

The application of biomodified fertilizers as a way to increase the effective fertility of orchard soils

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Abstract. The crucial trend in the intensification of gardening is the use of agrochemicals, including the systematic application of mineral fertilizers, regulated by the production flow chart of fruit products. Technological pressure on the soil causes aggravating the ecological problem of loss of the fertility level in the conditions of the orchard monoculture. The search for sustainable and environmentally effective approaches to solving the problem of managing fertility factors is aimed at studying the effects of biological and biomodified fertilizers. The changes in the main indicators of the effective fertility of the structural-metamorphic agrosem in the conditions of the orchard monoculture with the application of biomodified organo-mineral fertilizer were studied in dynamics. The prolonged effect of organo-mineral fertilizer on increasing the content of the main indicators of effective fertility in the soil was determined six years after application. The use of biomodified organo-mineral fertilizer in the orchard fertilization system is considered as an element of an integrated strategy for the management of orchard soil fertility.

1 Introduction

The growing demand for high-quality fruit products implies the saturation of the complex of agrotechnical measures of the fruit production process with intensification factors, exacerbating the environmental problem of technological pressure on the soil in monoculture conditions. One of the main factors of intensification is the systematic application of agrochemicals, which have a significant impact on the entire range of biological systems of the agroecosystem. Currently, in crop production, agrochemicals are most widely represented by chemical fertilizers, which are vital for optimizing the growth, development of plants and the formation of yield [1-3]. At the same time, global trends indicate the expansion of the market of biological and biomodified mineral fertilizers for agriculture, associated with an increase in demand from agricultural producers [4-6]. The motivation for the biologization of modern agriculture was high-technology monitoring scientific studies of the impact of long-term application of agrochemicals on the soil, plants and yield, increased requirements

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for the chemical composition of agricultural products, new knowledge about the synergistic effects in the «microorganisms-fertilizer-soil-plant» system [7-9]. The mechanisms of interaction of the system components identified by the researchers allow to consider the use of biomodifiers in combination with mineral resources as a new area of agroecological research aimed at studying and introducing effective microbial compositions compatible with minerals that have a positive impact on agrogenerally transformed soils, yield and the environment [10-12]. Within the framework of this research area, it is relevant to study the prolonged effect of biomodified fertilizers on the indicators of effective (economic) soil fertility in the conditions of an orchard monoculture, information about which is not available in the literature.

2 Materials and Methods

A granular organo-mineral fertilizer containing lowland peat, macro - and microelements, humic compounds and a biomodifier based on a strain of rhizospheric aerobic bacteria *Bacillus subtilis* H-13 was used in 2014 for the main application to the soil of the fruit-bearing apple orchard of 2009 planting, located in the experimental production farm of the North Caucasian Federal Scientific Center of Horticulture, Viticulture Wine-making. Application was carried out locally on both sides of the row at a rate of 2.2 kg per plant mixing the fertilizer with the soil. The methodological basis for the experiment was the relevant recommendations [13].

According to the presence of the agro-humus horizon, the chernozem soil of the experimental site is defined as a structurally metamorphic agrozem [14]. The characteristic features of the soil are: the lack of carbonates in the horizons A and B, the neutral acidity of the soil solution, the compacted composition, the reduced nitrification capacity, the satisfactory phosphate regime, the thickness of the humus horizon, the low humus content in the A_p (3,5-5,0 %). The microbial complex of the top soil is mainly represented by bacteria (more than 90 %) with a predominance of saprophytic species. The decrease in species diversity is associated generally with the features of agrogenerally transformed soils in monoculture conditions [15].

Soil studies were carried out one year and six years after fertilization in comparison with the data of analyses conducted before the start of the experiment. Soil sampling was carried out in the same calendar terms with a small diameter drill of S. F. Negovelov's design in 2015 and 2020 to a depth of up to 60 cm in layers every 20 cm. Russian Standard GOST 26423-85, 26212-91, 26213-91, 26489-85, 26951-86, 26204-91, 27821-88, 26428-85 were used during the analytic works.

3 Results and Discussion

The main indicators of effective soil fertility were analyzed in dynamics: nitrogen regime, the content of mobile compounds of the main biophilic elements, the content of humus, the actual and total acidity, the degree of soil saturation with bases.

A higher nitrifying capacity of the soil in the apple rhizosphere zone was determined in comparison with the control variant one year and six years after the application of the biomodified organo-mineral fertilizer (Fig. 1). Besides, the activation of the ammonifying ability of soils as one of the indicators of the activity of the soil microflora, as well as a higher total content of mineral nitrogen in the dynamics, was revealed (Fig. 2).

