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POTATO (*SOLANUM TUBEROSUM* L.) HEALTHY PLANTING MATERIAL DEVELOPMENT THROUGH INNOVATIVE METHODS

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SUMMARY

The article presents data on the study of in vitro growth efficiency of regenerated plants and tuber yield of minitubers of potato (*Solanum tuberosum* L.) cultivars under greenhouse conditions during 2022–2024. The shoot biomass growth and productivity of minitubers depended on the temperatures and biological parameters of potato genotypes. According to the results, the recorded maximum tuber yield formation appeared in cultivars Babayev, Tamasha, and Zhanaisan (84.6, 67.21, and 65.66 g/plant). The cultivar Babayev showed the best tuber yield, averaging over three years (72.5 g per plant and 1087.5 g/m^2). Moreover, the cultivar Babayev displayed the highest multiplication rate in the experiment (6.0 minitubers per plant in 2024 and 5.4 pieces on average for three years). The said promising cultivar can be effective as a donor parent for tubers in future breeding. Similarly, the bioorganic fertilizers' effect succeeded in determining the growth and development of virus-free test tube plants and the formation of potato minitubers. The findings revealed bioorganic fertilizers have a positive effect on the productivity of potato minitubers grown in the greenhouse. The biohumus in combination with liquid humic fertilizer increased the multiplication factor of the source material and its tuber yield in the primary seed production.

Keywords: Potato (*S. tuberosum* L.), cultivar, seed production, minitubers, biotechnology, greenhouse, bioorganic fertilizers, growth, productivity

Key findings: A series of experiments continued to ensure the maximum tuber yield of minitubers per unit area of potato (*S. tuberosum* L.) on protected soil. The organic fertilizers also revealed a positive effect on the growth and development of virus-free test tube plants and the formation of potato minitubers.

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INTRODUCTION

Potato (*Solanum tuberosum* L.) is one of the main food staples on the global scale, and for production and consumption, it occupies the third position in 150 countries globally. The potato has the characteristics of great plasticity, adaptability, and potential productivity (Haq *et al.,* 2021; Suraganova *et al.,* 2022; Azhimakhan *et al.,* 2023). In 2023, the worldwide sown area of potatoes was around 18 million hectares, with a gross tuber yield of 376.1 million tons, and the average tuber yield was 20.9 t ha^{-1} (World Potato Production, 2023). For Kazakhstan, the potato is a considered priority crop. In the past, potato cultivation had an area of 195,200 ha, with a gross tuber yield of 4 million tons, and the average yield was 20.5 t ha^{-1}, which was 2–3 times less than the yield in potato-growing countries (Devaux *et al.*, 2021).

Based on the physiological norm of nutrition, each inhabitant should have 100 kg of potatoes. Considering this, the country's need for potatoes as food is two million tons. In addition, 0.7 million tons of potatoes can serve annually for seed purposes for planting an area of about 200,000 hectares. Therefore, Kazakhstan requires a total of 2.7 million tons of potatoes. By analyzing the gross production and the need, the potato supply is around 148% (Official Statistics, 2023). Based on the yield data, one can argue that there is an overproduction of potatoes in the country. However, in Kazakhstan, the average yield of potatoes remains low (18–19 t ha^{-1}), and insufficiency of good quality potato seed material is one of the limiting factors.

An important stage of potato seed production is cultivation of minitubers from regenerated plants recovered from in-vitro culture. However, most often, it happens under greenhouse conditions (Anisimov *et al.*, 2017; Buckseth *et al.*, 2020). However, several well-known examples of successful production of planting material and food potatoes existed in countries with the same and even more arid conditions. Thus, the main suppliers of potatoes to Kazakhstan are Germany, the Netherlands, and Russia (Potato Market, 2017). This indicates the use of appropriate cultivars and technologies can provide better seed production and potato tuber yields.

For increasing potato yields, an essential technique is the use of quality seed materials. Healthy seeds can come from those recovering from viral pathogens by cultivating explants separated from the apex meristems. After obtaining healthy planting materials and multiplying them, potato mini plants' planting on the ground proceeds for testing, as the root system has to adapt to the new growing conditions. It also helps the plants through this period by using techniques that can mobilize the plant's defense system because the most difficult time is the first 15–20 days after planting the potato (Yalovik *et al.*, 2024).

