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APPLICATION OF NEW BIOFERTILIZERS AND BIOLOGICAL PRODUCTS IN THE CULTIVATION OF SPRING WHEAT (*Triticum aestivum* L.) AND POTATO (*Solanum tuberosum* L.)

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A b s t r a c t

Worldwide, the mineral fertilizers, because of their multiple negative effects, become less popular. Therefore, more producers prefer to use biofertilizer and biological preparations for obtaining high crop yield with good quality. Fertilizers fill the soil with additional material, while biologicals contribute to effective mobilization of soil organic matter and biota. At All-Russian Research Institute of Reclaimed Lands (VNIIMZ) the KMN biofertilizer (multi-purpose compost) has been developed. Advantage of the KMN as a base fertilizer lies in its high nutritional value, physiological, ecological and biogenic properties. Also, a novel biological product, the LPB, have been developed. It is characterized by the presence of physiologically relevant amounts of growth factors and energy sources in a combination favorable to the plant. The LPB composition allows to maintain soil fertility and crop productivity. In the present study, we evaluated the effectiveness of the KMN and LPB on the potato (*Solanum tubetosu*m L.) variety Zhukovsky and spring wheat (*Triticum aestivum* L.) variety Irgina. The micro plot tests were conducted in 2011-2013 on the experimental field of VNIIMZ (Tver' Province). With spring wheat, the KMN biofertilizer was used at a dose of 7 t/ha, and NPK dose was 300 kg/ha. Biological product (LPB stock preparation) was diluted with tap water as 1:300, 1:500 and 1:1000 and applied at 0.1 l/m^2 by spraying plants. In control no fertilizers were used. In total, there were 12 combinations of plant treatment. In wheat, a total yield, weight of 1000 grains, and the grain protein content were estimated. With potato, only KMN (4 t/ha) was used as fertilizer. Potato plants were treated with LPB three times (at sprouting, budding and flowering) by means of a hand sprayer. In this, four LPB doses (0.05, 0.1, 0.2 and 0.3 l/m^2) and two dilutions (1:30 and 1:300) of the stock preparation were used. Control potato plants were not treated with LPB. The potato yield and the tuber distribution by size were estimated. The intensity of redox processes in the soil was evaluated by the oxidative-reduction ratio (ORR) as the catalase to dehydrogenase activity rate. Spraying spring wheat with 1:300 LPB solution at 0.1 l/m^2, additionally to KMN application, resulted in the highest yield among all the studied variants (27.5 kg/ha), and it was 15 % higher compared to LPB application together with NPK. The rich harvest was obtained due to larger grains. Mobilizing effect in the soil under spring wheat was higher if no basic fertilizers were used, and also when NPK was used without biopreparation. At the same time, the crop yield with NPK and without fertilizers was generally inferior to that obtained with NPK together with biologicals, when the yield increased due to activity of LPB microflora, and with KMN due to activation of microflora of biofertilizer and bioprparation, particularly at high concentration of the biopreparation (1:300). The highest yield of potatoes (372.1 kg/ha, including 352.1 kg/ha of commercial tubers) was obtained by using LPB (1:300) at 0.1 l/m^2 with KMN as the basic fertilizer. Crop spraying with LPB was enough to supply plants with nutrients at the key growth phases. The KMN role was to supply plants at the early development with available nutrients. Note, the soil after harvesting remained free from chemical pollution and enriched with helpful microflora, contributing to the reproduction and preservation of soil fertility. Therefore, the developed biologicals can be successfully used in crop cultivation.

Keywords: multi-purpose compost, LPB, spring wheat, *Triticum aestivum* L., potato, *Solanum tuberosum* L., productivity, cultivation, agrotechnology.

The global experience of agriculture shows that the crop yield is directly dependent on the amount of fertilizer used. However, a sharp increase in their price and the general deterioration of environmental conditions force the search for efficient and environmentally friendly ways to increase yields [1, 3] that ensure the preservation of soil structure and the balance of soil organic compounds, trace and mineral elements [4, 5] and facilitate self-regulation of soil ecosystems [6, 7] and that are cheaper at the same time [8, 9]. There are a lot of plant growth regulators that determine the growth and formation of various plant organs, the timing and nature of flowering, and the time of ripening due to biologically active compounds [10]. Many microorganisms from the soil or the root zone of plants are known as agriculturally beneficial and can serve as a basis for the creation of bacterial preparations.

