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ORIGINAL ARTICLE

Agrobiological and ecological bases of productivity increase and genetic potential implementation of new buckwheat cultivars in the conditions of the Northeastern Forest-Steppe of Ukraine

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In the research, agrobiological features of growth, development and productivity of different buckwheat morphotypes cultivars depending on the action and interaction of studied agronomic cultivation factors are studied. The conditions for buckwheat cultivars productivity elements formation are determined. The dynamics of plants photosynthetic surface formation of buckwheat cultivars under influence of mineral nutrition level, biopreparation, growth regulator and microfertilizer are investigated. The comparative estimation of buckwheat production modern methods efficiency is given.

Selyanochka cultivar variant with complex use of seeds treatment with biopreparation, microfertilizer and application of growth regulator in the phase of budding, on the background of mineral fertilizers use (N16P16K16+N15) formed maximum yield -2.20 t/ha, increase from fertilizers use-+0.42 t/ha, from combination ofbiopreparation, microfertilizer and growth regulator-+0.27 t/ha.

The highest yield level of Slobozhanka cultivar (1.92 t/ha) was formed in the variant mineral fertilizers'application (N30P45K45+N15) into the rows, increase was-+0.41 t/ha comparable to control. The use of growth regulator Sodium humate also provided yield increase (+0.19 t/ha).

Keywords: Buckwheat; microbial preparations; microhumin; sodium humate; mineral fertilizers; cultivars

Introduction

Obtaining steady and high yields of agricultural crops is inextricably linked to the soil fertility, which depends on the intensity of organisms'processes in the soil.

It is known that the increase in plant productivity can be achieved not only by the introduction of necessary fertilizers rates and biological preparations in the complex of crops cultivating technological operations, but also by selection methods (Efimenko, 1992). Improving the agrotechnical methods of buckwheat cultivation through the technology elements combination (choice of cultivars, biological preparations, mineral fertilizers, plant growth regulators, microfertilizers) will contribute to the implementation of its genetic potential (Karpenko, 2012).

In the technology of growing crops, plant growth regulators are an important factor in controlling the growth and development of plants. Growth regulators give the opportunity to better realize the potential of plants, regulate the ripening periods, improve the quality of products and increase yields. The basis of microbiological preparations are live microorganisms, which are characterized by a complex of agronomic-beneficial properties-nitrogen fixation, phosphate mobilization, growth stimulation and antagonism to phytopathogens (Mashchenko, 2009).

Important role in the formation of crops is devoted to fertilizers, but there are questions remain of their interaction with microbial preparations and its impact on the productivity of buckwheat. By changing the chemical composition of the substances entering the plants, its number and time of receipt, it is possible to increase the yield, toenhance the growth, to improve the chemical composition and quality of the products, as well as to increase the plants resistance to adverse conditions.

The application effectiveness depends on the degree of its compliance with the biological requirements of agricultural crops in specific soil and climatic conditions (Gavrylyanchyk, 2001).

Literary data testify to the positive influence of microbiological agents and plant growth regulators on the production of grain crop yields(Trotsenko and Ilchenko, 2013). Improvement of plant productivity can be achieved not only by breeding methods, but also by introducing the necessary fertilizer rates and incorporating biological preparations into a set of successive technological cultivation operations (Radchenko et al., 2018).

The biopreparations action improves a powerful plants root system growth, which is a medium for the development of beneficial microorganisms, which, on the one hand, provides an improvement in water exchange and mineral nutrition, and on the other-activates physiological and biochemical processes in plants, which reflects in the crops yield (Alekseeva, 1992).

