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Virus-Free Potato Propagation in Greenhouse Conditions.

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ABSTRACT

Optimized seed-growing is one of the main approaches in increasing productivity of crops, including potatoes. To obtain high yields of potatoes, virus-free plants and appropriate agricultural methods, including fertilization regime, are used. Some aspects of virus-free potato propagation techniques and their profitability have not yet been studied in sufficient detail. Here, we investigated productivity of virus-free potato plants under different fertilization regimes in greenhouse conditions. Thirteen different options of fertilization regimes were tested, including different combinations of mineral, organic-mineral and microbiological fertilizers. The joint use of potassium-magnesium, organic-mineral fertilizer for potatoes, and Akvarin fertilizer resulted in maximal productivity per unit of greenhouse soil area, as well as the highest numbers of minibulbs and the greatest concentrations of protein and starch in bulbs. This option of fertilizing was also the most profitable, as its profitability made 226 %.
Keywords: seed-growing, virus-free potato, minibulbs, fertilizer.

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INTRODUCTION

Potato is one of the most economically important crops consumed world-wide. Russia holds the leading position in the world by amount of the annual potato production, however average potato productivity in Russia (9-11 t/hectare) is lower than the world average (15 t/hectare) [1]. Complexity of potato seed farming is bound to low coefficient of its vegetative reproduction and frequent affection by infectious diseases. Because of affection by diseases the potato crop can decrease by 50%, and in 10 years degeneration of fluke is at hand, potato will completely lose the initial qualities [2]. Therefore a basis of primary seed farming is receiving a healthy starting material, its manifolding and protection against repeated infection.

In addition to viroids and phytoplasma infections, more than 25 different virus diseases have been reported in potatoes [3]. Although not all of potato viruses cause severe diseases, such viruses as *Potato virus Y* (PVY), *Potato virus X* (PVX), *Potato leafroll virus* (PLV) are in the list of the world's "top" plant viruses, based on their scientific and economic importance [4]. Virus disease symptoms in plants are observed as alterations in shape, size, and texture of leaves, stems, and bulbs. Macroscopic alterations in bulbs are the most important economically and include changes in size and shape, cracking, flaccidity, and necrosis. Moreover, bulbs become the reservoirs of infection. Synergistic infections (e.g. PVY and PVX) may induce more severe symptoms, compared to single-virus infections. Plant infections spread via (i) mechanical contacts of contaminated and healthy plant parts, (ii) transmission with vectors (e.g. aphids, fungi, nematodes), and (iii) through the parts of plants used for propagation (seeds and bulbs) [3].

Production of virus-free plants has been established as an effective method to control viral diseases in potatoes, preventing yield losses and crop degeneration. Conducting potato seed farming on the basis of revitalized (virus-free) starting material increases productivity by 25%, and considerably reduces prime cost of end products in comparison with use of routine high-quality material. In this regard, potato production around the world is being transferred to a virus-free basis by use of apical meristem method. The method is based on plant cultivation from apical zones of the sharing cages, free from viral and other infections. Effectiveness of improvement depends on high-quality plant features, initial fluke virus contamination, and the size of isolated explants [5].

Aside from use of healthy sowing material, the big potato crop requires optimum combination of various factors: illuminating intensities, temperatures, soil and air humidity, as well as nutrient availability [6,7,8]. For normal growth and development potatoes need high content of nitrogen, phosphorus, potassium, calcium, magnesium, sulfur. Nitrogen is necessary for leaf apparatus and spouts growth, phosphorus – for full development of root system and bulb forming. Potassium regulates water balance of plant tissue, magnesium enhances photosynthesis, and manganese and boracium increase nonvolatile solid formation [9]. Sufficient fertilization provides all necessary elements, thus affecting bulb quality and potato yields [10,11,12], as well as potato resistance to different pathogens [9,13,14].

In spite of the fact that today there is a set ways of importation and effective fertilizer use, some aspects of fertilizer various combinations influence on crop forming are still studied insufficiently. The purpose of our research was to study the efficiency of test-tube potato revitalizing of "Zhukovsky early" fluke in hothouse conditions of nutrition regulation.

DATA AND METHODS

Researches were conducted in hothouse conditions in the Tatar Research Institute of Agriculture (FGBNU of "TATNIISKH") biotechnology laboratory. The revitalized test-tube plants of "Zhukovsky early" fluke grafted in Murasige-Skugu medium, then for 4 weeks were grewn at 16 hour photoperiod, air temperature varied within + 22^{0}C, illuminating intensity was 4 thousand lux, relative air humidity made 75%.

