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APPLICATION OF BACTERIAL AGENTS ON SUNFLOWER

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The results on the effectiveness of biofertilizer GroundFix (5 and 8 L/ha for seedlings) and bacterial agent HelpRost (3 L/ha in the "4 leaf pairs" phase) for confectionery sunflower are presented. When GroundFix was applied at a dose of 5 L/ha, the yield increased; the gain was plus 0.33 t/ha to the control without fertilizers and 0.36 t/ha with $N_{30}P_{30}K_{30}$. When a combination (GroundFix 5 L/ha + HelpRost 0.30 t/ha or 0.32 t/ha) was applied, the increment in the yield was 0.32 and 0.30 t/ha, respectively. An increase in the biofertilizer dose to 8 L/ha raised the yield by 0.32 and 0.30 t/ha, respectively; when this dose was co-applied with HelpRost – by 0.42 and 0.58 t/ha, respectively.

There was a positive correlation (r = 0.37−1.00) between the yield and precipitation amount during the growing period: a high positive effect of temperature in April (r = from 0.36–0.72) and in June (r = 0.33–0.59) was noted.

Key words*: sunflower, yield, bioagents, correlation coefficients, yield increments.*

Introduction. Today, the mainstreams in the cultivation of major crops are green products, reduction in energy consumption for tits production and elevated soil fertility. Recently, the global agricultural production has started to increasingly use microbial agents. They exert positive effects; in particular they maintain stable levels of organic matter in soil. Application of biological agents in crop cultivation technologies makes it possible to partially replace nitrogen from mineral fertilizers with cheaper biological nitrogen fixed by microorganisms from the air [1].

Bioagents are categorized by their action as follows:

− Protection of plants against phytophages, phytopathogens, murine rodents;

− Boost in resistance of plants to pests;

− Improvement of nutrition (nitrogen, phosphorus, potassium) and increase in plant yields;

− Stimulation of plant growth and development due to biologically active compounds;

− Improvement of soil structure and fertility [1].

Soil bacteria not only enrich soil with nutrients, but also improve physiological qualities of soil. The more beneficial bacteria there are in soil, the higher its fertility is. In most today's soils, however, some microorganisms, which are considered indicators of fertility, are on the verge of extinction. At the same time, young plant roots are inhabited by atypical, pathogenic microorganisms that compete with beneficial soil bacteria for nutrients. As a result, the crop does not produce a full-scale yield. Application of Phylazonit helps to increase yields by 15−40% depending on the crop while agricultural products meet the world and EU standards [2].

Biologization itself, without individual calculation for each crop and for a specific field, does not work. For example, bacteria from biologicals will simply die in some soils due to lack of oxygen, so one need to provide special farming techniques to improve air flow into soil. In some cases, there is no need for additional bacteria or fungi of several strains [3].

Ukraine is forcedly and spontaneously moving to organic farming with violations of its basic principles: achieving a deficit-free balance of organic matter and biogenic elements, adherence to scientifically sound crop rotations and soil-protecting technologies, use of biological nitrogen, effective control of weeds, pathogens and pests. Under such conditions, soils get

depleted and their physical and chemical properties deteriorate; the productivity of agroecosystems decreases and the product quality worsens [4].

Modern stimulants can not only regulate nutrient amounts consumed by plants, but also help to resist various undesirable natural factors reducing yields. It was proven that growth stimulant-treated seeds gave more even and hardier seedlings, which developed faster and had stronger root systems [5].

The maximum yield of soybeans (1.27 t/ha) was obtained due to a set of measures including microbiological agents applied during pre-sowing cultivation, pre-sowing seed treatment and spraying crops: the yield increment amounted to 0.19 t/ha. Application of microbiological agents with a complex mechanism of action, which are based on highly effective bacterial strains, in soybean cultivation technologies, even under extreme weather, was an effective measure that enhanced the crop productivity by 5.6-17.6% [6].

Seed treatment with bacterial agents significantly increased yields of all sunflower hybrids. Without Vympel, the Kyi hybrid increased its seed yield by 0.17−0.25 t/ha due to application of Diazophyt; use of this complex agent gave an increment of 0.22−0.23 t/ha. For the Yason hybrid, the increment was 0.13−0.17 t/ha; for the Zorepad hybrid, it was 0.15−0.32 t/ha. A similar gain in yields was achieved with another nitrogen-fixing agent, KL-9, in the Kyi hybrid. As to the other two hybrids, the effect of this agent was significantly stronger: the gain amounted to 0.27−0.31 t/ha in Yason and 0.34−0.41 t/ha in Zorepad, which was attributed to their longer vegetation periods. The strongest effect of bacterial agents was recorded with their combination: 0.22−0.23 t/ha (Kyi), 0.24−0.34 t/ha (Yason), and 0.38−0.49 t/ha (Zorepad) [7].