Thus, a series of biological preparations Radiance (developed in EM-Biotech and Novosibirsk State Agrarian University, Russia) includes several dozen species of microorganisms [11]. Albit (Albit Co., Russia) contains purified active substances from soil bacteria *Bacillus megaterium* and *Pseudomonas aureofaciens* [12]. Baykal EM-1 (EM-Center, Russia) is a composition of strains (photosynthetic bacteria, lactic acid producers, nitrogen-fixing bacteria, yeasts and fungi) [13]. Asolen (Institute of Biology, Ufa Scientific Center of RAS, Russia) was developed based on free-living nitrogen-fixing soil bacteria *Azotobacter vinelandii* IB 4 (cell titer from 4×10^9 to 8×10^9 CFU/ml) [14]. Azospirillum-based preparations (*Azospirillum lipoferum, A. brasilense* and *A. amazonense*) have been created (Tamil Nadu Agrarian University, India) [15]. In China, biological preparations based on nitrogen-fixing bacteria and phosphobacteria from bamboo rhizosphere are supposed to be used in liquid form in the composition of bio-organic fertilizers produced using the waste of this plant [16]. Due to the *Azotobacter chroococcum*-based microbial preparation (Punjab Agricultural University, India), carrot yield increased by 15.8 %, and carotene content increased by 30.6 % [17]. A biological preparation of *Bacillus megaterium* used by European reserchers increased the content of nitrogen and phosphorus under the inoculation of lentil beans [18]. Biological preparations provide effective mobilization of soil organic matter and biota which distinguishes them from fertilizers. Biological products are supposed to be used in complex with basic organic fertilizers.

Composting technologies in the production of biological fertilizers are various. For example, poultry manure [19], a mixture of peat, manure, zeolite, sawdust and broth resulted from fish waste processing to flour [20], ground reef corals, excrements of domestic animals, waste water, waste from vegetable fiber mixed in the presence of organic compounds [21] are used. In India, biological fertilizer is produced of cattle manure, composted coconut fiber and green fertilizer in combination with *Azospirillum* and phosphobacteria [22].

The properties and composition of multi-purpose compost (KMN, developed in the All-Russian Research Institute of Reclaimed Lands — VNIIMZ) [23, 24] make it possible to refer it to complete high-quality organic fertilizers (basic fertilizer and dressing). It is used in all crops grown in various regions of Russia and abroad, including potato and cereals. Local and overall KMN application KMN provides an average of double to triple activation of soil microflora and mobilization of biogenic elements (gain up to 25 %) which increases productivity. The value and advantages of KMN are its high nutritional value, physiological, ecological and biogenic properties. The balanced microbiological composition of KMN contributes to the maintenance of soil fertility, and as a consequence, not only the crop productivity increases, but also the quality of products improves.

Also, a radically new enzymatically-extraction technique to create liquid biological products of different classes was proposed in VNIIMZ [26, 27]. The

LPB product which includes nutritional elements and growth factors is one of them. The LPB nutritional value is provided by favorable acidity (pH 7.0-8.0), high content of K_2O (up to 9.5 g/l) and P_2O_5 (10.0 g/l), and a rich composition of trace elements including Mg, Zn, Mn, and Fe. The abundance of agronomically beneficial microflora reaches 10^{12} CFU/ml. Concentration of toxic elements in LPB is significantly lower compared to MAC (maximum allowable concentration), it contains no pathogenic microorganisms and parasites, so its use as a dressing is completely safe for the soil, vegetation and the final products intended for human consumption. LPB can be used to maintain soil fertility and crop productivity. LPB is recommended to be used as a biological growth and development stimulator by soil wetting and spraying, and as a biological product for soil fertilization by background soil wetting combined with the application of the basic fertilizer.

