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IMPROVEMENT OF BIOLOGICAL AGRICULTURAL METHODS OF GROWING PEAS IN STATIONARY CROP ROTATION

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Our research aimed to determine the effect of Mikofriend and Mikohelp biologics and Humifriend biofertilizer on the yield and quality grain of Metsenat pea variety depending on the background of nutrition in the Eastern Forest-Steppe of Ukraine. The expediency of seed treatment with biologics both separately and in combination with spraying of vegetative plants in the budding stage by Humifriend in doses of 0.4 and 0.5 l/ha under favourable growing conditions was established. It was found that regardless of the background of nutrition, treatment of seeds with combination of biologics and Maxim XL disinfectant (1.0 l/t) was ineffective, especially with insufficient level of soil moisture.

On average for three years (2018–2020) against the background without fertilizers, a significant increase in the yield of pea grain (0.27–0.30 t/ha) was obtained in the variants with combination of seed treatment with Mikohelp and application of Humifriend in doses of 0.4 and 0.5 l/ha. The basal application of $N_{30}P_{30}K_{30}$ fertilizers in variants with biologics treatment of seed caused an increase in pea yield by 0.57–0.65 t/ha. At the same time, the increase in grain yield due to the use of the Humifriend (0.4 and 0.5 l/ha) was 0.22–0.28 and 0.16–0.22 t/ha, respectively. The increase in pea yield in the studied variants led to a decrease in grain protein content, this indicator on a fertilized background was 0.33–0.71 %. Over years of research, pre-sowing seed treatment with biologics and application of Humifriend in doses of 0.4 and 0.5 l/ha on a background without fertilizers led to an increase in protein harvest by 0.450–0.475 t/ha, which is by 5.8–13.4 % more than the control (without spraying). Against the background of the basal application of $N_{30}P_{30}K_{30}$, these indicators were significantly higher. The maximum protein harvest was obtained in the variants with seed treatment by Mikofriend and application of Humifriend in doses of 0.4 and 0.5 l/ha – 0.631 and 0.637 t/ha, respectively, which is 8.0–8.9 % more compared to control. The increase in gross protein harvest per area unit depended more on the level of pea yield than on the protein content of the grain.

***Key words**: peas, nutrition background, seed treatment, crop spraying, biologics, biofertilizer, yield, grain quality, protein yield.*

In the system of organic agriculture, biological nitrogen, the use of biologics, organic fertilizers and plant protection from harmful objects without the use of chemicals require considerable attention. At the same time, crop rotation of at least 20 % should consist of crops which restore soil and accumulate nutrients [1, 2]. This applies primarily to legumes, among which peas take an important place (*Pisum sativum* L.) due to a symbiosis with nodule bacteria Rhizobium can fix up to 70–160 kg/ha of nitrogen and leave in the crop and root residues up to 30 % of digested its amount, which is then used by the following crops of the plant [3, 4]. Even in the case of low peas yield, nitrogen fixation by the plants from the air can reach 40–60 kg/ha [5]. Therefore, pea has great food, fodder and agrotechnical values. In addition, it forms significant grain yields in a short growing season [6, 7]. However, over the past 25 years, the sowing area of peas in Ukraine has decreased by 2.5 times. But since 2017, the area under legumes has increased to 405 thousand hectares [8]. This was encouraged by the high potential yield of modern leafless pea varieties (4.5–5.0 t/ha), as well as their resistance to lodging, the evenness of ripening and reducing the number of cracked pods, as well as the applicability of direct combining [9].

The optimization of agrotechnical methods of cultivation helps to increase the genetic potential implementation of leafless pea varieties in production conditions, but their effectiveness is largely determined by hydrothermal conditions during the growing season. Therefore, the variety productivity in arid growing conditions is not properly realized [10, 11]. Pea plants have an underdeveloped root system,

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they are very demanding of light, moisture and soil nutrition, so the fertilization system of this crop should be based on such biological features of its plants as nitrogen fixation from the atmosphere and phosphorus from insoluble forms of fertilizers and soil. [7, 12].