On 29.05.2014 tast-tube plants were planted in greenhouse on peat soil with standing thickness of 50 plants/m^2. Experiment frequency was quadruple. Placement of allotments was casual. Soil was enriched with fertilizers for nutrition, at the rate of the basic elements (N, P, K) maintenance for potato crop yield of 60 t/hectare, which is optimum for Central Volga Area. Padding fertilizers were introduced on different phases of plant development (table 1). 13 options of mineral nutrition were investigated. In option No.1 (observed) only background mineral nutrition was noted Table 1 Test scheme.

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Table 1

Variations	Plant development phases				
	Planting	Growth	Budding and blossoming	Tuber formation	End of Vegetation
1 (control)	-	-	-	-	-
2	GMN (100 kg/hectare)	-	-	-	-
3	KMG (100 kg/hectare)	-	-	-	-
4	KMG (100 kg/hectare) + KMG (100 kg/hectare)	-	-	-	-
5	KMG (100 kg/hectare) + KMG (100 kg/hectare)	Aquarin (3 kg/hectare)	Aquarin (3 kg/hectare)	Aquarin (3 kg/hectare)	Aquarin (3 kg/hectare)
6	-	Aquarin (3 kg/hectare)	Aquarin (3 kg/hectare)	Aquarin (3 kg/hectare)	Kelik potassium (0.5 l/hectare) + Raykat start (125 ml / 100 water l)
7	Raykat start (150 ml / 10 water l)	Raykat start (125 ml / 100 water l in 7 days)	Raykat start (125 ml / 100 water l in 7 days)	Nutrivant + (2 kg/hectare)	-
8	Raykat start (150 ml / 10 water l)	Raykat start (125 ml / 100 water l in 7 days)	Floron (150 ml / 100 water l in 7 days)	Kelik potassium (0.5 l/hectare) + Floron (150 ml / 100 water l in 7 days)	Kelik potassium (0.5 l/hectare) + Floron (150 ml / 100 water l in 7 days)
9	Raykat start (150 ml / 10 water l)	Razormin (0.5 l/hectare)	Razormin (0.5 l/hectare)	Nutrivant + (2 kg/hectare)	Kelik potassium (0.5 l/hectare) + Floron (150 ml / 100 water l in 7 days)
10	Flavobakterin	Flavobakterin in 7 days	Flavobakterin in 7 days	Flavobakterin in 7 days	Flavobakterin in 7 days
11	Planriz	Planriz in 7 days	Planriz in 7 days	Planriz in 7 days	Planriz in 7 days
12	ZHUSS	ZHUSS in 7 days	ZHUSS in 7 days	ZHUSS in 7 days	ZHUSS in 7 days
13	Exstrasol	Exstrasol	Exstrasol	-	-

Mineral and organic-mineral fertilizers introduced are: potassium magnesia (PM), Akvarin, Kelik potassium, Nutrivant +, organic-mineral fertilizer (OMF), Raykat Start; block of bio-stimulators: Floron, Razormin, ZUSS; block of bacteriemic fertilizers: Ekstrasol (basic rhizophore Bacillus subtilis Ch-13 bacteria), Flavobakterin (Flavobacterium basis), Planriz (basis of Pseudomonas fluorescens AP-33).

Observation was maintained during phenological phases. Biochemical indexes of bulbs defined were: solid basis, Amylum, Acidum ascorbinicum and protein. The crop accounting was carried out on 21.09.2014. Crop efficiency and structure analysis was held during harvesting [15].

Product profitability was accounted by formula:

$$Pp = P/Z \times 100\%$$

where Pp – profitability of production; P – profit from realized production; Z – cost of production.

For result statistical assessment we used the LED_{05} indicator – the least essential difference, with a significance level of 5%.

RESULTS AND DISCUSSION

Efficiency

Comparative assessment results of fertilizers and leaf-feeding dressing influence on potato efficiency are presented in table 2 and in figure 1.

