

EFFICIENCY OF PRE-SOWING INOCULATION IN CULTIVATION OF AGRICULTURAL CROPS UNDER DIFFERENT ORGANIC AGRARIAN BACKGROUNDS

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Objective. Explore the influence of different organic agrarian backgrounds and their combinations on the efficiency of pre-sowing seed inoculation and the development of introduced microorganisms in the root spheres of cultivated plants. **Methods.** Microbiological, gas chromatography, vegetation and field experiment, statistical. **Results.** In a long-term stationary field experiment on leached chernozem, the stimulating effect and aftereffect of intermediate green manure (lupine) on the manifestation of the efficiency of microbial preparations in the cultivation of potatoes, spring barley, peas and winter wheat in crop rotation was established. The application of 5 t/ha of straw had a weak effect on the efficiency of inoculation, but the combination of straw with green manure provided a significant increase in yields. The positive effect of straw on the efficiency of pre-sowing inoculation develops upon the aftereffects of this fertilizer. The application of 40 t/ha of cattle manure wiped out the efficiency of microbial preparations during the year of direct effect and the first year aftereffect of fertilizer. The negative impact of cattle manure on the action of biological preparations has decreased over time. During the cultivation of crops on the background of “cattle manure + green manure”, the negative effect of cattle manure on the effect of inoculation was significantly reduced. When the conditions of growing crops were simulated in the vegetation experiments and upon the use of genetically-labelled bacterial strains — biological agents of microbial preparations, it was found that during the year of application of organic fertilizers, the development of *Azospirillum brasilense* 410^{Str} in root spheres of plants is positively influenced by lupine manure, and cattle manure on the contrary results in significant reduction of the number of azospirilla. The combination of green manure with cattle manure to some extent compensated for the negative impact of the latter on the development of the introduced bacteria. During the first year aftereffects of organic fertilizers, these features are maintained in the root zone of spring barley plants. When growing peas, the relationship between the formation of root nodules *Rhizobium leguminosarum* 31^{Str} and the second year aftereffect of organic fertilizers is not observed. When cultivating winter wheat during the third year aftereffect, organic fertilizers have little effect on the development of *Paenibacillus polymyxa* KB^{Str} in the root spheres of plants. At the same time, in the variants of straw or green manure aftereffects, parameters are slightly higher than the control ones. A slight negative effect on the number of bacteria is still reported in the variant with the aftereffect of manure. **Conclusion.** The use of organic fertilizers can significantly affect the efficiency of pre-sowing inoculation. The effect and aftereffect of cattle manure negatively affects the development of agronomically beneficial bacteria introduced into the agrocenosis and significantly wipes out the positive effect of biological preparations on crop yields. The use of microbial preparations for inoculation of seeds of agricultural crops for their cultivation on the background of direct effect and aftereffect of intermediate lupine green manure, including the combination of green manure with straw provides intensive development of introduced microorganisms in root areas of plants and increased yields.

Keywords: inoculation, microbial preparations, straw, green manure, cattle manure, genetically-labelled bacterial strains.

Introduction. Soil bacteria and microscopic fungi play one of the essential roles in ensuring the viability of cultivated plants. The plant, provided with a full complex of microorganisms, actively develops roots, gets easily digestible nutrients and physiologically active compounds from the soil, which has a positive effect on its metabolism and production process as a whole. However, due to significant distortions in the application of certain agronomic techniques (unreasonable levels of mineral fertilizers, pesticides, crop rotations, etc.), the composition of groups of microorganisms, which requires appropriate correction is distorted in most soils of agrocenoses [1–8]. The optimal solution to this issue is the introduction of selected strains of agronomically beneficial microorganisms into agrocenoses using microbial preparations based on them.

Analysis of the novel studies and publications. Interest in the use of microorganisms in technologies for growing crops increased in the late 20th century due to the discovery of the phenomenon of associative nitrogen fixation and the ability of certain species of microbiota to actively reproduce in the root spheres of plants [9; 10]. Currently, in various research centres, biological preparations have been developed based on selected active strains of microorganisms for most types of crops, including non-leguminous [11–21]. Today, the production of certain biological preparations has a commercial basis.

The efficiency of microbial preparations can be impressively high. Numerous field and production experiments, studies in lysimetric units, experiments using ¹⁵N, etc. have shown that the efficiency of preparations by their impact on the production process can be equivalent to 30–60 kg/ha of mineral nitrogen, 15–30 kg/ha of phosphorus [14; 23]. This is due to the increase in the degree of assimilation of the active substance from fertilizers and the improvement of the constructive metabolism of plants, in which mineral compounds in the plant body are actively directed to the synthesis of organic substances [23–25].

A range of studies have convincingly shown the efficiency of pre-sowing inoculation of seeds in the cultivation of crops on mineral agrarian backgrounds, especially low [26–29]. At the same time, the productivity of bacterization by beneficial microorganisms under organic

