Increasing potato yield using foliar fertilization to boost growth

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Abstract. To date, the use of fertilizers has become firmly embedded in advanced crop cultivation technologies, as the main component of obtaining high and sustainable yields. The nutritional regime of plants cannot be optimized only with the help of macronutrients. They also need trace elements that can increase the resistance of plants to adverse growing conditions, diseases and pests. However, the high cost of such fertilizers makes it necessary to develop new more effective and less expensive drugs. Therefore, in modern potato cultivation technologies, much attention is paid to non-root top dressing. As a result of three-fold leaf treatments with the developed fertilizer, the yield increase of potato variety Gulliver was 0.4...5.2 t/ha, variety Vimpel 2.0...5.1 t/ha, variety Matushka 0.1...4.1 t/ha.

1 Introduction

The world experience and practice of agriculture show that obtaining high and stable yields of agricultural crops is associated not only with plant breeding, the creation and introduction of new highly productive varieties into agricultural production, but also with the effective use of modern macro- and micro-fertilizers.

It is known that agricultural crops have a selective ability to various trace elements, which take an active part in many vital processes occurring in the plant. So for winter and spring crops, the most important of the trace elements is copper and manganese; for fodder crops – boron, copper and molybdenum; for arable crops - boron, copper and manganese. The need of plants for trace elements increases with a decrease in soil acidity, with a high content of available phosphorus and nitrogen in the soil, with the introduction of large doses of phosphorus and nitrogen fertilizers [1,2]. Therefore, in modern technologies of cultivation of agricultural crops, much attention is paid to non-root fertilizing, in which the assimilation of nutrients occurs with the help of plant leaves.

In recent years, much attention has been paid to the development of promising chelated micronutrients that are practically non-toxic and highly soluble in water. They do not change their properties in a wide range of acidity and remain accessible to plants for a long time. Trace elements, along with biological molecular systems, provide the most important metabolic processes of intracellular metabolism. Without them, enzymes are not formed, photosynthesis, the formation of sugary and protein substances is impossible [3].

2 Materials and research methods

Experiment establishment, records and observations were carried out in accordance with the requirements of the methodology of field experiment [1], the methodology of research on potato culture [3] and the methodology of conducting agrotechnical experiments, records, observations and analyses on potatoes [4]. The results of the experiment were processed using the method of dispersion analysis of the data obtained by B.A. Dospekhov [5].

The soil of the experimental site was characterized as sod-podzolic sabulous with the following nutritional characteristics of the plowing horizon before experiment establishment: the soil of the site on which the experiment was located had high metabolic and hydrolytic acidity (pH KCl = 4.71; Ng = 3.27 mg-eq /100g of soil); low amount of absorbed bases and degree of saturation with them (S = 3.11 mg-eq/100g of soil; V = 48.7%); high content of mobile phosphorus (315 mg/kg of soil) and low – exchangeable potassium (97 mg/kg of soil); satisfactory humus content (1.91% of humus). The ultimate field water capacity of the soil (UFWC) is 13.3%. At the same time, the research program had the following content (Table 1).

Table 1. Scheme of experiment.

Variety	Depth of basic tillage, cm	Fertilizer	Presence of green manure
Gulliver (early)	10-15 cm	$N_{60}P_{60}K_{90}$	Legumes
Vimpel (middle-early)	10-15 cm	$N_{60}P_{60}K_{90}$	Legumes
Matushka (mid-season)	10-15 cm	$N_{60}P_{60}K_{90}$	Legumes

The area of the accounting plot averaged -12.5 m2; the repetition of the experiment was fourfold; the placement of plots was systematic.

The foliar fertilization of the studied potato varieties was carried out with an experimental preparation containing nitrogen, boron and copper, the chemical composition of which is presented in Table 2.

Table 2. Chemical composition of the tested fertilizer.

For vegetable crops	Trace elements, g/100 g		
	N	B	Cu
	16.77 - 20.57	3.25 - 6.89	0.270 - 0.276

Dosage of the drug during testing: water without the drug (control); concentration of an aqueous solution 1:1000; 1:500; 1:125.