According to numerous scientists, bacterial preparations improve the mineral nutrition of plants, accelerate their development, inhibit the harmful effects of phytopathogens, increase resistance to biotic and abiotic factors, improve grain quality [1, 13, 14]. The research results showed that the use of nitrogen-fixing and phosphorus-mobilizing biologics of the new generation for legumes can save 40–60 kg/ha of nitrogen and increase grain yield to 15–20 % [15, 16].

Aim. To establish how the different methods of biologics application have influenced on the pea yield and grain quality depending on the fertilizer background.

Materials and Methods. The research was conducted in 2018–2020 in the stationary 9-field crop rotation at the Plant Production Institute named after V. Ya. Yuryev of NAAS by the split-plot design. Soil was typical medium humus weakly leached chernozem. In crop rotation (without fertilizers), the gross content of lightly hydrolyzed nitrogen per 100 g of soil in the arable layer was low or medium (13.2–17.8 mg), content of mobile phosphorus (12.9–10.3 mg) and potassium (10.6–11.2 mg) was increased. In the case of the afteraction of manure, when the basal application of mineral fertilizers $N_{30}P_{30}K_{30}$, phosphorus (16.0–16.5 mg) and potassium (13.0–13.3 mg) content was high, and nitrogen – low or medium. The experimental design involved the seed treatment on such backgrounds as rotation (without fertilizers) and organomineral ones (manure afteraction + basal application $N_{30}P_{30}K_{30}$: 1. Control (without tillage); 2. Maxim XL dresser, 1.0 l/t; 3. Mikohelp biologics, 2.0 l/t; 4. Maxim XL, 1.0 l/t + Mikohelp, 2.0 l/t; 5. Mikofriend biologics, 1.0 l/t; 6. Maxim XL, 1.0 l/t + Mikofriend, 1.0 l/t. Plants were sprayed with Humifriend biofertilizer in doses of 0.3; 0.4 and 0.5 l/ha in the budding stage on plots with pre-sowing seed treatment with Mikofriend biologics (1.0 l/t) and Mikohelp (2.0 l/t).

Mikohelp is a multicomponent microbial preparation against root rot, which contains saprophytic antagonist fungi of the genus Trichoderma, living cells of bacteria Bacillus subtilis, Azotobacter, Enterobacter, Enterococcus, biologically active products of microorganisms-producers. *Mikofriend* - mycorrhizal biologics to enhance nutrition and protection of plants from fungal and bacterial diseases, includes mycorrhizal fungi Glomus VS, Trihoderma Harzianum. Humifriend biofertilizer contains humic and fulvic acids, amino acids, peptides, etc., as well as microelements to increase plant resistance to stress, improve growth, metabolic development and rate, which has a complex effect on increasing yield and improving grain quality.

The pea cultivation technology is generally accepted in field trials for the Forest-Steppe zone of Ukraine, excluding the studied agrotechnical methods. Predecessor was spring cereals. Sowing was carried out with a seeder Klen–1.5 M followed by rolling with sprocket packers. In the trials, we sowed Metsenat recognized variety with seeding rate of 1.2 million germinable seeds per hectare. Spraying of pea plants with Humifriend biologics was performed with a knapsack sprayer in the budding stage. During the growing season, crop protection was provided with Anticolorad Max insecticide (0.12 l/ha), when the epidemic threshold of harmfulness was exceed. Experimental design was systematic, replication – 3 times. Accounting area of the plot was 25 m^2. Observations, records and analyzes were performed in accordance with generally accepted methods [17]. The crop was harvested by direct combining with combine Samro-130. Grain quality was determined in the grain quality laboratory.

The obtained experimental data were processed by the variance analysis.