The modern innovative way to increase the productivity of agricultural crops is thebiopreparations usage that improves the conditions of nutrients use from both fertilizers and soil. When using microbial preparations, the supply of useful microorganisms in the required amount is providedat the optimal period and in the right place (Sharafetdinov, 2003). Creating a space for the domination of agronomically beneficial bacteria in the root zone of cultivated plants helps to ensure the mineral nutrition. At the same time microbial preparations, having in its composition physiologically active substances of bacterial origin (original growth stimulants, but not chemical), actively influence the root system growth and form the significant absorbent area, which, in general, contributes to the increase of fertilizer use degree by inoculated plants. In addition, vegetative treatments intensify the general development of plants with an orientation towards increasing their productivity and improving product quality (Shevchenko, 1998).

The leaves of buckwheat are large and remain green, photosynthesizing until the end of vegetation, but accumulated plastic materials are not enough to ensure all generative organs. Therefore, many buds, flowers, and even tied fruit dry up and fall off. To increase the crop productivity, first of all, it is necessary toenhance the productivity of photosynthesis by increasing the leaf surface and its ability to production (Shkurikhina, 1971).

Nychyporovych (1956) defined that for the optimal passage of the crop’sphotosynthesis, a certain area of leaf surface should be formed. About 30-40 thousand m^2/ha is sufficient for high harvests. Further its increase can negatively influence photosynthesis, as the illumination of leaves decreases and they inappropriately use the mineral nutrition elements.

Materials and methods of research

Experiments with buckwheat were conducted in the short-term field crop rotation of the Institute of Agriculture of the North East NAAS, which is located in the conditions of the northeastern Forest-Steppe of Ukraine. Research methods are field trials that included phenological, biometric observations and structural analysis of plants. Soils of experimental plots-typical black soil, weakly evolved, large-pealmedium-loamed, the arable layer of which is characterized by the main indicators: content of humus-4.1%, pH-6,3, amount of absorbed alkaline-31 mg equivalents, content of easy hydrolyzed nitrogen (by Cornfield)-11.2 mg/100 g.

Meteorological factors play an important role in the formation of buckwheat yield. Buckwheat has two critical periods, which, depending on the meteorological factors, can become the main factor for the crop yield level. Such periods are “sowing-germination” and “flowering-fruit-forming”. Optimal for the period of “sowing-germination” period is the daily average air temperature-+15-17 °C and the relative air humidity-50-60% (Bobyk & Mykhaylova, 1987).

Weather conditions duringresearch growing season of 2016-2018 were different and had a significant impact on buckwheat yield formation. That made it possible to investigate reaction of cultivars to the agronomic techniques that were studied in the experimental variants.

Weather conditions in 2016 were characterized by increase of average daily temperatures in the spring-summer period and uneven distribution of precipitation over decades. During the spring, average daily temperature was 10.2 °C, which was 2.1 °C higher comparable toaverage long-term (8.1 °C). Precipitation amount was 248.8 mm, that was 188% comparable to average long-term (132 mm). The sum of active air temperatures above +10 °C during the spring period was 795 °C, average long-term-620 °C.

During the summer period, the average daily air temperature was 21.5 °C, average long-term-19.2 °C. Precipitation amount was 87.6 mm, which was 104.8% comparable to average long-term (83.5 mm). The sum of active air temperatures above+10 °C during the summer period was 1982 °C, average long-term-1790 °C.

In 2017 “sowing-germination” period was provided with the main meteorological factors for the formation of seedlings at the level of optimal, or close to its parameters. During the spring period, the average daily temperature was 9.6 °C, which was 1.5 °C higher comparable to average long-term (8.1 °C). Precipitation amount was 54.4 mm, that was 41% comparable to average long-term (132 mm). The sum of active air temperatures above +10 °C during the spring period was 553 °C, average long-term-620 °C. The average daily air temperature during the summer period was 21.1 °C, which is 1.7 °C above the average long-term. The precipitation was 126 mm, which was 63% comparable to average long-term (200 mm). The sum of active air temperatures above+10 °C during the summer period was 1937 °C, average long-term-1790 °C.