Table 2: Test-tube plant efficiency

No.	Quantity of bulbs		Mass of bulbs		Average weight 1 bulb, g
	piece/bush	piece/m^2	g/bush	g/m^2	
1 (control)	3.1	155.0	78.6	3930.0	25.4
2	4.0	200	113.8	5690	28.5
3	4.1	205	119.3	5965	29.1
4	4.4	220	139.7	6985	31.8
5	5.3	265	244.0	12200	46.0
6	4.0	200.	106.2	5310	26.6
7	3.2	160	82.7	4135	25.8
8	3.6	180	86.8	4340	24.1
9	3.8	190	81.2	4060	21.4
10	3.2	160	99.8	4990	31.2
11	3.1	155	93.2	4660	30.1
12	3.2	160	102.1	5105	31.9
13	3.9	195	103.7	5185	26.6

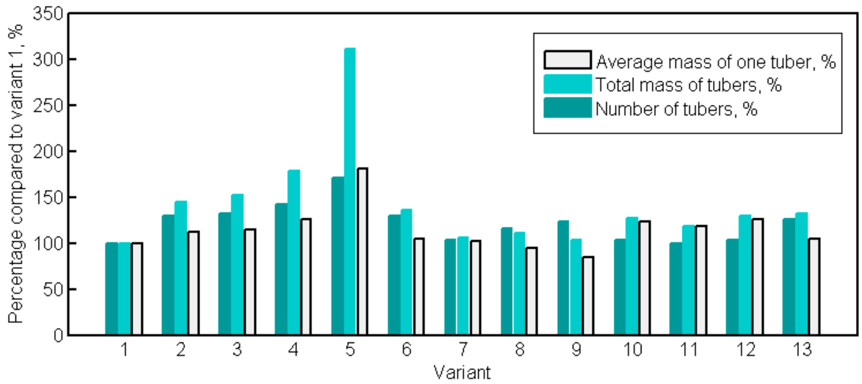

Figure 1: Percentage of bulbs total number, mass of bulbs and average mass of one bulb in options 1-13 (see table 1), compared to option 1(control, only basic fertilizer applied)

On the basis of the carried-out statistical processing it is established that options 2, 3, 4, 5, 6, 8, 9 and 13 authentically differ in bulb quantity; for observed options 7, 10, 11 and 12 reliability is not proved. Bulb mass of options 2, 3, 4, 5, 6, 8, 10, 11, 12 and 13 authentically differ from observed, for options 7 and 9 reliability is not proved.

In mineral and organic-mineral fertilizers block the significant increase in quantity of hothouse mini-bulbs was observed. In options 2, 6, 3, 4, 5 from 1 m^2 200, 200, 205, 220 and 265 mini-bulb p. respectively were harvested. Observed increase made 29 – 71%. In options with fertilizer processing by means of Raykat Start, Kelik Kaly, Nutrivant +, Floron and Razormin, the quantity of bulbs changed slightly, observed increase was 3 - 23%. In options with preparations ZUSS, Flavobakterin and Planriz the quantity of mini-bulbs differed from observed a little and made 155,0; 160 and 160 p/m^2. When processed by Ekstrasol 195 p/m^2 of mini-bulbs, yield increase by 26% (table 2, figure 1) was received.

The maximal productivity was provided by: processing by Akvarin – 5 kg/m^2 (+35% to observed), importation to OHM – 6 kg/m^2 (+45% to observed), KMG-of 6 kg/m^2 (+52% to observed), KMG + to OHM – 7 kg/m^2 (+78% to observed). Adding of KMG + OHM nutrition by Akvarin increased productivity to 12 kg/m^2. When processed with Raykat Start, Kelik Kaly, Nutrivant + Floron and Razormin the yield mass of mini-bulbs increased by 3 – 10%. In options with preparations ZUSS, Flavobakterin, Planriz and Ekstrasol efficiency grew respectively by 19, 27, 30 and 32%. Introduction of KMG+ OHM, KMG + OHM + Akvarin increased the average mass of 1 mini-bulb in comparison with observed by 25 and 81% and made respectively 32 and 46 g. Processing by preparations ZUSS 2, Flavobakterin and Planriz provided increase in average mass of 1 mini-bulb by 2, 23 and 26% (respectively 30; 31 and 32 g) (table 2, figure 1).

The best result combining the maximal mini-bulb quantity and mass yield with 1m^2 is received in option 5: bulb yield - 265 p/m^2, the mass of mini-bulbs – 12200 g/m^2, multiplication factor – 5.3 pieces, the average mass of 1 bulb – 46 g. Optimum humidity of the soil created opportunity for complete dissolution of the introduced fertilizers and their best assimilation. As a result plants developed good root system, potent leaf apparatus and managed to gain vegetative weight before the adverse period with high daytime temperatures; that favorably influenced the crop accumulation. Additional foliar dressing with Akvarin led to activation of metabolic and enzymatic processes in plants: microcells strengthened photosynthesis and carbohydrates outflow from leaves to bulbs, increased plant stress resistance. Besides, Akvarin extends the plant vegetation period that gives the plants a chance to completely saturate nutritious elements from fertilizers, complete mineralization occurs only in the second half of vegetation period.