agrarian backgrounds and their combinations has been insufficiently studied. A typical feature of existing publications is the statement about the effective interaction between microorganisms introduced into agrocenoses with organic backgrounds. Thus, it was noted that the maximum diameter of the heads, parameters of their raw and dry weight were registered during the cultivation of lettuce inoculated with azospirilla (GM1M1Az3) on the background of green manure and mulching [30]. It has also been reported that the interaction between green manure and inoculation of seeds with *Herbaspirillum seropedicae* had a positive effect on maize yield, contributing to the increased number of grains and cob weight [31]. There is also evidence of high efficiency of agronomically beneficial bacteria used against the background of cattle manure. For example, study by Lai et al. [32] showed that although the growth of lettuce in soil fertilized with swine manure when using *Azospirillum rugosum* IMMIB AFH-6 was significantly lower than when growing bacterized plants in soil fertilized with chemical fertilizers, but the variant “inoculation + animal manure + 1/2NPK” showed the highest yields and other studied parameters. Studies conducted in Turkey [33] show that the use of *Bacillus cereus*, *Rhizobium rubi* and *Brevibacillus reuszeri* when growing broccoli on a background of animal manure, contributed to an increase in crop yields by 17.0 %, 20.2 % and 24.3 % and chlorophyll content in leaves by 14.7 %, 14.0 % and 13.7 % compared to control (use of manure only), respectively. At the same time, the assimilation of macronutrients and micronutrients by plants increased. The use of manure and members of the genus *Azotobacter* for inoculation increased the biological yield of wheat grown in the region of Elam (Iran) [34]. Dutta et al. also reported an increase in maize yield with the use of bacteria of the genus *Azotobacter* and 10 t/ha of animal manure [35].

The review of the literature by Adesemoye and Kloepper [36], when considering the importance of agronomically useful microorganisms to increase the assimilation of nutrients from fertilizers by inoculate plants, does not differentiate animal manure and chemical fertilizers as substrates containing chemical elements. The authors consider promising the use of microbial preparations on the background of animal manure. At the same time, our previous

studies on leached chernozem indicate low efficiency of pre-sowing bacterization of crops grown under the effect and aftereffects of cattle manure [37]. Similar results were obtained by T. Miliutenko [38]. However, the reasons for this have not been clearly established yet.

Objective: to determine the efficiency of microbial preparations in the cultivation of potatoes, spring barley, peas and winter wheat under the effect and aftereffects of cattle manure, lupine green manure, straw and their combinations, to investigate the peculiarities of development of microorganisms introduced into the root zone of plants.

Materials and methods. Field studies were conducted in 2017–2019 in a stationary experiment of the Institute of Agricultural Microbiology and Agroindustrial manufacture of the NAAS on leached chernozem in conditions of short-rotation crop rotation (potatoes – spring barley – peas – winter wheat). The experiment was started in 2009. Agrochemical characteristics of the soil: pH — 5.3; humus content — 3.03 %; easily hydrolyzed nitrogen — 95 mg/kg of soil; mobile phosphorus compounds (P_2O_5) — 150 (according to Kirsanov); the content of exchangeable potassium (K_2O) (according to Kirsanov) — 108 mg/kg of soil.

In the experiment, crops were grown according to the scheme in 2 blocks — without pre-sowing bacterization and with the use of microbial preparations. Microbial preparations used in the experiment — Biohran for potatoes based on *Azospirillum brasilense* 410 (TU U 24.1-00497360-006:2009), Mikrohumин based on *A. brasilense* 410 and physiologically active substances of natural origin (TU U 24.1-00497360-007:2009), Ryzohumin on the basis of *Rhizobium leguminosarum* 31 (TU U 24.1-00497360-003:2007) and Polimiksobakteryn on the basis of phosphate-mobilizing bacteria *Pae-nibacillus polymyxa* KB (TU U 24.1-00497360-004:2009) are registered in the Ministry of Environmental Protection of Ukraine and approved for use.

Potatoes of the Skarbnytsia variety was grown according to the following scheme:

- 1 — without fertilizers;
- 2 — straw;
- 3 — green manure;
- 4 — animal manure;
- 5 — straw + green manure;
- 6 — animal manure + green manure;

7 — $N_{80}P_{80}K_{80}$.

Spring barley of the Gosia variety was grown according to the scheme (^a — first year aftereffect of organic matter):

- 1 — without fertilizers;
- 2 — straw^a;
- 3 — green manure^a;
- 4 — animal manure^a;
- 5 — straw^a + green manure^a;
- 6 — animal manure^a + green manure^a;
- 7 — $N_{60}P_{60}K_{60}$.

Peas of Hotivsky variety was grown according to the scheme (^b — second year aftereffect of organic matter):

- 1 — without fertilizers;
- 2 — straw^b;
- 3 — green manure^b;
- 4 — animal manure^b;
- 5 — straw^b + green manure^b;
- 6 — animal manure^b + green manure^b;
- 7 — $N_{30}P_{30}K_{30}$.

Winter wheat of Poliska 90 variety was grown according to the scheme (^c — third year aftereffect of organic matter):

- 1 — without fertilizers;
- 2 — straw^c;
- 3 — green manure^c;
- 4 — animal manure^c;
- 5 — straw^c + green manure^c;
- 6 — animal manure^c + green manure^c;
- 7 — $N_{60}P_{60}K_{60}$.

Similar variants were provided in the block of the experiment with bacterization.

Variants with the use of mineral fertilizers were included in the scheme of the experiment as a kind of control, for which high efficiency of biological preparations was expected.

Fresh organic matter was added to the potatoes. Shredded straw in the amount of 5 t/ha was placed into the soil immediately after harvesting winter wheat (in crop rotation — the predecessor of potatoes) by disking, and then intermediate green lupine was sown in the appropriate variants. Green-manure mass of narrow-leaved lupine (13–15 t/ha depending on the years of study) was placed in the soil by disking followed by shallow plowing (15 cm) in late autumn (late November). At the same time, cattle manure was applied into the soil at the rate of 40 t/ha in the relevant variants. Mineral fertilizers were applied each year according to the experimental scheme.

The area of the experimental plot is 43.2 m²

(7.2 × 6.0), the repetition is 4 times.

In addition to field studies, in 2020 under the conditions of vegetation experiments, the degree of survival of bacteria, which are the agents of relevant microbial preparations, in the root spheres of plants were determined. 2.5 L vessels were filled with 2 kg of soil each, the humidity was maintained at 60 % of the total moisture content.