During the research years, the amount of precipitation and air temperature differed significantly from the long-term averages. It was allowed to more fully assess the effectiveness of the studied agrotechnical methods. The spring-summer period in 2018 was characterized by high temperatures. In March, the amount of precipitation (109.3 mm) exceeded 4 times the norm, but in the May – July, total amount precipitation (113.4 mm) was 2.1 times less than normal, and the average monthly temperature was 2 times higher than normal by 4–4.5 °C. Such arid conditions defined a reduction in the interstage pe-

riods of growth and development for pea plants, deterioration of biometric indicators, premature ripening and reduction of grain weight.

In April 2019, air temperature and amount of precipitation were almost normal, and in May, these indicators exceed of long-term ones by 10 and 60 %, respectively. In June, abnormally hot weather was observed when the air temperature (23.8 °C) exceeded by 4.3 °C the norm under a deficit of precipitation (25.4 mm, or 60 % of the norm). Soil and air droughts have suppressed plant biomass growth, reduced the pod formation, seed filling duration, and caused a premature ripening of seeds and reducing its weight. Prolonged drought was observed to the harvest.

In April 2020, the arid conditions and low temperatures were prevalent. However, the lack of precipitation was fully compensated because in May, precipitation was 176.1 mm, which is 4 times more than the norm. At the same time, the average monthly temperature (13.1 ^{o}C) was lower 3.0 ^{o}C that led to increasing vegetative weight of plants. In June, the average daily temperature (21.3 ^{o}C) exceeded the norm by 1.1 ^{o}C under a deficit of precipitation. In July, against the background of high temperatures, the amount of precipitation was 107.8 mm, which had a positive effect on plant productivity. In August, the average daily air temperature exceeded the norm by 1.7 ^{o}C, and precipitation was only 12.8 mm.

Thus, during the growing season of peas, the hydrothermal regime was contrastive, with uneven distribution of precipitation. This helped to comprehensively determine the influence of the studied factors.

Results. It was shown that plants more intensively developed in the initial period under suitable moisture supply in the variants with presowing seed treatment with biologics, and additional spraying with Humifriend in the budding intensified their growth processes. This effect was not observed in the arid conditions, especially in 2019. It was almost not detected differences in the beginning dates and duration of phenological phases of pea plants in all variants with biologics. We observed only a slight difference in dates of the development stages depending on fertilized or unfertilized nutrition backgrounds (2–3 days).

It was found that on average for 2018–2020 on both nutrition backgrounds, the seed treatment with Mikofriend (1.0 l/t) and Mikohelp (2.0 l/t) biologics in combination with the Maxim XL dresser (1.0 l/t) was not effective. The increase in pea yield was observed only in the variants when the biologics without fungicides were used. Thus, on an unfertilized background in the case of seed treatment with Mikohelp and Mikofriend biologics, the increase in grain yield to the control was 0.15 and 0.22 t/ha, respectively (yield in the control was 1.88 t/ha) (Table 1). At the same time, after the basal application of mineral fertilizers at the rate of $N_{30}P_{30}K_{30}$, the increase in grain yield was insignificant (yield in the control was 2.63 t/ha). We can explain this fact by biologics which did not provide significant increases in grain yield on a fertilized background in the arid conditions 2018–2019.

In 2020, it was obtained a significant increase in pea grain yield in condition of favorable soil moisture and after $N_{30}P_{30}K_{30}$ application in the variants of seed treatment with Mikohelp and Mikofriend, it was 0.17 and 0.24 t/ha, respectively (LSD_{05} = 0.16 t/ha). On average for 2018–2020, the fertilizer application of $N_{30}P_{30}K_{30}$ increased the pea yield by 0.75 t/ha.

