

Article

Prospects for Enhanced Growth and Yield of Blueberry (*Vaccinium angustifolium* Ait.) Using Organomineral Fertilizers for Reclamation of Disturbed Forest Lands in European Part of Russia

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Abstract: This article presents the results of research on the use of a new granular organomineral fertilizer for growing plants of half-highbush cultivars of the lowbush blueberry (*Vaccinium angustifolium* Ait.). The purpose of the research is studying the effect of a new granular organomineral fertilizer on the agrobiological characteristics of *V. angustifolium* plants on a peatland in the conditions of the north of the European part of Russia. The developed composition of organomineral fertilizer (NPK 8:8:8, Fe 0.5%, Zn 0.2%, Cu 0.4%) differs from existing fertilizers in a more balanced ratio of micro- and macroelements and the content of vermicompost containing spore forms of bacteria *Bacillus subtilis* H-13, *B. mucilaginosus*, and *Azotobacter chroococcum*. The use of a new organomineral fertilizer on high-moor peat (pH 2.9) contributed to the highest yield of *V. angustifolium* fruits (190.2 g/bush), which is 1.2 times more than other mineral fertilizers (NPK, etc.). The best morphophysiological indicators of *V. angustifolium* plants (leaf area, total and working surface of the roots, root weight) when using the developed organomineral fertilizer were noted in September. An increase of 1.2–1.3 times in the collection of dry matter and sugars in fruits was revealed, compared with other fertilizer options, while the vitamin C content practically did not change. New organomineral fertilizer contributes to the optimal supply of the necessary micro- and macroelements throughout the growing season and increases the productivity of *V. angustifolium* plants when growing depleted peat deposits in the natural and climatic conditions of the European part of Russia.

Keywords: organomineral fertilizers; berry plants; blueberry; *Vaccinium angustifolium*; substrate; peat; microorganisms; land reclamation; soil microbiology



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1. Introduction

Disturbed lands are considered to have lost their original natural and economic value and, as a rule, are a source of negative impact on the environment. Disturbance and degradation of landscapes can occur under the influence of both natural and anthropogenic factors. Disturbed lands appear during the development of mineral deposits and peat, during exploration, survey, construction and other works, as well as a result of the activities of processing industry enterprises [1–7]. In the field of reclamation of disturbed lands in Russia, the issue of further development of peat mining in the north and northwest of the European part of the country for forestry purposes is quite relevant [8,9]. Currently, more than 140 million hectares in Russia are covered with swamps [10], a significant part

of which (more than 70%) is located on the lands of the forest area [11]. Throughout the 20th century, Russia implemented major nationwide projects for peat extraction. The soils in the exhausted peat deposits are characterized by high acidity and poverty of mineral nutrition elements, as well as by poor thermal properties [10–12]. Peat of the high-moor and transitional types is characterized by low or even very low content of mobile forms of phosphorus and potassium. Unlike mineral soils, the residual layer of peat, especially topsoil, has poor physico-chemical, microbiological, and hydrothermal characteristics, increased toxicity, which complicates its use in agriculture. The high acidity, low ash content and instability of the water temperature regime of the developed peatlands prevent the natural settlement of xerophilic and hydrophilic herbaceous and woody vegetation here. The sites remain without any cover for a long time and in the dry season are the object of increased burning. Developed peat deposits are the cause of peat fires, clogging of reservoirs with flood runoff and other negative phenomena [10,12–16]. The issues of land reclamation that have emerged from peat extraction and their further use are of important environmental and national economic importance. Biological reclamation of unused non-forest lands, in particular those that have emerged from peat extraction, and their further use is currently a rather serious problem of forest management, which is of important environmental and economic importance, especially in the European part of the Russian Federation [15,17–19].

Wild berries such as cranberry, lingonberry, blueberry, and arctic bramble often grow on peat deposits of the upper and transitional types before their development. The inventory of these economically valuable berries is steadily decreasing, and peat processing plays an important role here. The creation of plantations of forest berry plants on the exhausted peat bogs will greatly contribute to the restoration of their thickets. This method of reclamation of depleted peat bogs has already been successfully implemented all over the world [15,20–28]. Berry plants from the genus *Vaccinium* L. of the Ericaceae family are low in demand for soil fertility and tolerate high acidity and temporary flooding. Many researchers in the Baltic countries, Belarus, and Ukraine have shown the prospects of growing such species as European cranberry (*V. oxycoccus* L.), lingonberry (*V. vitis-idaea* L.), bog blueberry (*V. uliginosum* L.), as well as introduced North American species—highbush blueberry (*V. corymbosum* L.), lowbush blueberry (*V. angustifolium* Ait.), American cranberry (*V. macrocarpon* Ait.)—on exhausted peat bogs [15,21,29–32]. Such positive properties as the possibility of reproduction by seed and vegetative methods, as well as the use of minimal doses of mineral fertilizers, contribute to reducing the cost of growing forest berry plants [33–35].