During “sowing-germination” in 2018, frostbite was observed on the soil surface from -1 °C to 0 °C. The last frost on the soil surface was registered on May 29. The average daily temperature of air was 16-20 °C, precipitationwas 60-70 mm, and the relative humidity of the soil was 60-70% for the period of “flowering-fruit-forming”. The average daily air temperature during the summer period was 22.4 ° C, which is 3 °C above the average long-term. The precipitation was 100.1 mm, which was 50% comparable to average long-term (200 mm). The sum of active air temperatures above +10 °C during the summer period was 2683 °C, average long-term-2247 °C.

Studies with buckwheat were conducted in a three-factor experiment during 2016-2018, where: factor A-cultivars of different morpho-type; factor B-rate of mineral fertilizers ($N_{16}P_{16}K_{16}$, $N_{30}P_{45}K_{45}$, N_{15}); Factor C-biological preparation (Microhumin-200 g/ha), microfertilizer (Reakom"Grain"-0.5 l/ha), plant growth regulator (sodium humate-1.0 l/ha).

Variants were replicated four times, area of the sown area-30 m^2, calculated-25 m^2. Ammonium nitrate (N_{15}) was used for nutrition in the budding phase, other mineral fertilizers were applied under pre-sowing cultivation ($N_{30}P_{45}K_{45}$) and into rows ($N_{16}P_{16}K_{16}$). Placement of plots was systematic according to the methodological recommendations (2001), taking into account all trial methodology requirements by Dospekhov (1985).

Phenological monitoring of plants growth, development and biometric indices were determined during the main stages of organogenesis according with method of State Service for Rights Protection of Plant Cultivars (2003). The statistical processing of collected data was carried out according to dispersion method by using Statistica 6.0 and Microsoft Excel.

Results and discussion

The area of plants assimilation apparatus is most important for the formation of crop yield. Originally createdorganic substances by the process of photosynthesis make up about 90-95% of yielddry weight. This increases the necessityof plastic materials for plants, and its lack leads to decrease of yield. In addition, buckwheat plants have a significantly smaller leaf surface per flower comparable to other cereals. Improvement of mineral nutrition contributes to increase of leaf surface area, enhance of photosynthetic activity, which is reflected in flowers formation.

In the experiments of 2016-2018 it was found the influence of mineral fertilizers,biopreparation, microfertilizer andplant growth regulator on the formation of buckwheat inflorescences and its maintenance by photosynthetic leaf layer (Table 1).

The greatest growth of leaf surface was observed during the period of flowering-beginning of fruit production. Subsequently, the leaf surface continued to increase, but the intensity of its growth was low.

The maximum leaf area of the buckwheat plants of Selyanochka cultivar was observed on the variant of complex application of seed inoculation with biopreparation, plant growth regulator and mineral fertilizer application (depending on the fertilizer rate varied within the range of 230.5-271.3 cm^2). The same variant with Slobozhanka cultivar formed the maximum leaf surface area depending on the fertilizer rate (308.4-321.4 cm^2).

Table 1. Number of inflorescences and leaf surface area of buckwheat plants depending on the fertilizer system (average for 2016-2018).

Biopreparation, microfertilizer, plant growth regulator (Factor C)	**Rate of mineral fertilizers, kg of active substanceper 1 hectare (Factor B)**	**Cultivars (Factor A)**			
		Selyanochka		**Slobozhanka**	
		Number of inflorescences per plant, pcs.	**Leaf surface area of 1 plant in the flowering phase, cm^2**	**Number of inflorescences per plant, pcs.**	**Leaf surface area of 1 plant in the flowering phase, cm^2**
Without treating (seed treated with water) – control	Without fertilizer	13	228.5	21	304.3
	$N_{30}P_{45}K_{45}$	19	247.5	17	312.1
	$N_{30}P_{45}K_{45}$ + N_{15}	15	263	15	287.5
	$N_{16}P_{16}K_{16}$into rows	14	267.4	20	293.1
	$N_{16}P_{16}K_{16}$ + N_{15}	13	212.8	23	315.6
Microhumin 200 g/ha (treated seed)	Without fertilizer	14	231.2	20	307.3
	$N_{30}P_{45}K_{45}$	15	247.6	16	314.2
	$N_{30}P_{45}K_{45}$ + N_{15}	13	255.3	18	283.5
	$N_{16}P_{16}K_{16}$ into rows	12	263.1	24	278.7
	$N_{16}P_{16}K_{16}$ + N_{15}	11	268.4	17	312.7
Microfertilizer Reakom 4 l/ton (treated seed)	Without fertilizer	15	237.4	23	310.3
	$N_{30}P_{45}K_{45}$	17	244.6	20	304.3
	$N_{30}P_{45}K_{45}$ + N_{15}	14	251.3	22	296.7
	$N_{16}P_{16}K_{16}$ into rows	12	267.2	19	312.3

