AgroLife Scientific Journal - Volume 9, Number 1, 2020
ISSN 2285-5718; ISSN CD-ROM 2285-5726; ISSN ONLINE 2286-0126; ISSN-L 2285-5718

FORMATION OF THE YIELD AND SEED QUALITIES OF POTATO IN THE NURSERY OF BASIC SEED PRODUCTION UNDER THE CONDITIONS OF THE SOUTH OF UKRAINE

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Abstract

The article presents experimental data on yield, yield structure and quality of seed potatoes of the varieties Skarbnitsa, Levada and Yavir, depending on fertilizer and treatment with growth regulators Emistim S, Regoplant and Stimpo. On average, over three years of research, the enrichment of $N_{45}P_{45}K_{45}$ and $N_{90}P_{90}K_{90}$ increased the yield on 5.45 and 7.09 t ha^{-1} (37 and 48%). With background nutrition $N_{45}P_{45}K_{45}$, growth regulators increased yields from 3.6% to 21.7%, depending on the variety and regulator. Fertilizers and growth regulators increased the dry matter content in tubers on 0.8 and 1.1%, starch - on 0.4 and 0.9%. Due to the use of fertilizers, the content of vitamin C decreased on 3.9 and 7.4%, nitrates increased on 30.1 and 60.4%. The maximum productivity of the early variety Skarbnitsa and medium early Levada was formed with the combined use of mineral fertilizers in a dose of $N_{45}P_{45}K_{45}$ with the Regoplant growth regulator treatment - 21.85 and 22.12 t ha^{-1}. When growing a mid-season variety Yavir, there was a need to use a dose of $N_{90}P_{90}K_{90}$ fertilizers without growth regulator treatment, the yield was 22,65 t ha^{-1}.

Key words*: fertilizers, growth regulators, potato, seed productivity, varietal qualities.*

INTRODUCTION

The best way to obtain seed potatoes in southern Ukraine that are less susceptible to degeneration due to high air temperatures is to plant summer freshly harvested tubers in a two-crop culture (Vozhegova et al., 2014a). Insufficient frost free period and the absence of irrigation in the north and center of the country do not allow the use of the two-crop method for the production of seed potatoes. Therefore, in these regions and in the South of Ukraine, in most households, seed potatoes are grown according to the traditional scheme of seed production - only during spring planting and harvesting under biological maturity of tubers. The development of a complex of measures to improve the productivity of seed potatoes in this scheme is relevant.

For seed potato technology to be considered expedient, it must ensure high yields, seed productivity and quality of the harvest. It is possible to solve this aim while providing all the needs of the plant, for which many factors need to be taken into account, as well as the use of complex growth regulators as an additional source to increase productivity and crop quality.

The use of multicomponent growth regulators can increase field germination, survival, increase plant resistance, allow them to accumulate more tops and roots (Calvo et al., 2014; Jardin, 2015; Usha et al., 2009). Chemical and biological growth regulators are also used in potato production to accelerate germination, reduce incidence of scabies (*Actinomyces scabies*), rhizoctonia (*Rhizoctonia solani*), alternaria (*Alternaria solani*) and fusarium (*Fusarium radici*), increase seed output, decrease seed output losses during long-term storage, etc. (Pavlista, 2011; Cheremisin and Kumpan, 2018; Araujo et al., 2019; Awati et al., 2016; Bhattarai, 2017; Bomok, 2019; Chekmarev et al., 2015; Głosek-Sobieraj et al., 2018; Gugała et al., 2019; Kumar at al., 2015; Lei, 2019; Naraghi et al., 2012; Otroshy and Struik, 2008; Pashkova and Kuz'minykh, 2018; Rex, 1992; Sekhon and Singh, 1985; Weiyan, 2015; Wierzbowska et al., 2015; Zamalieva et al., 2019).