Blueberries are the last of the main forest berry plants mastered by agricultural production [36,37]. Lowbush blueberry (*Vaccinium angustifolium* Ait.) was introduced into culture in the USA and Canada about 100 years ago [38]. Up to now *V. angustifolium* was grown in North America as a semi-culture, where the growth and fruiting of natural populations were improved by clearing and special logging and rejuvenation of the thicket by burning [39–41]. *V. angustifolium* plantations are concentrated mainly in the places of its indigenous distribution, in the northeastern United States and in a number of provinces of Canada [42–47]. High winter hardiness, frost resistance of flowers and buds, resistance to diseases, premature entry into the stage of full fruiting, early maturity, and the ability to grow and give good yields on poor, excessively moist, acidic soils make this species promising for cultivation in the natural and climatic conditions of the north of the European part of Russia. The ability of *V. angustifolium* to grow successfully and bear fruit well on peat soils, while fastening the surface layer of peat with numerous rhizomes and partial bushes, can be successfully used for biological reclamation of depleted peatlands on forest areas which is confirmed by world experience [15,21,23,24,46–52].

Many authors have noted that for normal growth and development, and abundant fruiting, blueberries need fertilizing with mineral fertilizers. The main ones are nitrogen, phosphorus, and potassium. Calcium, magnesium, and sulfur are used in smaller quantities, but sometimes there is a need for their periodic application. These elements are replenished

by the addition of substances such as gypsum, dolomite, powdered sulfur, and limestone. One-time use of these substances gives an effect for several years. In addition, elements such as boron, manganese, copper, zinc, iron, molybdenum, and cobalt are required in small quantities. Most soils contain a sufficient amount of trace elements which are introduced only when there are symptoms of its deficiency [53–58]. Blueberry is very demanding of the soil, and this is what serves as a serious obstacle to its spread.

However, for the industrial production of blueberries, it is very important to maintain the optimal content of macro- and microelements in the soil and a soil solution acidity level (pH) from 2.8 to 4.0. Equally important is the biological activity of the soil. In agro- and natural phytocenoses of annual and perennial plants, 90% of harmful and widespread micromycete species are soil (or root-tuberous) and land–air (or leaf–stem) phytopathogens [59]. In the process of pathogenesis, some species of the genus *Fusarium* synthesize toxic metabolites that have a negative effect on plant growth processes [60]. The peculiarity of soil microorganisms consists in its ability to decompose the most complex high-molecular compounds into simple end products: gases (carbon dioxide, ammonia, etc.), water and simple mineral compounds. Each type of soil has its own specific profile distribution of microorganisms. At the same time, the number of microorganisms and their species composition reflect the most important properties of the soil: the reserves of organic matter, the quantity and quality of humus, the amounts of nutrients, acid reaction, moisture availability, and the aeration degree. The biomass of fungi and bacteria reaches 5 t/ha. The number of bacteria in 1 g of soil reaches 1 billion cells. The formation and dynamics of biochemical, nutrient, redox, and air regimes of soils, and its acid-base conditions are closely related to the activity of microorganisms [61]. Anthropogenic factors limiting the size of the spread of conditionally pathogenic and pathogenic micromycetes include environmentally safe technological techniques, in particular the enrichment of the rhizosphere with antagonists and physiologically valuable groups of spore bacteria. In general, the substrates for growing blueberries are not rich in microflora. A significant role of the soil microflora is the translation of hard-to-reach compounds into mobile and easily digestible forms for plants.

Blueberry has a shallow root system with no root hairs. Fibrous blueberry roots require open, porous, well-aerated soils for successful growth [62]. The deficiency of macro- and microelements on waterlogged soils leads to partial death of the root system and a significant decrease in crop productivity. Annual replenishment of macronutrients is required for normal growth of blueberry. The dose of fertilizers depends on the soil type, age, and development of plants, as well as on the types of fertilizers themselves. There is no consensus in the literature about the doses and the ratio of individual components in them. Recently, it is recommended to use leaf diagnostics to determine the required amount of fertilizers: from 453.6 to 759.8 kg/ha is proposed of complete mineral fertilizer in the ratio N:P:K 1:1:1, 5:10:5, 7:7:7, 8:8:8, 9:9:7, etc., depending on the blueberry-growing area [55]. The first top dressing is carried out early in spring at the beginning of growth and up to 2/3 of the entire dose is applied, 1/3 of the fertilizers are applied during the second top dressing, which is carried out at the end of June, and these doses are recommended for bushes of 6–7 years of age. The norms for young plants are determined by the fact that every year the dose introduced the year before (from the first to the fifth year) doubles, and then they remain constant [63–65]. Today there are very few complex fertilizers to increase blueberry productivity. A nutritional system for *V. angustifolium* when grown on peat bogs in the conditions of the north of the European part of Russia has not yet been developed. In this regard, it is necessary to develop the composition of a new type of organomineral fertilizer for plantation cultivation of this species in the Northern regions of the European part of Russia.

The purpose of the research is to study the effect of a new granular organomineral fertilizer on the agrobiological characteristics of *V. angustifolium* plants on a peat bog in the conditions of the European part of Russia.

2. Materials and Methods

The research was carried out in the southwestern part of the Kostroma Oblast, which is located in the northeast of the European part of the Russian Federation, in the north-central part of the East European (Russian) Plain, in the natural climatic conditions of the southern taiga, with a temperate continental type of climate. The experimental plot is located on a berry plantation in the Kostroma district of the Kostroma Oblast, on the site of a depleted peat deposit (N 58.1077, E 40.9837). The deposit is represented by high-moor peat with underlying highly watered fluvioglacial sands; the residual layer of peat on the site is 1.3 m. The characteristics of peat on the experimental site are as follows: degree of decomposition—17%; acidity of the salt suspension (pH_{KCl})—2.9; ash content—4.5%; mass fractions of mobile forms of phosphorus (P_2O_5)—4.25 mg/100 g; potassium (K_2O)—1.24 mg/100 g. The size of the experimental plot is 1 ha.