The soil for vegetation experiments was selected in the spring in the appropriate variants of the field stationary experiment, the scheme of which is described above. Therefore, organic fertilizers were not introduced. Accordingly, the soil for the experiment with potatoes contained organic fertilizers applied since autumn, i.e. their effect was direct. Soils for experiments with barley, peas and wheat were characterized by the first, second and third years aftereffects of organic fertilizers, respectively. In the variants with mineral fertilizers, their appropriate doses, equivalent to the field norms, were introduced.

Bacteria used in the experiment were pre-adapted by the resistance to streptomycin sulfate, which serves as a convenient genetic marker. The method of spontaneously occurring mutants by the antibiotic gradient in the digest medium described by V. Zibalskyi was used [39]. The selected mutants were resistant to 3,000 µg/mL streptomycin sulfate doses and did not differ from the parental forms in basic physiological and biochemical parameters.

In the vegetation experiment with potatoes, three fragments of potato tubers of 1 × 1 × 2 cm³ with the same weight and one bud were planted in the soil in each vessel. Upon planting, each part of the tubers was treated with a suspension of *Azospirillum brasilense* 410^{Str} at a rate of 500 thousand CFU/bud. After germination, the number of potato plants was reduced to two per vessel.

In the experiment with barley, 10 seeds were planted in the soil of each vessel. Before planting, they were treated with a suspension of *Azospirillum brasilense* 410^{Str} at a rate of 225 thousand CFU/seed. After germination, the number of seedlings was reduced to 5.

In the vegetation experiment with peas, 10 seeds were planted in each vessel. Before planting, they were treated with a suspension of *Rhizobium leguminosarum* 31^{Str} at a rate of 500 thousand CFU/seed. After germination, the

number of seedlings was reduced to 5.

Vegetation experiment with wheat involved the use of a suspension of *Paenibacillus polymyxa* KB^{Str} at a rate of 400 thousand CFU/seed. Ten seeds were planted in each vessel, and after the germination, the number of seedlings was reduced to 5.

Repetition of experiments is three times.

Sampling of rhizosphere soil and washed roots (as well as root nodules in the experiment with peas) was carried out according to the appropriate methods [40] over time, at Day 15, 30 and 45 after germination. The number of *A. brasilense* 410^{Str} was determined using the semi-liquid medium Nfb [39] by the limiting dilutions method. Additionally, an acetylene test was used to establish positive (with a “+”) dilutions [41]. Acetylene reduction activity was determined on a Chrom-5 gas chromatograph with a flame ionization detector. The calculation of the number of azospirilla was carried out by McCready tables. To determine the number of *R. leguminosarum* 31^{Str}, an aliquot of the root nodules of peas (each nodule separately) was destroyed with a sterile glass rod in the sterile test tubes with the addition of 1 mL of sterile tap water, after which the resulting suspension was sown on Petri dishes with pea agar (with the addition of streptomycin sulphate 2,000 µg/mL). The dilution of rhizosphere soil and washed wheat roots to detect *P. polymyxa* KB^{Str} was sown on MPA with streptomycin sulfate at a dose of 2,000 µg/mL.

The repetition of microbiological tests is 9 times.

The significance of differences between variants was evaluated by Student's t-test at $p \leq 0.05$. Test results are presented in the tables using the smallest significant difference, in the figures — as the arithmetic mean and the arithmetic mean error.

Statistical processing of experimental data was performed using Microsoft Office Excel 2003–2007.

Results and discussion.

Field experiments. Determining the dependence of potato yield levels on fertilizer indicates high efficiency of 40 t/ha of cattle manure (Table 1).

Significantly lower crop yields, although with a significant gain in control parameters, were observed with the use of lupine green manure. With the introduction of winter wheat

Table 1. Influence of fertilization and inoculation on potato yield

Variants of experiments	Yield (average for three years)	Gain from fertilizers and inoculation	Gain from inoculation
	t/ha		
<i>Without inoculation</i>			
Without fertilizers (control)	13.0	–	–
Straw	13.4	0.4	–
Green manure	14.6	1.6	–
Animal manure	22.8	9.8	–
Straw + green manure	16.2	3.2	–
Animal manure + green manure	24.0	11.0	–
N ₈₀ P ₈₀ K ₈₀	24.6	11.6	–
<i>With Biohran</i>			
Without fertilizers	14.7	–	1.7
Straw	14.3	1.3	0.9
Green manure	16.5	3.5	1.9
Animal manure	23.1	10.1	0.3
Straw + green manure	19.7	6.7	3.5
Animal manure + green manure	25.9	12.9	1.9
N ₈₀ P ₈₀ K ₈₀	26.1	13.1	1.5
HIP ₀₅	1.1	–	–

straw, we expected a decrease in potato yield due to the possible immobilization of mineral nitrogen compounds in the soil, but the data indicate no intensive development of this process — yield in this case was at the control level. This can be explained by the fact that under the conditions of a long-term stationary field experiment, the processes of biological transformation of nitrogen compounds were balanced. The combination of straw with green manure provided a significant increase in crop yields. Lupine green manure helped to increase productivity also in combination with animal manure. Thus, green manure provided an increase in the effective fertility of leached chernozem.

Potato yields when mineral fertilizers were introduced to the soil, were practically at the level of the “animal manure + green manure” variant.

The efficiency of Biohran depended on the characteristics of the crop fertilization. A significant increase in inoculation parameters was reported in the variant without fertilizers. The predicted increase in yield was obtained by growing inoculated plants on the background of

N₈₀P₈₀K₈₀. Under the exposure to 5 t/ha of straw and Biohran, a tendency to increase crop productivity only was noted. The effect of the preparation on the formation of yields when growing potatoes on a green manure background should be clearly emphasized. At the same time, the efficiency of potato inoculation was higher against the background of green manure with straw. When growing the crop on the background of animal manure, the efficiency of the biological preparation was smoothed down, but the cultivation of inoculated plants under combining animal manure with lupine green manure provided a significant increase in crop yield.