There is currently no data on the effect of growth regulators Emistim C, Regoplant and

Stimpo on seed potato productivity in irrigated southern Ukraine. Therefore, there was a need to conduct research on the complex effect of fertilizers and growth regulators on the development and yield of seed potatoes of different ripeness groups.

The purpose of the research was to determine the yield, seed productivity and quality of biological ripeness potatoes under the action of growth regulators and different levels of mineral nutrition.

MATERIALS AND METHODS

Field experiments, laboratory and analytical studies during 2016-2018 were carried out at the Institute of Irrigated Agriculture of the NAAS of Ukraine (Kherson region, Naddniprians'ke) located on the right bank of the river Dnieper in the zone of the Ingulets irrigation system. The soil of the research plot is a dark chestnut medium-loamy. There was used the method of split plots with four repeats and two-row plots. The accounting area of the plot of the first order (variety factor) was 88.2 m^2, the second (factor of mineral nutrition level) - 29.4 m^2, the third (treatment with growth regulators) - 7.35 m^2, the total - 14.7 m^2. The area of nutrition of one plant was 70 × 25 cm. Previous crop was winter wheat (1st and 2nd year) and corn for grain. The agrotechnics used in the experiment were applied according to the guidelines for potato cultivation on irrigated land, developed by the Institute of Irrigated NAAS, except for the studied factors (Vozhehova et al., 2014b) and taking into account all the requirements of the method of research with potato (Kutsenko et al., 2002). The reliability of the results was determined using the Agrostat® software and information complex based on Microsoft Office® Excel®. The dry matter content was determined with gravity metod (GOST 13496.3-92); starch - for Evers, vitamin C - for Murri (GOST 24556-89); nitrates - potentiometric ion-selective electrode (GOST 13496.19-93).

We used as seed material the super-super elite of the varieties Skarbnytsya, Levada and Yavir breeding of the Institute of Potato NAAS, recommended for cultivation in the South of Ukraine in the experiment.

The Skarbnytsya is an early table, high-yielding variety. The taste qualities are good. Tubers are oval, yellow with creamy crumb. Levada is middle-early variety, tubers are rounded, light pink, creamy crumb. Yavir is a medium-ripe variety of tableware, high-yielding. Tubers are rounded, yellow, with a mesh skin, creamy crumb. These varieties are listed in the State Register of Plant Varieties Suitable for Distribution in Ukraine, respectively, from 2008, 2007 and 2000 (Institute of Potato and Institute of Irrigated Agriculture NAAS, 2012).

Mineral fertilizers in the form of nitroamophos (containing N, P and K content of 16%) were applied locally to the comb when planting at the rate of 45 or 90 kg of active substance nitrogen, phosphorus and potassium per hectare. The day before planting potatoes of the respective options were treated with 0.1% solution of Emistim C, Stimpo and 0.25% solution of Regoplant. In the phase of complete sprouting and budding, potato plants were treated with 0.01% solution of Emistim C, Stimpo and 0.025% solution of Regoplant. The growth regulators used in the experiment have a complex composition of plant origin regulators. Developer is "Agrobiotech".

Emistim C is a water-alcohol solution of metabolites of epiphytic fungi. It contains a complex of phytohormones of auxin, gibberellin and cytokinin nature, amino acids, carbohydrates, fatty acids, microelements. Regoplant is a multicomponent preparation for the products of vital activity of fungi-micromycetes from the root system of ginseng (saturated and unsaturated fatty acids - C14-C28), polysaccharides, 15 amino acids, analogues of the phytohormones of cytokinin and auxin nature) contains a complex of biogenic microelement, potassium salt of alpha-naphthylacetic acid and aversectin C. Stimpo includes the products of micromycetes fungi, a complex of biogenic microelement and aversectin C.

RESULTS AND DISCUSSIONS

The three-year average yield in the experiment is 18.86 t/ha. Variety characteristics did not affect on productivity - the average yield of the three varieties differed by a maximum of 0.21

t/ha, which was within the least significant difference for this factor (Table 1).