The objects of research are plants of half-highbush cultivars of blueberry (*Vaccinium angustifolium* Ait.) as Northblue, Putte, Lakomka, and Neya. Planting material was obtained by clonal micropropagation and adapted to non-sterile conditions [66–69]. The number of plants was 3330 pcs. per 1 ha (with a layout of 1.5×2.0 m) (Figure 1).



Figure 1. Lowbush blueberry (*Vaccinium angustifolium* Ait.) plantings on peat substrate.

In the 3rd ten days of April, using a planting pipe “Pottiputki”, fertilizers of varying composition were added to the soil. Characteristics of the fertilizer-application options used in the experiment are given in Table 1.

The option without applying fertilizer was considered as a control. The layout of experimental plots on the site is presented in Figure 2. About 825 pcs. plants were processed in each variant of the experiment.

For each treatment, the total content of mobile forms of nitrogen (N), phosphorus (P_2O_5), and potassium (K_2O) was measured.

Table 1. Characteristics of the fertilizer-application options.

Fertilizer Name	Manufacturer	Composition										Dose, g/kg	
		Ratio of Mobile Forms			Contents of Elements, %								Additional Components
		N	P	K	Zn	Fe	Cu	S	Mn	Mo	B		
Mineral fertilizer NPK 16:16:16	Minudobreniya, Russia	16	16	16								6.0	
Complex mineral fertilizer “Solution for Ericaceae” (Ericaceae fertilizers)	Buyskiy Himicheskiy Zavod, Russia	20	16	10	0.01		0.01	5.6	0.1	0.001	0.01	4.0	
New organomineral fertilizer (New OMF)	Author’s development	8	8	8	0.2	0.5	0.4				Vermicompost containing spore forms of bacteria <i>Bacillus subtilis</i> Ch- 13 and <i>B. mucilaginosus</i> , and <i>Azotobakter chroococcum</i>	6.4	

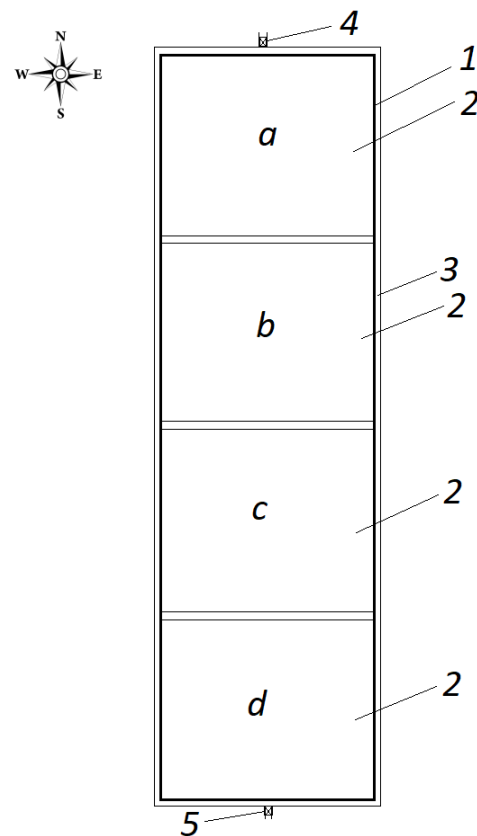


Figure 2. Layout of experimental plots on the site: 1—boundary of the experimental field; 2—experimental plot; 3—irrigation drain; 4—water inlet gate; 5—water outlet gate; a—control (peat); b—peat + Ericaceae fertilizers 6 g/kg; c—peat + NPK 16:16:16 4 g/kg; d—peat + New OMF 6.4 g/kg.

Studies of the chemical composition of berries were carried out using generally accepted methods in plant biochemistry [70]. To determine the microelement composition of fruits, samples weighing 250 g were crushed using a blender into a paste-like state and homogenized by stirring for 30 min. To determine the microelement composition of the solid phase of the samples, part of the resulting crushed mass was centrifuged in a laboratory centrifuge for 10 min at a rotor speed of 3000 rpm. The resulting crushed mass of samples and samples of the solid phase of the samples were laid out in a layer 3 mm

thick on a steel baking sheet covered with polyethylene film, frozen in a freezer for 20 h at a temperature of -24°C and dried for 24 h in a food sublimator SB-2 (SKh-Tekhnika, Kazan, Russia) at a temperature of $+40^{\circ}\text{C}$, a pressure in the chamber of 100 Pa, and a condenser temperature of -40°C . The resulting dry samples were ground to a powder in a porcelain mortar and sifted through a nylon sieve with a mesh size of 1 mm. Samples weighing 0.1 g were placed in Teflon autoclaves and dissolved in 10 mL of 7% HNO_3 at a temperature of $+180^{\circ}\text{C}$ using a microwave sample preparation system. The resulting solutions were diluted 100 times with deionized water. Using inductively coupled plasma mass spectrometry (ICP-MS), the content of macroelements (P, K, Ca, Mg) and microelements (Fe, Cu, Mn, B, I) was determined in prepared samples of substrate, plants, and fruits and its solid phase. Analysis of the prepared samples was carried out using a Nex ION 300D instrument (Perkin Elmer Inc., Shelton, CT, USA). To process the measurement results, we used the MultiChrom-Spectrum program (Ampersand, Moscow, Russia), which contains a database of certified chromatographic and spectral parameters of UV-absorbing substances.