Securing healthy potato planting materials with high-sowing and yielding qualities is the main task of primary seed production (Asil *et al.*, 2020). The quality of potato seed materials is one of the chief factors determining its tuber yield. The prevalence of infectious diseases of a viral nature in agrocenoses is becoming more widespread. Liberation of seed potatoes from viral and bacterial infections and other diseases and preservation of high-yielding qualities of cultivars can result from the virus-free potato seed production. Its primary task is the recovery and accelerated multiplication of virus-free planting materials with subsequent inclusion in the reproduction process (Buckseth *et al.*, 2022; Kim *et al.*, 2022; Semchuk *et al.*, 2023).

Obtaining a quality potato source for material includes the process of freeing potato cultivars from virus infection using biotechnological methods (Zhevora *et al.*, 2019; Oves *et al.,* 2020). Modern technology of original potato seed production primarily seeks the recovery of cultivated cultivars, their accelerated multiplication, and protection of the obtained material from infection in potatoes. Obtaining pathogen-free and healthy planting materials that provide better growth energy and productivity is the principal goal in potato seed production (Uskov, 2009). Various methods of accelerated multiplication served to strengthen the necessary volumes of healthy planting source materials (Dzgoev *et al.,* 2011; Gerieva *et al.,* 2015). In the search for effective ways to optimize the process of minituber production, it is crucial to reduce the labor, material, and energy resources (Tokbergenova *et al.*, 2017).

In seed potato cultivation, one of the important tasks is to achieve an optimal level of tuber yield and quality yield of the seed tubers' standard fraction. Furthermore, it should ensure the yield of seed potatoes at the level of the required standards established for the relevant categories of seed potatoes. The biotechnology's various methods provide work solutions on the preservation of quality and increased crop yield. However, the efficiency of recovery depends on the optimal organization of the whole seed production. A lack of high-quality planting seed materials, untimely varietal renewal, and introduction of maladaptive cultivars can reduce potato productivity with low seed output (Murzin *et al.,* 2024).

Improving methods of potato samples' recovery from viral pathogens is relevant to accelerating the process of obtaining resistant varieties that also retain genetic stability, requiring the least labor and cost in production (Kulikova *et al.,* 2020). One of the promising directions is the development of technology for the cultivation of healthy minitubers. With their small size and less weight, the minitubers' use as planting material reduces the cost of planting, storage space, and transportation of seeds. The minitubers' consumption per hectare is around 50,000–60,000 pieces or 300–500 kg, while a per-hectare potato crop requires 3–4 tons of standard seed.

Production of minitubers also has several advantages over the existing method of micro-clonal propagation of test tube plants. By propagating the minitubers, the multiplication factor (up to 7–8 times) and labor productivity increase for a year-round production of virus-free micro- and minitubers, with a real possibility of boosting multiplication and wide introduction of new cultivars of Kazakhstan selection (Hamman, 1974; Babayev and Tokbergenova, 2004).

Investigation of the possibilities to adjust the hormonal balance to improve quality and productivity is an urgent task, which is solvable with the help of plant growth regulators (PGRs) and biologically active substances. In developing methods of rooting regenerant plants in in-vitro and in-vivo culture, previous studies commenced on the effect of microalgae suspension (*Chlorella vulgaris*) and IAA (indole-3-acetic acid) from the auxin group. The use of the Murashige-Skoog nutrient medium served for the in vitro cultivation of the plant. The auxin IAA (100, 200 mg/L) and microalgae suspension (*Chlorella vulgaris*) in concentrations of 25 and 50 mg/L were solutions used as inducers of rhizogenesis before planting into in vivo conditions (Tokbergenova, 2015).

The significance of the presented study relies on the efficiency of shoot biomass growth in plants regenerated through in vitro for the formation of minitubers under greenhouse conditions for original potato seed production in Kazakhstan. The latest research also aimed to ensure the maximum yield of potato minitubers per unit area in greenhouse conditions by increasing the reproduction rate based on biotechnological methods and the application of various biological fertilizers.

