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CROP PRODUCTION

The Role of Microbiological Fertilizers and Green Manures in Increasing the Productivity and Quality of Potatoes

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Abstract—This paper presents the research results of three short-term experiments carried out in 2010–2017 on the impact of green manures and mineral and bacterial fertilizers on potato productivity. The purpose of the study was to increase the productivity and quality of potato tubers while reducing the anthropogenic load on the agrocenosis through the integrated use of binary green manures and lower doses of mineral fertilizers in combination with microbiological preparations. In a stationary field experiment (2010–2012) on leached chernozem, the maximum potato productivity (32.2–35.5 t/ha) was obtained using mineral fertilizers $N_{45–90}P_{60–120}K_{60–120}$ in the crop rotation link oil radish + vetch – potato, while the efficiency of the treatment of tubers with the bacterial preparations Azotovit + Fosfatovit was 9.2–15.0%. In experiments on sod-podzolic soil, the yield increase from the microbiological preparation Agrinos for the potato cultivar Udacha in 2015 amounted to 12.4% along with higher content of starch and vitamin C in production. In the relatively moist 2016 and 2017, the yield increase in the midearly maturing cultivar Gala reached 8.5 t/ha or 24.5% to the mineral background level ($N_{90}P_{90}K_{90}$). In the variant with a 30% reduced NPK dose and the use of Agrinos ($N_{60}P_{60}K_{60}$ + Agrinos A + B (5 + 2.5 L/ha), the yield was 5.8 t/ha or 16.7% higher than with the full dose of NPK, and high starchiness and vitamin C content, excellent culinary qualities, and low levels of nitrates were also observed.

Keywords: potato, soil fertility, mineral and bacterial fertilizers Azotovit, Fosfatovit, Agrinos A + B, binary green manures

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INTRODUCTION

In the opinion of many practitioners, especially beginners, mineral fertilizers are the main means of increasing crop yields. For potato, large farms introduce 145 kg of active substances of mineral fertilizers or an average of 300–500 kg/ha in physical mass [1]. However, significant deficiencies of many mineral fertilizers include the content of accompanying ballast elements (fluorine, sodium), toxic heavy metals (cadmium, lead, arsenic, strontium) [2, 3], and a narrow set of nutrients, usually nitrogen, phosphorus, and potassium. Simple and double superphosphate, regardless of the source of raw materials, as well as ground phosphate from most of the deposits, contain significant admixtures of strontium, from 0.2 to 1.2%, and cadmium of phosphates, similar to calcium in terms of properties, is difficult (and expensive) to separate from phosphate ores [4, 5]. At the same time, there are numerous experimental data that potato tubers obtained with high doses of mineral fertilizers are characterized by low starchiness, lack a bright taste, smell, and friable pulp consistency, often contain lots of nitrates and heavy metals, and store poorly [6, 7].

Around the world, the intensive transformation of natural grassland and forest lands into arable lands and pastures has led to the loss of soil carbon stocks and soil dehumusification. Traditional land use techniques inevitably reduce its productivity [8]. If we do not see soil as a living ecosystem and do not put into practice the laws of agriculture (return of nutrients, their minimum, optimum, maximum, cumulative effect of factors, crop change), a catastrophe is inevitable due to the soil cover destruction and reduced health of future generations. Therefore, one should strive to reduce the gap in the supply of organic matter to the soil between natural biocenoses and agrocenoses in potato cultivation technologies [9].

The purpose of this work is to increase potato yield and product quality while reducing the anthropogenic load on the agrocenosis through the integrated use of binary green manures and lower doses of mineral fertilizers in combination with microbiological preparations.