	$N_{16}P_{16}K_{16}$ + N_{15}	17	252.4	24	307.5
Plant growth regulator – sodium humate 1.0 l/ha (plants treated in the budding phase)	Without fertilizer	16	234.2	22	287.3
	$N_{30}P_{45}K_{45}$	12	264.5	26	315.1
	$N_{30}P_{45}K_{45}$ + N_{15}	14	251.6	20	304.7
	$N_{16}P_{16}K_{16}$ into rows	13	254.7	27	295.6
	$N_{16}P_{16}K_{16}$ + N_{15}	12	256.3	23	317.3
Microhumin and Reakom (treated seed) + Sodium humate(plants treated in the budding phase)	Without fertilizer	15	230.5	24	308.4
	$N_{30}P_{45}K_{45}$	17	253.7	26	319.2
	$N_{30}P_{45}K_{45}$ + N_{15}	18	261.4	23	321.4
	$N_{16}P_{16}K_{16}$ into rows	14	267.2	27	295.1
	$N_{16}P_{16}K_{16}$ + N_{15}	19	271.3	28	310.3

The complex use of the biopreparation for pre-sowing seed treatment provided development improvement of both aboveground bioweight and root system of plants.Especially as a result of plant growth regulator activity, which contributed to rhizosphere surface growth for introduced microorganisms and, consequently, improved mineral nutrition of plant that is an important condition for yield formation.

The results of mineral fertilizers, biopreparation, growth regulator and micronutrient influence on the formation of buckwheat plants productivity in 2016-2018 years have revealed that the structure of the buckwheat crop was significantly influenced by the use of biomaterial. The intensity of plants growth and development was uneven and depended on hereditary properties and conditions of the environment.

The structural plants analysis was carried out in order to detect and characterize the influence of investigated factors on the elements of productivity in different buckwheat morphotypes cultivars. The inoculation of buckwheat seeds with the biopreparation increased the number and weight of buckwheat grains compared with the variant without biologic agent application.

According to the results (Table 2), the average number of grains per plant and the weight of 1000 grains were higher in variants of Selyanochka cultivarcomparable with Slobozhanka.

Maximum number of grains per plant (48 pcs.) was recorded in variant of Selyanochka cultivar with plant growth regulator (Sodium humate 1.0 l/ha in the budding phase) in combination with mineral fertilizer $N_{16}P_{16}K_{16}$ application into rows.Moreover, minimumnumber of grains per plant (40 pcs.)was formed by Selyanochka cultivarin variants without mineral fertilizers, seeds treated with water and seeds treated with Microhumin 200 g/ha, which indicates a negative effect of additional mineral nutrition absence.

Slobozhanka cultivar formed average 45 seeds perplant. Among the studied variants, the largest number of grains per plant (48 pcs.) was in the variantswith plant growth regulator (Sodium humate 1.0 l/ha in the budding phase) on the background of $N_{30}P_{45}K_{45}$ and $N_{16}P_{16}K_{16}$+N_{15}.