MATERIALS AND METHODS

The research on obtaining and micro-cloning of healthy planting materials of potato (*S. tuberosum* L.) commenced in 2022–2024 at the Potato Regional Branch Kainar LLP—Kazakh Research Institute of Fruit and Vegetable Growing, Almaty Region, Kazakhstan. Minitubers' cultivation occurred in the greenhouse of the biotechnological complex, "Plant for production of potato minitubers." Optimal temperature in the greenhouse was +18 °C…+22 °C during the day and +16 °C – +17 °C for the night temperature, with air humidity at 75%–80%. In the greenhouse, the use of lights with high-pressure sodium lamps (SON-T400) had an illuminance of 10000 lux. Soil, sand, and chernozem were the types of substrate used for growing potato minitubers.

In the study experiments, the medium maturing cultivars, viz., Karasaysky, Babayev, and Zhanaisan, as well as the medium-early cultivars Tokhtar and Ushkonyr, were the samples used, which are widely spread in cultivation and production. An additional study on the early maturing cultivar Tamasha ensued. Regenerated plants with 5–7 internodes and developed roots obtained resulted from micro-cuttings under aseptic conditions in vitro, removed from tubes, and adapted in distilled water for a day. Adapted plants proceeded to sow in the greenhouse in early March in a previously prepared substrate with the scheme 15 cm × 20 cm and 30 plants per m^2. A total of 300 plants reached planting for each cultivar, with the plants watered after every two days, weeded, and perched as grown.

On the 14th day after planting the regenerated plants in the greenhouse, the work on counting the onset of active growth of shoots, budding, flowering, and wilting of haulm began. The following morphometric indices, determined during the vegetation period, included plant height (cm), the number of shoots and leaves, and leaf area (m^2 ha^{-1}). Morphometric indices of shoot growth, measured three times during the whole vegetation period, were as follows: seven days after planting, during the period of active growth (20 days after planting), and during budding (the beginning of flowering when the maximum vegetative mass of shoots was reached). Collecting the harvest from the greenhouse transpired manually in the last week of June. Productivity evaluation comprised the number of tubers per plant, average weight per tuber (g), total tuber weight per plant (g), the largest tuber diameter (mm), and tuber yield per square meter (g). The study also determined the presence of tuber damage by diseases and pests.

Separate studies on the effect of bioorganic fertilizers on the growth and development of virus-free test tube plants and the formation of minitubers applied the following formulations: biohumus (2 and 4 t ha^{-1}), MEGAVit (5 l ha^{-1}—3 times), ZhGU (3 l ha^{-1}—3 times), and biohumus (2 t ha^{-1}) in combination with MEGAVit (5 l ha^{-1}) and ZhGU (3 l ha^{-1}). Biohumus is a rich, 100% organic fertilizer, containing total humus (29.98%), hydrolyzable nitrogen (288.4 mg/kg), mobile phosphorus (748 mg/kg), mobile potassium (8775 mg/kg), absorbed calcium (42/1.5 mg/mg-eq.), absorbed magnesium (30/1.49 mg/mg-eq.), CO_2 (1.53%), and pH (7.9). The biochemical analysis continued in LLP—Kazakh Research Institute of Soil Science and Agrochemistry, named after U. Uspanov.

Biofertilizer MEGAVit (Kazakhstan) composition contains acids (succinic, oxalic, citric, and orthophosphoric), extracts from biohumus, unripe coals, nanocarbon, N, P, K, B, Ca, and S. Likewise, it is highly rich with the chelate form of Mg (3 g/l), B (2 g/l), Fe (2 g/l), Zn (1 g/l), Cu (1 g/l), and Mn (1 g/l). The liquid humic fertilizer—ZhGU (Republic of Belarus) composition contains all the components of biohumus in a dissolved state, i.e., humic acids, fulvic acids, vitamins, natural phytohormones, micro- and macro-elements in the form of bioavailable organic compounds, and mass fraction of nutrients (per 100 g of absolutely dry matter): N (1500 mg), P (1600 mg), and K (2500 mg).

