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Assessing the effect of joint application of mineral fertilizers and biohumus on potato yield quality indicators

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ABSTRACT

Background: The production of "healthy food" heavily relies on fertilizers, which also nurture the plants. While chemical fertilizers offer short-term benefits, they can have a negative long-term environmental impact. Utilizing both organic and chemical fertilizers together can mitigate ecological pollution, addressing concerns about food security.

This can also increase crop yield and reduce chemical fertilizer use. As a result, nutritionally rich products will be produced. In all agricultural zones of the republic, potatoes are cultivated as the second bread for the population.

Objective: Researchers aim to evaluate the effects of combining mineral fertilizer with biohumus on potato yield, its structural elements, and its chemical composition in brown soil.

Methods: A study was conducted in 2020-2022 in the Sisian region of the Syunik region of the Republic of Armenia in a randomized complete block design (RCBD), with five treatments and three replications to see how the combined application of increasing doses of mineral fertilizers and biohumus affected the quality of Impala and Arinda potato harvests.

Results: The combined application of mineral and organic fertilizers increased soil humus content by 31.03-96.55% compared to the control group. Moreover, nitrogen, phosphorus, potassium, and nitrogen content increased significantly. Combining biohumus - fon+5.0; 10.0; 20.0 t/ha improved potato yield from 39.8-40.5%; 53.2-56.5%; 72.69-71.0%, tuber marketability was 73.7-88.4%, quality indicators also improved: dry matter 1.81-14.0%, starch 1.63-17.4%, ascorbic acid 18,0-22,9 mg/%, nitrate concentrations did not exceed maximum permissible concentrations (maximum permissible concentration: 300 mg/kg). Combining fertilizers is the most effective way to control microelement accumulation in tubers.

Conclusion: Potato cultivation that combines organic-mineral fertilizers, especially biohumus, and mineral fertilizers is promising, since it complies with sustainable agriculture technologies. As a result, a product with high functionality and nutritional value is obtained.

Keywords: Biohumus, combined fertilization, sustainable potato cultivation, nutrient uptake, bioactive compounds

Graphical Abstract: The effects of combining mineral fertilizer with biohumus on potato yield

INTRODUCTION

Using organic fertilizers in conjunction with chemical fertilizers to increase crop yields will also reduce environmental pollution to a certain extent [1-7,12,13,43]. It has been found that "green agriculture" can stimulate crop growth and protect against various pathogens. In sustainable agriculture, organic fertilizers play a crucial role in ensuring long-term soil fertility and sustainability [8,15,28,29,74,75]. Global experience proves that biohumus, considered a bioorganic fertilizer, positively affects the agrochemical, physicochemical, and biological activity of the soil, increases its fertility and, consequently, crop yield, and contributes to ecologically safe products [33,73]. Biohumus is also rich in useful microflora, contains about 12-18% humus, 2.2% nitrogen, phosphorus, and potassium - 2.6 and 2.7%, respectively, and has a neutral reaction, which is favorable for the growth and development of microbes and microorganisms, pH=6.8-7.2 [9,14,27,29]: Microorganisms are known to be an environmentally safe alternative to chemical fertilizers in increasing crop growth and soil fertility. Microorganisms provide vital nutrients to crops and are a powerful tool for sustainable agriculture [15,28,46-47,49].

Agriculture plays an important role in food security. To meet consumer demand for healthy eating, manufacturers are developing innovative products such as functional foods [10-11,16]. Functional food, in addition to serving as a source of alkaline nutrition, also exhibits properties that positively affect health. Thanks to the bioactive compounds they contain, these substances enhance physiological functions and reduce the risk of chronic diseases. Based on the scientific basis and the current requirements, functional foods are part of the personalized nutrition system as key foods [17-18,20]. Potatoes are a crucial component of the human diet, often referred to as the "second bread." The food security and safety of a country are significantly influenced by the volume of potato production, highlighting its strategic importance. As a staple crop worldwide, potatoes are not only a versatile and delicious food, but also a rich source of nutrients and bioactive compounds, positioning it as a functional food with the potential to improve health and aid in the prevention and management of various chronic diseases. As potato cultivation technologies progress, it is important to select appropriate fertilizers, as these can significantly impact tuber quality and their status as a functional food. The potential accumulation of harmful compounds in potato tubers poses risks to consumer health, making careful fertilizer selection essential [32,34,65,68].