Selyanochka cultivar maximum weight of 1000 grains (26.3-27.5 g) was obtained in the variant with complex seeds inoculation by biopreparation, microfertilizer and plant treatment. These variants obtained maximum weight of grains from plant (1.27 g).

The dependence between the weight of 1000 grains and weight of grains per plant was not noted in Slobozhanka cultivar. The highest level of the weight of 1000 grains was formed in the with plant growth regulator on the background of $N_{30}P_{45}K_{45}$+N_{15}-25.9 g, while the weight of grains per plant was 1.12 g, which is average for experiment.Complex seed inoculation with biopreparation, microfertilizer and plants treatment by plant growth regulator provided the weight of grains per plant in the range of 1.18-1.21g, but the weight of 1000 grains was 25.1-25.6 g.

According to the results of buckwheat plants productivity elements determination, it was noted that plant growth regulator usage, which was introduced separately as well as in mixtures with biopreparation, imposes a positive effect on productivity performance that exceed control.

Table 2. Results of fertilizer system influence on formation of buckwheat plants productivity (average for 2016-2018).

Biopreparation, microfertilizer, plant growth regulator (Factor C)	**Rate of mineral fertilizers, kg of active substanceper 1 hectare (Factor B)**	**Cultivars (Factor A)**					
		Selyanochka			**Slobozhanka**		
		Seeds per plant, pcs.	**Weight of grains per plant, g**	**Weight of 1000 grains, g**	**Seeds per plant, pcs.**	**Weight of grains per plant, g**	**Weight of 1000 grains, g**
Without treating (seed treated with water)-control	Without fertilizer	42	1.06	25.3	46	1.17	25
	$N_{30}P_{45}K_{45}$	41	1.06	26.2	47	1.19	25.5
	$N_{30}P_{45}K_{45}$ + N_{15}	44	1.09	25.5	44	1.09	25.1
	$N_{16}P_{16}K_{16}$ into rows	46	1.2	25.8	43	1.03	23.9

	$N_{16}P_{16}K_{16}$ + N_{15}	44	1.12	25.9	45	1.19	25.7
Microhumin 200 g/ha (treated seed)	Without fertilizer	40	1.02	25.2	42	1.08	25.3
	$N_{30}P_{45}K_{45}$	44	1.13	25.3	44	1.07	24.4
	$N_{30}P_{45}K_{45}$ + N_{15}	45	1.13	25.8	46	0.9	24.4
	$N_{16}P_{16}K_{16}$ into rows	46	1.19	26.1	46	1.09	24
	$N_{16}P_{16}K_{16}$ + N_{15}	47	1.19	25.8	47	1.19	25
Microfertilizer Reakom 4 l/ton (treated seed)	Without fertilizer	45	1.19	26.3	45	1.12	24.9
	$N_{30}P_{45}K_{45}$	42	1.07	25.6	43	1.05	24.5
	$N_{30}P_{45}K_{45}$ + N_{15}	43	1.04	26.1	44	1.09	24.6
	$N_{16}P_{16}K_{16}$ into rows	43	1.12	26.2	46	1.15	25.3
	$N_{16}P_{16}K_{16}$ + N_{15}	42	1.09	26.1	44	1.09	25.1
Plant growth regulator-sodium humate 1.0 l/ha (plants treated in the budding phase)	Without fertilizer	40	0.97	25.1	44	1.06	24.8
	$N_{30}P_{45}K_{45}$	40	1.06	26.2	46	1.12	24.5
	$N_{30}P_{45}K_{45}$ + N_{15}	42	1.11	26.8	43	1.12	25.9
	$N_{16}P_{16}K_{16}$ into rows	48	1.14	26	41	1.04	25
	$N_{16}P_{16}K_{16}$ + N_{15}	44	1.12	25.3	48	1.12	24.6
Microhumin and Reakom (treated seed)+Sodium humate (plants treated in the budding phase)	Without fertilizer	44	1.15	26.3	47	1.21	25.4
	$N_{30}P_{45}K_{45}$	42	1.12	26.5	48	1.19	25.1
	$N_{30}P_{45}K_{45}$ + N_{15}	43	1.15	26.4	47	1.18	25.6
	$N_{16}P_{16}K_{16}$ into rows	45	1.16	25.8	46	1.19	25.3
	$N_{16}P_{16}K_{16}$ + N_{15}	46	1.27	27.5	46	1.12	25.1