The purpose of this study was to evaluate the effectiveness of the KMN biological fertilizer and LPB preparation in the row and cereal crops (potatoes and spring wheat) for the two main backgrounds of fertilizers.

Technique. The research was held in 2011-2012 on the Zhukovskii potato variety and in 2012-2013 on Irgina spring wheat variety in the experimental field of the All-Russian Research Institute of Reclaimed Lands (Tver' region) in the micro plot tests. Plots were located randomly, separated by protective bands [29].

The experiment in spring wheat included the following variants: 1 — control (no fertilizers and biological products applied); 2, 3, 4 — spraying with LPB (dose of 0.1 l/m^2) diluted with tap water as 1:300, 1:500 and 1:1,000, respectively; 5 — NPK application (3 cwt/ha); 6, 7, 8 — spraying with LPB as 1:300, 1:500, 1:1,000, respectively, with the background of NPK; 9 — KMN application (7 cwt/ha); 10, 11, 12 — spraying with LPB as 1:300, 1:500, 1:1,000, respectively, with the background of KMN. Plot discount area was 9 m^2, experiments were performed in triplicate. The plants were mowed down by hand in the phase of full ripeness. After drying, ears were threshed, grain was cleaned and weighed. Productivity and the weight of 1,000 grains at each plot were estimated in accordance with the procedure [29, 30]. The amount of protein in grain was assessed by the Kjeldahl method (State Standard GOST 51417-99).

The experiment with potato planting was held with the background of KMN at a dose of 4 t/ha. Plot discount area was 7 m^2, experiments were performed in triplicate. The plantings were treated with LPB in triplicate (in the phases of sprouting, budding, and flowering) using hand sprayer. Four LPB doses of 0.05, 0.1, 0.2 and 0.3 l/m^2 and two dilutions of 1:30 and 1:300 of the stock preparation were used. Control areas were not treated with LPB. The crops were harvested by hand, the yields and the fractional composition were determined according to the procedure [30, 31].

Soil samples were aseptically collected from the arable layer (0-20 cm), assays were performed according to the approved standard techniques [32, 33]. The intensity of redox processes in the soil was evaluated by the oxidative-reduction ratio (ORR) as the catalase to dehydrogenase activity rate.

The data were processed using Microsoft Excel 2003.

Results. High yield was observed in spring wheat variety Irgina not treated with the basic fertilizer (control), but sprayed with LPB diluted as 1:500 and 1:1,000 (Fig. 1, A). If NPK was used as the basic fertilizer, the greatest increase in the yield was obtained with the use of LPB diluted as 1: 300. With the combined use of the KMN biofertilizer and the LPB biological product

(1:1,000), a decrease in the wheat yield was observed, but this value increased significantly with the LPB dilution of 1:500.

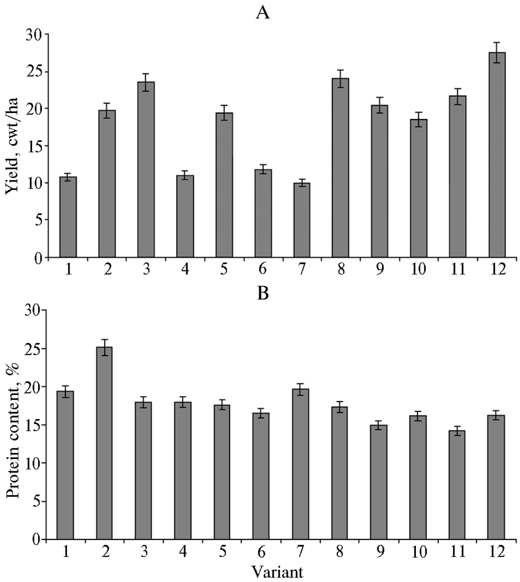

Fig. 1. Yield (A) and protein content in air-dry substance of the grain (B) of spring wheat (*Triticum aestivum* L.) variety Irgina depending on the application of biologicals and fertilizers in wheat crops: 1 — control, 2 — biological product LPB 1:300, 3 — LPB 1:500, 4 — LPB 1:1,000, 5 — NPK (3 cwt/ha), 6 — NPK + LPB 1:300, 7 — NPK + LPB 1:500, 8 — NPK + LPB 1:1,000, 9 — multi-purpose compost (KMN, 7 cwt/ra), 10 — KMN + LPB 1:300, 11 — KMH + LPB 1:500, 12 — KMN + LPB 1:1,000 (Tver' Region, 2012-2013).