When peas in the budding stage was sprayed with Humifriend biofertilizer and pea seeds were dressed with Mikofriend or Mikohelp, it was found that biofertilizer action was more effective under favorable conditions for growing peas (Table 2). Thus, in 2020, on an unfertilized background depending on Humifriend rate, the increase in grain yield varied. In variants when seeds were dressed with Mikofriend, it was 0.16–0.28 t/ha (grain yield in the control was 3.20 t/ha), and when seeds were dressed with Mikohelp – 0.21–0.46 t/ha (in control – 2.98 t/ha).

On the background of $N_{30}P_{30}K_{30}$ application, in variants when seeds were dressed with Mikofriend and Mikohelp, the yield was significantly higher i 3.92 and 3.85 t/ha, respectively. The increase in pea grain yield due to additional spraying plants with Humifriend in rates of 0.4 and 0.5 l/ha was 0.36–0.41 and 0.30–0.37 t/ha, respectively, to control (without spraying).

1. Pea grain yield depending on the fertilizer background and seed treatment with biologics, t/ha (2018–2020)

Seed treatment with (factor A)	Fertilizer background (factor B)			
	without fertilizers	yield gain, t/ha	$N_{30}P_{30}K_{30}$	yield gain, t/ha
2018				
Control (without treatment)	2.04	-	2.96	-
Maxim XL, 1 l/t	2.05	+0.01	2.96	0.0
Maxim XL, 1 l/t + Mikohelp, 2 l/t	2.01	-0.03	2.77	-0.19
Mikohelp, 2 l/t	2.09	+0.05	2.86	-0.10
Maxim XL, 1 l/t + Mikofriend, 1 l/t	2.02	-0.02	2.78	-0.18
Mikofriend, 1 l/t	2.12	+0.08	3.03	+0.07
LSD_{05} A – 0.19; B – 0.11; AB – 0.27				
2019				
Control (without treatment)	0.87		1.24	
Maxim XL, 1 l/t	0.99	+0.12	1.20	–0.04
Maxim XL, 1 l/t + Mikohelp, 2 l/t	0.90	+0.03	1.16	–0.08
Mikohelp, 2 l/t	1.01	+0.14	1.28	+0.04
Maxim XL, 1 l/t + Mikofriend, 1 l/t	0.81	-0.06	1.18	–0.06
Mikofriend, 1 l/t	1.08	+0.21	1.34	+0.10
LSD_{05} A – 0.09; B – 0.14; AB – 0.21				
2020				
Control (without treatment)	2.72	–	3.68	–
Maxim XL, 1 l/t	2.80	+0.08	3.66	–0.04
Maxim XL, 1 l/t + Mikohelp, 2 l/t	2.91	+0.19	3.81	+0.13
Mikohelp, 2 l/t	2.98	+0.26	3.85	+0.17
Maxim XL, 1 l/t + Mikofriend, 1 l/t	3.02	+0.30	3.90	+0.22
Mikofriend, 1 l/t	3.10	+0.38	3.92	+0.24
LSD_{05} A – 0.12; B – 0.11; AB – 0.16				
Average for 2018–2020				
Control (without treatment)	1.88	–	2.63	–
Maxim XL, 1 l/t	1.95	+0.07	2.61	-0.02
Maxim XL, 1 l/t + Mikohelp, 2 l/t	1.94	+0.06	2.58	-0.05
Mikohelp, 2 l/t	2.03	+0.15	2.66	+0.03
Maxim XL, 1 l/t + Mikofriend, 1 l/t	1.95	+0.07	2.62	-0.01
Mikofriend, 1 l/t	2.10	+0.22	2.76	+0.13
LSD_{05}, t/ha for interaction of factors – 0.16–0.27				

It should be noted that in arid conditions, the effectiveness of the application sharply decreased. Thus, in 2018, a significant increase in grain yield (0.34 t/ha) was obtained only when Humifriend was applied in a rate of 0.5 l/ha at the seed treatment with Mikofriend on the background of the basal application of $N_{30}P_{30}K_{30}$. In the strongly arid year 2019, on both nutrition backgrounds, the biofertilizer did not provide a significant increase in grain yield. The yield on the unfertilized and fertilized backgrounds was 0.95 and 1.24 t/ha, respectively (Table 2).