The first year aftereffect of organic fertilizers generally had a positive effect on the yield of the next crop in the crop rotation — spring barley (Table 2). However, the straw aftereffect showed only a tendency towards the increase yields. A significant increase was reported in straw plus lupine green manure aftereffect. As with potato growing, this combination contributed to higher yields than with each of these fertilizers individually.

The yield of barley increased by 1.33 t/ha under animal manure aftereffects, but against

Table 2. Influence of fertilization and inoculation on spring barley yield

Variants of experiment	Yield (average for three years)	Gain from fertilizers and inoculation	Gain from inoculation
	t/ha		
<i>Without inoculation</i>			
Without fertilizers (control)	2.07	–	–
Straw ^a	2.21	0.14	–
Green manure ^a	2.41	0.34	–
Animal manure ^a	3.40	1.33	–
Straw ^a + green manure ^a	2.67	0.60	–
Animal manure ^a + green manure ^a	3.64	1.57	–
N ₆₀ P ₆₀ K ₆₀	2.94	0.87	–
<i>With Mikrohumín</i>			
Without fertilizers	2.53	0.46	0.46
Straw ^a	2.69	0.62	0.48
Green manure ^a	2.90	0.83	0.49
Animal manure ^a	3.64	1.57	0.24
Straw ^a + green manure ^a	3.25	1.18	0.58
Animal manure ^a + green manure ^a	4.02	1.95	0.38
N ₆₀ P ₆₀ K ₆₀	3.40	1.33	0.46
HIP ₀₅	0.21	–	–

the background of the aftereffect of this fertilizer applied together with green manure, an increase of 1.57 t/ha was obtained.

The direct impact of mineral fertilizers on the productivity of the agrocenosis was at the level of 0.87 t/ha.

The use of Mikrohumín for pre-sowing inoculation of seeds contributed to a significant increase in barley yield for all studied agrarian backgrounds, but the lowest rate in the experiment was observed in the first year aftereffect of cattle manure.

When cultivating peas based on the second year aftereffect of organic fertilizers, a positive effect of all agrarian backgrounds on crop yields was reported. Furthermore, the aftereffect of 5 t/ha of straw provided a significant increase in yield (Table 3).

The aftereffect of cattle manure was almost at the level of the aftereffect of lupine green manure, but the effect of the combined application of these two types of organic fertilizers was much higher than the effect of each of them separately.

The highest yields in the experiment were obtained by direct action of N₃₀P₃₀K₃₀.

The efficiency of Ryzohumín, used for pre-sowing inoculation of pea seeds, was almost at the same level for all organic agrarian backgrounds. It was slightly higher under the direct action of N₃₀P₃₀K₃₀ (Table 3).

Under the third year aftereffects of organic fertilizers, their influence on the formation of winter wheat yield was insignificant and was within the statistical error of the results (Table 4). The only exception was the aftereffect of animal manure and lupine green manure applied together, which provided a yield increase of 0.28 t/ha. The highest parameters of crop yield in the experiment were obtained by direct action of mineral fertilizers at the rate of N₆₀P₆₀K₆₀.

The positive effect of the microbial preparation Polimiksobakteryn on the yield of winter wheat was manifested in all variants of the experiment, but when growing the crop in the third year aftereffect of organic fertilizers, it was much smaller than under direct action of mineral fertilizers. There was also no significant difference in the efficiency of the biological preparation in the cultivation of the crop under the aftereffects of organic fertilizers.

Table 3. Influence of fertilization and bacterization on pea yield

Variants of experiment	Yield (average for three years)	Gain from fertilizers and inoculation	Gain from inoculation
	t/ha		
<i>Without inoculation</i>			
Without fertilizers (control)	2,16	–	–
Straw ^b	2.33	0.17	–
Green manure ^b	2.38	0.22	–
Animal manure ^b	2.44	0.28	–
Straw ^b + green manure ^b	2.38	0.22	–
Animal manure ^b + green manure ^b	2.58	0.42	–
N ₃₀ P ₃₀ K ₃₀	2.70	0.54	–
<i>With Ryzohumin</i>			
Without fertilizers	2.48	0.32	0.32
Straw ^b	2.63	0.47	0.30
Green manure ^b	2.73	0.57	0.35
Animal manure ^b	2.78	0.62	0.34
Straw ^b + green manure ^b	2.77	0.61	0.39
Animal manure ^b + green manure ^b	2.94	0.78	0.36
N ₃₀ P ₃₀ K ₃₀	3.19	1.03	0.49
HIP ₀₅	0.16	–	–

The obtained results of the influence of microbial preparations on the formation of crop yields during their cultivation upon organic backgrounds indicate the ambiguous nature of the manifestation of the efficiency of microbiological factors. Thus, the positive effect of biological preparations is smoothed out at the year of direct action of cattle manure and is gradually restored over time under the aftereffects of this factor.

We attribute this to the fact that a huge number of microorganisms enter the soil along with animal manure [42; 43], which can create a strong competitive environment for the agronomically useful microorganism introduced into the agrocenosis. Although animal manure microorganisms are represented by many species of bacteria and micromycetes, including those that are not characteristic of effective interaction with plants, they can provide high competition for the substrate and occupy free ecological niches and create unfavourable conditions for survival in the root spheres of bacterial plants which is the basis of the studied biological preparations. We have previously [37] hypothesized non-specific bacterization of the soil with

the introduction of animal manure, which may prevent the successful introduction of agronomically beneficial microorganisms in agrocenoses.