The average yield on non-fertilized variants was 14.68 t/ha. Application of $N_{45}P_{45}K_{45}$ increased the potato yield by 5.45 t/ha, or 37.1%, and the double fertilizer dose $N_{90}P_{90}K_{90}$ - by 7.09 t/ha (48.3%).

Table 1. Potato yield (t/ha) depending on variety, fertilizer and growth regulator, 2016-2018

Variety (factor A)	Fertilizer (factor B)	Growth regulator treatment (factor C)				Average by factors	
		Without treatment	Emistim C	Regoplant	Stimpo		
Skarbnitsa	without fertilizer	14.79	14.64	15.08	15.43	14.68	18.90
	$N_{45}P_{45}K_{45}$	19.51	20.22	21.85	21.12	20.13	
	$N_{90}P_{90}K_{90}$	21.79	21.49	20.28	20.59	21.76	
Levada	without fertilizer	14.88	14.43	14.33	14.20	18.75	18.94
	$N_{45}P_{45}K_{45}$	18.17	19.70	22.12	20.15		
	$N_{90}P_{90}K_{90}$	23.06	22.70	21.73	21.96		
Yavir	without fertilizer	15.45	14.29	14.01	14.64		18.73
	$N_{45}P_{45}K_{45}$	18.41	19.59	20.55	20.16		
	$N_{90}P_{90}K_{90}$	22.65	22.52	22.00	20.46		
Average by factors		18.75	18.84	19.11	18.75		
Significance of the main effects							
LSD_{05} A		LSD_{05} B				LSD_{05} C	
0.41		0.47				0.38	

Regulators influenced the yield - average yields in control without treatment and with Stimpo treatment were 18.75 t/ha, with treatment Emistim C - 18.84, Regoplant - 19.11; that is 0.1 and 0.36 t/ha (0.5 and 1.9%) more control.

Regulators combined with no fertilizer on all varieties except Skarbnitsa had a negative impact, reducing the yield from 1.0 to 9.3%. A double dose of fertilizers in combination with regulators also had some negative impact on the yield - from -0.6 to -9.7%. The decrease in potato yield on fertilizer-free and $N_{90}P_{90}K_{90}$ variants was due to the overdevelopment of the vegetative mass of potato due to the action of growth regulators.

The application of $N_{45}P_{45}K_{45}$ in combination with treatment with the investigated preparations had a positive effect overall, increasing the yield from 3.6 to 21.7%, depending on the variety and the regulator.

Maximum yield was 23.06 t/ha on variety Levada, without treatment, with $N_{90}P_{90}K_{90}$; the smallest was 14.01 t/ha on variety Yavir, without fertilizers and after treatment with Regoplant. The maximum positive effect of the growth regulator was recorded on the Levada variety with the $N_{45}P_{45}K_{45}$ and treated with Regoplant regulator - 21.7% of the control without treatment.

The highest yield of potato varieties was recorded on the $N_{90}P_{90}K_{90}$ variant without the use of growth regulators. This dose of fertilizer was recommended for potato cultivation under irrigation according to previous long-term studies (Vozhehova, 2014a). However, the yield of potato varieties with less than half the nutrition level and the use of growth regulators was almost at the recommended dose level. With this technology, material costs for mineral fertilizers are significantly reduced, as the cost of growth regulators is several times lower (7.5, 11 and 15 times).

The genotypic response to the use of stimulants was the highest in the Levada variety and the highest yield was obtained by treatment with Regoplant - 21.85 t/ha.

The smallest increase in yield due to the actions of regulators was observed in the Skarbnitsa variety - 0.71; 2.34 and 1.61 t/ha (3.6; 12.0 and 8.3%). In the Yavir variety, the increase was 1.18; 2.14 and 1.75 t/ha (6.4; 11.6; 9.5%). The best response to the treatment was received in the Levada variety - the increase was 8.4, 21.7 and 10.9%. The average increase from the

treatment by regulators against the background of mineral fertilizer application at the dose of $N_{45}P_{45}K_{45}$ was 1.14, 2.81 and 1.78 t/ha (6.1; 15.0 and 9.5%) (Table 2).