On average, in 2018–2020, when the basal application of mineral fertilizers in the rate of $N_{30}P_{30}K_{30}$ was used, the pea yield increased by 0.57–0.65 t/ha depending on biologics for the seed treatment. On the background without fertilizers, the significant increases in grain yield were obtained only in the variant when spraying plants with Humifriend in rates of 0.4 and 0.5 l/ha and at seed treatment with Mikohelp (0.27 and 0.30 t/ha, respectively) compared to control (without spraying). On the background of basal application of $N_{30}P_{30}K_{30}$, depending on the seed treatment with biologics, the Humifriend application in rates of 0.4 and 0.5 l/ha increased grain yield by 0.22–0.28 and 0.16–0.22 t/ha, respectively.

Nowadays, main attention is being paid to grain quality, especially, the issue of fodder

and food protein production. Therefore, increased protein content in grain together with a high level of yield is an additional reserve to increase the gross protein harvest. On average for three research years, it is established that the protein content in grain ranged from 20.66 to 20.94 % in the variants without fertilizers and when pre-sowing seed treatment was performed with biologics, and on the background of the basal application of $N_{30}P_{30}K_{30}$, this indicator increased to 21.60 – 21.89 %

2. Pea grain yield depending on the nutrition background, seed treatment with biologics and plant spraying with biofertilizer, t/ha (2018–2020)

Humifriend, l/ha (A)	Seed treatment with (B)			
	Mikofriend (1.0 l/t)		Mikohelp (2.0 l/t)	
	without fertilizers	$N_{30}P_{30}K_{30}$	without fertilizers	$N_{30}P_{30}K_{30}$
2018				
Control (without spraying)	2.15	2.84	2.08	2.87
0.3	2.02	2.77	2.10	2.93
0.4	2.03	3.01	2.21	2.92
0.5	2.16	3.18	2.30	3.08
LSD_{05} A – 0.10; B – 0.21; AB – 0.30				
2019				
Control	0.95	1.24	0.95	1.24
0.3	1.02	1.30	1.14	1.31
0.4	1.12	1.37	1.21	1.36
0.5	1.10	1.35	1.16	1.32
LSD_{05} A – 0.10; B – 0.14; AB – 0.22				
2020				
Control	3.20	3.92	2.98	3.85
0.3	3.36	4.12	3.19	3.97
0.4	3.44	4.28	3.39	4.15
0.5	3.48	4.33	3.44	4.22
LSD_{05} A – 0.13; B – 0.16; AB – 0.21				
Average for 2018–2020				
Control	2.10	2.67	2.00	2.65
0.3	2.13	2.73	2.14	2.74
0.4	2.20	2.89	2.27	2.81
0.5	2.25	2.95	2.30	2.87
LSD_{05}, t/ha for interaction of factors – 0.21–0.30				

Regardless of the nutrition background and biologics for seed treatment, the increase in pea yield due to Humifriend application in rates of 0.4 and 0.5 l/ha caused decrease in grain protein content. At the same time, the highest protein content in grain over the years was obtained when Humifriend was applied at a rates of 0.3 l/ha (Table 3). Thus, on the background without fertilizers under the seed treatment with Mikofriend (1.0 l/t) and Mikohelp (2.0 l/t) due to spraying plants with biofertilizer at a rate of 0.3 l/ha, the grain protein content was 21.12 and 21.14 % that was higher by 0.46 and 0.20 % compared to the control (without spraying). On the background of $N_{30}P_{30}K_{30}$, these indicators were significantly higher – 22.23 and 21.79 %, respectively, and the increases in grain protein content were 0.34 and 0.19 %. The only exception was the unfavorable strongly arid 2019, as there was a premature ripening of grain and a decrease in its absolute weight. It should be noted that in all years of research, the application of biologics increased the harvest of protein content per 1 ha of sown area (Table 4).