The study of the processes of growth, development, and formation of the harvest of berry crops when using new types of organomineral fertilizers in cultivation technology was carried out in the conditions of vegetative experience in accordance with generally accepted methods [71]. Morphometric indicators, physiological and biochemical factors, chlorophyll content, and plant photosynthesis productivity were studied using the Tyurin–Lukashek method [61,72]. The number of the main physiological groups of microorganisms was taken into account in accordance with the recommendations set out in E. Szegi’s manual [73] on solid nutrient media: ammonifiers—MPA (meat-peptone agar); solvent phosphate—GAA (glucose-aspartic agar); micromycetes—Chapek medium; nitrogen fixators—Ashby medium (Figures 3–7).

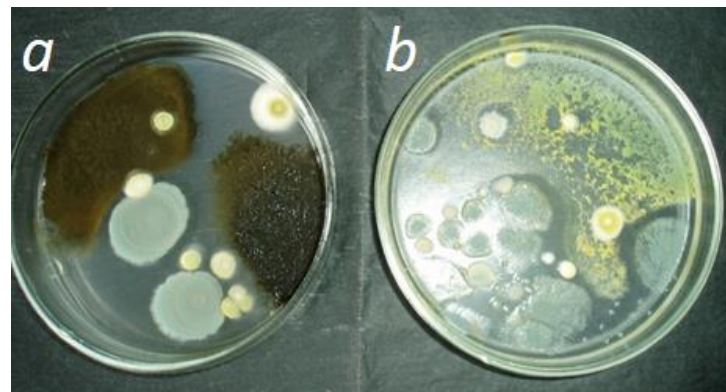


Figure 3. Peat substrate on Czapek nutrient medium at a dilution of 10^4 (a) and 10^5 (b).

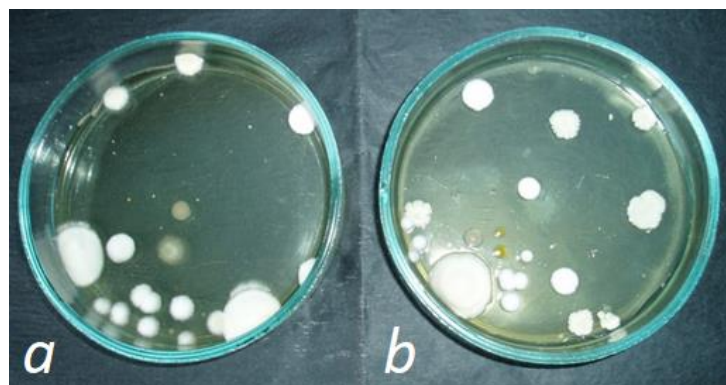


Figure 4. Control substrate on MPA nutrient medium at a dilution of 10^4 (a) and 10^5 (b) 3 days after applying mineral fertilizers.

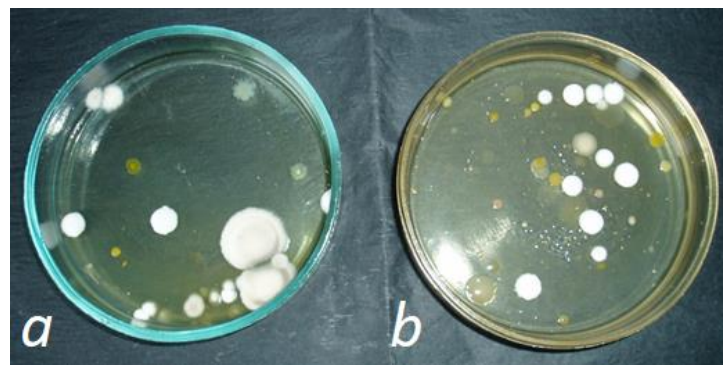


Figure 5. Experienced substrate on MPA nutrient medium at a dilution of 10^4 (a) and 10^5 (b) 3 days after applying organomineral fertilizers.

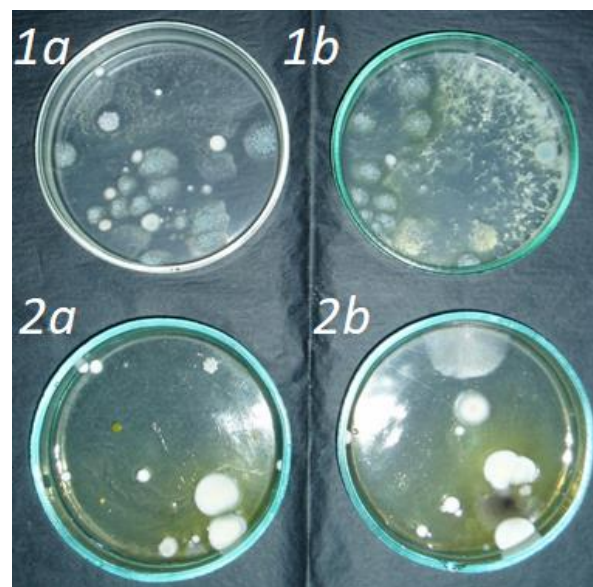


Figure 6. Control substrate on Czapek (1) and MPA (2) nutrient media at a dilution of 10^4 (a) and 10^5 (b) 2 weeks after applying mineral fertilizers.