The several studies proceeded according to classical methods and the methodology of experimental work in vegetable and melon growing (Belik, 1992; Litvinov, 2011). The processing and analysis of the obtained material continued using mathematical and statistical methods, engaging standard programs, i.e., Microsoft Excel 2007.

RESULTS

The survival rate of regenerated plants of potato (*S. tuberosum* L.) ranged from 70% to 85% under the greenhouse conditions, which depended on varietal characteristics and temperature settings in the greenhouse. In 2022, the highest rate of survival (85%, 83%, and 80%) was notable for the cultivars Babayev, Tokhtar, and Tamasha, respectively, while cultivars Karasaysky, Zhanaisan, and Ushkonyr took root in about 70% of the planted plants. In 2023 and 2024, the value of this indicator was lower, with preservation of the noted varietal specificity (Table 1).

Table 1. Adoption of potato regenerated plants under greenhouse conditions during 2022–2024.

Potato cultivars	Number of plants planted	Number of established plants	
		Number	%
2022			
Babayev	300	255	85
Zhanaisan	300	204	68
Karasaysky	300	198	66
Tamasha	300	240	80
Tokhtar	300	249	83
Ushkonyr	300	207	69
2023			
Babayev	300	246	82
Zhanaisan	300	189	63
Karasaysky	300	186	62
Tamasha	300	231	77
Tokhtar	300	243	81
Ushkonyr	300	204	68
2024			
Babayev	300	249	83
Zhanaisan	300	195	65
Karasaysky	300	192	64
Tamasha	300	228	76
Tokhtar	300	240	80
Ushkonyr	300	204	68

At the stage of planting regenerated plants, the shoot height was 5.0–7.0 cm (Figure 1). However, at the second measurement, on average, it increased three times. After 40–45 days, the intensity of plant growth significantly rose and reached the maximum. The highest shoot height at the budding phase was evident in the potato cultivar Ushkonyr (40.7 cm), while the lowest was in the cultivar Karasaysky (35.0 cm).

At planting time, each regenerated plant had one shoot. At the first stage of vegetative growth and two weeks after planting, the number of shoots averaged at 1.0–2.0. The most shoots were apparently in potato cultivars Karasaysky and Tamasha, as well as in the cultivar Ushkonyr (2.2). The cultivars Babayev, Tokhtar, and Zhanaisan did not differ significantly for shoots and, on an average, formed just one shoot. For the third measurement and at the budding and flowering phase, the number of shoots increased sharply. Significantly ($P \leq 0.05$) more number of shoots resulted in the cultivars Tamasha (6.9) and Ushkonyr (6.3). The potato cultivars Babayev, Karasaysky, and Tokhtar formed five shoots, while the fewest shoots occurred in the cultivar Zhanaisan (4.7) (Figure 2).

At planting, the number of leaves averaged 4–6 per plant. At the second measurement, the maximum number of leaves (42) was visible in the potato cultivars Karasaysky, Tamasha, and Ushkonyr, followed by the cultivar Tokhtar (39). The cultivar Babayev formed the minimum number of leaves by the second measurement (38). At the third measurement, the most leaves were prominent in the cultivar Ushkonyr (185 pieces), followed by the cultivar Babayev (180), with the least number recorded on the shoots in the cultivar Zhanaisan (165). By the beginning of tuberization, the maximum shoot obliquity (ratio of the number of leaves to the length of the shoot) manifested in the cultivars Tamasha and Ushkonyr (Figure 3).

Leaf area, as well as the values of other traits, enhanced at the budding phase and, on average, 10–12 times. The largest leaf area surfaced in the cultivar Ushkonyr (422,000 m^2), followed by the cultivar Tamasha (393,000 m^2). The minimum leaf area emerged in the cultivar Zhanaisan