Table 2. Effect of growth regulators on the background of $N_{45}P_{45}K_{45}$ on the yield and seed quality of potato, average for 2016-2018

Growth regulator	Yield, t/ha	Number of tubers per plant, pcs.	Weight of average tuber, g	Marketability, %	The output of the seed fraction, %	Weight of seed tubers, g
Without treatment	18.70	6.6	58.5	83.7	52.7	66.5
Emistim C	19.84	7.0	60.4	85.0	55.8	70.2
Regoplant	21.51	7.2	61.6	86.3	57.3	73.8
Stimpo	20.48	7.0	60.4	85.4	55.5	71.4

The maximum number of tubers from the plant in the experiment was formed by the variety Skarbnytsia - 7.6, Yavir slightly less - 6.9; least - Levada - 5.5 (Table 3). The application of $N_{45}P_{45}K_{45}$ and $N_{90}P_{90}K_{90}$ helped to increase the number of tubers by 1.2 and 1.5 pcs/bush; as a whole, only the treatment with the Regoplant regulator significantly increased the number of tubers, while on the background $N_{45}P_{45}K_{45}$ all stimulants increased the indicator by 0.4; 0.6 and 0.4 pcs.

As for the weight of average tuber, the effect of the variety is opposite - in the first place Levada - 71.7 g, in the second Yavir - 54.5 g; and Skarbnytsia on the latter - 49.8 g, which is 44% less than Levada. That is, the impact of the variety on this indicator, as on the previous one, is the most significant; after all fertilizers increased it by 6.6 g (12%) and 8.5 g (16%), and regulators as a whole are not reliable. Against the background of $N_{45}P_{45}K_{45}$ regulators significantly increased it by 1.9; 3.1 and 1.9 g (3; 5; 3%).

Table 3. Crop structure and seed properties of potatoes depending on variety, fertilizer and growth regulator (average by factors), 2016-2018

Variety/ Fertilizer/ Growth regulator	Number of tubers per plant, pcs	Weight of average tuber, g	Marketability, %	The output of the seed fraction, %	Weight of seed tubers, g
Skarbnytsia	7.6	49.8	82.0	56.2	61.0
Levada	5.5	71.7	88.1	51.5	75.1
Yavir	6.9	54.5	80.9	53.4	67.9
without fertilizer	5.8	53.6	79.8	48.8	59.3
$N_{45}P_{45}K_{45}$	7.0	60.2	85.1	55.3	70.5
$N_{90}P_{90}K_{90}$	7.3	62.1	86.1	56.9	74.3
without treatment	6.6	58.2	82.9	52.8	66.9
Emistim C	6.7	59.1	83.5	53.7	68.3
Regoplant	6.7	59.0	84.4	54.6	69.1
Stimpo	6.7	58.3	83.8	53.6	67.8
Significance of the main effects					
LSD_{05} variety	0.17	0.76	1.12	1,04	1.57
LSD_{05} / fertilizer	0.10	1.61	1.68	1,52	2.53
LSD_{05} growth regulator	0.14	1.35	1.33	1,62	2.13

The highest marketability is in the Levada variety (88%), the indicators of the variety Yavir and Skarbnytsya differed on 1% - 81-82%. Here the impact of the variety is also highest, but fertilizers at the same level increased the marketability of potatoes - by 5 and 6%; Regoplant - up to 1.5%. Against the background of the $N_{45}P_{45}K_{45}$, the percentage of Stimpo and Regoplant commercial potatoes was significantly increased by 1.6 and 2.5%, respectively.