According to the previous researches (Radchenko et al., 2018), the effect of using mineral fertilizers, growth regulators, microfertilizers, biopreparations is directed to stimulating seeds germination, photosynthesis, transport of substances, development processes (improvement of filling and size of fruits), resistance to abiotic (lack of water, low or high air temperatures) and biotic factors (disease, pest damage). Plant growth regulators, also referred as biostimulants, are kind of "doping", through which agricultural crops gain more vitality to produce yield. When potassium humate is applied to crops, plant is not so sensitive to frostbite, prolonged drought, too high nitrogen or pesticides rates and lack of oxygen in the soil during prolonged rainfall.

According to the results of the research, the use of the growth regulator, which was introduced separately as well as in mixtures with biopreparation, imposed a significant influence on the formation of buckwheat grains yield and exceeded the control variant (Figures 1 and 2).

The results show that the Selyanochkacultivarhad better reaction to the use of seed inoculation and the fertilizer application comparable with Slobozhanka.The increase from this measure variedin the range of +0.05-0.27 t/ha, with average +0.14 t/ha. Mineral nutrition provided the average yield increase (+0.22 t/ha) which was 0.01 t/ha lowerto compare with Slobozhanka cultivar and varied in range of 0.06-0.45 t/ha. The variant with complex use of seeds treatment with biopreparation, microfertilizer and application plant growth regulator in the phase of budding, on the background of mineral fertilizers ($N_{16}P_{16}K_{16}$+N_{15}) formed maximum yield (2.20 t/ha) and increase from fertilizers was+0.42 t/ha, from biopreparation, microfertilizer and plant growth regulator-0.27 t/ha.

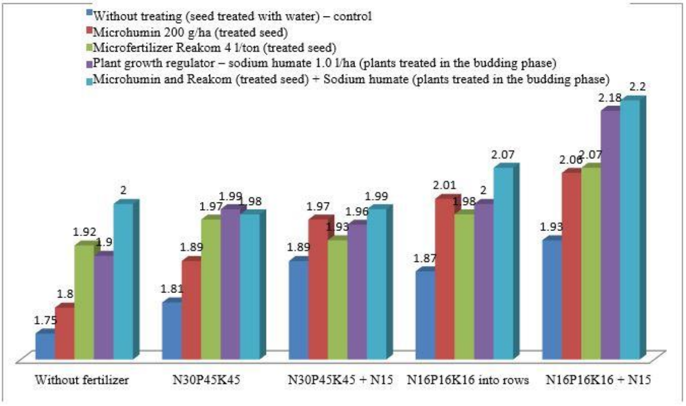

Figure 1. Dependence of Selyanochka buckwheat grain yield from the fertilizer system influence (average for 2016-2018).

A slightly lower yield (2.18 t/ha) was obtained in the variant with introduction of plant growth regulator into the phase of budding, with increase +0.25 t/ha, but from mineral fertilizers-+0.43 t/ha. Among the variants with inoculation of Selyanochka seeds, the highest yield was obtained after application of microfertilizer-2.07 t/ha (increase to control (seed treated with water) was-0.14 t/ha).

For seeds inoculation by Microhumin, the highest level of yield increase (+0.31 t/ha) was recorded with mineral fertilizers $N_{16}P_{16}K_{16}$+N_{15}, which was 0.13 t/ha higher compared to control variant without seed treatment.