In terms of production and cultivated areas, potato (Solanum tuberosum L.) is one of the world's most important vegetables. It belongs to the Solanaceae family, which includes about 90 genera and 2000 species [30-31]. Potatoes play a significant role in the economy. After wheat, corn, and rice, potato is considered the fourth most significant crop [28,48]. The potato has gained wide distribution, is grown in all agricultural zones of the country, and serves as a second bread for the population. Globally, over 376 million metric tons of potatoes were produced in 2021, up 17 percent from 2000, as reported by the Food and Agriculture Organization of the United Nations (FAO). According to statistics from 2022, the Republic of Armenia (RA) planted 19.2 thousand hectares of potatoes, harvesting 251.4 thousand tons. According to FAO data, irrigated lands have steadily increased worldwide [61]. This has contributed to rising yields and overall production of potatoes despite a slight decline in the global harvested area for potatoes [62].

Potato tubers contain on average up to 25% dry matter, including more than 20% starch, protein substances about 2%, fats - 0.15%, ash elements - 1.0%. The role of potatoes as group C and B is a great source of vitamins (B1, B2, B6). Potato tubers contain on average up to 25% dry matter, including more than 20% starch, protein substances about 2%, fats - 0.15%, ash elements - 1.0% [19]. In addition, it is rich in carotenoids, and flavonoids, which reduce oxidative stress and inflammation in the body. Acid vitamins, solanine, and potassium are also necessary to maintain healthy blood pressure and nerve function [58]. Vitamin B6 is essential for brain development and metabolism [59].

Potatoes also have nutritional value because 1 kg of tubers contains 16 g of digestible protein, which is equivalent to 0.3 feed units. In contrast 1 kg of potatoes is estimated at 0.12 feed units. It has 20 g of digestible protein, 3.3 g of calcium, and 0.7 g of phosphorus. Tubers have 16g of digestible protein, equivalent to 0.3 food units. 1 kg of meat is estimated at 0.12 feed units and contains 20 g of digestible protein, 3.3 g of calcium, and 0.7 g of phosphorus [56-57].

Alternatively, excessive application of conventional mineral fertilizers can reduce soil fertility and increase heavy metal pollution, which contributes to carcinogenic diseases in humans [64,66,78]. As well as buffering heavy metals, it also reduces their toxicity [76-79]. Crops require nitrogen for growth and development, but it must be managed carefully to avoid negative consequences. Yield losses can be significant if nitrogen fertilization is insufficient [36-37]. Nevertheless, excess nitrogen in the soil can disrupt calcium and zinc absorption and balance [38]. The synthesis of potato bioactive compounds, including antioxidants, can also be negatively affected by high nitrogen levels [39]. Potato tubers can also accumulate nitrates when residual nitrogen levels are high. As a result of ingesting these nitrates, nitrites and nitrosamines are formed, which are carcinogenic compounds that pose serious health risks [40-41,45]. Therefore, high nitrate levels can reduce potato health benefits, reducing its value as a functional food. For this reason, traditional mineral fertilizers are replaced with organic fertilizers since they do not harm the soil or plants [42,51-52,54].

The research aims to evaluate the effect of the combined application of biohumus and mineral fertilizers on the quality indicators of the harvest of early potato varieties. It also aims to assess the application of these as raw materials in functional food.

MATERIAL AND METHODS

An assessment of the effects of mineral fertilizer and biohumus applied to potato varieties Impala and Arinda grown on brown-gray soils in the Sisian region, Syunik region, in RA was conducted. The experimental site lies at an altitude of 1600 meters above sea level and is characterized by dense forests and alpine meadows. In the Köppen climate classification, the region has a temperate continental climate classified as DFB [50,72]. Sisian has a long winter in which snow layers last 3-4 months. The average January temperature is -4.8 °C, the annual average is 6.9 °C, and the absolute minimum is -34 °C.