For three years of research, the following indicators of seed productivity of potato varieties were established: Levada is

characterized by the heaviest seed tuber among other varieties - 75.1 g and the lowest yield of the seed fraction - 51.5%. In the second place Yavir - 68 g and 53%, respectively. Skarbnytsya has the lightest seed tuber and the highest yield of this fraction - 61 g and 56%.

Fertilizers provided the following effect: 7% and 8% increased the yield of seed fraction and 11 and 15 g, respectively, of seed tubers (19% and 25%). On average, Regoplant increased by 2 g the weight of seed tubers and by 2% yield of the seed fraction (both indicators were at the level of the least significant difference). Against the background of $N_{45}P_{45}K_{45}$, the effect of all regulators was significantly higher: +4, +7, +5 g (6, 11, and 7%) of seed potato weight and +3, +5, +3% yield of seed fraction. The average yield of the seed fraction of potatoes was 10.26 t/ha. The lowest seed productivity was observed in the Levada variety - 9.85 t/ha, the highest in the Skarbnitsa variety - 10.76. The application of mineral fertilizers at a dose of $N_{45}P_{45}K_{45}$ increased the content of the conditioned seeds by 55.7%, $N_{90}P_{90}K_{90}$ by 72.1%, compared to the unfertilized control. The use of growth regulators did not affect the yield of the seed fraction of potatoes in the whole research. Against the background of the $N_{45}P_{45}K_{45}$, seed productivity increases were recorded for Stimpo (1.51 t/ha higher than the untreated control) and Regoplant (2.47 or 24.9% higher).

In 2016-2018, potatoes accumulated 21.7% of dry matter in tubers on average. In 2016, the average dry matter content was 21.9%, in 2017 - 23.4%; in 2018 - 19.7%.

Early-ripening Skarbnitsa and middle-ripe Yavir accumulated the same amount of dry matter - 22.5% (Figure 1).

The middle-early Levada is behind in this indicator by 19.9%. The application of mineral fertilizers increased its content by 0.9% and 1.1% in the three varieties. The use of growth regulators also had a positive impact on this indicator +0.8%; 1.1% and 0.8% of the whole research and +0.8; +1.5 and + 0.8% against the $N_{45}P_{45}K_{45}$ background.

