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Spring Wheat Cultivation Using a New Bioproduct

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Abstract

Spring wheat is a strategically significant agricultural crop all over the world. Increasing yields of the crop need increasing use of the mineral fertilizers and chemical fungicides – using which becomes less and less popular. They are being substituted with various bioproducts being developed all over the world, including Russia. All-Russian Research Institute of Reclaimed Lands (VNIIMZ) has created a novel bioproduct – LBP – featuring physiologically significant amounts of growth factors and nutritive elements favorable for the plants. This work evaluates an LBP effect on spring wheat, Irgina sort, when using LPB as a supplementary fertilizer with a mineral fertilizer as a basic one. The research was carried out in microplot experiments at a VNIIMZ's test site, Tver Region, Russian Federation, in 2009-2010. Among all options studied, a 0.1 l/sq.m LBP dose (added by spraying on bushing-out and earing plants) proved to be the most effective. That option yielded 16.31 metric centners/hectare, which is 27.3% higher than the same without LBP is. A grain quality analysis showed the following nutritive value rise compared to references: cellulose, oil and calcium (CaO) increased by 10…12%, 9…10%, and 10…12%, respectively. Soils of the plants treated with LBP generally contained more nitrogen compounds, less amylolytic microorganisms (competing for nitrogen) and Fusarium wilt ones - which totally provided better conditions for the spring wheat growth.

Keywords: spring wheat, bioproducts, LBP, crop yield, soil, nutritive elements, microorganisms

1. Introduction

Spring wheat is one of the oldest and popular crops in the world. In Russia, spring wheat gives 23% of the total grain yield. Its grain is reach in protein and gluten. It is excellent in baking. Even wheat bran is a valuable concentrated forage for agricultural animals; the latter are also fed with spring wheat straw or chaff. Moreover, spring wheat needs no hot climate, which is why it is grown in many regions of the Russian Federation (Physiology of Agricultural Plants, 1969). Spring wheat has a short vegetation period and its roots have a lowered uptaking capacity – so it has high requirements to the soil in the beginning of its vegetation period and, consequently, needs valuable fertilizers (Markhieva, 2004). Constant use of mineral fertilizers ruins the environment. in this connection, using biological fertilizers and other bioproducts can optimize the biological indices of the soil and provide high yields of the agricultural crops (including grain) featuring a high quality (Buchanan et al., 2000).

There exist many plant growth regulators using their biologically active compounds to affect the crucial physiological events such as growth and shaping of various plant organs, blossoming time and type, maturity time (Mishra, 2001).

In 2011-2013 Roshchinsky state farm, Bashkortostan, Russia conducted field experiments to study Fitosporin-M (a biological fungicide based on endophytic bacterium *Bacillus subtilis* 26D in a humic carrier) effect on spring wheat Ekada 70. The analysis of the results for three years on the average showed that a seed treatment with Fitosporin-M gave a greater yield and mass of 1,000 grains compared to the reference – they were 0.31 tonn/hectare and 3.85 g, respectively. When the seeds and plants were treated with the bioproduct at the stage of bushing-out, root rots affected the test plants 10.1% less than reference ones. The mass portion of the raw gluten was greater by 3.6% in that case (Davletshin et al., 2014).

The experiments done in Ryazan Region on Priokskaya spring-wheat from April to October 2006 included soil treatment with Azolen immediately before planting, as well as spraying at three-leaf seedlings. Azolen is a multifunctional microbiological fertilizer created on the basis of free-living nitrogen-fixing soil bacteria

Azotobacter vinelandii IB 4 (cell titer is 4-8×10^9 CFU/ml) developed by Institute of Biology, Ufa Scientific Center of the Russian Academy of Science (Loginov et al., 2005). The treatment with bioproduct Azolene did not affect the germinability of the spring wheat seeds, but accelerated passing through phenological stages and reduced the plant vegetation period by four to five days compared to the references. In addition, Azolen improved the yield structure and raised the crop productivity. The extra crop collected was 4.6 metric centners/hectare (14.4%) and proved to be reliable – $MSD_{0.5}$ = 1.89. In every experimental option the spring wheat was affected by the brown rust, but the disease developed on the reference was more harmful and exceeded by 5% to 10% that parameter for the plots treated with the bioproduct (Korshunova et al., 2007).