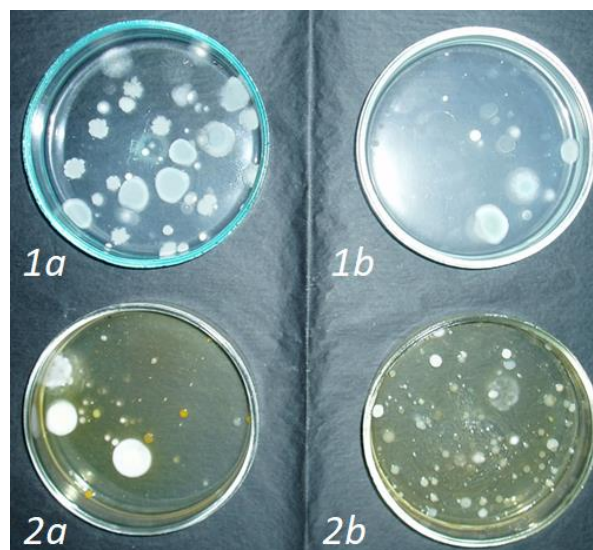


Figure 7. Experienced substrate on Czapek (1) and MPA (2) nutrient media at a dilution of 10^4 (a) and 10^5 (b) 2 weeks after applying organomineral fertilizers.

For statistical processing of experimental data, StatSoft Statistica 10.0.1011 and Microsoft Office Excel 2019 software with one-way analysis of variance were used. The least significant difference for a 5% significance level (LSD_{05}) was used to assess the reliability of differences between the average data of experimental variants, the parametric Pearson criteria (R^2) was used to determine the relationship and dependence between various indicators.

3. Results

We have developed a new type of organomineral fertilizer (OMF) for growing blueberries with the composition NPK 8:8:8, Fe 0.5%, Zn 0.2%, Cu 0.4%. This type of fertilizer is distinguished by the fact that, in addition to the balanced composition of macro- and microelements, there is a biohumate containing spore forms of bacteria *Bacillus subtilis* H-13 and *B. mucilaginosus*, *Azotobakter chroococcum* (as part of preparations Bisolbiphite, Phosphatovite, and Azotovite), capable of high biological activity in mineralization of complex substances and transformation of organo- and mineral phosphates in a form accessible to plants and fixation of atmospheric nitrogen.

A microbiological and agrochemical analysis of substrates using fertilizers, an assessment of the morphophysiological parameters, yield, and fruit quality of *V. angustifolium* plants on the site, as well as an analysis of the content of useful elements in the substrate, plants, and fruits were carried out.

Microbiological and agrochemical characteristics of substrates. Since the new type of fertilizer contains a bacterial consortium, the dynamics of the number of the main physiologically valuable groups of soil microorganisms was established (Table 2).

Table 2. Dynamics of the number of the main soil groups of microorganisms when using different types of fertilizers.

Variation	The Number of Soil Groups of Microorganisms, Thousand CFU/g			
	Ammonifiers	Micromycetes	Phosphate-Mobilizing	Nitrogen-Fixing
Control (peat)	20	180	20	20
Peat + Ericaceae fertilizers 6 g/kg	50	360	30	20
Peat + NPK 16:16:16 4 g/kg	40	370	20	10
Peat + New OMF 6.4 g/kg	160	210	60	30

When using mineral fertilizers, micromycetes prevailed in the substrate, their number fluctuated at the level of 360–370 thousand CFU/g. Heterotrophic ammonifying bacteria numbered 40–50 thousand CFU/g. The indicators of phosphoric bacteria and nitrogen fixators were low in these variants. The number was 20–30 and 20 thousand CFU/g, accordingly. When a new type of organomineral fertilizer was introduced into the substrate for blueberries, the ratio of bacterial and fungal microflora changed. The activity of ammonifying bacteria significantly increased to 160 thousand CFU/g, which is 3–4 times higher than in the variants with the use of mineral fertilizers. The number of fungal microflora decreased slightly and amounted to 210 thousand CFU/g; however, the activity of micromycetes was higher than the control indicators, which indicates more favorable conditions prevailing in the rhizosphere of blueberry plants.

Agrochemical analysis of substrates with the introduction of various types of fertilizers for growing blueberries confirmed a greater accumulation of mobile compounds of macronutrients in the variant using a new type of organomineral fertilizer (Table 3).

Therefore, the phosphorus content increased by 4.3–4.6 mg/L, potassium by 38.4 mg, and nitrogen by 17.2–13.7 mg. Correlation analysis made it possible to establish a close relationship between the content of nitrogen total and mobile potassium in the soil ($r = 0.929$), between the content of nitrogen total and mobile phosphorus ($r = 0.896$), and

between nitrogen accumulation in the soil and the number of free-living nitrogen fixators ($r = 0.859$). In addition, an average relationship ($r = 0.518$) between the content of mobile phosphorus and the activity of phosphate-dissolving bacteria was noted (Table 4). The conditions prevailing in the substrates with the introduction of various types of fertilizers affected the functional activity of blueberry plants.