Another situation is registered upon the cultivation of crops on the background of lupine green manure. The biomass of green manure is relatively weakly contaminated with microbiota and, in our opinion, does not interfere with the successful introduction of agronomically valuable bacteria. At the same time, green manure contains a significant amount of water-soluble organic substances, proteins and starch [44], which are rapidly mineralized and can additionally provide microorganisms with easily digestible organic compounds. Also, this organic fertilizer has a positive effect on plant nutrition, due to which they increase the root system and the production of root exudates [45], which can stimulate the reproduction of microorganisms.

This is confirmed by the improvement of the situation when combining green manure with straw and even animal manure.

Straw as a fertilizer has little effect on the efficiency of pre-sowing inoculation, which confirms the well-known thesis that it rather has influence on the potential fertility of the soil

Table 4. Influence of fertilization and bacterization on wheat yield

Variants of experiment	Yield (average for three years)	Gain from fertilizers and inoculation	Gain from inoculation
	t/ha		
<i>Without inoculation</i>			
Without fertilizers (control)	3.92	–	–
Straw ^c	3.95	0.03	–
Green manure ^c	4.04	0.12	–
Animal manure ^c	4.12	0.20	–
Straw ^c + green manure ^c	4.03	0.11	–
Animal manure ^c + green manure ^c	4.20	0.28	–
N ₆₀ P ₆₀ K ₆₀	4.42	0.50	–
<i>With Polimiksobakteryn</i>			
Without fertilizers (control)	4.24	0.32	0.32
Straw ^c	4.35	0.43	0.40
Green manure ^c	4.53	0.61	0.49
Animal manure ^c	4.42	0.50	0.30
Straw ^c + green manure ^c	4.43	0.51	0.40
Animal manure ^c + green manure ^c	4.62	0.70	0.42
N ₆₀ P ₆₀ K ₆₀	5.30	1.38	0.88
HIP ₀₅	0.21	–	–

(due to the high content of carbon and the possibility of its sequestration) than on the effective one. At the same time, the use of straw can affect the efficiency of biological preparations to some extent through the impact on the processes of biological transformation of nitrogen compounds.

Both positive and negative effects of organic fertilizers fade over time, which is quite logical given the changes in the state of the microbiota in the soil, and due to the gradual shortage of nutrients.

Study of the survival of biological agents of microbial preparations in root spheres of plants. To clarify some assumptions about the influence of organic agrarian backgrounds on the survival of agronomically useful microorganisms in the root spheres of plants, studies were conducted under the conditions of vegetation experiments.

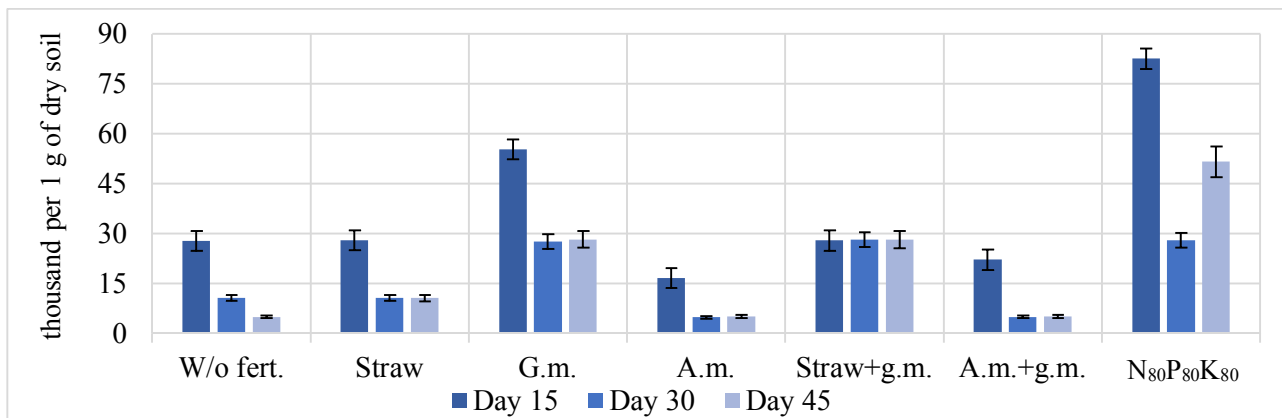
Studies of the development of *A. brasilense* 410^{Str} in the root spheres of potato plants have revealed significant differences between the variants. The development of the introduced microorganism in the rhizosphere soil is the largest under the mineral agrarian background (Fig. 1).

Compared to other variants of the experiment, azospirilla develop more intensively under the action of lupine green manure, as well as when combining green manure with winter wheat straw.

The lowest number of the studied bacteria in the rhizosphere soil were observed when growing potatoes against the background of cattle manure.