During winter, the weather is very stable. There are many windless days during winter. The maximum oxygen weight is 254 g/m^3. "Moderate frost" (when the daily air temperature is -12.5 °C) and significant frost (when the average daily air temperature is -21.5 °C) seasons prevail. Spring is cool, long (two to three months), and moderately cold. Spring typically begins between the 11th and 20th of April and ends between the 11th and 20th of June. May precipitation ranges from 70 to 100 millimeters. It is moderately hot during summer, lasts for 2-3 months, and has clear weather most of the time. The climatic July temperature is 17.9 °C, and the absolute maximum reaches 36 °C. Annual rainfall varies from 25-56 mm. Summer is dry in certain years. Summer is moderately hot, lasting 2-3 months, and clear weather prevails. The average temperature in July is 17.9 °C, and the absolute maximum reaches 36 °C. Multi-year average annual precipitation ranges from 320-470 mm. In summer, the "sunny, moderately humid" weather type prevails, with 16 days in a month. The "very hot and very dry" weather is completely absent, which positively evaluates Sisian's summer weather regime. Autumn is cool. The first autumn frosts occur in the first and second ten days of October, sometimes in the first ten days of September. Frost-free days are 120-180 days. Autumn is stable, sunny, and windless. The atmosphere's oxygen content is 240 g/m3.

Potato variety description: Potatoes were fertilized with organic-mineral fertilizers (increasing amounts of biohumus + mineral fertilizers) on the brown-gray soils of Sisian, Syunik marz, using the early maturing varieties "Arinda" and "Impala".

Intense, high-yielding, and renowned for its large tubers and exceptional taste, the Impala potato (Solanum tuberosum L. cv. Impala) is an intensive, high-yielding variety of Dutch origin. Impala potatoes are distinguished by their large size (80-160 g) and oval shape. The pulp is creamy or light-yellow, while the skin is thin, light, and nearly transparent. As an early-ripening variety, it requires lots of soil moisture.

The bushes are tall, the tubers are oval and yellow, and they are excellent for storage. The plant resists bacterial and viral infections.

The Arinda potato (Solanum tuberosum L. cv. Arinda) – It is a Dutch medium-early variety that can be grown in different soil conditions based on its biological characteristics. Its flowers are white, and its tubers are ovoid, oval-oblong, light yellow, and disease-resistant.

Experimental Design: The research was conducted using a randomized complete block design (RCBD) T=5, R=3 [60].

Checker (without fertilization)

1. $N_{60}P_{60}K_{60}$ kg/ha – Background
2. Background + bio humus – 5 t /ha
3. Background +bio humus – 10 t / ha
4. Background + bio humus – 20 t / ha

A 60x70 cm interrow space was used in the experiment, and a planting depth of 8-12 cm was applied. We determined the duration of potato plant growth and development stages after phenological observations were made. This was based on the average data of 25 plants during the second ten days of April. Fertilizer applications affect yield, quality indicators, and functional value of tubers [43-44]. Field experiments used the unfertilized version as a control and the $N_{60}P_{60}K_{60}$ kg/ha version as a background. Before furrowing, biohumus and mineral fertilizers were incorporated into the soil.

Description of the applied organic fertilizer: The biohumus was produced from various organic wastes (weeds, crop residues, leaves from trees and bushes, sawdust, etc.) using a mixture of soil bacteria (lactic acid, photosynthetic, nitrogen-fixing bacteria, aerobic bacteria that degrade cellulose, actinomycetes, yeast, and fungal strains) as a bioproduct. Jam juice was used as a carbon source for microorganism growth. After bacteria growth, the bacterial solution was added to the accumulated organic waste. It was moistened with a solution (1:100 ratio, in water), and covered with a polyethylene film. More than 20% of the total compost mass was composed of manure or poultry manure to speed up the process. Then soil was added in proportion to 10% of the accumulated mass (which promotes long-term moisture retention in the accumulated mass and absorption of nitrogen compounds). Periodically, every 8-10 days, containers were opened, watered, mixed, and covered again. Biohumus preparation takes two months [49,67-68,73,75,80].