3 Results and discussions

The size of the aboveground mass in many cases are the decisive factors determining the intensity of accumulation and the amount of yield. The productivity of potato plants under normal conditions of growth and development is directly dependent on the capacity of its aboveground mass.

The parameters of plant bush development are related to both general metabolic processes and external soil and climatic conditions. Taking into account the importance of biometric indicators of the development of the tops in the formation of the crop, the biometric indicators of plant development are taken into account in Table 3.

Table 3. Biometric indicators of potato plants in the potato flowering phase, average values.

Technological reception	Plant height, cm	Weight of the tops, kg /bush	Assimilation surface of leaves, m^2/bush	Number of tubers, pcs./bush	Weight of tubers, kg/bush
Gulliver					
1. Control	31	0.34	0.19	7.5	0.25
2. Experiment, 1:1000	33	0.34	0.21	7.8	0.24
3. Experiment, 1:500	33	0.35	0.23	9.0	0.29
4. Experiment, 1:125	35	0.39	0.25	11.0	0.33
Vimpel					
1. Control	42	0.43	0.28	11.0	0.31
2. Experiment, 1:1000	41	0.43	0.28	12.0	0.37
3. Experiment, 1:500	44	0.46	0.30	11.0	0.42
4. Experiment, 1:125	41	0.45	0.30	11.0	0.38
Matushka					
1. Control	31	0.34	0.15	7.5	0.25
2. Experiment, 1:1000	33	0.34	0.16	7.8	0.24
3. Experiment, 1:500	33	0.35	0.18	9.0	0.29
4. Experiment, 1:125	35	0.39	0.19	11.0	0.33

Foliar fertilization with the test preparation affected the biometric indicators of potato plant development. It can be noted that, depending on the dose of the drug used on all varieties, the weight of the tops and the area of the leaf surface are slightly higher in the variants with the use of the drug than in the control variant, where the leaf treatment was carried out only with water. On the Gulliver variety, the weight of the tops in the variants with the use of drugs was 0.34...0.39 kg/bush, and in the control variant - 0.34 kg/bush; on the Vimpel variety - 0.43 ...0.45 kg/bush, in the control variant - 0.43 kg /bush; on the Matushka variety - 0.34 ...0.39 kg/bush, in the control variant - 0.34 kg /bush.

At the same time , the potato yield of the variants with the use of the test preparation was: on the Gulliver variety – 20.9...25.8 t/ha, which turned out to be higher than the yield in the control by 0.4...5.2 t/ha, on the Vimpel variety - 21.7...24.9 t/ha, which turned out to be higher than in the control by 2.0...5.1 t/ha; on the Matushka variety – 16.0... 20.0 t/ha, which turned out to be higher than in the control by 0.1...4.1 t/ha.

Table 4. Effect of increasing doses on potato yield, t/ha (2022).

Variant	1 repeat.	2 repeat.	3 repeat.	4 repeat.	Average	± to control	
						t/ha	%
Gulliver							
1 Control (water)	17.0	22.4	23.0	19.8	20.6	0	-
2 (1 to 1000 water)	20.8	22.6	22.0	18.2	20.9	0.4	1.5
3 (1 to 500 water)	25.0	27.5	26.6	23.9	25.8	5.2	25.2
4 (1 to 125 water)	22.4	25.2	23.8	23.4	23.7	3.2	15.0
Average by variety	-	-	-	-	22.8	-	-
LSD_{05} by variety, t/ha	-	-	-	-	2.13	-	-

Continuation of Table 4.