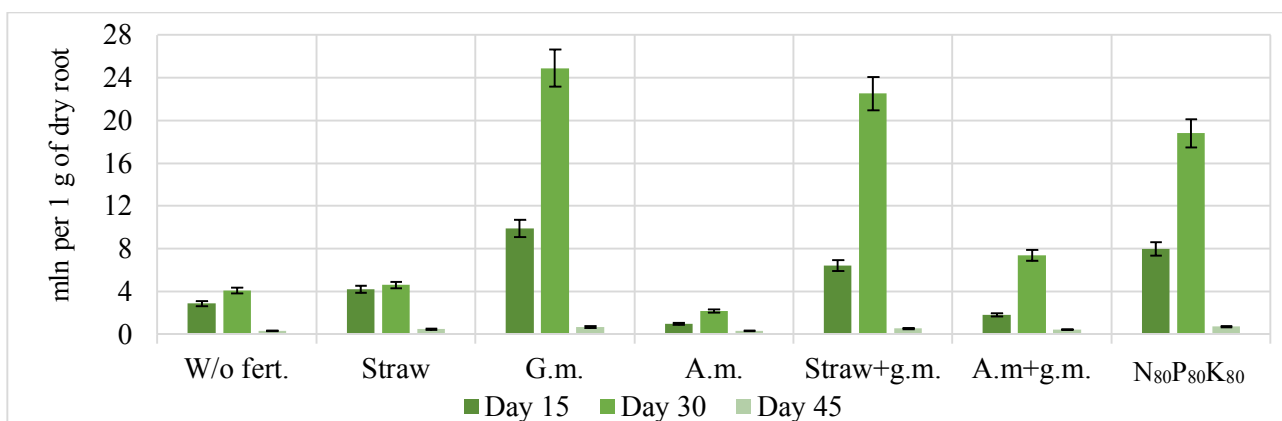
The number of azospirilla during the cultivation of plants on a background of straw has almost no difference from the control parameters. We explain this by the fact that in the year of straw application, the processes of its mineralization are only beginning to develop and do not significantly affect the number of *A. brasilense* 410^{Str}.

The dependence of *A. brasilense* 410^{Str} development from the agrarian background on the roots of potato plants has a much more contrasting appearance (Fig. 2). Azospirilla develop intensively on the roots under a mineral agrarian background, however the highest parameters of the number of bacteria are noted under the cultivation of plants on a green manure background. Whilst they are the highest in the exper-



W/o fert.: without fertilizer; G.m.: green manure; A.m.: animal manure

Fig. 1. Number of *A. brasilense* 410^{Str} in rhizosphere soil of potato plants depending on the agrarian background.



W/o fert.: without fertilizer; G.m.: green manure; A.m.: animal manure

Fig. 2. Development of *A. brasilense* 410^{Str} on the roots of potato plants depending on the agrarian background.

iment. Introduced azospirilla are extremely poorly developed on the roots of plants grown on the background of cattle manure. No significant difference was observed between the parameters of the number of *A. brasilense* 410^{Str} upon growing potatoes in the control variant and on the background of straw both in the rhizosphere soil, and on the roots of plants. At the same time, when combining straw with lupine green manure, the intensity of development of azospirilla increases significantly.

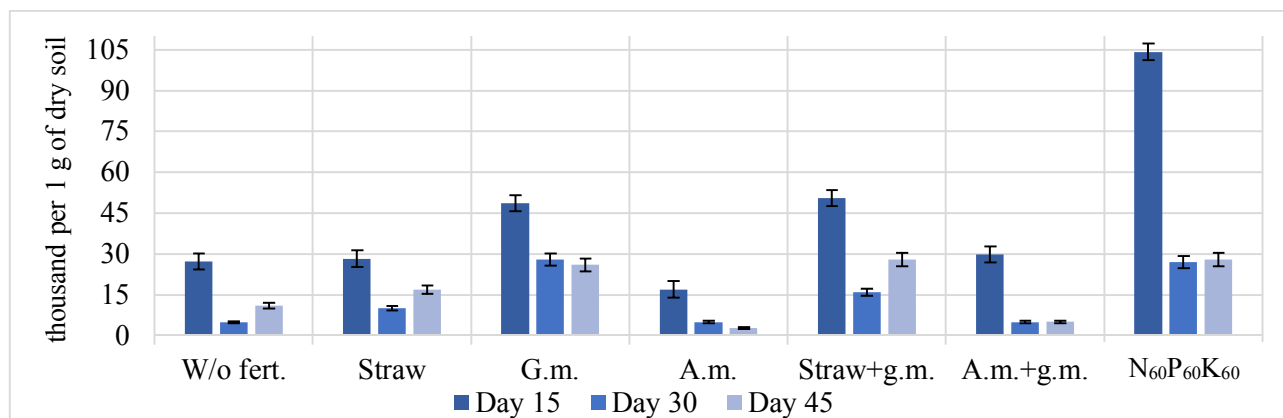
The reported peculiarities of *A. brasilense* 410^{Str} development in the root spheres of potato plants are largely maintained in the experiment with spring barley, where the first year aftereffect of organic fertilizers on the survival of azospirilla was studied. The highest parameters of the number of streptomycin-resistant azospirilla in the rhizosphere soil of barley plants were observed for growing plants on a mineral background (Fig. 3). Relatively high intensity of *A. brasilense* 410^{Str} development is observed in

the first year aftereffect of lupine green manure, including the combination of this fertilizer with straw.

The lowest values of streptomycin-resistant azospirilla were observed upon the aftereffects of cattle manure.