Research was conducted using soil research methods, field studies of soil samples, and plant samples. For soil analysis, two soil pits up to 80 cm were placed. Soil samples were collected from the arable layer (0-27 cm) and after morphological description -40 cm. Burkle Soil Sampling Kit was used to collect all soil samples. As soon as the samples arrived in the laboratory, the stones and plant remain were removed from them and the samples were dried in the laboratory (20-22°C). After drying, the samples were ground and passed through a 2 mm sieve.

Phenological observations and biometric measurements were conducted during the growing season. The soil pH was estimated by dipping the pH electrode meter in the saturation paste (1:5, soil: water) [81]. Tiurin's method for measuring organic carbon (using phenyl anthranilic acid titration) was used to assess humus substance content. The classical pipette method determined the physical clay and evaluated it according to the N.A. Kachinsky classification scale. The nutrient content in the samples was extracted and determined: Available nutrients (nitrogen (N)-according to I. V. Tyurin and M. M. Kononova, phosphorus (P_2O_5)-according to B. M. Machigin, potassium (K_2O)-according to A. L.

Maslova), the mobile or leachable microelements fraction was extracted with a buffer solution of acetic acid–ammonium hydroxide adjusted for pH 4.8.

The samples were soaked in the buffer solution 24 hours at room temperature and shaken 5-7 times during soaking. After 24 hours, the solution was shaken again and filtered. An atomic absorption spectrophotometer (AAS-1) was used to quantify the mobile or leachable forms of microelements (Cu, Zn, Cd, Mn, Pb) in the filtrate [69, 82]. The dry matter of plant samples (tubers) was determined by weight, starch by specific gravity methods (Arinushkina), and nitrates by Nitrate-tests/MORION-OK/ [53].

Ascorbic acid content determination: Iodometric titration was used to determine the ascorbic acid content [55].

Statistical analysis: Using dispersion analysis, the yield data was mathematically analyzed to determine the experimental error (Sx, %) and the most significant difference (MSD 0.95, c/ha).

The research was conducted in the laboratory of the Scientific Center of Soil Science, Agrochemistry and Melioration after Hrant Petrosyan" Branch of Armenian National Agrarian University (ANAU) Foundation.

RESULTS AND DISCUSSION

Based on the results of multi-year (2020-2022) agrochemical average indicators for the test plot, it was determined that the soils have a medium and low humus content, a loamy medium mechanical composition, alkaline reaction, mobile nitrogen, poor phosphorus supply, and good potassium supply (table 1).

Table 1. Mean agrochemical indicators data of the experimental plot of the Sisian base

The depth of the soil sample, cm	Humus, %	Physical Clay, %	pH	Mobile nutrients, mg in 100g of soil		
				N	P_2O_5	K_2O
0-27	2,9	37,9	7,4	2,8	1,7	29,0
27-40	1,3	43,1	8,0	1,2	0,65	30,0

Table 2. The effect of joint application of mineral fertilizers and biohumus on the growth of potato plants

Treatments	Varieties	Stem length, three-year average		
		I	II	III
Checker (without fertilization)	Arinda	35,0	48	57
	Impala	37,0	51	68
$N_{60}P_{60}K_{60}$ kg/ha – Background	Arinda	42	56	62
	Impala	45	61	68
Background + bio humus- 5 t /ha	Arinda	47	64	78
	Impala	50	66	75
Background + bio humus-10 t /ha	Arinda	48	68	78
	Impala	51	71	81
Background + bio humus- 20 t /ha	Arinda	54	73	82
	Impala	59	78	89