Morphophysiological parameters of plants. Studies have shown that in soils with the introduction of a new type of organomineral fertilizer, blueberry plants developed a powerful root system with high indicators of an active working surface (Table 5).

During the growing season, blueberry plants grown using a new composition of organomineral fertilizer developed an active working surface of the roots, which significantly exceeded the indicators of the variant with NPK 16:16:16 mineral fertilizer by 2.1–5.7% and Ericaceae fertilizers by 1.3–1.5%. The root mass increased by 10.54% and 8.61%, accordingly. The work of the root system ensures the functioning of the above-ground part of the plants. With an insignificant increase in the leaf area per blueberry plant, photosynthesis productivity increased significantly by 0.26 mgS/dm² when NPK 16:16:16 was applied and by 0.26 mgS/dm² using Ericaceae fertilizers. When using the new OMF, the photosynthesis productivity of blueberry plants was the highest throughout the growing season and amounted to 2.76–4.82 mgS/dm². On pure peat, the obtained indicators were lower relative to all fertilizers used.

Correlation analysis allowed us to establish a close relationship between photosynthesis productivity and the working surface of the roots ($r = 0.89$) (Table 6). This circumstance directly affects not only the productivity of blueberry plants, but also the quality of the products obtained.

Table 3. Agrochemical indicators of the soil when using various types of fertilizers for growing *V. angustifolium*.

Variation	pH	Phosphorus, mg/kg	Potassium, mg/kg	Nitrogen Total mg/kg
Control (peat)	2.7	16.5	51.2	<2.5
Peat + Ericaceae fertilizers 6 g/kg	3.2	21.8	52.0	8.6
Peat + NPK 16:16:16 4 g/kg	2.8	21.5	68.9	12.1
Peat + New OMF 6.4 g/kg	3.8	26.1	90.4	25.8
LSD ₀₅		0.388	0.521	0.189

Table 4. The correlation matrix of the number of the main soil groups of microorganisms and agrochemical indicators of the soil when using various types of fertilizers for growing *V. angustifolium*.

r	Ammonifiers	Micromycetes	Phosphate-Mobilizing	Nitrogen-Fixing	pH	Phosphorus, mg/kg	Potassium, mg/kg	Nitrogen Total mg/kg
Ammonifiers	1							
Micromycetes	0.006941989	1						
Phosphate-mobilizing	0.022942276	0.076739	1					
Nitrogen-fixing	0.299711926	0.287705	0.098321	1				
pH	0.11277192	0.40678	0.761005	0.031005	1			
Phosphorus, mg/kg	0.582131913	0.03001	0.268559	0.540517	0.057723	1		
Potassium, mg/kg	0.858506841	0.039469	0.000392	0.674965	0.106931	0.703417	1	
Nitrogen total, mg/kg	0.732324451	0.009067	0.08089	0.738821	0.005461	0.895738	0.929041	1

Table 5. Morphophysiological parameters of *V. angustifolium* plants when using fertilizers (average for 3 years).

Variation	Photosynthesis Productivity, mgS/dm ²	Leaf Area of the Plant, dm ²	The Total Surface of the Roots, m ⁻³	Working Surface of Roots, m ⁻³	Root Weight, g
<i>June</i>					
Control (peat)	2.58	2.2	23.8	15.9	1.5
Peat + Ericaceae fertilizers 6 g/kg	2.43	2.3	33.1	22.6	1.7
Peat + NPK 16:16:16 4 g/kg	2.69	2.2	32.4	21.6	1.6
Peat + New OMF 6.4 g/kg	2.76	2.4	33.4	22.9	1.7
LSD ₀₅	0.067	0.441	0.923	0.641	0.216
<i>July</i>					
Control (peat)	2.44	3.1	46.3	23.2	2.8
Peat + Ericaceae fertilizers 6 g/kg	2.52	3.5	53.1	27.3	3.3
Peat + NPK 16:16:16 4 g/kg	2.89	3.8	55.9	28.5	3.2
Peat + New OMF 6.4 g/kg	3.81	3.7	58.1	29.1	3.3
LSD ₀₅	0.397	0.565	0.416	0.493	0.49
<i>September</i>					
Control (peat)	3.86	6.8	31.8	25.9	3.8
Peat + Ericaceae fertilizers 6 g/kg	4.56	8.1	44.8	32.6	4.3
Peat + NPK 16:16:16 4 g/kg	4.61	8.4	42.0	31.4	4.2
Peat + New OMF 6.4 g/kg	4.82	8.5	54.3	33.3	4.7
LSD ₀₅	0.301	0.795	0.998	1.588	0.478

Table 6. The correlation matrix of morphophysiological parameters of *V. angustifolium* plants when using fertilizers.

r	Photosynthesis Productivity, mgS/dm ²	Leaf Area of the Plant, dm ²	The Total Surface of the Roots, m ⁻³	Working Surface of Roots, m ⁻³	Root Weight, g
Photosynthesis productivity, mgS/dm ²	1				
Leaf area of the plant, dm ²	0.742655	1			
The total surface of the roots, m ⁻³	0.22798	0.005361	1		
Working surface of roots, m ⁻³	0.79425	0.894512	0.03691	1	
Root weight, g	0.747372	0.893164	0.023431	0.996802	1

Yield and quality of fruits. A valuable property of the new type of fertilizer is the fact that when applying a granular form of organomineral fertilizer, mineralization occurs slowly. The main elements are released from the granule with the participation of microflora gradually—they are not washed out and do not evaporate in comparison with mineral

forms of fertilizers. Organomineral granular fertilizers have a prolonged effect and do not require additional fertilizing during the growing season of plants. Having a constant influx of macro- and microelements in plants increases productivity and improves fruit quality indicators (Table 7).