Plant growth regulators, microfertilizers and pesticides increase sunflower seed production by 0.08−0.17 t/ha in lines and by 0.14-0.21 t/ha in hybrids, accelerating propagation of new hybrids and ensuring additional profits of 17,746−26,577 UAH/ha and 231−597 UAH/ha, respectively [8].

The average yield was 4.38 t/ha in control and 5.36 t/ha in treated fields. The gain was 0.98 t/ha. These results were obtained through two sprayings with agent Biocomplex BTU for technical crops during the growing period [9].

Sunflower cultivation on mineral fertilization combined with a microbial agent increased the yield by 0.24 t/ha; mineral fertilizer itself, without microbial agent, increased the yield by 0.27 t/ha; organo-mineral fertilizer − by 0.45 t/ha; organo-mineral fertilizer combined with microbial agent − by 0.51 t/ha. Microbial agents significantly increased the sunflower yield on organo-mineral fertilization, while the yield increment without seed inoculation was 0.22 t/ha [10].

The study was aimed to examine the effects of bacterial agents combined with two variants of mineral fertilization on the sunflower yield.

Materials, methods and conditions. The main field experiments were carried out in Department of Plant Production and Variety Investigations of the Plant Production Institute named after V.Ya. Yuriev of NAAS of Ukraine in 2016−2018.

Winter wheat served as a forecrop for sunflower. Biofertilizer GroundFix (5 and 8 L/ha) was applied after sowing, on seedlings. Bioagent GroundFix (3 L/ha) on the Hudvin sunflower hybrid was used in the “3 true leaves” phase according to the experiment design.

The experiments were carried out in three replications. The record plot area was 50 m^2; the plots were arranged systematically. Mineral fertilization variants:

− No fertilizer (crop rotation background);

− $N_{30}P_{30}K_{30}$ during pre-sowing cultivation.

Variants of application of biological agents:

1. Control
2. GroundFix 5 L/ha (spraying the soil);
3. GroundFix 5 L/ha + HelpRost 3 L/ha (“4 leaf pair” phase);
4. GroundFix 8 L/ha (spraying the soil);
5. GroundFix 8 L/ha + HelpRost 3 L/ha (“4 leaf pair” phase).

The soil was deep granular slightly leached chernozem. It had the following agrochemical parameters: humus content (Tyurin’s method) − 5.8%; pH − 5.8; hydrolytic acidity − 3.29

mg/eq per 100 g of soil. The nutrient reserves in the control (no fertilizer): nitrogen – 132 mg/kg; phosphorus – 104 mg/kg; potassium – 128 mg/kg. The nutrient amounts with mineral fertilizer ($N_{30}P_{30}K_{30}$): nitrogen – 130-140 mg/kg; phosphorus – 180−200 mg/kg; potassium – 170−190 mg/kg of soil.

Data were statistically processed by variance and correlation analyses [11, 12].

HelpRost is an organo-mineral fertilizer for foliar application (spraying) of sunflower plants during the growing period. Treatment during vegetation is recommended to be conducted in combination with biologicals or plant protectors. HelpRost contains the following elements and substances (g/L): major mineral elements (N − 82.5; P − 49.5; K − 77), mesoelements (S − 26.4; Mg − 27.5), trace elements (B − 16.5; Zn − 7 .7; Fe − 1.65; Mn − 8.8; Cu − 4.4), biologically active compounds (vitamins − 0.22; amino acids − 11; peptides − 5.5; polysaccharides − 0.55). The dose was 1−3 L/ha, from the "2 leaf pair" phase to the head formation.

GroundFix® is soil biofertilizer for mobilization of phosphorus and potassium from insoluble compounds, nitrogen fixation and enhancement of the efficiency of mineral fertilizers

The spring in 2016 was excessively wet and warm. The precipitation amount in March, April and May exceeded the multi-year average by 28.4, 29.2, and 48.0 mm, respectively, or by 100, 82, and 110% respectively. The average daily temperatures in March, April and May exceeded the multi-year average by 4.1, 3.3, and 0.9ºC: the sum of effective temperatures in April and May was by 59.3 and 67.6ºC higher than the optimal one − 42.2 and 143.0ºC, respectively.

In June, the average daily temperature was by 1.1ºC higher than the multi-year average, and the sum of effective temperatures during this month was by 63.2ºC higher than the optimal value (275.0ºC). The precipitation amount was lower than the multi-year average by 20.0 mm or by 32%.

The average daily temperatures in July and August were higher than the multi-year averages by 1.9 and 2.2ºC, respectively. The sum of effective temperatures was much higher than the optimal values (411.5 and 396.2ºC, respectively, with the multi-year averages of 346.7 and 282.0ºC, respectively). The amount of precipitation exceeded the norm by 34.7 and 3.7 mm or by 50 and 8%, respectively.