Variant	1 repeat.	2 repeat.	3 repeat.	4 repeat.	Average	± to control	
						t/ha	%
Vimpel							
1 Control (water)	29.4	14.6	22.8	12.2 19.8		0 -	
2 (1 to 1000 water)	28.8	24.6	24.8	10.4	22.2	2.4	12.1
3 (1 to 500 water)	29.2	28.8	25.8	15.6	24.9	5.1	25.8
4 (1 to 125 water)	26.0	19.0	23.2	18.6	21.7	2.0	9.6
Average by variety	-	-	-	-	22.2	-	-
LSD_{05} by variety, t/ha	-	-	-	-	1.82	-	-
Matushka							
1 Control (water)	15.6	15.6	16.0	16.4	15.9	0	-
2 (1 to 1000 water)	16.6	15.9	19.6	17.7	17.5	1.6	10.1
3 (1 to 500 water)	20.6	18.0	20.2	21.2	20.0	4.1	25.8
4 (1 to 125 water)	15.8	15.7	16.1	16.5	16.0	0.1	0.6
Average by variety	-	-	-	-	17.4	-	-
LSD_{05} by variety, t/ha	-	-	-	-	1.66	-	-
LSD_{05}, total, t/ha	-	-	-	-	3.06	-	-
LSD_{05}, variety, t/ha	-	-	-	-	2.42	-	-
LSD_{05}, application of the drug, t/ha	-	-	-	-	1.32	-	-

In the arid conditions of 2022, for all three varieties, the best option turned out to be the option with a foliar fertilization with the tested drug in a concentration of 1:500. The increase in yield relative to the control was significant and reliable.

The size of tubers with the largest transverse diameter according to the standard should be at least 30 mm – for rounded-oval and 28 mm – for elongated tubers [7]. The yield structure of potato tubers is shown in Table 5.

Table 5. Yield structure (%), 2022.

Variety	Variant	Fractional composition, mm					
		<30	31-45	46-53	53-60	61-70	>70
Gulliver	Control (water)	7	47	28	8	10	0
	1:1000	6	58	24	12	0	0
	1:500	5	46	30	16	3	0
	1:125	7	49	28	16	0	0
Vimpel	Control (water)	5	63	19	6	7	0
	1:1000	6	52	24	18	0	0
	1:500	7	60	29	4	0	0
	1:125	4	53	30	9	4	0
Matushka	Control (water)	12	74	14	0	0	0
	1:1000	15	67	12	6	0	0
	1:500	13	75	6	6	0	0
	1:125	12	81	7	0	0	0

It can be seen from the table data that the mass of non-commercial tubers with a diameter of less than 30 mm in cross-section is insignificant in comparison with the total mass of tubers. Tubers of the early Gulliver variety are slightly larger than tubers of the Vimpel and Matushka varieties. The marketability of the tuber harvest significantly depended on the conditions of the year and the use of the drug, so the average percentage of commercial tubers in the variants of the Gulliver variety was 93-95%, in the variants of the Vimpel variety – 93-96%, in the variants of the Matushka variety – 80-84%

The main indicators of the quality of potato tubers include: the content of dry matter and starch. These two indicators are closely related to each other and to a greater extent depend on varietal characteristics and nutritional conditions. The content of dry matter in tubers is of great importance. It affects the yield of products and is one of the main indicators of the suitability of potatoes for processing. Many studies have shown that a high content of solids and starch provides an increased yield of finished products [8]. The more dry matter in potatoes, the better the quality of processed products (taste, crispy properties, mealiness) [9-10].

It is important to get not only a large potato crop, but also to achieve a high content of dry matter and starch in tubers. This is primarily determined by the biological characteristics of the variety, as well as these indicators can vary significantly from growing conditions. According to Table 6, the starch content of Gulliver tubers ranged on average between 13.2...15.6%, Vimpel tubers - 15.1...19.0%, Matushka tubers - 16.2...18.1%. Dry matter content – 18.9...21.6%; 20.8...24.8% and 21.8...23.9%, respectively.

Table 6. The content of starch and dry matter in potato tubers, depending on the concentration of the drug (2022), %.