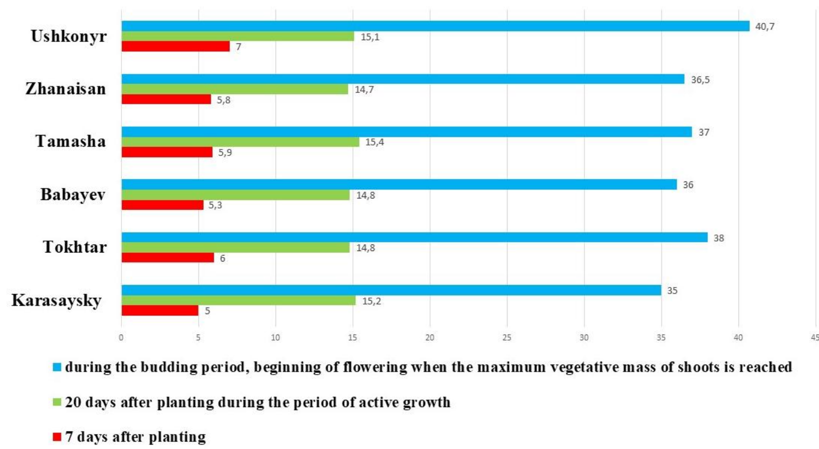

Figure 1. Dynamics of shoot height (cm) of potato regenerated plants.

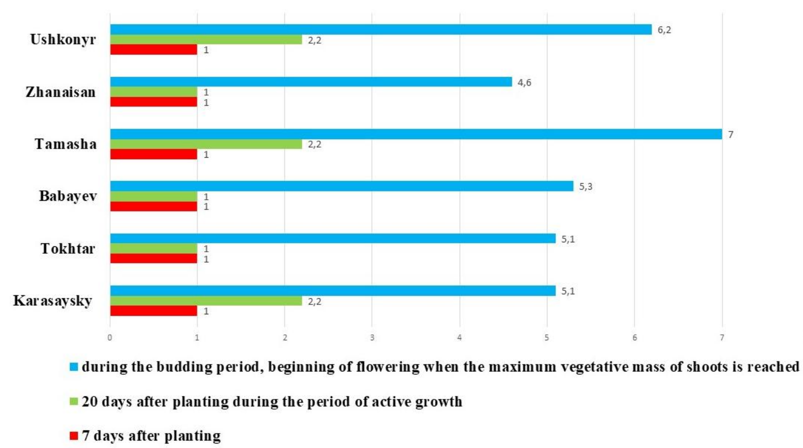

Figure 2. Dynamics of the number of shoots of potato regenerated plants.

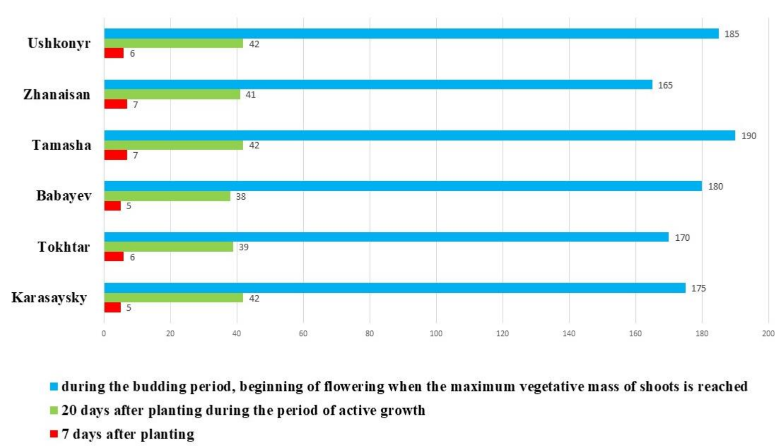

Figure 3. Dynamics of the number of leaves of potato regenerated plants.

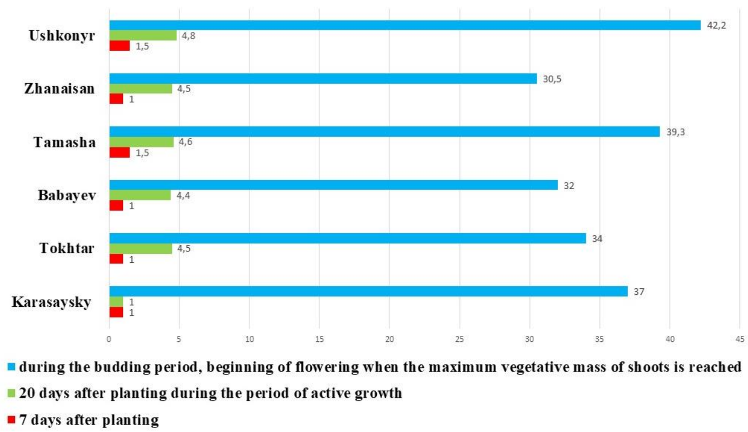

Figure 4. Dynamics of leaf area per square meter of potato regenerated plants.