Table 7. Yield and quality of *V. angustifolium* products.

Variation	Yield, g/Bush	Sugar, %	Sugar Collection, g/Plant	Total Acidity, %	Dry Matter, %	Collection of Dry Matter g/Plant	Vitamin C, mg/%
Control (peat)	150.1	10.2	15.3	0.60	9.8	14.7	9.4
Peat + Ericaceae fertilizers 6 g/kg	163.5	11.0	17.98	0.57	10.3	17.38	10.6
Peat + NPK 16:16:16 4 g/kg	160.2	11.1	17.76	0.71	10.1	16.16	10.2
Peat + New OMF 6.4 g/kg	190.2	11.9	22.61	0.60	10.8	20.52	10.4
LSD ₀₅	9.603		0.386			0.446	

The use of a new granular organomineral fertilizer made it possible to reliably obtain the highest yield of blueberry fruits (190.2 g/bush), which is significantly higher than in the variants with mineral fertilizers by 29.9–47.2 g/bush or by 14–16%. By the method of paired correlations, a close relationship between the crop, phosphorus bacteria, and mobile phosphorus was established at the level of 92–25% ($R^2 = 0.92\text{--}0.95$). The collection of dry matter and sugar increased by 4.36–5.79 g/bush and 4.85–6.88 g/bush, accordingly, and amounted to 20.52–22.61 g/bush. The content of vitamin C in the products changed slightly and only in the version without fertilizers decreased by 0.8–1.2 mg/% of the indicators of the variants with fertilizers.

Content of nutrients in the “substrate–plant–product” system. Investigating the accumulation of nutrients in the “substrate–plant–product” system, a certain pattern of their movement was revealed (Table 8).

Table 8. The content of macro- and microelements in the substrate, plants, and fruits of *V. angustifolium*.

Elements, mg/kg	Variation			
	Control (Peat)	Peat + Ericaceae Fertilizers 6 g/kg	Peat + NPK 16:16:16 4 g/kg	Peat + New OMF 6.4 g/kg
<i>In the substrate</i>				
B	1.39 ± 0.12	2.10 ± 0.16	1.18 ± 0.09	2.32 ± 0.19
Ca	2813 ± 89.55	3102 ± 122.42	1120 ± 94.22	3562 ± 147.32
Cu	0.48 ± 0.05	1.12 ± 0.10	0.99 ± 0.07	0.38 ± 0.04
Fe	32.8 ± 2.65	39.16 ± 3.02	28.3 ± 2.12	59.8 ± 5.14
I	1.26 ± 0.11	2.20 ± 0.17	1.01 ± 0.08	0.90 ± 0.06
K	696 ± 55.87	423 ± 35.78	218 ± 17.44	836 ± 69.21
Mg	753 ± 68.20	628 ± 55.78	307 ± 19.98	523 ± 36.53
Mn	70 ± 6.54	189 ± 15.56	101 ± 9.45	308 ± 20.45
P	214 ± 11.49	320 ± 28.96	173 ± 11.20	389 ± 29.21

Table 8. Cont.

Elements, mg/kg	Variation			
	Control (Peat)	Peat + Ericaceae Fertilizers 6 g/kg	Peat + NPK 16:16:16 4 g/kg	Peat + New OMF 6.4 g/kg
<i>In plants</i>				
B	59.6 ± 4.95	78.9 ± 6.88	78.0 ± 6.65	89.3 ± 7.54
Ca	4123 ± 130.77	6215 ± 250.32	5787 ± 211.38	7336 ± 299.33
Cu	5.32 ± 0.39	6.77 ± 0.48	6.33 ± 0.45	8.12 ± 0.75
Fe	33.6 ± 2.86	49.6 ± 4.02	42.3 ± 3.55	48.2 ± 3.87
I	1.12 ± 0.09	1.99 ± 0.15	2.13 ± 0.19	2.03 ± 0.14
K	15,215 ± 677.90	17,339 ± 732.56	16,315 ± 690.46	18,102 ± 760.25
Mg	2153 ± 78.99	4012 ± 167.65	3521 ± 144.32	4592 ± 178.88
Mn	1520 ± 92.24	1927 ± 97.05	1899 ± 89.79	2184 ± 104.67
P	1998 ± 90.21	2834 ± 108.45	2484 ± 102.23	3511 ± 125.87
<i>In fruits</i>				
B	0.25 ± 0.02	0.24 ± 0.02	0.23 ± 0.03	0.15 ± 0.01
Ca	18.44 ± 0.98	19.12 ± 1.15	16.1 ± 0.95	23.12 ± 1.86
Cu	2.32 ± 0.18	2.30 ± 0.19	2.18 ± 0.17	2.10 ± 0.15
Fe	180.6 ± 12.13	189.5 ± 13.66	170.2 ± 11.14	200.1 ± 16.65
I	1.50 ± 0.10	1.13 ± 0.08	1.10 ± 0.08	0.96 ± 0.06
K	64.2 ± 5.04	77.30 ± 6.27	51.11 ± 4.56	82.31 ± 6.97
Mg	9.66 ± 0.73	10.87 ± 0.81	8.96 ± 0.67	11.30 ± 0.92
Mn	95.70 ± 8.01	106.31 ± 9.88	90.30 ± 7.88	118.32 ± 10.22
P	7.25 ± 0.55	11.98 ± 0.90	13.2 ± 1.18	14.12 ± 1.21