Sparaying with LPB in the variant of 1:300 additionally to KMN provided the maximum yield increase. With respect to the pure control without fertilizers, it was 154 %; to KMN background, it was 35 %, to the variant of NPK background spraying with LPB it was 15 %. Such a significant increase was due to larger grains. Thus, the weight of 1,000 grains increased significantly: it was 33.28 g in the pure control, 45.52 g in the variant of KMN, 63.19 g with KMN + LPB (1:300), 49.08 g with NPK + LPB (1:300).

A variety of factors were involved in the formation of the harvest, including the elemental composition of the soil and the intensity of redox processes defined by the soil microflora and the biologicals used. The ORR value with no fertilizers was almost equivalent to that in the variant of LPB treatment at a dilution of 1:1,000, and decreased at 1:500 and 1:300. The maximum ORR value was obtained with the pure NPK background, the use of the product decreased it approximately as twice. At this, ORR was relatively high in the variant of LPB 1:300. The complementarity between NPK and more concentrated biological can be explained by a significant number of active LPB microflora using the available resources. ORR was not high with KMN applied additionally to LPB and without LPB. It is obvious that the crop was formed due to the elements of nutrition and development of agronomically beneficial microflora, so the intensity of redox processes decreased.

Thus, mobilizing effect in the soil under spring wheat was higher if no basic fertilizers were used (biopreparation at a beneficial dose activated the potential of the very soil), and also when NPK was used without biopreparation (effect of mineral fertilizer). At the same time, the crop yield with NPK and without fertilizers was generally inferior to that obtained with NPK together with biologicals (the yield increased due to activity of LPB microflora) and with KMN (due to activation of microflora of biofertilizer and biopreparation, particularly at its lower dilution of 1:300).

Protein accumulation in wheat was higher in control and with the NPK background (see Fig. 1, B). This value reached its maximum (25.1 %) in the variant of LPB (no fertilizer) at a dilution of 1:1,000. High protein content (19.6 %) was also observed with the use of biopreparation diluted as 1:500 with the NPK background.

Based on the yield data, we can conclude that the use of the novel biological product LPB in cultivation of spring wheat is expedient for all examined fertilizer backgrounds (both NPK and KMN). The greatest effect was reached by the combined use of KMN and LPB diluted as 1:300 (even compared to the traditional for this crop mineral fertilizer of azophoska). However, despite the decline in yields, formation of higher-quality grain was observed in the variants with no fertilizer.

In the experiment with potatoes, not all LPB concentrations and doses impacted the formation of productivity favorably. The best effect was provided by a more diluted LPB (1:300), at this the doses of 0.05 и 0.1 l/m^2 ensured an approximately the same increase of 7 %, and the doses of 0.2 and 0.3 l/m^2 decreased the yield by 6 and 10 %, respectively, compared to control (KMN, Table).

Potato (*Solanum tuberosum* L.) variety Zhukovsky yield depending on the use of LPB biological preparation and multi-purpose compost (KMN) (Tver' region, 2011-2012)

Variant	Yield, cwt/ha			
	total	versus control	commercial	versus control
KMN (control)	347.5		318.5	
KMN + LPB 1:30 (0.05 l/m^2)	349.7	+2.2	323.0	+4.5
KMN + LPB 1:30 (0.1 l/m^2)	353.4	+5.9	332.4	+13.9
KMN + LPB 1:30 (0.2 l/m^2)	330.9	–16.6	312.7	–5.8
KMN + LPB 1:30 (0.3 l/m^2)	305.6	–41.9	294.6	–23.9
KMN + LPB 1:300 (0.05 l/m^2)	369.3	+21.8	347.2	+28.7
KMN + LPB 1:300 (0.1 l/m^2)	372.1	+24.6	352.1	+33.6
KMN + LPB 1:300 (0.2 l/m^2)	323.5	–24.0	294.7	–23.8
KMN + LPB 1:300 (0.3 l/m^2)	309.7	–37.8	285.1	–33.4
$HCP_{0.5}$	18.6		19.4	

