment with bio-organic-mineral fertilizer WORMic. In terms of cadmium content, the variant treated with BioZZ solution in the stages of full sprouts + flowering + budding was at the same level as the control variant

with 0,0062 mg/kg. The lowest cadmium content of 0,0058 mg/kg was observed in the variant treated with BioZZ solution in the stages of budding.

The plants treated with bio-organic-mineral fertilizers WORMic and BioZZ did not exceed the maximum allowable concentration of arsenic and mercury and were less than 0,02 and less than 0,0025 mg/kg.

The highest yield of potatoes showed the variant treated with bio-organic-mineral fertilizer WORMic in the stages of full sprouts + flowering + budding, which amounted to 18,6 t/ha. This result exceeds the control variant by 6,7 t/ha. Productivity in the variant treated with WORMic solution in the stage of full sprouts + flowering + budding was 91% and with WORMic solution in the stage of budding -90%. When treated with bio-organic-mineral fertilizer BioZZ during the stage of full sprouts and BioZZ during the stage of flowering, the yield was at the same level and amounted to 14,0-14,3 t/ha. The highest yield of 92% was observed in the variant treated with bio-organic-mineral fertilizer BioZZ during the stage of budding.

Conclusion

Thus, it is to be concluded that the highest efficiency was shown in the variants where the potato was treated with BioZZ solution in the stage of full sprouts + flowering and with WORMic solution in the stage of full sprouts + flowering. The quality indicators of the treated potato tubers increased, that is, the content of dry matter, starch, and ascorbic acid. At the same time, the content of nitrates and toxic elements in potato tubers in all variants was at the level of MAC (Maximum Allowable Concentration). The treatment with bio-organic-mineral fertilizers WORMic and BioZZ depending on the stage of plant development has no negative impact on the accumulation of toxic elements in potato tubers. At the same time, WORMic has a positive effect on productivity. The cultivation of potatoes, treated with bio-organic-mineral fertilizers WORMic and BioZZ depending on the stage of plant development, improve quality indicators, and marketability, and increases yields of potato seeds.

Author's Contributions

All authors equally contributed to this study.

Ethics

This article is original and contains unpublished material. The corresponding author confirms that all other authors have read and approved the manuscript and that ethical issues have been involved.

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