A field experiment done on the base of Novosibirsk State University showed that bioproduct Bioplant Flora was positive for spring wheat Kantegirskaya 89 crops. Bioplant Flora is a fertilizer based on humic acids and trace elements. It is produced from natural, environmentally pure raw materials using microbiological and nano-technologies. The bioproduct increased the 1.000 grains' mass, especially in a double treatment (28.1 g compared with the control to 26.7 g only). The bioproduct raised the crops by 7% to 10% (Vyshegurov et al., 2010).

For several years, researchers have been studying the ways to increase the quantity and quality of the spring wheat in West Siberia with the help of biologically active products of a vegetative origin, such as bioklad, bius and larus. They could stimulate the plants' immunity, resistance to phytopathogens, and promoted plants' growth. The treatment of the vegetating plants activated the crop's growth by raising its parameters such as plants' height and biomass. Larus provided the best results. The bioproducts lowered the degree of plants' diseases, and promoted plants' growth - which increased the grain production versus reference by 14.4% to 18% when used at the bushing-out stage or by 10.4% to 53.8% at the earing stage. The maximum extra grain yield was provided by bius and larus in the first case and bioklad and larus in the second one. A certain protein content rise was also noted in the wheat grain. The wheat treatment during its vegetation favored the 1000 grains' mass – it grew relevantly (compared to reference) in all experimental options by 3.7% to 4.6% (bushing-out treatment) and by 3.8% to 5% (earing treatment) (Vlasenko et al., 2013).

All-Russian Research Institute of Reclaimed Lands developed an LBP bioproduct, which is a dark-brown liquid containing all nutritive elements and trace elements (Mg, Zn, Mn, Fe) necessary for plants' growth and development. Additionally, it features agronomically useful microorganisms in the concentration of 10^{12} colony-forming units/ml (Rabinovich et al., 2009).

LBP is recommended for use as a growth stimulator for agricultural crops and as a ground-fertilizing bioproduct to support soil fertility. Currently, the bioproduct is being tested widely on different crops. The objective of this work is to evaluate the effect of LBP on a cereal – such as sort Irgina spring wheat.

2. Method

The research was done as microplot experiments at the institute's testing site in 2009-2010. The soil there was a dryable, sod-podzol, sandy-loam one (pH_{KCl} – 5.4; P_2O_5 – 47.3; K_2O – 16.4; NO_3 – 0.42; NH_4 – 0.53 mg/100 g).

A combined mineral fertilizer N50P50K50 active substance/hectare was used as a basic fertilizer on the spring wheat fields. The experiment has been arranged in triple repeats on the plots randomly located and provided with environment protection belts. In 2009, we studied an optimum way to add LBP: watering under the plant or spraying on it. A dose of 0.4 l/sq.m LBP was used in the working concentration of 1:30, twice in the period of vegetation – once at the bushing-out stage and once at the earing one. In 2010, we used LBP as the additional fertilizer in five different doses: 0.05; 0.1; 0.2; 0.3; 0.4 l/sq.m, and treated the plants only by spraying on them from a manual sprayer – in the same concentration and at the same growth stages as in the previous year. Besides, we also used a screening product Baikal EM1 as recommended by the manufacturer. Plots without the LBP treatment were used as references. The wheat was gathered by manual mowing at the stage of full maturity, with evaluating the morphological and biometrical parameters of the plants. After drying, the ears were directed through a small and simple threshing machine. The grains were weighed, and each plot's crop was evaluated. The quality of the grains was evaluated by various parameters. Soil samples were taken from the plough-layer (0 cm to 20 cm) four times during the spring wheat vegetation period.

Microsoft Excel 2003 and Statgraphics 6.0 software were used for statistical data processing.

3. Results and Discussion

Evaluation of the total production of the spring wheat in 2009 showed that LBP spraying gave the best plant growth. In this case, the yield was 15.32 metric centner/hectare. When the plots were watered with LBP, the yield was 14.86 metric centner/hectare. The reference (without LBP) yielded 13.15 metric centner/hectare (minimum substantial difference $MSD_{0,5} = 1.12$). The major components determining the wheat yield are the number of productive caules on a unit area, as well as individual ear's size and production. The maximum density of the caules was reached when LBP was sprayed (Table 1). The second yielding parameter is the number of grains in the ear. In this case, the LBP spray was the leader too. Meanwhile, the grains in ears for both LBP administration ways were developed comparably (1000 grains' mass was 28.2 g and 28.1 g, which was somewhat higher than reference). Grain mass versus straw mass showed a difference between the reference and LBP tests, suggesting that LBP promoted forming the grain.