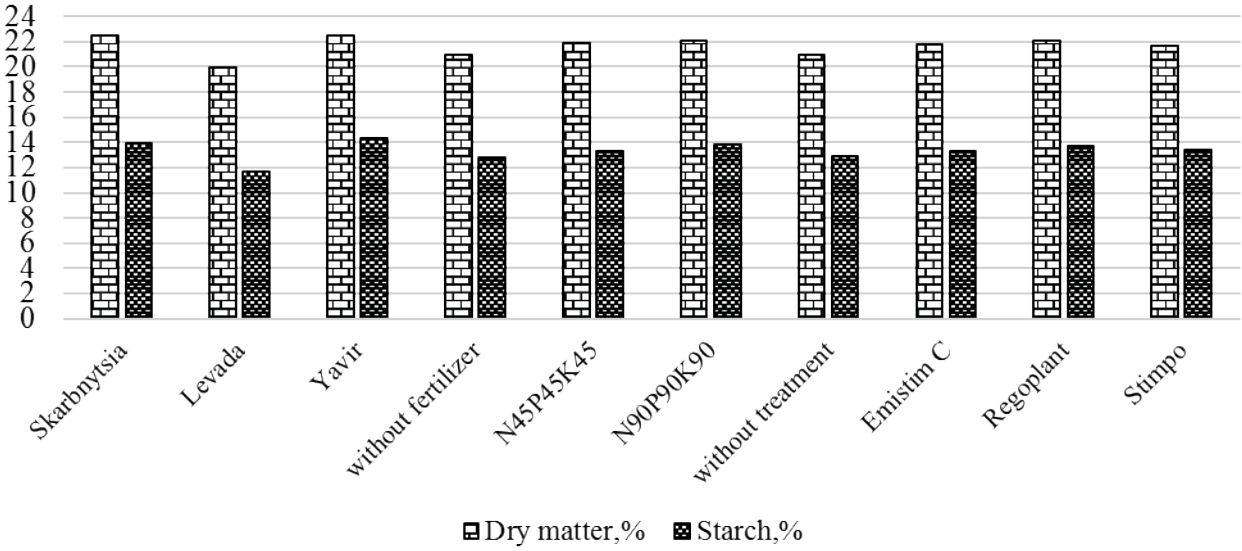

Figure 1. The content of dry matter and starch (%) in potatoes depending on the variety, fertilizer and growth regulator (average by factors), 2016-2018

The potato starch content in the three years averaged 13.3%. The relatively low starch content of the potato under study can be explained by the composition of the soil (on medium- and heavy-loam soils the starch content decreases) and the high temperatures during the period of reaching the tubers. Also, this indicator, as well as the previous one, differed significantly by years of research - 12.9% in 2016, 14.2% in 2017 and 12.7% in 2018. As we can see, 2017 was not only favorable for the formation of a high yield of potatoes (the highest in years of research), but also conducive for the accumulation of dry matter and starch in tubers. The most starchy variety was Yavir - 14.3%. The lowest starch content was in the Levada variety - 11.7%. The

Skarbnitsa took the intermediate place with 13.9% of starch.

Fertilizer application has influenced this indicator not so much as varietal features. Regulators increased potato starch content by 0.4, 0.8 and 0.5% at all nutrition levels and by 0.8, 1.4 and 0.9% against $N_{45}P_{45}K_{45}$. Vitamin C content was 173.5 mg/kg over three years. In 2016 - 206, in 2017 - 175, in 2018 - the least: 140 mg/kg. Varietal features influenced this indicator as follows: Skarbnitsa contained 178 mg, Yavir - 176, Levada - 167 mg/kg. Therefore, it can be concluded that, unlike the Skarbnitsa and Yavir varieties, Levada accumulates significantly less dry matter, starch and vitamin C.

There was a negative tendency of the effect of fertilizer on the accumulation of vitamin C: the application of $N_{45}P_{45}K_{45}$ reduced the vitamin C content by 6.9 mg/kg (3.9%); $N_{90}P_{90}K_{90}$ - by 13.5 mg/kg (7.5%). Regulators reduced vitamin C content, by whole, by 1.5; 2.9 and 3.2%. However, in most cases with $N_{45}P_{45}K_{45}$ there was even a slight increase over the untreated control. The content of nitrates in the tubers did not exceed the limit in Ukraine value (120 mg/kg) in all the years of the study. The average value is 57.5 mg/kg. In the Levada tubers it was 62.5 mg/kg, tubers of Skarbnitsa and Yavir accumulated 58.5 and 51.4 mg/kg nitrates respectively. On this indicator, the varietal characteristics were influenced not so much as the amount of fertilizer applied: tubers in variants without fertilizer accumulated 44.2 mg/kg nitrates, with $N_{45}P_{45}K_{45}$ - 57.46 mg/kg, with $N_{90}P_{90}K_{90}$ - 70.8 mg/kg. Thus, the application of these amount of fertilizer increased the nitrate content by 30.1 and 60.4%.

Regulators Emistim C and Stimpo reduced the average nitrate content by 2.0 and 5.5%, respectively. For this indicator there is a noticeable difference of influence of regulators depending on the level of mineral nutrition: on the background without fertilizers there is an increase of nitrate content from treatment by regulators from 1.9 to 12.0%; on the $N_{45}P_{45}K_{45}$ background, regulators also increase nitrate content (except Stimpo); while on a high fertilizer background, nitrate content is reduced to 21.3%. In the experiment of Pavlista (2011) also used growth regulators of complex

Application of $N_{45}P_{45}K_{45}$ increased starch content from 12.8 (control variants) to 13.3% (by 0.5%); $N_{90}P_{90}K_{90}$ - up to 13.7% (0.9%).

composition, which at early harvest increased the yield of the Atlantic potato by 13-15%. In the experiment of Chekmarev et al. (2015), a two-fold treatment with commercial growth regulators increased yields by 5.18-7.16 and 4.16-5.20 t/ha. Głosek-Sobieraj et al. (2018) have shown that complex growth regulators increase the yield and the percentage of medium-sized tubers.