Variety	Variant	Average weight of 1 tuber, g	Starchiness, %			Dry substances, %		
			%	Average	± to control	%	Average	± to control
Gulliver	1 Control (water)	140	15.2	14.2	-	20.9	19.9	-
		78	13.2			18.9		
	2 (1 to 1000 water)	90	13.9	14.6	0.4	19.7	20.3	0.4
		68	15.2			20.9		
	3 (1 to 500 water)	111	14.5	15.1	0.9	20.3	21.0	1.1
		80	15.6			21.6		
	4 (1 to 125 water)	110	14.1	14.5	0.3	19.8	20.3	0.4
		76	14.9			20.7		
	average	94	14.6	14.6	-	20.4	20.4	-
	LSD_{05}	-	-	0.32	-	-	0.40	-
Vimpel	1 Control (water)	105	16.3	16.8	-	22.1	22.6	-
		59	17.3			23.1		
	2 (1 to 1000 water)	107	18.4	18.7	1.9	24.2	24.5	1.9
		59	19.0			24.8		
	3 (1 to 500 water)	88	18.7	18.2	1.4	24.5	24.0	1.4
		63	17.7			23.5		
	4 (1 to 125 water)	112	15.1	16.4	-0.4	20.8	22.2	-0.4
		60	17.6			23.6		
	average	82	17.5	17.5	-	23.3	23.3	-
	LSD_{05}	-	-	0.95	-	-	0.95	-
Matushka	1 Control (water)	74	16.4	16.8	-	22.2	22.6	-
		60	17.2			22.9		
	2 (1 to 1000 water)	93	16.7	16.9	0.1	22.4	22.6	0
		63	17.0			22.7		
	3 (1 to 500 water)	106	18.1	17.6	0.8	23.9	23.3	0.7
		56	17.0			22.7		
	4 (1 to 125 water)	60	16.2	16.7	-0.1	21.8	22.3	-0.3
		47	17.1			22.8		
	average	70	17.0	17.0	-	22.7	22.7	-
	LSD_{05}	-	-	0.35	-	-	0.37	-

Moreover, higher values of starch and dry matter content in tubers of all studied varieties were obtained in variants with foliar fertilization with the tested preparation at a concentration of 1:500.

Non-root nutrition of plants until recently was not considered a mandatory method in the cultivation of agricultural crops. However, at present, the relevance and necessity of its application in agricultural production is a standard technological procedure that, in addition to balanced plant nutrition, allows agricultural producers to obtain high-quality products at the lowest cost. The methodology of economic evaluation of the effectiveness of fertilizer application is based on a comparison of the conditional net income from the use of the drug with the costs incurred for fertilizer.

The approximate cost of the drug is 10,000 rubles for 1.0 liter. The flow rate of the working fluid is 300 l/ha. The main basic costs according to economists for crop processing are 151,200 rubles/ha (Tables 7-9).

To calculate the conditional net income for each variety in the conditions of 2022, potatoes of only the "commercial" fraction (more than 30 mm in transverse diameter) were taken into account. We accepted the conditional sale price of 15 and 25 rubles/kg. Then, after calculating the commodity yield, we determined the amount of estimated revenue for the options at the estimated selling price of potatoes of 15 and 25 rubles/kg. And we received an estimated (conditional) net income from the use of the drug.

Table 7. Calculation of costs and conditional net income for the Gulliver variety depending on the concentration of the drug used in the conditions of 2022.

Indicators	**Control variant**	**Variants with the use of the drug**		
Dose of the drug during foliar fertilization, l/ha	0	0.3 (1:1000)	0.6 (1:500)	2.4 (1:125)
Main basic costs, thous. rub./ha	151.2	151.2	151.2	151.2
Cost of the preparation for 3 foliar fertilizations, thous. rub./ha	0	9.0	18.0	72.0
TOTAL costs, thous. rub./ha	151.2	160.2	169.2	223.2
Average gross yield, t/ha	20.6	20.9	25.8	23.7
Commodity yield, %	93	94	95	93
Commodity yield, t/ha	19.2	19.6	24.5	22.0
Revenue at the price of 15 rubles/kg, thous. rub./ha	287.4	294.7	367.7	330.6
Revenue at the price of 25 rubles/kg, thous. rub./ha	479.0	491.2	612.8	551.0
Income at the price of 15 rubles/kg (revenue minus expenses), thous. rub./ton	136.2	134.5	198.5	107.4
Income at the price of 25 rubles/kg (revenue minus expenses), thous. rub./ton	327.8	331.0	443.6	327.8
Conditional net income (CNI) from the use of the drug at the selling price of potatoes 15 rub./ kg	-	-1.7	62.3	-28.8
CNI from the use of the drug at the selling price of potatoes 25 rub./kg	-	3.2	115.8	0.1

Table 8. Calculation of costs and conditional net income for the Vimpel variety depending on the concentration of the drug used in the conditions of 2022.