(305,000 m^2). Thus, by the beginning of minitubers' formation, the largest photosynthetic apparatus was noticeable in the cultivars Ushkonyr and Tamasha (Figure 4).

All the recorded morphometric parameters gave the highest values in 2022—on average of cultivars for plant height (41.8 cm), number of shoots (6.4), leaves (207.7), and leaf area (409,000 m^2). In 2023, the minimum indicators of plant height obtained was 34.9 cm, and in 2024, the number of shoots per plant averaged 4.5 pcs, the number of leaves 174.6 pcs, and leaf area at 331,000 m^2.

In the cultivation of potato seed planting materials, the most important indicator is the multiplication factor, i.e., the number of tubers per plant. On average for three years, the most minitubers formed came from the cultivar Babayev (5.4), followed by the cultivars Ushkonyr (5.2), Tokhtar (4.1), Zhanaisan (4.2), Karasaysky (4.1), and Tamasha (4.0). Thus, the reproduction rate of the potato cultivar Babayev was higher than all other cultivars. The cultivar Ushkonyr also considerably excelled the other cultivars by 5.2 tubers per plant; however, it was inferior to the cultivar Babayev. Four cultivars, Karasaysky, Tokhtar, Zhanaisan, and Tamasha, were differing unreliably by this vital trait (Table 2).

On average over three years, the heaviest tuber weight was evident in the potato cultivar Tamasha (13.5 g), and the said trait was significantly lightest in the cultivar Ushkonyr (11.3 g). On average, the maximum tuber weight was outstanding in 2024 (14.3 g), while the lowest was in 2022 (10.8 g). An essential component of tuber yield, as regulated by GOST 7176-2017 in seed potato, is the diameter of tubers by the largest transverse diameter. For minitubers, it was 9–60 mm (GOST, 2017). The largest tubers formed appeared in the plants of cultivars Tamasha (44.4 mm) and Babayev (45.8 mm). However, the cultivars Zhanaisan and Ushkonyr were also not significantly inferior in tuber size.

In three years' average, the biggest tuber weight per plant came from the cultivar Babayev (72.5 g), while the smallest was in the cultivar Karasaysky (48.4 g). The maximum tuber weight was evident on cultivar Babayev in 2024 (84.6 g), while the minimum was in cultivar Tamasha in 2022 (38.7 g) (Table 3). The minitubers' yield fluctuated significantly by years, and on average, the highest mini tuber yield resulted in the cultivar Babayev (1087.5 g), with the minimum was in the cultivar Karasaysky (725.45 g).

Table 2. Yield components of minitubers yield structure in potato during 2022–2024.

Potato cultivars	Tubers per plant				Average weight per tuber (g)				Largest tuber diameter (mm)			
	2022	2023	2024	3-year average	2022	2023	2024	3-year average	2022	2023	2024	3-year average
Karasaysky	3.5	4.0	4.9	4.1	11.6	11.3	12.1	11.6	38.4	38.9	40.4	39.2
Tokhtar	3.8	4.2	5.1	4.3	11.3	11.9	12.5	11.9	40.0	39.0	39.2	39.3
Babayev	5.1	5.3	6.0	5.4	12.6	13.0	14.1	13.2	47.7	43.5	46.1	45.8
Tamasha	3.0	4.3	4.7	4.0	12.9	13.5	14.3	13.5	48.9	45.3	38.9	44.4
Zhanaisan	3.5	4.2	4.9	4.2	12.0	12.7	13.4	12.7	42.9	39.2	42.1	41.4
Ushkonyr	4.6	5.1	5.9	5.2	10.8	12.1	11.2	11.3	40.1	40.6	40.4	40.3
$LSD_{0.05}$		0.7		0.4		0.8		0.4		1.0		0.6

Table 3. Minituber yield in potato during 2022–2024.