In the experiment of Awati et al. (2016), growth regulators increased the total yield, the number of tubers from the bush from 2.6 to 3.4 pcs. In the Bhattarai (2017) experiment, paclobutrazole treatment increased the weight and size of tubers. The use of ethephon growth regulators (ETH) and chlormequat chloride (CCC) in different doses has led to an increase the total number of tubers and a decrease in the weight of tubers, as a consequence - a decrease in marketability (Sekhon and Singh, 1985). The yield of marketable potatoes from the combined use of growth stimulant at the beginning of the growing season and the inhibitor at the end of the growing season increased by 9.16% in the experiment of Kumar et al. (2015). With the use of Epin Extra Pashkova and Kuz'minykh (2018), the crop increased by 1.9 t/ha, the dry matter content increased by 2.3-2.6% and the starch by 0.7-1.3%. In the experiment of Araujo et al. (2019), potato were treated with paclobutrazole (PBZ) and trinexapac-ethyl (TE) at the end of the growing season, which led to a decrease in starch and reduced sugars content in tubers. In addition to the growth regulator and the weight of the seed potatoes, the potato growth parameters were significantly influenced by the variety factor (Otroshy and Struik, 2008).

Wierzbowska et al. (2015) stated that although biostimulants improved the quality of potatoes in their experiment, it was more dependent on the characteristics of the variety than on the biostimulants used.

CONCLUSIONS

Maximum productivity of early and middle-early varieties Skarbnitsa and Levada was

formed by the application of mineral fertilizers at a dose of $N_{45}P_{45}K_{45}$ treated with growth regulator Regoplant - 21.85 and 22.12 t/ha. The middle-ripe variety Yavir is better grown with $N_{90}P_{90}K_{90}$, with a yield of 22.65 t/ha. The genotypic response to stimulant use was highest in the Levada variety. The growth regulators increased yield of tubers biological maturity on the background $N_{45}P_{45}K_{45}$ by 1.14 t/ha (Emistim C); 1.78 t/ha (Stimpo) and 2.81 t/ha (Regplant) compared to untreated control. The number of tubers, the weight of average tuber, the amount of dry matter and starch, the content of nitrates were influenced by fertilizers and growth regulators, although most significantly - the characteristics of studied varieties. Fertilizer application had a negative impact on vitamin C.

The application of mineral fertilizers at a dose of $N_{45}P_{45}K_{45}$ and the complex treatment of tubers and plants with growth regulators have increased the seed productivity of potato varieties. The output of the seed fraction increased by 7% (action of fertilizers) and 3-5% (action of regulators), the mass of seed tubers - by 19 and 6-11%. The highest profitability in the experiment - against the background of $N_{45}P_{45}K_{45}$ with Levada cultivar treatment - 149.2%. With the $N_{45}P_{45}K_{45}$, regulators increased profitability of ssed popato production by 10.1% (Emistim C), 15.8% (Stimpo) and 24.7% (Regoplant).

ACKNOWLEDGEMENTS

The publication contains the results of the research, within the budget program of the Cabinet of Ministers, under the CPCWC 6591060 "Basic research, applied scientific and scientific-technical development, implementation of works on state targeted programs and government procurement in the field of agro-industrial complex, training of scientific personnel, providing technical support institutions, development of scientific infrastructure and objects of national heritage". The researches were carried out according to the NAAP NAAN 17 "Scientific-methodical and analytical support of an innovative model of development of the potato industry".

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