Thus, on average in 2018–2020, against the background without fertilizers in variants with different rates of Humifriend for spraying

3. Protein content in pea grain depending on the application method of biologics and nutrition background, % (2018–2020)

Humifriend, l/ha	Grain protein content, %			Average for 3 years	± to control, %
	2018	2019	2020		
Background – without fertilizers, seed treatment with Mikofriend (1.0 l/t)					
Control (without spraying)	19.06	20.79	22.13	20.66	–
0.3	19.21	21.66	22.49	21.12	+0.46
0.4	18.51	22.64	21.21	20.79	+0.13
0.5	19.17	22.18	21.98	21.11	+0.45
Background – without fertilizers, seed treatment with Mikohelp (2.0 l/t)					
Control (without spraying)	19.89	21.91	21.01	20.94	-
0.3	20.10	21.84	21.47	21.14	+0.20
0.4	20.05	21.94	20.66	20.88	–0.06
0.5	19.97	22.00	20.01	20.66	–0.28
Background – $N_{30}P_{30}K_{30}$, seed treatment with Mikofriend (1.0 l/t)					
Control (without spraying)	20.66	21.96	21.89	21.89	–
0.3	20.06	23.03	22.23	22.23	+0.34
0.4	20.00	22.54	21.84	21.84	–0.05
0.5	19.18	22.44	21.56	21.56	–0.33
Background – $N_{30}P_{30}K_{30}$, seed treatment with Mikohelp (2.0 l/t)					
Control (without spraying)	20.12	22.10	22.57	21.60	–
0.3	20.33	21.74	23.31	21.79	+0.19
0.4	17.92	21.92	22.83	20.89	–0.71
0.5	19.32	21.68	22.68	21.23	–0.37
LSD_{05}, % for factors: A – Experimental variants B – Nutrition background	A – 0.09 B – 0.12 AB – 0.16	A – 0.12 B – 0.15 AB – 0.20	A – 0.11 B – 0.14 AB – 0.21		

4. Gross harvest of pea protein depending on the nutrition background, seed treatment with biologics and plant spraying with biofertilizers, t/ha (2018–2020)

Variant (A)	Fertilizer background (B)					
	without fertilizers	protein gain		$N_{30}P_{30}K_{30}$	protein gain	
		t/ha	%		t/ha	%
Mikofriend, 1 l/t (seed treatment, control)	0.433	–	–	0.584	–	–
Mikofriend, 1 l/t + Humifriend, 0.3 l/ha	0.450	0.017	3.9	0.607	0.023	3.9
Mikofriend, 1 l/t + Humifriend, 0.4 l/ha	0.458	0.025	5.8	0.631	0.047	8.0
Mikofriend, 1 l/t + Humifriend, 0.5 l/ha	0.475	0.042	9.6	0.636	0.052	8.9
Mikohelp, 2 l/t (seed treatment, control)	0.419	–	–	0.572	–	–
Mikohelp, 2 l/t + Humifriend, 0.3 l/ha	0.432	0.013	3.1	0.597	0.025	4.4
Mikohelp, 2 l/t + Humifriend, 0.4 l/ha	0.469	0.050	11.9	0.587	0.015	2.6
Mikohelp, 2 l/t + Humifriend, 0.5 l/ha	0.475	0.056	13.4	0.609	0.037	6.5
LSD_{05}, t/ha for factors: A – 0.012; B – 0.016; AB – 0.021						

plants and pre-sowing treatment of seeds with Mikofriend and Mikohelp, the protein harvest was 0.450–0.475 and 0.432–0.475 t/ha, respectively, which is 3.9–9.6 and 3.1–13.4 % more than in the control (without spraying). Against the background of $N_{30}P_{30}K_{30}$, these indicators were significantly higher. Over the years of research, the highest gross protein harvest was 0.631 and 0.637 t/ha when Mikofriend seed treatment was combined with Humifriend application in rates of 0.4 and 0.5 l/ha, which is 8.0–8.9 % higher compared to control. Thus, the gross protein harvest per 1 ha of sown area depended more on the pea yield level than on protein content in grain.