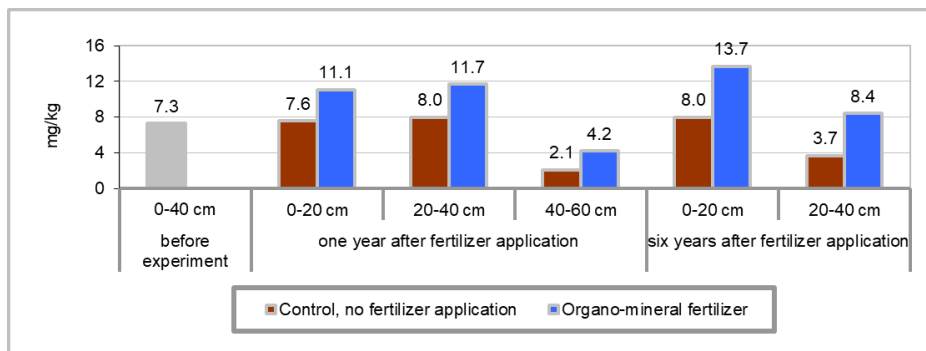


Fig. 1. Nitrification capacity of the soil one year and six years after fertilization. LSD ($p \leq 0.05$) = 0.74 (0-20 cm); LSD ($p \leq 0.05$) = 0.97 (20-40 cm); LSD ($p \leq 0.05$) = 0.79 (40-60 cm) - one year after fertilizer application; LSD ($p \leq 0.05$) = 1.62 (0-20 cm); LSD ($p \leq 0.05$) = 0.72 (20-40 cm) - six years after fertilizer application

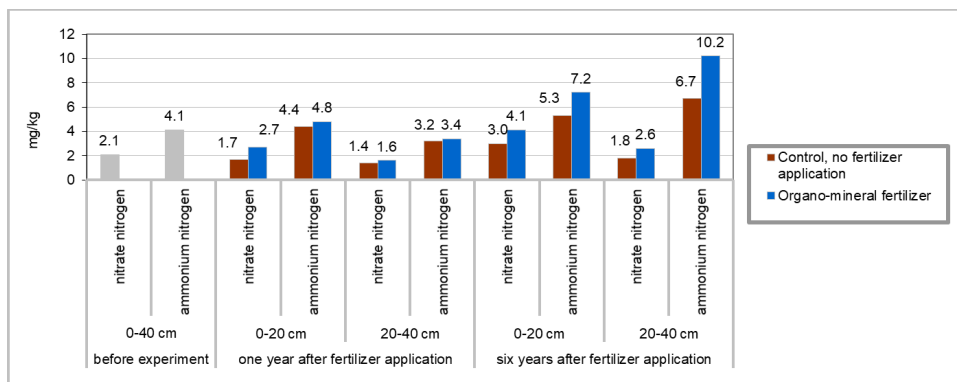


Fig. 2. Dynamics of mineral nitrogen content in the orchard soil

The differences between the variants remained against the background of a decrease in mobile phosphorus in the orchard soil six years after the start of the experiment. The content of phosphorus available to plants in the soil layer of 0-40 cm was more than 30% higher in the variant with the introduction of organo-mineral fertilizer than in the control variant.

The content of exchangeable potassium in the soil at a constant level was determined six years after the application of biomodified organo-mineral fertilizer with a decrease in K_2O in the control variant (Fig. 3). The prolonged effect of fertilizers is probably associated with the synergistic interaction of fertilizers and the microbiological component of the preparation, as well as the biosolubilization of hard-to-reach forms of potassium by bacteria of the genus *Bacillus*, which was previously identified by researchers [11, 16, 17].

In 2015 the change in the acid-base balance of the soil was detected in the control variant in the soil layer of 0-40 cm in comparison with the data of 2013 (before the start of the experiment). The values of the actual acidity index (pH_{H_2O}) decreased on average from 7.24 to 7.11 (0-20 cm) (LSD ($p \leq 0.05$) = 0.10) and from 7.19 to 7.13 (20-40 cm) (LSD ($p \leq 0.05$) = 0.05). A slight decrease in the pH_{H_2O} . from 7.18 to 7.10 was observed at a depth of 40-60 cm in the rhizosphere zone in the variant with the introduction of fertilizers. In 2020 the actual acidity in the soil layer of 0-40 cm was determined in the range of 7.16-7.22 in all variants, which corresponded to the values of the indicator before the start of the experiment. When the total soil acidity (H_{acid}) was measured, no significant differences were found between the variants one year and six years after fertilization. The values of the indicator in the soil layer of 0-40 cm averaged 2.53 mg-eq./100 g (control) and 2.28 mg-eq./100 g

(application of organo-mineral fertilizer) in 2015, and 1.92 mg-eq./100 g and 1.90 mg-eq./100 g in 2020, respectively.