Within Slobozhanka cultivar, the use of seeds inoculation and introduction of fertilizers in the phase of plant budding contributed to yield increase not for all variants, the average result was positive with increase of 0.06 t/ha. But the increase from the use of mineral fertilizers in all variants was positive and ranged from +0.04 to 0.41 t/ha with average-0.23 t/ha (Figure 2).

The highest yield level (1.92 t/ha) was obtained in the variant with mineral fertilizers application intorows $N_{30}P_{45}K_{45}$+N_{15} with increase-+0.41 t/ha to control. Plant growth regulator Sodium humate provided +0.19 t/ha. The yield level (1.89 t/ha) after application$N_{30}P_{45}K_{45}$+N_{15} with inoculation of buckwheat seed with microfertilizer was 0.38 t/hahigher than in variant without mineral fertilizers and 0.16 t/hahigher compared to the variant without seed treatment but with the same rate of mineral fertilizers.

The variant with complex application of biopreparation, microfertilizer and plant growth regulator Sodium humateformed 1.83 t/ha, increase to control (without fertilizers and seeds treatment with water) was +0.32 t/ha.

Seeds inoculation of Slobozhanka cultivar by Microhuminobtained the highest yield with application of mineral fertilizers $N_{16}P_{16}K_{16}$+N_{15} (1.82 t/ha), which was 0.04 t/hahighercomparable to variant without seed inoculation and with the samerate of mineral fertilizers.

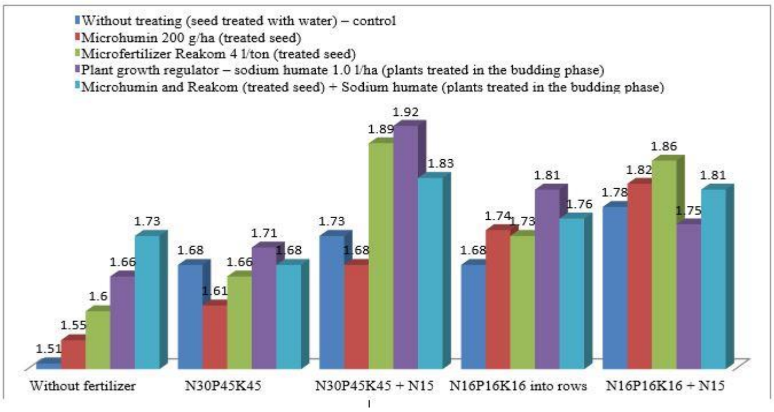

Figure 2. Dependence of Slobozhanka buckwheat grain yield from the fertilizer system influence (average for 2016-2018).

Comparing cultivars of different morphotypes to each other, the average yield for 2016-2018 ofSelyanochkacultivar was 1.96 t/ha and ranged from 1.75 to 2.20 t/ha. But Slobozhanka cultivaraverage yield was lower-0.23 t/ha (1.73 t/ha) and ranged from 1.51 to 1.92 t/ha.

Conclusion

Accordingly to results of our research in the conditions of the northeastern forest-steppe of UkraineSelyanochka cultivar was better responding to the use of seed inoculation and fertilizer application than Slobozhanka cultivar. The yield increase from this measure was in the range of +0.05-0.27 t/ha with average +0.14 t/ha.

The variant of complex use of seeds treatment withbiopreparation, microfertilizer and introduction of plant growth regulator in the phase of budding of buckwheat plants, on the background of mineral fertilizers use $N_{16}P_{16}K_{16}$+N_{15} achieved maximum yield-2.20 t/ha,with increase from fertilizers-+0.42 t/ha, from biopreparation, microfertilizer and plant growth regulator-+0.27 t/ha.

The highest yield level of Slobozhanka cultivar (1.92 t/ha) was obtained in the variant with mineral fertilizers application into rows$N_{30}P_{45}K_{45}$+N_{15} with increase-+0.41 t/hacompared to control. The yield increase from the use of plant growth regulator Sodium humate was 0.19 t/ha.

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