Conclusion

On the basis of the conducted researches it is possible to draw the following conclusions:

1. In the conditions of the eastern Forest-Steppe, seed treatment with Mikofriend (1.0 l/t)

and Mikohelp (2.0 l/t) provided a significant increase in grain yield only under favorable moisture conditions. Regardless of the nutrition background, the treatment of seeds with biologics in combination with the Maxim XL dresser (1.0 l/t) was ineffective.

2. On average for 2018–2020, the basal application of mineral fertilizers in the rate of $N_{30}P_{30}K_{30}$ depending on the biologics for seed treatment led to an increase in pea yield by 0.57–0.65 t/ha. Depending on the variant of seed treatment with biologics and spraying plants with Humifriend biofertilizer at rates of 0.4 and 0.5 l/ha in the budding stage, the increases in grain yield were at the level of 0.22–0.28 and 0.16–0.22 tons/ha, respectively.

3. Against the background without fertilizers, significant increases in pea grain yield were obtained only in the combination of Mikohelp seed treatment and application of Humifriend at rates of 0.4 and 0.5 l/ha, 0.27 and 0.30 t/ha respectively to control (without spraying).

4. In the favorable year 2020, on an unfertilized background, the increase in grain yield depending on the application rate of Humifriend and seed treatment was 0.16–0.46 t/ha, and on the background of $N_{30}P_{30}K_{30}$ – 0.30–0.41 t/ha.

5. In the strongly arid year 2019, the biofertilizers did not cause a significant increase in grain yield: the indicators on the unfertilized background were 0.95 t/ha, on the fertilized one – 1.24 t/ha.

6. The increase in pea yield in the variants with Humifriend application in rates of 0.4 and 0.5 l/ha decreased the grain protein content, regardless of the nutrition background and seed treatment with biologics.

7. On average over three years, the highest grain protein content was obtained in the variant with Mikofriend dresser (1.0 l/t) and spraying plants with Humifriend biofertilizer (0.3 l/ha) on unfertilized backgrounds and basal application of $N_{30}P_{30}K_{30}$, 21.12 and 22.23 %, respectively, which exceeded control by 0.46 and 0.34 %.

8. When Mikofriend seed treatment was combined with Humifriend application at rates of 0.4 and 0.5 l/ha, it was obtained the highest gross protein harvest – 0.631 and 0.637 t/ha, which is 8.0–8.9 % more than control. The gross protein harvest per 1 ha of sown area depended more on the pea yield than on the protein content in the grain.