In general, the spring-summer period (March−July) can be described as warm and sufficiently wet; the precipitation amount was 120.3 mm, or by 50% more than the multi-year average.

The warm weather persisted in August and September. The average daily air temperature was higher than the multi-year average by 2.2 and 0.4ºC, respectively. The precipitation amount in August was by 3.7 mm or by 8% higher than the multi-year average; in September it was by 28.8 mm or by 66% lower than the multi-year average.

The spring in 2017 was wet and warm. The average daily temperatures in April and May were very close to the multi-year averages; the precipitation amount in April exceeded the multi-year average by 5.5 mm and it was less than the multi-year average by 19% in May. At the same time, the greatest amount of precipitation (as showers) fell during the second 10 days of April and May − by 147 and 113% more than the multi-year average, respectively.

In June and July, the average daily temperatures also approached the multi-year averages; the precipitation amount was by 71 and 56% less than the multi-year average, respectively.

The average daily temperature in August was by 4.1ºC higher than the multi-year average; and the precipitation amount was by 35.5 mm or by 76% lower than the multi-year average.

The weather in the spring-summer period of 2018 was dry. Thus, the precipitation amount in April-August was by 160.1 mm or by 61% less than the multi-year average. The average daily temperature exceeded the multi-year average by 2.7ºC. March in 2018 was by 3.1°C colder than the multi-year average, but all the other months were much warmer, especially April (by 2.8°C), May (by 3.08°C), and August (by 4.0°C).

On average across the study years (2016−2018), March, April and August were warmer by 2.3, 2.0 and 3.4°C, respectively.

At the same time, 2018 can be described as insufficiently wet. The precipitation amount was by 81 mm more than the multi-year average in March only; in the precipitation amounts in other months were lower than the optimal values: from 19.8 mm in June to 46.9 mm in August. On average across the study years, March had more precipitation than the multi-year average (by 35.2 mm); April and May were characterized by optimal amounts (plus 4.0 mm to the multi-year average in each month); and the precipitation was insufficient in June, July and August (minus 25.4, 16.1 and 26.2 mm from the multi-year average, respectively).

Such contrasting weather allowed us to fully assess the adaptability and plasticity of oilseeds.

Under the experimental conditions, combination of biofertilizer GroundFix and bacterial agent HelpRost was the most effective variant (Table 1). When GroundFix was used at a dose of 5 L/ha without fertilizer, the yield increased by 0.33 t/ha compared to the control; when it was used with $N_{30}P_{30}K_{30}$ (basic fertilizer), the yield increased by 0.36 t/ha. When we applied GroundFix 5 L/ha + HelpRost, the yield increment was 0.30 and 0.32 t/ha, respectively. The efficiency of application HelpRost 3 L/ha in the "5−6 leaf pairs" phase of the crop was -0.03 and -0.04 t/ha in the respective variants of mineral fertilization. When the biofertilizer dose was increased to 8 L/ha, the yield increased by 0.32 and 0.30 t/ha, respectively; when the increased dose was co-applied with HelpRost, the yield increment amounted to 0.42 and 0.58 t/ha, respectively. In our study, application of HelpRost plus GroundFix 8 L/ha allowed us to additionally obtain 0.11 t/ha in the control and 0.28 t/ha with mineral fertilizer.

Table 1

Hudvin sunflower hybrid yield depending on basic fertilization, biofertilizer and bacterial agent application, 2016−2018, t/ha

Variant (factor B)	Basic fertilization (factor A)		Increment resulted from fertilization
	No fertilizer(control)	$N_{30}P_{30}K_{30}$	
Control	2.57	2.83	0.20
GroundFix 5 L/ha	2.90	3.18	0.28
+/- to/from the control	0.33	0.36	
GroundFix + HelpRost	2.87	3.15	0.28
+/- to/from the control	0.30	0.32	
HelpRost effect	-0.03	-0.04	
GroundFix 8 L/ha	2.89	3.12	0.23
+/- to/from the control	0.32	0.30	
GroundFix + HelpRost	3.00	3.41	0.41
+/- to/from the control	0.42	0.58	
HelpRost effect	0.11	0.28	
LSD_{05}	A – 0.19; B – 0.20; AB – 0.18		

Correlation analysis between the sunflower yield affected by biological agents and weather/climatic conditions during the study period revealed a positive correlation (r = 0.37 - 1.00) between the yield and precipitation amount during the growing period. The only exception was GroundFix 8 L/ha + HelpRost 3 L/ha on $N_{30}P_{30}K_{30}$ fertilization and precipitation in June (r = 0.21 (Fig. 1).