METHODS

In 2010–2012, a field stationary experiment was carried out using biological preparations Azotovit:

Azotobacter chroococcum; Fosfatovit: *Bacillus mucilaginosus*; and green manures for the early potato cultivar Udacha. Leached medium loamy chernozem (Pervomaisky district of Tambov oblast) was characterized by a high content of mobile phosphorus and increased content of exchangeable potassium: pH_{KCl} 5.14–5.20, Ng 5.6–6.5 mmol/100 g of soil, S 29.4–31.0 mmol/100 g of soil, V 81.9–84.6%, P_2O_5 126–206 mg/kg of soil, K_2O 76–100 mg/kg of soil, and humus content 5.53–5.79%.

The year 2010 was characterized by extremely dry conditions: in the Central District of the Nonblack Earth Region of the Russian Federation, the period without rains was 60–65 days, while that in the Central Black Earth Region was 90 days or more (hydrothermal coefficient 0.63). In 2011, precipitation deficit was observed from May to the end of July, and the entire vegetation period showed 159.2 mm of precipitation or 61.1% of the average annual rate (hydrothermal coefficient 0.67). The vegetation period of 2012 (hydrothermal coefficient 1.26) was close to the average annual climate norm (hydrothermal coefficient 1.29); however, the air temperature in July was above the norm by 2.7°C, and the amount of precipitation was 2.8 times lower (hydrothermal coefficient 0.43, severe drought).

In 2015, studies were carried out in a field experiment on the early maturing potato cultivar Udacha on the territory of the Matveevka farm in Lukhovitsky district of Moscow oblast with another microbiological fertilizer, Agrinos A+B. This preparation has two forms: Agrinos A, a bacterial fertilizer based on a consortium of bacteria of the genus "Azotobacter vinelandi", "Clostridium pasteurianum", etc., a titer of CFU/mL of aerobic ones 1.5×10^7, anaerobic ones 1.5×10^7; Agrinos B, a liquid organic fertilizer based on amino acids: amino acids 4%, glucosamine 4%, and chitosan 4%. The area of one plot was 210 m^2, repetition was threefold, and plots were located randomly. The soil is sod-podzolic medium-loamy. The vegetative season of this year was characterized as moderately humid (hydrothermal coefficient 1.67).

In 2016–2017, the tests of the new microbiological fertilizer Agrinos A+B were continued on the midearly maturing potato cultivar Gala in the territory of the pilot experimental base Korenevo in Lyubertsy district of Moscow oblast. The soil was sod-podzolic sandy loam with high exchange and hydrolytic acidity (pH_{KCl} 4.7–4.9, Hg 3.5–3.9 mmol/100 g soil), average values of the amount of absorbed bases and the degree of saturation with them (S 3.7–4.1 mmol/100 g soil, V 48.7–53.9%), high content of mobile phosphorus (265–356 mg/kg soil) and medium content of exchangeable potassium (127–154 mg/kg soil), and typical humus content (1.7–1.9%). The years of research 2016 and 2017 were characterized as moist and very moist with the hydrothermal coefficients of 2.1 and 2.31, respectively, against a climatic norm of 1.3–1.4.

The working solution of the microbiological preparation Agrinos A (5.0 L/ha, the flow rate of the working fluid 30–50 L/ha) was introduced by spraying the tubers and the tuber bed during planting. In the phase of complete budding of potatoes, foliar spraying with Agrinos B was carried out at the rate of 2.5 L/ha, and the flow rate of the working fluid was 250–300 L/ha.

Accounting and observations in the experiments were carried out in full accordance with GOST and standard methods. The validity of differences between the mean values was calculated by the method of one- and two-factor analysis of variance at a 5% significance level (Dospekhov, 1985).

RESULTS AND DISCUSSION

The systematic application of physiologically acidic mineral fertilizers on the main soil types increased their acidity, accelerated the leaching from the arable horizon of calcium, magnesium, potassium, and nitrate forms of nitrogen and increased the content of mobile aluminum [10, 11]. At the same time, humus was destroyed, the structure, soil density, and availability of air, moisture, and nutrients deteriorated, and labor costs for mechanical processing increased [12–14].