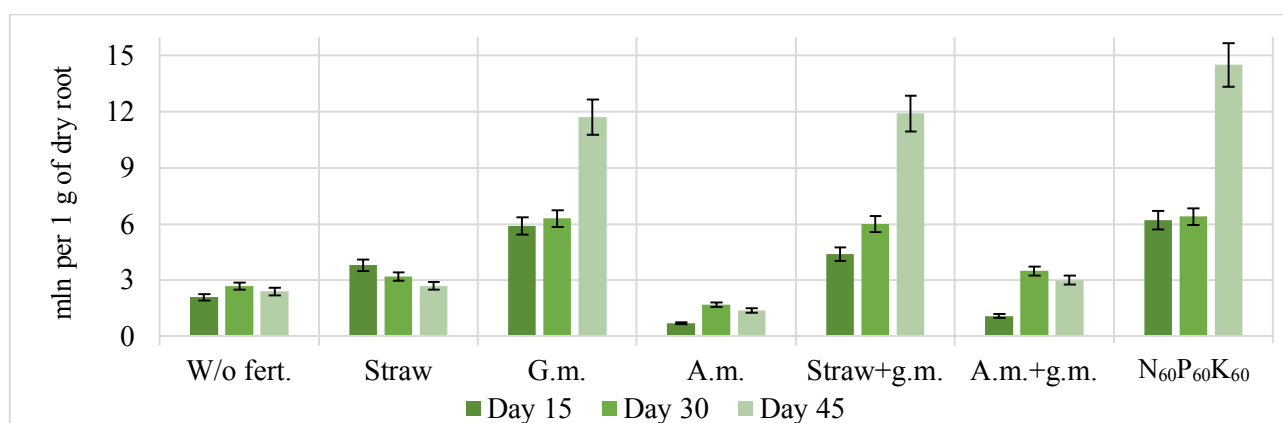
The development of *A. brasilense* 410^{Str} on the roots of barley plants also depended on the agrarian background (Fig. 4). The highest values were reported under the cultivation of plants on the mineral background, as well as under the aftereffects of green manure, including combination with wheat straw. Variants with cattle manure are still unfavourable for the development of *Azospirillum brasilense* 410^{Str}. A slight positive effect is observed from the aftereffect of wheat straw.

In the vegetation experiment with peas, which studied the effect of the second year aftereffects of organic fertilizers on the formation of nitrogen-fixing nodules with the involvement of *Rh. leguminosarum* 31^{Str} we have found no



W/o fert.: without fertilizer; G.m.: green manure; A.m.: animal manure

Fig. 3. Number of *A. brasilense* 410^{Str} in rhizosphere soil of spring barley depending on the agrarian background.



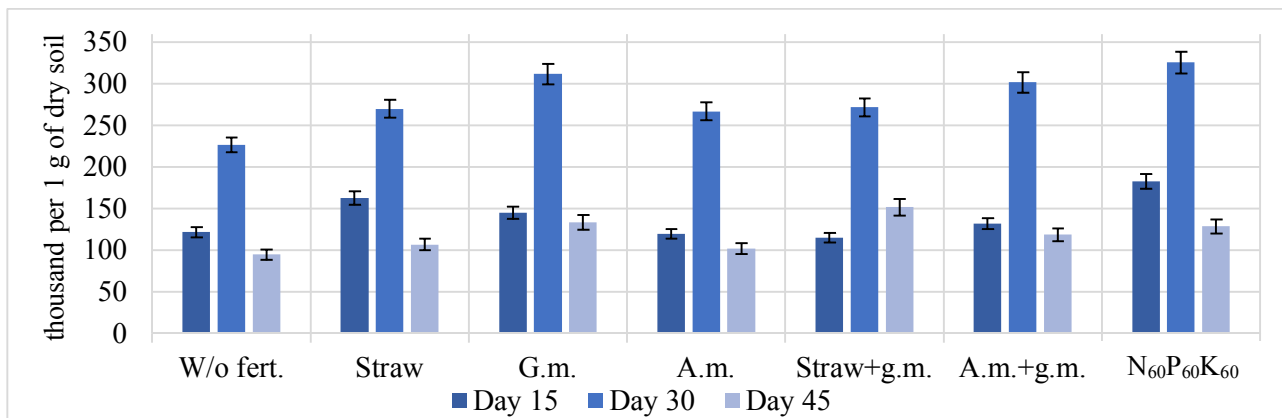
W/o fert.: without fertilizer; G.m.: green manure; A.m.: animal manure

Fig. 4. Development of *A. brasilense* 410^{Str} on the roots of spring barley depending on the agrarian background.

significant differences between the variants. This can be explained both by a decrease in the effect of organic fertilizers on the efficiency of bacterial introduction over time, and (or) the lack of significant competition between microorganisms in the formation of nitrogen-fixing symbioses. These studies should be continued using other methods, including serological.

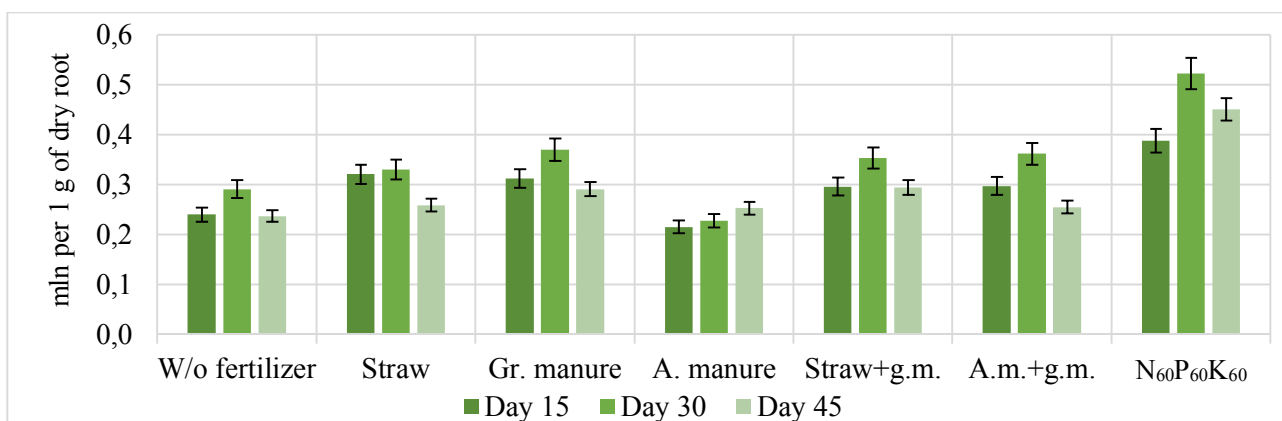
In the vegetation experiment with winter wheat upon the third year aftereffect of organic fertilizers, a significant smoothing up of both the negative impact of cattle manure and the positive effect of lupine green manure on the development of *P. polymyxa* KB^{Str} in the root spheres was registered (Fig. 5 and 6). At the same time, the parameters of variants with green manure still exceed the value of control, which indicates its positive impact on the development of plant-microbial interactions even in the fourth year aftereffect. A slight negative impact on the studied parameter is still observed in the variant with animal manure.