Based on these findings, the maximum length of potato stems with three-year averages, regardless of external characteristics, was measured in the amount of background + biohumus 20 t/ha (in terms of active substances) in 2020-2022 when mineral fertilizers were applied (in terms of active substances). In the case of the "Arinda" variety, it was 19 cm at the beginning of flowering, 28 cm at widespread flowering, and 26.0 cm after flowering, while for the "Impala" variety, it was 22, 30, and 30 cm, respectively (table 2). Based on the research results, the combination of biohumus and mineral fertilizers affected soil agrochemical indicators differently. A 6.9% decrease in humus content was observed in 2020-2022 when $N_{60}P_{60}K_{60}$ kg/ha dosage was applied compared to the control. In the case of the application of $N_{60}P_{60}K_{60}$ kg/ha + organic humus 5, 10, 20t/ha, the content of humus (organic matter) increased accordingly by 6.9; 24.1; and 41.4%.

Compared to the control, the combined use of biohumus and mineral fertilizers did not have a significant effect on soil solution reaction and mechanical composition, but the number of mobile nutrients increased by 2.25-4.29 times, 2.82-20.2 times, 1,46-2,77 times (table 3).

Table 3. The effect of joint application of mineral fertilizers and biohumus on agrochemical parameters of the experimental plot (The mean data of 2020-2022)

Treatments	**Humus, %**	**pH**	**Physical Clay, %**	**Mobile nutrients, mg in 100g of soil**		
				N	P_2O_5	K_2O
Checker (without fertilization)	2,9	7,7	38,9	2,8	1,7	26,0
$N_{60}P_{60}K_{60}$ kg/ha (background)	2,7	7,6	38,9	6,3	4,8	38,0
Background + biohumus- 5 t /ha	3,1	7,6	37,8	8,0	7,3	42,0
Background + bio humus- 10 t/ha	3,6	7,6	37,6	10,5	22,4	56,1
Background + bio humus- 20 t /ha	4,1	7,6	37,1	13,7	34,2	72,0

A high-quality potato yield can often be achieved by fertilizing the soil with organic fertilizers and having a light mechanical composition. To ensure optimal growth and development of potato plants, organic preparations rich in macro- and micronutrients can be applied during the vegetative growth phase. [21-24,33,70-71]. It is not only the intensity of potato tuber accumulation but also the amount of harvest [29,35,44,74].

Table 4. The effect of joint application of mineral fertilizers and biohumus on the potato crop

Treatments	**Varieties**	**Mean yield, c/ha**			**The meaning of three years, c/ha**		**Yield increase**	
		2020	2021	2022			c/ha	%
Checker (without fertilization)	Arinda	216,0	224,0	208,0	216	-	-	-
	Impala	189,0	210,0	200,0	200	-	-	-
	Arinda	240,0	254	259	251	-	35,0	16,2

Treatments	**Varieties**	**Mean yield, c/ha**			**The meaning of three years, c/ha**		**Yield increase**	
		2020	2021	2022			c/ha	%
$N_{60}P_{60}K_{60}$ kg/ha (background)	Impala	228	234	237	233	-	33,0	16,5
Background + bio humus - 5 t/ha	Arinda	304	312	290	302	-	86,0	39,8
	Impala	269	280	253	281	-	81,0	40,5
Background + bio humus - 10 t/ha	Arinda	330	342	320	331	-	125	53,2
	Impala	316	324	298	313	-	113	56,5
Background + bio humus - 20 t/ha	Arinda	367	380	371	373	-	157	72,69
	Impala	340	356	329	342	-	142	71,0
Sx %	Arinda	-	-	-	1,98	-	-	-
	Impala	-	-	-	2,01	-	-	-
$SSD_{0.95}$	Arinda	-	-	-	31,0	-	-	-
	Impala	-	-	-	28,7 c/ha	-	-	-

Table 4 shows that regardless of potato varietal characteristics, the efficiency of combined fertilizer application is determined by biohumus amounts. 69%, "Impala" variety: 33.0-142 c/ha or 16.5-71.0%. Research by many authors indicated that mineral, organo-mineral, and organic fertilizers improved potato yields and crop quality [21-26,63,83].