It is known that radical methods of soil protection include liming, sowing of perennial grasses, application of organic fertilizers (traditional, alternative), introduction of green manure fallow, and treatment of soils leaving a mulching upper layer (for example, chopped straw). In the stationary experiment (2010–2012) under black earth conditions, the plowing of green manures and the introduction of mineral and bacterial fertilizers reliably influenced the increase in the content of mobile phosphorus, exchange potassium, and nitrate nitrogen in the soil. Thus, in the crop rotation link oil radish + vetch – potatoes, applying the full ($N_{90}P_{120}K_{120}$) and half dose ($N_{45}P_{60}K_{60}$) of mineral fertilizers before planting potatoes in combination with the treatment of tubers with the bacterial preparations Azotovit + Fosfatovit contributed to an increase of mobile phosphorus in the soil content by 69 and 22 mg/kg, exchangeable potassium by 32 and 11 mg/kg, and nitrate nitrogen by 11 and 34 mg/kg, respectively. In 2011–2012, the maximum productivity of potatoes (32.2–35.5 t/ha) was obtained in the same crop rotation link, where the efficiency of treatment of tubers with the bacterial preparations before planting was 9.2–15.0% (Fig. 1).

Over the years of research, the effect of the bacterial preparations was particularly evident in the crop rotation link buckwheat + vetch – potatoes, both in unfertilized soil (24.6%) and in the case of their half dose (20.2%). A high effect from bacterial fertilizers was also obtained in recultivation of potatoes in one

place (2010, 2011, 2012): from 10.6% in the case of full and half dose of NPK.

Plowing binary green manure buckwheat + vetch in the variant without fertilizers increased the yield of potatoes to 19.1 t/ha and radish + vetch to 20.2 t/ha, which is 39.4–47.4% higher than in the repeated cultivation of potatoes for 3 years. The productivity of potatoes during replanting in one place significantly increased (by 65% or to 22.6 t/ha) due to the NPK dose decrease by 50% and application of bacterial preparations as compared to the absolute control (13.7 t/ha). The use of mineral fertilizers and bacterial preparations against the background of plowing of these binary green manures positively influenced the quality of tubers, while the treatment of seed material with bacterial preparations increased the quality of products against the background without fertilizers and their full and half doses.

The results of studies carried out in the field experiment (2015) on the early maturing potato cultivar Udacha under conditions of sod podzolic soil with the microbiological fertilizer Agrinos A + B also confirmed the importance of biopreparations for potato growing (Table 1). When measuring biometric indicators (July 14, 2015), a positive effect of this preparation on the growth and development of potato plants was observed compared with similar indicators of mineral background and control without fertilizers. Thus, in the average sample of plants (20 bushes), depending on the variant, the number of stems varied from 2.5 to 3.5 pieces/plant, their height from 58 to 63.5 cm, the number of tubers from 8.0 to 10.0 pieces/plant, and the weight of the tops from 724 to 1016 g/bush. The greatest values of intervals were characteristic for plants of variant $N_{90}P_{90}K_{90}$ + Agrinos A + B. The application of Agrinos on the mineral background contributed to an increase not only in yield by 12.4% but also in starch and vitamin C content in the production.

According to the results of research for 2016 and 2017, the maximum increase in the yield of potatoes of the cultivar Gala of 8.5 t/ha (or 24.5% to NPK) was obtained using Agrinos A and B on the mineral background (Table 2). In the variant with a 30% reduced dose of NPK and a combination of Agrinos A and B, it was higher by 5.8 tons or 16.7% than on the mineral background, while the content of starch, dry matter, and vitamin C in tubers was practically at the level of the unfertilized control and significantly higher than on the mineral background. Low levels of nitrates in tubers and their good taste were also noted.

The combination of seed treatment with the biopreparation Agrinos A and the foliar spraying of plants with Agrinos B against the background of a full dose of fertilizers was an economically beneficial agricultural technique that contributed to the formation of high yields (43.2 t/ha) and marketability (92.8%) of potatoes.