Conclusion. The efficiency of microbial preparations in the system of organic farming largely depends on agrarian backgrounds. The use of cattle manure offsets the positive effect of inoculation in the year of direct action of the fertilizer and in the first year aftereffect, due to the low level of survival of the microorganism introduced into the agocenosis in the root spheres of plants under these conditions. Over time, the negative effect of animal manure on the efficiency of biological preparations decreases. The use of green manure (narrow-leaved lupine) for fertilization helps to increase the efficiency of pre-sowing inoculation both in the year of direct action of this fertilizer and under its aftereffects. To reduce the negative impact of litter manure on the efficiency of microbial preparations, it is proposed to use lupine green manure together with animal manure. This is confirmed both by the level of crop yield and by studies of the survival of microorganisms introduced into agocenoses in the root



W/o fert.: without fertilizer; G.m.: green manure; A.m.: animal manure

Fig. 5. Number of *P. polymyxa* KB^{Str} in rhizosphere soil of winter wheat plants upon different agrarian backgrounds



W/o fert.: without fertilizer; G.m.: green manure; A.m.: animal manure

Fig. 6. Development of *P. polymyxa* KB^{Str} on the roots of winter wheat depending on the agrarian background

spheres of plants. The use of straw as a fertilizer does not significantly affect the efficiency of microbial preparations upon the first and second year aftereffects. Over time, the influence of straw on the efficiency of inoculants increases. To increase the effect of biological preparations on crop productivity, the combination of straw with green manure deserves attention.

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ЕФЕКТИВНІСТЬ ПЕРЕДПОСІВНОЇ ІНОКУЛЯЦІЇ У ВИРОЩУВАННІ СІЛЬСЬКОГОСПОДАРСЬКИХ КУЛЬТУР ЗА РІЗНИХ ОРГАНІЧНИХ АГРОФОНІВ

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Мета. Дослідити вплив різних органічних агрофонів та їх поєднань на ефективність передпосівної інокуляції насіння та розвиток інтродукованих мікроорганізмів у кореневих сферах культурних рослин. **Методи.** Мікробіологічні, газохроматографічний, вегетаційного та польового дослідів, статистичні. **Результати.** У тривалому польовому стаціонарному досліді на чорноземі вилуженому встановлено стимулювальну дію та післядію проміжного сидерату (люпин вузьколистий) на прояв ефективності мікробних препаратів за вирощування картоплі, ячменю ярого, гороху та пшениці озимої в сівозміні. Застосування 5 т/га соломи слабо впливало на ефективність інокуляції, проте поєднання соломи із зеленим добривом забезпечувало суттєве зростання показників урожайності. Позитивний вплив соломи на ефективність передпосівної інокуляції проявляється за післядії цього добрива. Внесення 40 т/га підстилкового гною великої рогатої худоби (ВРХ) нівелювало ефективність мікробних препаратів у рік прямої дії та першого року післядії добрива. З часом негативний вплив гною на дію біопрепаратів зменшувався. За вирощування сільськогосподарських культур по фоні «гній + сидерат» негативна дія гною на вплив інокуляції суттєво знижувалася. За моделювання умов вирощування сільськогосподарських культур у вегетаційних дослідях та використання генетично маркованих штамів бактерій — біологічних агентів мікробних препаратів — встановлено, що в рік внесення органічних добрив на розвиток *Azospirillum brasilense* 410^{Str} у кореневих сферах рослин позитивно впливає люпиновий сидерат, а використання підстилкового гною ВРХ — навпаки, призводить до суттєвого зменшення чисельності азоспірил. Поєднання зеленого добрива з гноєм ВРХ деякою мірою компенсувало негативний вплив останнього на розвиток інтродукованої бактерії. В умовах першого року післядії органічних добрив в кореневій зоні рослин ячменю ярого ці особливості зберігаються. За вирощування гороху залежність між утворенням корневих бульбочок *Rhizobium leguminosarum* 31^{Str} та другого року післядії органічних добрив не простежується. За вирощування пшениці озимої в умовах третього року післядії органічні добрива незначною мірою впливають на розвиток *Raenibacillus polytuxa* KB^{Str} у кореневих сферах рослин. Водночас у варіантах післядії соломи або сидерату показники децю перевершують контрольні. Незначний негативний вплив на чисельність бактерії все ще проявляється у варіанті з післядією гною. **Висновки.** Використання органічних добрив може суттєво впливати на ефективність передпосівної інокуляції. Дія та післядія підстилкового гною ВРХ негативно впливає на розвиток інтродукованих в агроценоз агрономічно корисних бактерій і значною мірою нівелює позитивний вплив біопрепаратів на урожайність культур. Застосування мікробних препаратів для інокуляції насіння

сільськогосподарських культур за їх вирощування по фоні прямої дії та післядії проміжного лютинового сидерату, у т. ч. й за поєднання зеленого добрива з соломною, забезпечує інтенсивний розвиток інтродукованих мікроорганізмів в корневих сферах рослин і зростання урожайності.

Ключові слова: *інокуляція, мікробні препарати, солома, сидерат, гній ВРХ, генетично марковані штами бактерій.*

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