In the conducted studies, it was also shown that an increase in biohumus doses ($N_{60}P_{60}K_{60}$ kg/ha) affected potato crop structure. In the case of applying biohumus against mineral fertilizers, compared to the control, the marketability of potato tubers (the number of tubers with a weight of 50-100 and 100g in the whole crop fraction) and the weight of marketable tubers increased according to three-year average data. Thus, if in the amount of $N_{60}P_{60}K_{60}$ kg/ha, the commerciality of tubers in the harvest fraction was 71.0 and 76.1% in the studied varieties (Arinda, Impala), the proportion of biohumus (5, 10, 20 t/ha) and $N_{60}P_{60}K_{60}$ kg/ha in the case of joint application was 13.8-11.8%, 14.7 and 14.0, 16.0 and 16.4%, respectively.

Table 5. The effect of joint application of mineral fertilizers and biohumus on the potato productivity (2020-2022)

Treatments	**Varieties**	**Mean yield, c/ha**	**Fractions of tubers, %**			**Tuber marketability**
			100g high	50-100g	up to 50 g	%
Checker (without fertilization)	Arinda	216	21,9	38,0	40,1	59,9
	Impala	202	25,0	41,0	34,0	66,0
$N_{60}P_{60}K_{60}$ kg/ha (background)	Arinda	249,7	40,0	31,0	29,0	71,0
	Impala	233	33,0	43,1	23,9	76,1

Treatments	Varieties	Mean yield, c/ha	Fractions of tubers, %			Tuber marketability
			100g high	50-100g	up to 50 g	%
Background + biohumus - 5 t/ha	Arinda	309,0	31,8	11,9	26,3	73,7
	Impala	267,3	34,0	43,8	22,2	77,8
Background + bio humus - 10 t/ha	Arinda	330,7	32,6	42,0	25,4	74,6
	Impala	312	35,8	44,5	19,7	80,3
Background + bio humus - 20 t/ha	Arinda	369,3	33,1	42,8	24,1	75,9
	Impala	342,3	37,4	45,0	17,6	82,4

Table 6. The effect of joint application of mineral fertilizers and biohumus on quality properties of potatoes

Treatments	Varieties	Starch, %	Ascorbic acid, mg/%	NO_3^- mg/kg	Dry matter, %
Checker (without fertilization)	Arinda	16,1	18,0	206	20,0
	Impala	17,7	18,8	192	21,5
$N_{60}P_{60}K_{60}$ kg/ha (background)	Arinda	15,8	18,6	276	19,8
	Impala	16,9	19,2	283	21,2
Background + bio humus - 5 t/ha	Arinda	16,8	19,8	245	21,7
	Impala	18,0	21,0	231	21,9
Background + biohumus - 10 t/ha	Arinda	17,5	21,8	243	22,0
	Impala	19,1	22,9	234	23,0
Background + bio humus - 20 t/ha	Arinda	17,9	22,5	210	22,8
	Impala	19,8	22,9	204	24,3

Our research results indicate that combining biohumus and mineral fertilizers positively affected some potato quality indicators. In the case of applying $N_{60}P_{60}K_{60}$ kg/ha (background) + biohumus 5 t/ha doses, starch content increased by 4.25 and 1.69% in Arinda and Impala tubers, vitamin C by 10.0 and 11.7%, and dry matter by 8.5 and 1.86%.

Nitrate levels increased by 0.97 and 6.25% but were within permissible limits. The best option for the combined application of mineral fertilizers and biohumus is the dose of $N_{60}P_{60}K_{60}$ kg/ha + biohumus 20 t/ha, which improves starch content in tubers by 16.1 and 17.4%, vitamin C by 25.0 and 21.8%, dry matter by 14.0 and 13.0%, nitrates rise - 1.94 and 6.25%, but nitrates concentrations decrease by 14.29 and 6.25% when compared to background + biohumus 5 t/ha doses. Thus, the effectiveness of the joint application of biohumus on the background of mineral fertilizers on the qualitative indicators of potato tubers is determined by the increasing doses of biohumus (Table 6). Table 7 shows increasing doses of biohumus applied to mineral fertilizers reduced microelements in tubers over the years (2020-2022).