Receiving technological minibulbs

Important task in mini-bulb cultivation is receiving the maximum quantity of technological mini-bulbs per 1m^2. For our conditions mini-bulbs weighing over 10 g (table 3) are such.

Table 3: Exit of hothouse mini-bulbs weighing over 10 g

No.	Bulb total, piece/m2	Quantity of bulbs weighing over 10 g		Total bulb weight, g/m^2	Total bulb weight over 10 g	
		piece/m^2	%		g/m^2	%
1 (control)	155	105.0	67.6	3930	3497.0	88.9
2	200	125	62.5	5690	5571	95.8
3	205	125	60.9	5965	5895	93.4
4	220	135	61.4	6985	6250	89.5
5	265	200	75.5	12200	12053	98.8
6	200	135	67.5	5310	4875	91.8
7	160	90	56.3	4135	3750	90.7
8	180	120	66.7	4340	3875	89.3
9	190	115	60.5	4060	3666	90.3
10	160	100	62.5	4990	4461	89.4
11	155	90	58.1	4660	3495	75.0
12	160	90	56.3	5105	4661	91.3
13	195	120	61.5	5185	4718	91.0

In block with organic-mineral fertilizers the quantity of technological mini-bulbs made 63 – 76%, weight yield - 90 – 99% of the total crop. The maximal yield of mini-bulbs was received in option 5 – 200 pieces weighing 12053 g. When processing by preparations Raykat Start, Kelik Kaly, Nutrivant + Floron and Razormin the quantity of technological bulbs made 56 – 67%, with weight of 90 - 91% from the total crop. The maximum quantity of such bulbs was received in the 8th option – 120 pieces weighing 3875 g/m^2. When processing by Flavobakterin, ZUSS, Planriz and Ekstrasol per 1m^2 we received 90 – 120 pieces of technological mini-bulbs weighing 3495 - 4718 g, that made 56 – 63% by quantity, by weight – 90 – 91% of the total crop.

Mini-bulb biochemical structure

The high content of nonvolatile solids and Amylum in bulbs is noted in option 1 (table 4). Under the influence of various fertilizer introduction decrease in these potato mini-bulb quality indexes was observed. Despite smaller starchiness of bulbs in these options, application the organic-mineral fertilizers significantly increased collecting Amylum per 1 hectare at the expense of increase in culture productivity. The maximum output of Amylum per 1 hectare is received in organic-mineral fertilizers block – 6961 kg/hectare (KMG), 8822 kg/hectare (KMG+ OHM) and 14933 kg/hectare (Kmg+omu+akvarin). In options 11 and 13 the yield of Amylum made respectively 6407 and 6238 kg/hectare. The content of redoxon in bulbs varied from 9% to 13%. The maximal yield of redoxon per 1 hectare is received in option 5 – 14 kg/hectare. In next option it made 4 – 8 kg/hectare. In other research options the content of redoxon was within 5 - 6 kg/hectare. According to the content of sugars options differed slightly - 2 - 3%. The content of nitrates in bulbs (figure 2) was within norm and made 101 – 222 mg/kg (marginal norm – 250 mg/kg).

Table 4: Mini-bulb biochemical structure

No. option	The contents in bulbs:							
	Dry matter	Protein,		Amylum,		Vitamin C		Sugar,
	%	% of dry mass	kg/hectare	%	kg/hectare	mg%	kg/hectare	%
1 (control)	19.9	2.2	872.5	14.8	5800.7	10.2	3.97	2.83
2	16.3	2.2	1240.4	9.1	5155.1	10.0	5.7	2.5
3	15.7	1.8	1079.7	11.7	6961.2	9.8	5.9	2.7
4	18.9	2.2	1564.6	12.6	8822.0	12.1	8.4	2.3
5	17.5	2.0	2391.2	12.2	14932.8	11.3	13.8	3.2
6	16.3	2.5	1338.1	10.9	5782.6	9.4	5.0	3.4
7	17.3	2.5	1017.2	8.4	3469.3	13.1	5.4	2.5
8	16.9	2.2	1076.3	11.3	4882.5	12.7	5.4	2.6
9	17.2	2.8	897.3	12.0	4888.2	12.7	5.1	3.0
10	20.1	1.9	1382.2	11.2	5578.8	10.6	5.3	2.4
11	17.0	2.3	899.4	10.9	5088.7	11.6	5.4	2.4
12	16.9	2.5	1189.5	12.6	6406.8	9.9	5.0	2.3
13	16.7	2.4	1234.0	12.0	6237.5	9.9	5.1	2.4