Compared with the variants with Ericaceae fertilizers and NPK 16:16:16, the content of phosphorus and potassium macronutrients both in the substrate and in plants was significantly higher when using the new composition of organomineral fertilizer; therefore, it increased by 7.0–10.0% and 6.0–38.0% in products. Such important trace elements as Mg, Mn, Fe, and Ca also had higher values; their content in berries was, respectively, 11.3, 118.32, 200.1, and 23.12 mg/kg.

4. Discussion

Organomineral fertilizers are of increasing interest in the cultivation of berry plants, since they are able to adsorb and retain nutrients by increasing the total surface area, and the high capacity of absorption of peat granules and moisture retention prevents the possibility of leaching important nutrients. The porous structures of organomineral fertilizers contribute to an increase in the contact of their interaction with the root system of plants. All this makes it possible to significantly reduce the rate of application of mineral fertilizers, thereby avoiding additional costs in fertilization. The use of organomineral fertilizers will reduce salinization and unjustified mineralization of organic matter, improve the biological environment, and increase plant productivity. In this regard, the development of the production of specialized organomineral fertilizers and their introduction into the practice of production of all types of crop production will allow us to comprehensively solve the issues of natural resources, ecology, and environmental protection, and ensure further increase in berry products and their quality.

To date, tests are continuing to improve agricultural techniques for growing blueberries in the open ground, including the development of fertigation systems, irrigation

mulching and other elements and timely implementation of planting care measures. The results of research on its effectiveness are not inferior to the current developments in the field of application of mineral fertilizers to improve the nutrition of blueberries *V. corymbosum* [74–90], *V. angustifolium* [91–96], and *V. ashei* [97]. This indicates the prospects of using the data obtained to improve blueberry-cultivation technologies on disturbed lands where additional nutrition systems are required, and with proper preliminary preparation of the site they can be used in various soil and climatic zones. But this indicates the promise of using the obtained data to improve blueberry-cultivation technologies for the conditions of the regions where they are grown (North America, Western Europe).

The climate of the north of European part of Russia is characterized by harsh winters and a short growing season (no more than 90 days). During this period, the fruits of blueberry must ripen and the wood of the annual growths must ripen for the formation of generative buds. Peat soils, also characteristic of the European part of Russia, contain mycorrhiza and organic matter, and have natural acidity and active mobile forms of N, P, K, which are optimal conditions for the cultivation of blueberries as a circumboreal species. In this regard, the use of fertigation technologies used in North America and Western Europe, where blueberries are grown on mineral soils using artificial acidification with an electrolyte and the use of high concentrations of mineral fertilizers for plant growth and development, is not acceptable here. In addition, currently in Russia, an insufficient amount of mineral and organomineral fertilizers is produced for growing Ericaceae family plants, and even the available fertilizer compositions do not satisfy the nutritional needs of the non-native species *V. angustifolium* in the Northern regions of the European part of Russia.

The creation of industrial plantings of lowbush blueberry on depleted peat deposits and other unused disturbed forest lands can help organize rational use and reduce the fire hazard of such territories, restore the natural resources of wild berry plants, and preserve genetic biodiversity. However, in order to improve the quality of the grown material, it is necessary to create certain conditions, which requires the improvement and optimization of cultivation technologies. The organomineral fertilizer developed by the authors containing spore forms of bacteria *Bacillus subtilis* Ch-13 and *B. mucilaginosus*, *Azotobakter chroococcum* helps improve soil microflora and better absorption of essential nutrients by blueberry plants, which is important for the growth and development of plants and the formation of subsequent crops in the conditions of developed peatlands. The use of the developed fertilizer composition will improve the quality of planting material and create favorable conditions for its adaptation to the natural and climatic conditions of the European part of Russia. The obtained results of experimental studies can be used as an element for improving the adaptive and environmentally friendly technology for growing high-quality planting material of forest berry plants on an industrial scale in the northern regions.

5. Conclusions

The use of a new composition of organomineral fertilizer made it possible to optimize the microflora of substrates, provide blueberry plants with the necessary macro- and microelements, activate the morphophysiological processes of *V. angustifolium* plants, increase the yield of berries, and improve the quality of the products obtained. This element of the technology can be used in plantation cultivation of blueberries on depleted peatlands in the European part of Russia for the purposes of both biological reclamation of such territories and obtaining berry products. The results obtained can be used for plantation cultivation of blueberry in the conditions of the European part of Russia. It is necessary to continue research in the field of developing the composition of organomineral fertilizers for other economically valuable forest berry plants that can successfully grow on peatlands (lingonberry, cranberry, cloudberry, arctic bramble, etc.).

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