Potato cultivars	Tuber weight plant^{-1} (g)				Tuber yield per m^2 (g)			
	2022	2023	2024	3-year average	2022	2023	2024	3-year average
Karasaysky	40.6	45.2	59.29	48.4	609.0	678.0	889.35	725.45
Tokhtar	42.94	49.98	63.75	52.2	644.1	749.7	956.25	783.35
Babayev	64.26	68.9	84.6	72.5	963.9	1033.5	1269.0	1087.5
Tamasha	38.7	58.05	67.21	54.6	580.5	870.75	1008.15	819.0
Zhanaisan	42.0	53.34	65.66	53.7	630.0	800.1	984.9	805.5
Ushkonyr	49.68	61.71	58.24	56.5	745.2	925.65	873.6	847.5
$LSD_{0.05}$		1.8		1.8		2.1		2.1

The most successful crop season was 2024, during which the highest average yield was 1,269 g of tubers per m^2, while the lowest (580.5 g of tubers per m^2) occurred in 2022. The crop season of 2024 was the most productive; the yields of cultivars Babayev, Ushkonyr, and Tamasha were higher than the other cultivars. However, the lowest yields appeared in the cultivars Tokhtar and Karasaysky. The latter cultivars distinctly formed numerous small tubers and, therefore, on average, did not provide the higher yield of biomass.

In a separate study, assessing the influence of bioorganic fertilizers on the growth and development of virus-free test tube plants and the formation of potato minitubers also ensued. Biometric studies sought to determine the intensity of potato plant growth and development and the formation of vegetative biomass and product organs, depending on different types of bioorganic fertilizers. Improvement in potato nutrition conditions by applying different biofertilizers promoted the construction of well-developed biomass compared with the unfertilized plots (control). In the control variant, the study recorded the lowest values of rooting rate of potato test tube plants (81.8%), plant height (45 cm), average weight per plant (208 g), and number of leaves per plant (159.3). With the application of bioorganic fertilizers, the enhanced values materialized on the survival rate of potato test tube plants (87.9%–93.2%), plant height (50.2–54.6 cm), average weight per plant (216–305 g), and the number of leaves per plant (160.6–175.5) (Table 4).

Thus, by improving potato plants' nutrition conditions and by applying different biofertilizers, these contributed to creating more developed biomass than the unfertilized control. In greenhouse conditions, the minitubers under the control variant revealed the number of minitubers per plant was three and the tuber weight per plant was 30.3 g. With biofertilizer application, the number of minitubers per plant (3.5-6.3) and the tuber weight per plant (47.5-76.7 g) considerably rose (Table 5).

Table 4. Effect of types and combinations of bioorganic fertilizers on the growth and development of virus-free in-vitro potato plants under greenhouse conditions.

Experimental variants	Cultivation rate of test tube plants (%)	Plant height (cm)	Average weight plant^{-1} (g)	Number of leaves plant^{-1}
Control (without fertilizers)	81.8	45.0	208	159.3
Biohumus (2 t ha^{-1})	90.1	52.5	222	170.3
Biohumus (4 t ha^{-1})	93.2	54.6	305	175.5
MEGAVit (5 l ha^{-1}, 3 times)	87.9	50.2	216	160.6
MEGAVit (3 l ha^{-1}, 3 times)	89.3	51.5	225	171.4
Biohumus (2 t ha^{-1}) + MEGAVit (5 l ha^{-1})	88.7	52.0	232	173.8
Biohumus (2 t ha^{-1}) + ZhGU (3 l ha^{-1})	91.3	53.1	283	172.2

Table 5. Effect of types and combinations of bioorganic fertilizers on the number and weight of potato minitubers under greenhouse conditions.