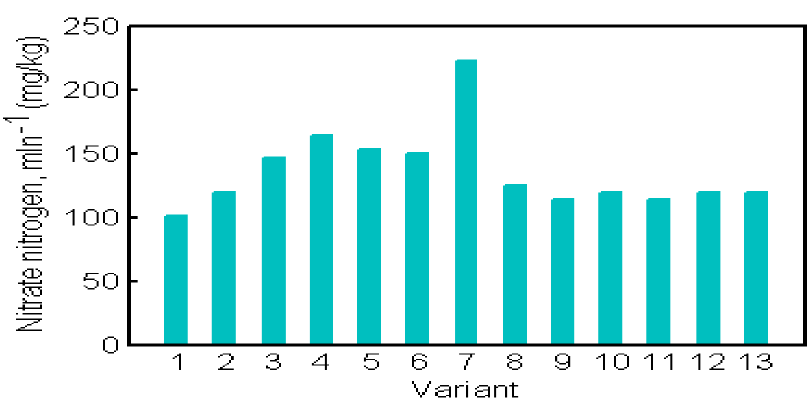

Figure 2: Nitrates concentration in mini-bulbs in options 1-13 (see table 1), where option is control (only basic fertilizer applied), and the norm for nitrogen concentration is 250 mg/kg.

Profitability of various fertilizers application options

The comparative economic analysis showed that profitability of the studied options varied from 92 to 226% (figure 3, table 5). Cultivation of such options appeared the most economic: 5 (profitability of 226%), 4 (profitability of 171%), 3 (profitability of 154%), 6 (profitability of 148%).

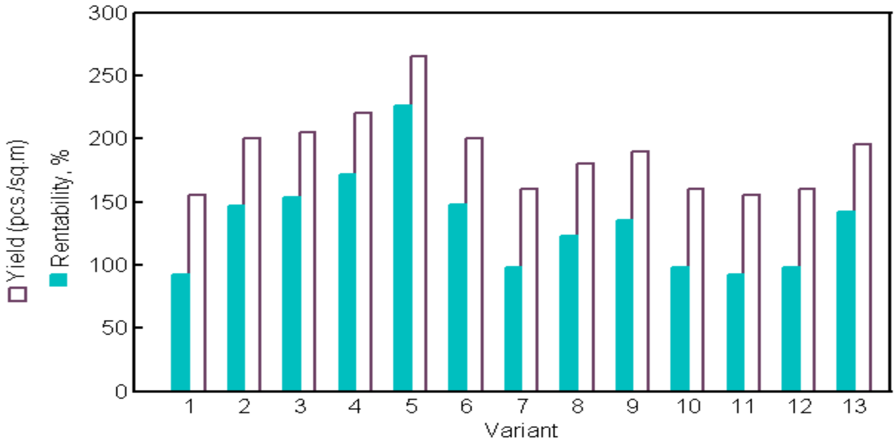

Figure 3. Yield (white bars) and profitability (colored bars) in options 1-13 (see table 1), where option is control (only basic fertilizer applied)

SUMMARY

From 13 studied options the maximal efficiency per $1m^2$ was received in Kalimagneziya's option + an organic-mineral fertilizer + Akvarin. Efficiency made 265 bulbs with total weight of 12200 g, a multiplication factor of 5.3 pieces, average mass of 1 bulb made 46 g. In this option also the maximum quantity of technological mini-bulbs was received - 200 pieces weighing 12053 g. This combination of fertilizers also provided the maximal yield of protein (2391 kg/hectare), Amylum (149328 kg/hectare) and redoxon (14 kg/hectare) in bulbs. The content of nitrates in bulbs of all research options were within admissible norm.

CONCLUSION

The following options are most economically profitable: Kalimagneziya + organic-mineral fertilizer + Akvarin (profitability of 226%), Kalimagneziya + organic-mineral fertilizer (profitability of 171%), Kalimagneziya (profitability of 154%), Akvarin (profitability of 148%).

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