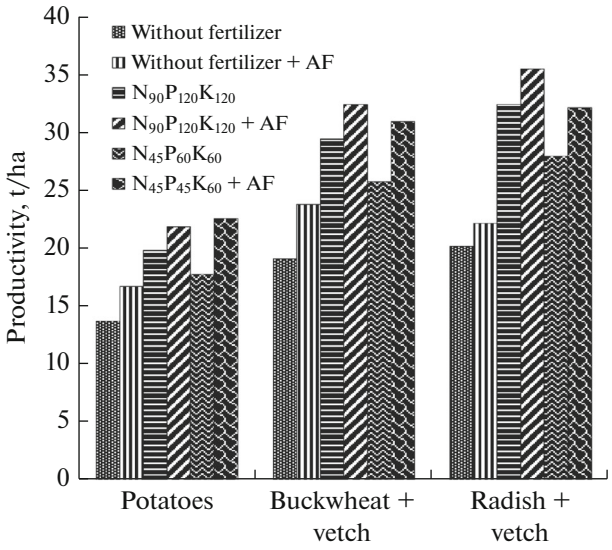

Fig. 1. Dependence of yield of potato cultivar Udacha (2010–2012) on its predecessor and mineral and bacterial fertilizers (Azotovit + Fosfatovit – AF).

Table 1. Yield of potato cultivar Udacha, 2015

Variant	Yield, t/ha	Increase to				Output of the food fraction, t/ha	Mass, g/quantity (pieces) of marketable tubers per 1 bush
		control		background			
		t/ha	%	t/ha	%		
No fertilizer	34.6	–	100			31.7	88/8.0
$N_{90}P_{90}K_{90}$	47.4	12.8	37.0	–	100	45.0	122/8.5
$N_{90}P_{90}K_{90}$ + Agrinos	53.3	18.7	54.0	5.9	12.4	50.2	115/10.0
$N_{60}P_{60}K_{60}$ + Agrinos	49.5	14.9	43.1	2.1	4.4	45.4	108/9.4
LSD_{05}			1.5				
LSD_{05}%			3.6				

Table 2. Productivity of potato cultivar Gala

Variant	Productivity, t/ha			Average content for 2016–2017				
	2016	2017	average	marke tability, %	starch, %	vitamin C, mg %	NO_3, mg/kg	taste score
No fertilizer	28.9	24.2	26.5	87.5	13.1	21.3	99	7.0
$N_{90}P_{90}K_{90}$	35.8	33.6	34.7	89.3	11.8	20.1	227	6.3
$N_{90}P_{90}K_{90}$ + Agrinos	43.2	43.1	43.2	92.8	11.3	21.7	229	6.4
$N_{60}P_{60}K_{60}$ + Agrinos	38.4	42.7	40.5	89.7	12.7	21.3	199	6.6
LSD_{05}	1.4	1.7		4.3–5.0	0.6–0.9	1.1–1.9	37–41	0.3–0.5
LSD_{05}%	3.2	4.4						

Thus, in the cultivation of potatoes in modern conditions it is first of all necessary to provide for an increase in soil fertility by increasing the share of perennial grasses or using green manure. Reduction of doses of mineral fertilizers by 30–50% in combination with preplanting treatment of tubers with bacterial preparations promotes the same level of potato yield as when applying a full dose of NPK, while simultaneously having a greater product quality and lower costs for mineral fertilizers.

In personal subsidiary farms, planting seed material treated with a mixture of bacterial preparations is ecologically safe and cost effective, both with the introduction of lower doses of mineral fertilizers and without their use. For the conditions of the Central Black Earth Region and Nonblack Earth Region, it is recommended to plant potatoes treated with biological preparations against a background of 1/2 dose of NPK after the cropped fallow: oil radish + vetch or against a background of 2/3 doses of NPK after grain predecessors.

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