Experimental variants	Number of minitubers plant^{-1}	Average weight of minituber^{-1} (g)	Tuber weight plant^{-1} (g)
Control (without fertilizers)	3	15.0	45.0
Biohumus (2 t ha^{-1})	5	21.0	105.0
Biohumus (4 t ha^{-1})	8	26.0	208.0
MEGAVit (5 l ha^{-1}, 3 times)	3	19.0	57.0
ZhGU (3 l ha^{-1}, 3 times)	4	16.1	64.4
Biohumus (2 t ha^{-1}) + MEGAVit (5 l ha^{-1})	4	17.1	68.4
Biohumus (2 t ha^{-1}) + ZhGU (3 l ha^{-1})	6	22.5	135.0

In the variant with biohumus (4 t ha^{-1}), the number of minitubers was 8.0 and showed five more tubers and by 155 g over the control variant. By combining biohumus (2 t ha^{-1}) with the biofertilizer ZhGU (3 l ha^{-1}), the number of minitubers was 6.0, and the mass of the tubers per plant was 135.0 g. In the variant with biohumus (2 t ha^{-1}), the number of minitubers was 5.0, and the average mass of the tubers per plant was 105.0 g. The lowest values for the number and weight of minitubers resulted in the variant with the application of biofertilizer MEGAVit (5 l ha^{-1} and 3 times), where the mass of the tubers per plant was 57.0 g.

DISCUSSION

To date, the method of growing in a substrate under greenhouse conditions is still the primary way to obtain the initial seed material of potatoes in the form of minitubers (Anisimov *et al*., 2013; Khutinaev *et al.*, 2021). The integrating final indicator for assessing plant productivity is the yield of minitubers per square meter. Comparing the morphometric analysis results of the shoots' vegetative mass growth and the potato plants' yield does not allow scientists to draw an unambiguous conclusion on the plant growth's influence and the size of aboveground biomass on the minitubers' yield (Khutinaev *et al.*, 2016).

The large photosynthetic apparatus formed by the cultivar Tamasha had a positive effect on the tuber weight, size, and yield of the minitubers. However, the cultivar Ushkonyr, also with a large vegetative mass, showed low tuber yields, with an increased number of minitubers per plant. According to the data of researchers Terentyeva and Tkachenko (2018), from one microplant in the greenhouse, the tuber yield was 9–10 pieces, while in these studies, on average for three years, minitubers formed 4–6 pieces.

Biologization provides for the maximum use of biological factors to increase the fertility of arable soils, reduce the anthropogenic load, and produce environmentally friendly products. The most valuable components of the fertilization system are the use of traditional organic fertilizers. The utilization of organic fertilizers in countries with developed agriculture is ahead of the application of mineral fertilizers. This creates conditions for increasing soil fertility with the simultaneous growth of crop yields (Chekmarev and Lukin, 2012).

By conducting research on the fertilization of bioorganics, a close relationship between potato productivity and plant habitat became a realization. The more powerful the development of potato plants, the higher their productivity. Potato plants with strong biomass showed the higher resistance to pests and diseases. This contributes to obtaining the greater yields of potato tubers with better quality indicators and ecological purity (Budanov *et al.*, 2023).

One of the stages of the technological process of original seed potato production is the cultivation of healthy in-vitro microplants in the spring-summer greenhouse to obtain minitubers. The positive influence of bioorganic fertilizers on the processes of growth and development in potato plants has been successful (Shishchenko and Barsukova, 2021). Cultivation of potatoes treated with bioorganic fertilizers biohumus (4 t ha^{-1}) and biohumus (2 t ha^{-1}) + ZhGU (3 l ha^{-1}) depended on the plant development stage, which improved the quality indicators and enhanced the potato tuber yield by 15%–20%.

CONCLUSIONS

The promising research has established the efficiency of shoot biomass growth and productivity of regenerated plants largely depend on the potato (*S. tuberosum* L.) varietal characteristics. On average, the maximum tuber yield resulted in the cultivars Babayev, Tamasha, and Zhanaisan. On average over three years, the best yield emerged in the cultivar Babayev, which also had the highest multiplication rate. Application of biohumus (4 t ha^{-1}) and biohumus (2 t ha^{-1}) + ZhGU (3 l ha^{-1}) is favorable for use in organic potato farming. In general, the studied bioorganic fertilizers showed the higher efficiency in growth and development of potato minitubers grown under greenhouse conditions, with high recommendations for organic potato production.

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