Table 1. Morphological and biometrical parameters of spring wheat (2009)

Treatment type	Average caulis length, cm	Average ear length, cm	Total number of caules, pcs	Number of grains in the ear, pcs	1000 grains' mass, g	Grains/Straw
No LBP	66.76	6.18	482	18	27.1	1:1.5
LBP spraying	70.12	7.82	513	24	28.2	1:1.3
LBP watering	68.62	6.52	506	21	28.1	1:1.3

The soil reaction to LBP was evaluated from various agrochemical and microbiological parameters. The number of ammonium-fixing microorganisms grew with LBP but fell throughout all vegetation without LBP. The difference in the number of the ammonium-fixing microorganisms as a function of the way of adding LBP was insignificant – however, spraying gave some predominance over watering.

Dynamics in the number of amylolytic microorganisms – competing against plants for mineral nitrogen – showed a total contrast: it was the reference that showed the maximum values throughout the whole vegetation period.

Soils in the LBP tests showed elevated nitrogen, in both ammonium and nitrate forms, throughout the whole vegetation period (Table 2). After the first LBP treatment by the earing stage there was a sharp rise in both nitrogen forms, followed by a total soil nitrogen content fall. However, this fall was less in the LBP tests than in the reference. Considering the ways of adding LBP, the nitrogen reaction depended on the nitrogen form: ammonium was maximum at the earing stage - when LBP was sprayed, but at the stages of milky ripeness and full ripeness - in case of LBP watering. However, the nitrate nitrogen reaction to the ways of adding LBP was fully contrary.

Table 2. Dynamics in ammonium and nitrate nitrogen content in soil under wheat (2009)

Parameter, mg/100g soil	Treatment type	Sampling period			
		Bushing-out	Earing	Milky ripe	Fully ripe
NO_3	No LBP	0.48±0.006	0.62±0.012	0.56±0.010	0.48±0.010
	LBP spraying	0.48±0.007	0.76±0.014***	0.65±0.012**	0.60±0.011***
	LBP watering	0.49±0.008	0.81±0.016***	0.60±0.011*	0.48±0.011
NH_4	No LBP	0.17±0.004	0.18±0.005	0.10±0.003	0.07±0.004
	LBP spraying	0.17±0.003	0.29±0.006****	0.18±0.006***	0.15±0.006***
	LBP watering	0.18±0.003	0.25±0.007***	0.20±0.006****	0.17±0.008***

Note. Here and further, difference between the reference and LBP test is reliable: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$; **** $p < 0.001$.

The NO_3 content was maximum when sprayed – which finally provided a higher spring wheat yield in this test type. Wheat production as a function of nitrate nitrogen content in the soil can be described by regression equation $y = –3.36588 + 30.4663x$, correlation coefficient $R = 0.91$, which suggests a strong correlation between the variables. At the same time, wheat production as a function of ammonium nitrogen content in the soil can be described by regression equation $y = 10.8152 + 19.8136x$, correlation coefficient $R = 0.63$, which suggests a moderately strong correlation between the variables.

Thus, the spring wheat treatment with LBP caused an active transformation of the nitrogen-containing soil compounds – which, undoubtedly, produced an effect on the wheat production, and it was spraying that produced the maximum effect.

Besides, concentration of microscopic fungi (forming humus compounds and covering soil particles with their mycelium) was also evaluated. The fungi structure the soil, improving its fertility. In addition to the useful fungi, soil contains many pathogens hampering plant growth. In this connection, we evaluated content of Fusarium wilt microorganisms (especially harmful for cereals) in the plant test soils. Table 3 shows that their number when using LBP was less than in the reference – throughout the whole vegetative period. This observation suggests that this LBP can serve as a protector.

Table 3. The number of Fusarium wilt microorganisms in the soil under the wheat

Treatment type	Sampling period			
	Bushing-out	Earing	Milky ripe	Fully ripe
No LBP	5.8±0.09	4.7±0.08	3.9±0.09	3.8±0.09
LBP spraying	4.8±0.08***	2.4±0.07***	3.5±0.07*	2.8±0.06***
LBP watering	3.6±0.08***	2.4±0.05****	2.3±0.07***	2.2±0.04***

In the second year of the studies in LBP effects on spring wheat, we spread the LBP spray dose range. It should be noted that the vegetation period of 2010 turned out to be extremely unfavorable: abnormal heat and minimum precipitations (which was clearly bad for the crops).