The distribution of potato fractions on the number of tubers per plant in control appeared about the same, and in the best variants of LPB use an increase in the number of larger potatos was observed. The ratio of potato fractions per plant proved that nearly the entire crop consisted of large and medium-sized potatos. The weight of marketable potatos in the variant of LPB spraying at a dose of 0.1 l/m^2 (dilution of 1:300) increased by 33 cwt/ha as compared to control.

The abundance of agronomically beneficial microflora under potatoes during the growing season varied with no regularities, and in the period of tuber formation only there was a clear link between the number of microorganisms and the yield. Thus, LPB diluted as 1:30 had no effect on the abundance of ammonifying microorganisms (Fig. 2). The use of LPB solution diluted as 1:300 resulted in a significant increase of this value. The number of phosphate mobilizing microflora was increased in variants with LPB dosages of 0.05 and 0.1 l/m^2 in both dilutions, which correlated with potato yield.

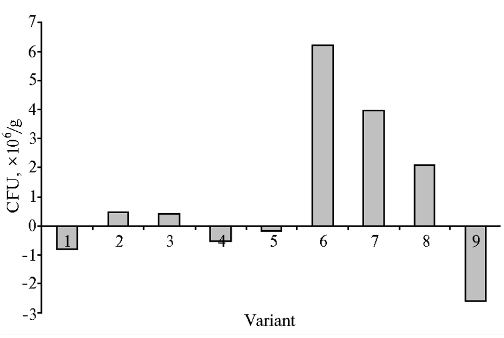

Fig. 2. Changes in the number of ammonifying microorganisms in the soil under potato (*Solanum tuberosum* L.) variety Zhukovsky by the experiment completion relative to the beginning the growing season in the variants of the use of a LPB biological product and multi-purpose compost (KMN): 1 — KMN (control), 2 — KMN + LPB 1:30 (0.05 l/m^2), 3 — KMN + LPB 1:30 (0.1 l/m^2), 4 — KMN + LPB 1:30 (0.2 l/m^2), 5—KMN + LPB 1:30 (0.3 l/m^2), 6 — KMN + LPB 1:300 (0.05 l/m^2), 7 — KMN + LPB 1:300 (0.1 l/m^2), 8 — KMN + LPB 1:300 (0.2 l/m^2), 9 — KMN + LPB 1:300 (0.3 l/m^2) (Tver' region, 2011-2012).

The role of KMN local application with potato planting was to supply plants with available nutrients at their early development. At the time of flowering and early tuber formation, the role of phosphorus and potassium in plant development increased. At this stage, LPB contributed to the formation of reproductive organs and reserve substances in the crop commercial part.

The results indicate that LPB is advisable to be used as a growth and development promoter in potato variety Zhukovsky. Sowing is to be sprayed with the biological preparation at a concentration of 1:300 and doses of 0.05-0.1 l/m^2. In the direct LPB contact with potato tops, plants' needs in nutrition elements was satisfied, and the microorganisms of the agent attributed to the activation of biochemical reactions in the process of potato ontogenesis. As a result of this combined effect of the biological preparation, a significant increase in the yield was observed, and the number of soil microflora grew as well.

Thus, the combined effect of KMN (multi-purpose compost) and LPB (biological preparation which includes nutritious elements and growth factors) on the yield of spring wheat and potatoes was favorable. The increase was due to the formation of larger grains or enlargement of potato tubers (the proportion of marketable potatoes increased significantly). After harvesting, the soil remained free from chemical pollution and enriched with microflora contributing to the reproduction and preservation of soil fertility. The biologicals developed can replace traditional fertilizers and preparations in agro-technologies of the crops studied.

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