References

1. Kaminskyi, V. F. (2000). Scientific principles of organic farming in the context of climate change. *Zbirnyk naukovyh pratc NNC "Instytut zemlerobstva"* [Collection of scientific works of the NSC "Institute of Agriculture"], *5*, 3–15. [in Ukrainian]
2. Yeshchenko, V. O. (2015). The role of crop rotations in modern agriculture. *Zemlerobstvo* [Agriculture], *1*, 23–27. [in Ukrainian]
3. Adamen, F. F. (1999). Nitrogen fixation and the main directions of improving the nitrogen balance of soils. *Visnyk agrarnoi nauky* [Bulletin of Agricultural Science], *2*, 9–17. [in Ukrainian]
4. Negi, S., Sing, R., Dwivedi, O. (2006). Effect of biofertilizers, nutrient sources and lime on growth and yield of garden pea. Legume research, *29*, 4. 282–285.
5. Petrychenko, V. F., Kaminskyi, V. F., Patyka, V. P. (2003). Legumes and sustainable development of agroecosystems. *Kormy i kormovyrobnytstvo* [Feed and feed production], *51*, 3–6. [in Ukrainian]
6. Kaminskyi, V. F. (2000). Status and prospects of pea production in Ukraine. *Visnyk agrarnoi nauky* [Bulletin of Agricultural Science], *5*, 22–25. [in Ukrainian]
7. Tsybulko, V. S., Buriak, Yu. I., Popov, S. I. Chernobab, O. V. (2000). *Goroh, vyka ozyma, lucerne. Nove v tehnologii vyroschuvannya na nasinnya* [Peas, winter wheat, alfalfa. New in seed growing technology]. Kharkiv: Plant Production Institute nd. a. V. Ya. Yur-yev. 100 p. [in Ukrainian]
8. *Stastychnyi buleten Ukrainy* za *2019 rik* [Statistical bulletin of Ukraine for 2019]. [in Ukrainian]. URL: www.ukrstat.gov.ua
9. Kyrychenko, V. V., Popov, S. I., Kobyzieva, L. N., Bondarenko, Ye. S. et al. (2017). Catalog of varieties and hybrids of field crops of Plant Production Institute nd. a. V. Ya. Yuryev. Kharkiv: PE “Style-Izdat”, 72 p. [in Ukrainian]
10. Kaminskyi, V. F., Dvoretska, S. P., Kostyna, T. P. (2012). Influence of weather conditions and fertilizer system on the formation of productivity of pea varieties. Zbirnyk naukovyh prats NNC "Instytut zemlerobstva UAAN" [Collection of scientific works of the NSC "Institute of Agriculture"], 3–4. P. 82–90. [in Ukrainian]
11. Burykina, S. I., Welver, M. O., Kapustina, G. A. (2020). Agronomic efficiency of fertilizers in pea growing under the conditions of climate change of the Black Sea Steppe. *Tavrida Scientific Herald*. 114. 33–43. DOI:https://doi.org/10.32851/2226-0099.2020.114.5
12. Hospodarenko, G. M. (2016). *Zernobobovi kultury v intensyvnomu zemlerobstvi* [Fertilization of agricultural crops]. Kyiv: SIK GROUP UKRAINE LLC. 276 p. [in Ukrainian]
13. Korol, L. V., Prysiazhniuk, O. I. (2017). Formation of photosyn-thetic apparatus of peas depending on the influence of fertilizers and growth regulators in the Forest-Steppe of Ukraine. *Agrobiologiya* [Agrobiolo

gy], *1*, 121–127. [in Ukrainian]
14. Hamaiunova, V. V., Tuz, M. S. (201). Influence of elements of cultivation technology on productivity of pea varieties in the Southern Steppe. *Zbirnyk naukovyh prats NNC "Instytut zemlerobstva NAAN"* [Collection of scientific works of the NSC "Institute of Agriculture"], *1*, 46–57. [in Ukrainian]
15. Lapa, I. V., Kaminskyi, V. F., Smoliar, M. I. (1996). Productivity of peas depending on a dose and a ratio of mineral fertilizers. *Zbirnyk naukovyh prats NNC "Instytut zemlerobstva UAAN"* [Collection of scientific works of the Institute of Agriculture of UAAS]. Kyiv, *1*, 221–227. [in Ukrainian]
16. Petrychenko, V. F., Sereda, L. M., Bernadzikovskyi, S. A. (2003). Productivity of legumes depending on the influence of intensification factors in the Forest-Steppe of Ukraine. *Zbirnyk naukovyh prats* VDAU [Collection of scientific works of VNAU], *14*, 3–9. [in Ukrainian]
17. Dospekhov, B. A. (1985). *Metodika polevogo opyta s osnovami statisti-cheskoy obrabotki rezul'tatov issledovaniy* [Methodology of field experience with the basics of statistical processing of research results] (5th ed. rev.). Moscow: Ahropromizdat. 352 p. [in Russian]