Table 7. The effect of joint application of mineral fertilizers and biohumus on heavy metal accumulation in tubers (mean data of 2020-2022)

Treatments	Varieties	Microelements, mg/kg				
		Cu	Zn	Cd	Mn	Pb
Checker (without fertilization)	Arinda	6,8±0,28	21,0±1,63	0,21±0,09	38,1±1,4	1,3±0,16
	Impala	6,2±0,16	18,7±0,72	0,14±0,01	38,0±1,6	1,5±0,21
$N_{60}P_{60}K_{60}$ kg/ha (background)	Arinda	7,1±0,18	23,1±0,61	0,13±0,03	40,4±1,9	1,6±0,18
	Impala	6,4±0,21	20,6±1,00	0,12±0,01	39,8±1,6	1,7±0,09
Background + bio humus - 5 t/ha	Arinda	5,4±0,17	17,4±0,75	0,08±0,06	36,0±1,4	1,1±0,06
	Impala	5,2±0,15	17,2±1,2	0,07±0,012	36,1±1,5	1,1±0,10
Background + bio humus - 10 t/ha	Arinda	4,8±0,12	16,0±0,96	0,06±0,013	34,8±1,7	0,92±0,06
	Impala	4,2±0,21	15,3±0,78	0,06±0,001	33,0±1,2	0,90±0,04
Background + biohumus - 20 t/ha	Arinda	4,3±0,16	12,8±0,24	0,05±0,001	26,5±1,4	0,58±0,06
	Impala	4,0±0,12	12,1±0,09	0,04±0,002	24,1±0,97	0,50±0,03

Thus, the content of copper in tubers of the "Arinda" variety decreased by 1.26-1.58 times, zinc by 1.21-1.64 times, cadmium in the case of application of increasing amounts of mineral fertilizers $N_{60}P_{60}K_{60}$ kg/ha (background) and biohumus compared to the control. 2.63-3.00, manganese: 1.06-1.44, lead - 1.18-2.24 times. Similar patterns were also recorded in "Impala" tubers (table 7).

CONCLUSION

As a result of the joint application of increasing amounts of biohumus and mineral fertilizers ($N_{60}P_{60}K_{60}$ kg/ha), humus (organic matter) and available nutrients increased in the soil, creating favorable growth and development conditions for plants.

The length of potato stems in brownish-gray soils is determined by biohumus application rates. The difference between the stem lengths of Arinda and Impala cultivars under the same ecological conditions is not significant.

The combined use of mineral fertilizers and biohumus is considered an important factor in increasing potato yield. The increase in yield compared to control was 86.0-167 c/ha or 32.34-69.31%.

A potato tuber's ability to accumulate heavy metals depends on the amount of biohumus applied, regardless of its chemical characteristics or varietal composition.

Adding biohumus to mineral fertilizers increases potato varieties' structural elements (productivity) and chemical composition, improving their quality as functional foods. These positive effects improve and increase potato tubers' nutritional and functional value. An ecologically sound food production system can be achieved through a composting system.

Abbreviations: FAO: Food and Agriculture Organization, RCBD: randomized complete block design.

Contributions: TJ-conceptualization, methodology, data Authors' curation, resources, writing-original draft preparation, writing-review, editing, and supervision, SH methodology, data curation, writing-review and editing, AM-conceptualization, methodology, validation, resources, data curation, writing-original draft

preparation, writing review, editing and supervision, SY-resources, writing review and editing, data curation, AE-resources, writing review and editing; MB-resources, writing-review and editing; GG-conceptualization, methodology, validation, resources, data curation, writing-original draft preparation, writing-review, and editing. All authors read and approved the final version of the manuscript.

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