The evaluation of spring wheat production on the test plots showed that LBP treatment in any test dose promoted the spring wheat production, with the maximum extra crops in case of 0.1 l/sq.m (Table 4). LBP doses greater than 0.1 l/sq.m lowered gradually the spring wheat production (because of plant-growth and grain-forming inhibition).

Also, a screening bioproduct Baikal EM1 promoted wheat production compared to the reference, but this extra production was lower than from 0.1 liter LBP /sq.m.

Table 4. Effect of bioproducts on spring wheat productivity (2010)

Treatment type	Productivity	+ To the reference	
	-------centner/hectare------	------centner/hectare------	------%-----
No bioproduct	12.81	-	-
LBP – 0.05 l/sq.m	14.85	2.04	15.9
LBP – 0.1 l/sq.m	16.31	3.50	27.3
LBP – 0.2 l/sq.m	14.93	2.12	16.5
LBP – 0.3 l/sq.m	14.19	1.38	10.8
LBP – 0.4 l/sq.m	14.05	1.24	9.7
Baikal EM1 – 0.2 l/sq.m	15.51	2.70	21.1
Minimum substantial difference $MSD_{0.5}$	1.59		

LBP and the screening bioproduct mostly acted on forming grains – they increased the 1000 grains' mass (the best result was in spraying LBP, 0.1 l/sq.m – the mass increased by 10%). In addition to that, grain/straw ratio lowered (Table 5), suggesting that a greater grain mass is produced from a straw unit mass. It should be noted that this effect is typical for all test types. Again, Table 5 shows that the bioproducts promoted a favorable effect on all parts of wheat: the average caulis and ear lengths increased by 4% and 25% respectively, the number of caules from 1 sq.m grew by 3%.

Table 5. Morphological and biometrical parameters of spring wheat in case of using bioproducts (2010)

Treatment type	Average caulis length, cm	Average ear lengths, cm	Total number of caules, pcs/sq.m	Number of grains in caulis, pcs	1000 grains' mass, g	Grain mass/ straw mass
No bioproduct	66.96	5.85	473	18	22.2	1:2
LBP – 0.05 l/sq.m	70.85	6.47	485	21	22.8	1:1.9
LBP – 0.1 l/sq.m	70.66	6.22	488	19	24.4	1:1.6
LBP – 0.2 l/sq.m	67.94	5.81	484	19	23.6	1:1.6
LBP – 0.3 l/sq.m	68.20	5.97	485	17	23.4	1:1.6
LBP – 0.4 l/sq.m	69.91	6.07	483	19	23.8	1:1.9
Baikal EM1 – 0.2 l/sq.m	67.81	5.73	485	21	23.1	1:1.7

Spraying bioproducts affected, first of all, grain forming. However, it had an effect on the soil under the spring wheat too.

In contrast to the previous year of research, that year's soil reacted more actively on the bioproduct, because most of the test soils featured higher phosphorus content throughout the whole vegetation period. There, the maximum mobile phosphorus content was observed when LBP was sprayed (0.1 l/sq.m) or the screening bioproduct applied (6% above the reference, $p < 0.01$).

Adding LBP in doses of 0.1…0.4 l/sq.m promoted a reliably greater potassium content in those tests' soils. For example, LBP spraying in dose 0.1 l/sq.m added 7% to 15% potassium ($p < 0.01$).

Nitrate nitrogen dynamics was practically identical in all test types. However, scrutinizing ammonium nitrogen dynamics (Figure 1) shows that its content was almost the same in all test types – when the plants required much nitrogen for their growth. The only exclusion was the LBP 0.1 l/sq.m test, where the first treatment at the bushing-out stage gave a significant ammonium nitrogen increase in the soil by the earing stage, but this advantage vanished before the vegetation end (the effect of ammonium nitrogen content in the soil on the productivity can be described by regression equation $y = 193.532 – 62.4524x$ with a negative correlation coefficient $R = -0.47$). Nevertheless, the additional nitrogen at the stage of spring wheat vegetation system generation helped the yield.