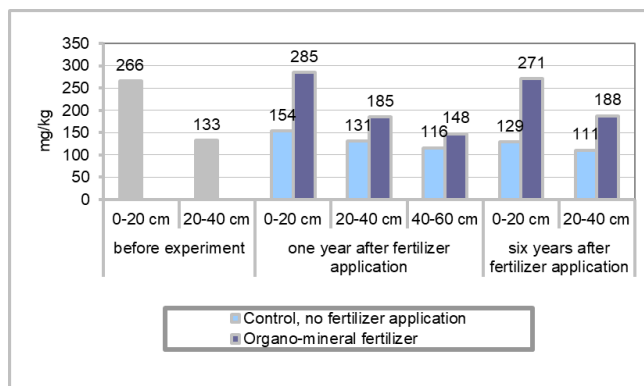


Fig. 3. The dynamics of the content of exchangeable potassium in the soil
 LSD ($p \leq 0.05$) = 31,56 (0-20 cm); LSD ($p \leq 0.05$) = 14,99 (20-40 cm); LSD ($p \leq 0.05$) = 10,55 (40-60 cm) – one year after fertilizer application; LSD ($p \leq 0.05$) = 69,51 (0-20 cm); LSD ($p \leq 0.05$) = 23,13 (20-40 cm) – six years after fertilizer application

In 2020, locally applied biomodified fertilizers contributed to a significant increase in the number of absorbed bases in the 0-20 cm soil layer compared to the control variant (Table 1). The part of the total capacity accounted for by the absorbed bases also increased significantly.

Table 1. Indicators characterizing the absorption capacity of the orchard soil, mmol/100 g

Indicators	one year after fertilizer application		six years after fertilizer application	
	Control, no fertilizer	Organo-mineral fertilizer	Control, no fertilizer	Organo-mineral fertilizer
Sum of absorbed bases	41.6	42.3	40.7	44.4
LSD ($p \leq 0.05$)	0.71		1.20	
Total absorption capacity	44.1	44.6	42.6	46.5
LSD ($p \leq 0.05$)	1.20		1.02	

In 2015 the composition of the soil exchange bases in the 0-60 cm layer was characterized by an average calcium content of 22.86 to 23.93 mmol/100 g. The average calcium content was 22.92-24.0 mmol/100 g against the background of fertilization. After six years the amount of exchangeable calcium increased slightly, on average to 25.41-26.78 mmol/100 g, in the variant with the application of biomodified organo-mineral fertilizer.

The analysis of the humus state of the soil revealed the most significant changes in the soil layer of 0-40 cm in the variant without fertilization. the decrease in the humus content was on average more than 13 % over six years of intensive cultivation of the orchard compared to the data before the start of the experiment. At the same time, dehumidification was not observed against the background of the application of biomodified organo-mineral fertilizer. (Table 2).

Table 2. The dynamics of the content humus in the orchard soil, %

Soil layer	before experiment bookmar-king	one year after fertilizer application		six years after fertilizer application	
		Control, no fertilizer	Organo-mineral fertilizer	Control, no fertilizer	Organo-mineral fertilizer
0-20 cm	3.32	3.32	3.74	2,71	3,76
LSD (p ≤ 0.05)	-	0.18		0.30	
20-40 cm	2.99	3.05	3.24	2,77	3,24
LSD (p ≤ 0.05)	-	0.19		0.16	

4 Conclusion

The dynamics of changes in the main indicators of effective fertility of the structurally metamorphic agrosystem in the conditions of the orchard monoculture with the application of biomodified organo-mineral fertilizer was studied.

Applied locally at a rate of 2.2 kg per tree, organo-mineral fertilizer did not contribute to the change in the acid-base balance of the soil one year and six years after the start of the experiment. An increase in the number of absorbed bases in the soil layer of 0-20 cm was observed in comparison with the control variant (without fertilizers). The part of the total capacity of the absorbed bases was also increased significantly.

The prolonged effect of organo-mineral fertilizer enriched with rhizosphere bacteria on the content of the main biophilic elements in the orchard soil was revealed six years after fertilization. The phosphorus available for plants in the soil layer of 0-40 cm was on average 30 % higher than in the control variant, while the K₂O content was 92% higher. An increase in the nitrification and ammonification processes in the soil was also determined in comparison with the control variant (without fertilization).

Processes of dehumidification in the conditions of the orchard monoculture were revealed in the variant without fertilization after six years. At the same time, no humus losses were observed against the background of organo-mineral fertilizer application.

Thus, biomodified organo-mineral fertilizer provides a stable high level of effective fertility in the system of fertilizing the orchard cultivated using intensive technology due to the synergistic interaction of its components and the soil. Moreover, biomodified organo-mineral fertilizer can be a key link in this system in the future. This approach in the development of the technological scheme of application of fertilizers can be considered as an integrated strategy for managing the fertility of orchard soils.

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