Indicators	Control variant	Variants with the use of the drug		
Dose of the drug during foliar fertilization, l/ha	0	0.3 (1:1000)	0.6 (1:500)	2.4 (1:125)
Main basic costs, thous. rub./ha	151.2	151.2	151.2	151.2
Cost of the preparation for 3 foliar fertilizations, thous. rub./ha	0	9.0	18.0	72.0
TOTAL costs, thous. rub./ha	151.2	160.2	169.2	223.2
Average gross yield, t/ha	19.8	22.2	24.9	21.7
Commodity yield, %	95	94	93	96
Commodity yield, t/ha	18.8	20.9	23.2	20.8
Revenue at the price of 15 rubles/kg, thous. rub./ha	282.2	313.0	347.4	312.5
Revenue at the price of 25 rubles/kg, thous. rub./ha	470.3	521.7	578.9	520.8
Income at the price of 15 rubles/kg (revenue minus expenses), thous. rub./ton	131.0	152.8	178.2	89.3
Income at the price of 25 rubles/kg (revenue minus expenses), thous. rub./ton	319.1	361.5	409.7	297.6
Conditional net income (CNI) from the use of the drug at the selling price of potatoes 15 rub./ kg	-	21.9	47.2	-41.7
CNI from the use of the drug at the selling price of potatoes 25 rub./kg	-	42.5	90.7	-21.5

Table 9. Calculation of costs and conditional net income for the Matushka variety depending on the concentration of the drug used in the conditions of 2022.

Indicators	Control variant	Variants with the use of the drug		
Dose of the drug during foliar fertilization, l/ha	0	0.3 (1:1000)	0.6 (1:500)	2.4 (1:125)
Main basic costs, thous. rub./ha	151.2	151.2	151.2	151.2
Cost of the preparation for 3 foliar fertilizations, thous. rub./ha	0	9.0	18.0	72.0
TOTAL costs, thous. rub./ha	151.2	160.2	169.2	223.2
Average gross yield, t/ha	15.9	17.5	20.0	16.0
Commodity yield, %	88	85	87	88
Commodity yield, t/ha	14.0	14.9	17.4	14.1
Revenue at the price of 15 rubles/kg, thous. rub./ha	209.9	223.1	261.0	211.2
Revenue at the price of 25 rubles/kg, thous. rub./ha	349.8	371.9	435.0	352.0
Income at the price of 15 rubles/kg (revenue minus expenses), thous. rub./ton	58.7	62.9	91.8	-12.0
Income at the price of 25 rubles/kg (revenue minus expenses), thous. rub./ton	198.6	211.7	265.8	128.8
Conditional net income (CNI) from the use of the drug at the selling price of potatoes 15 rub./ kg	-	4.2	33.1	-70.7
CNI from the use of the drug at the selling price of potatoes 25 rub./kg	-	13.1	67.2	-69.8

From Tables 7-9, we can say that for the potato variety Gulliver in the variant of three-fold foliar fertilization with a concentration of the drug 1:500 (0.6 l/ha), you can get a conditional net income of 62.3...115.8 thous. rub./ha, for the Vimpel variety 47.2...90.7 thous. rub./ha, for the Matushka variety 33.1 ...67.2 thous. rub./ha.

4 Conclusion

The conducted studies have shown that non-root treatments of the cultivated crop not only increase the yield, but also increase some of their qualitative indicators compared to the control variant. Moreover, the greatest increase in yield was obtained for all potato varieties at a concentration of the tested preparation of 1:500. According to the results of field tests, the yield increase of potato variety Gulliver was 0.4...5.2 t/ha, potato variety Vimpel 2.0...5.1 t/ha, potato variety Matushka 0.1...4.1 t/ha. With three-fold foliar fertilization with a concentration of the drug 1:500 (0.6 l/ha), you can get a conditional net income for the potato variety Gulliver 62.3 ...115.8 thous. rub./ha, for the Vimpel variety 47.2 ...90.7 thous. rub./ha, for the Matushka variety 33.1 ...67.2 thous. rub./ha.

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