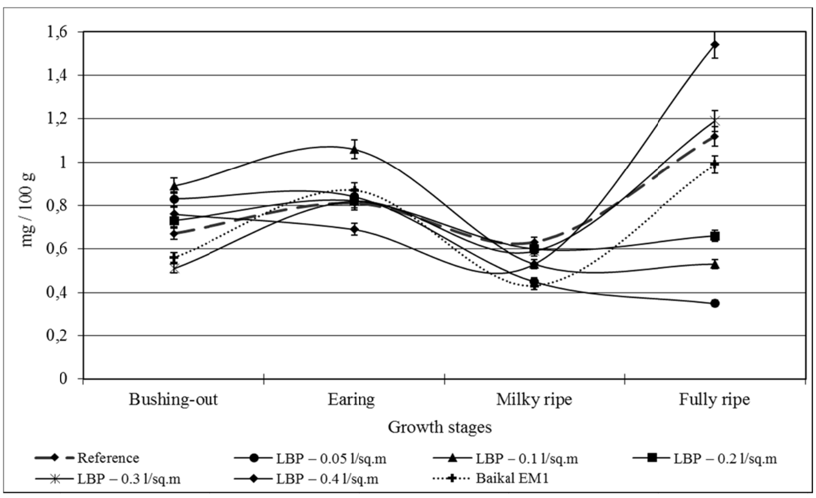

Figure 1. Dynamics of ammonium nitrogen in the soil under spring wheat (2010)

An insufficient nutrition for the spring wheat without the bioproducts can be confirmed by active redox reactions in the soil. They can be evaluated through a redox coefficient (ROC), that is soil enzyme activity ratio, catalase versus dehydrogenase. The reference showed an elevated ROC (Figure 2) reflecting necessary activation of microbiological and biochemical processes in the soil that could lower the nutrition deficit. Spraying crops with

LBP helped weaken the redox reactions – suggesting that those test types provided optimum nutrition. It should be noted that not each LBP dose showed that effect. LBP in 0.05 l/sq.m and 0.4 l/sq.m demonstrated high ROC values. Bioproduct Baikal EM1 showed high ROC values too.

The reference soil, just like in the research a year before, showed higher concentration of amylolytic microorganisms throughout the whole vegetation period. The LBP test soils had by 20% to 25% less amylolytic microorganisms. In some cases, the difference reached 35% versus the reference. The Baikal treatment produced only 22% decrease.

Generally, the elevated nutrition elements content in the soil at the key wheat growth stages, as well as the lowered number of the amylolytic microorganisms, had a substantial effect on the spring wheat productivity when treated with bioproducts (especially with LBP in 0.1 l/sq.m).

Grain quality studies showed its higher nutritive value. The best productivity test (LBP spraying 0.1 l/sq.m) demonstrated the following results versus the reference: more cellulose, oil and calcium (CaO) by 10%…12%, 9%…10%, 10%…12%, respectively.

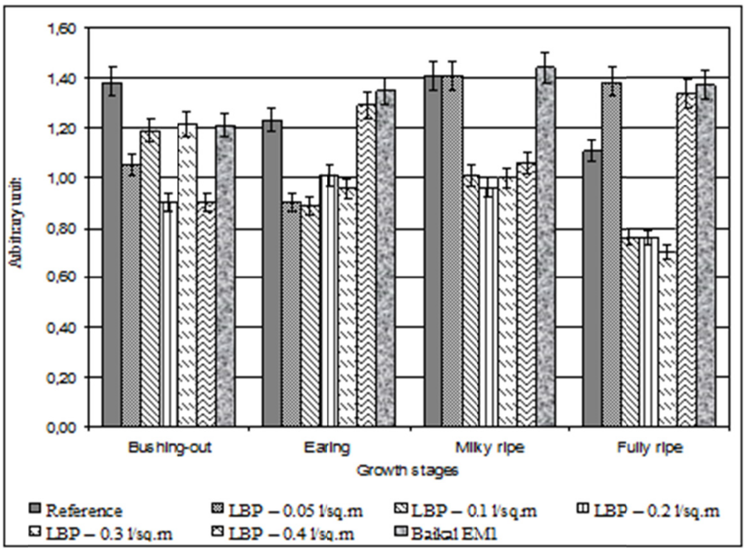

Figure 2. Dynamics of redox coefficient (ROC) in the soil under spring wheat treated with bioproducts (2010)

4. Conclusion

Thus, the new bioproduct LBP proved out to be effective for spring wheat. LBP should be added by spraying onto plants at bushing-out and earing stages. The most effective LBP dose was 0.1 l/sq.m. That LBP test type gave a higher productivity than screening bioproduct Baikal EM1. Trace elements, oil and cellulose content in the grain rose, suggesting a comprehensive LBP competitiveness.

The productivity rise was accompanied by positive changes in the soil. At key stages of spring wheat growth, the soil contained more assimilable nitrogen, less amylolytic and pathogenic microorganisms, which caused Fusarium wilt of plants.

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