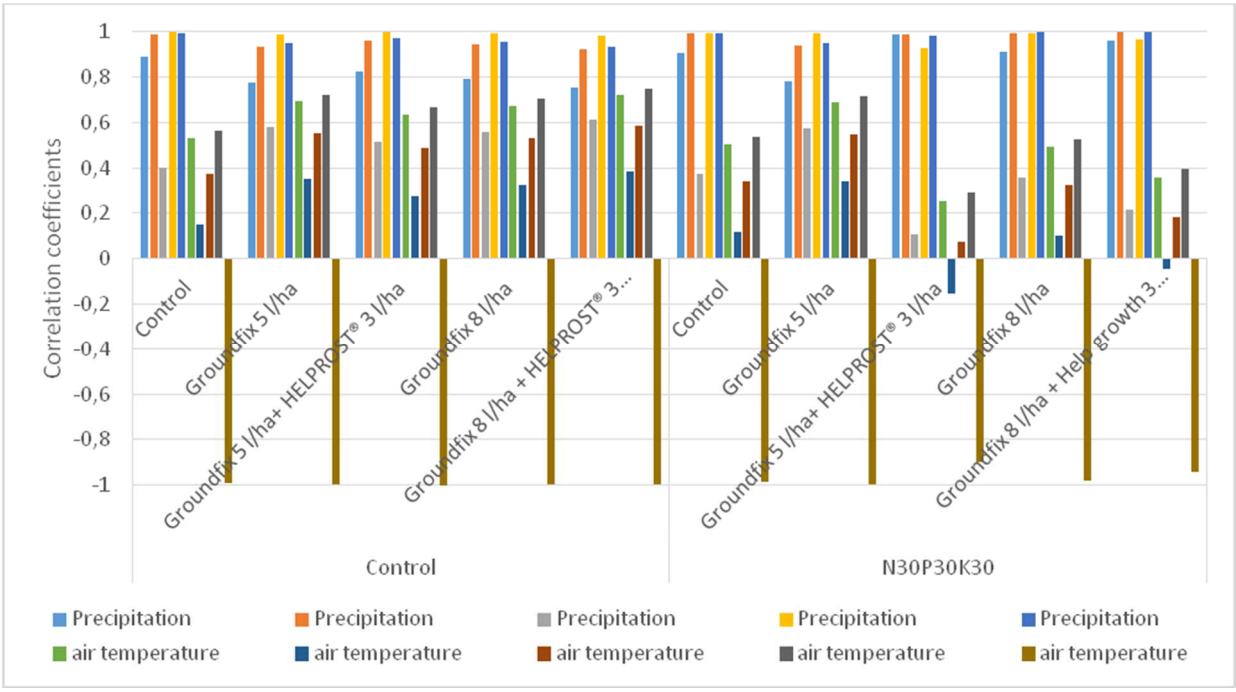

Fig. 1. Pearson's correlation coefficients between yield, precipitation amount and average daily air temperature, 2016–2018

The average daily air temperatures had a much greater impact on the yield. There was a strong positive effect of April temperatures, with correlation coefficient of 0.36–0.72, and of June temperatures (r = 0.33–0.59), except for the 'GroundFix 5 L/ha + HelpRost 3 L/ha' combination on basic fertilization with $N_{30}P_{30}K_{30}$ (r = - 0.25 and r = - 0.07, respectively). May temperatures had a positive effect in the following variants: GroundFix 5 L/ha, GroundFix 8 L/ha and GroundFix 8 L/ha + HelpRost 3 L/ha (r = 0.35, 0.32 and 0.39, respectively) as well as for the 'mineral fertilizer + GroundFix 5 L/ha' combination (r = 0.34). In the other variants, the impact of this factor was insignificant (r = 0.05–0.28). July temperatures had a strong positive effect on the yield (r = 0.39–0.72), while August temperatures, on the contrary, exerted a strong negative effect (r = - 1.00– - 0.90).

Conclusions. When GroundFix was used at a dose of 5 L/ha without fertilizer, the yield increment was 0.33 t/ha compared to the control; when GroundFix was used at the same dose with $N_{30}P_{30}K_{30,}$ the increment amounted to 0.36 t/ha. By combining GroundFix 5 L/ha with HelpRost, we obtained the yield increments of 0.30 and 0.32 t/ha, respectively. Increasing the biofertilizer dose to 8 L/ha gave the yield gain of 0.32 and 0.30 t/ha, respectively. When the increased dose was co-applied with HelpRost, the gain was 0.42 and 0.58 t/ha, respectively.

There was a positive correlation (r = 0.37–1.00) between the yield and precipitation amount during the growing period. We noted a strong positive effect of April temperatures, with correlation coefficient of 0.36–0.72, and of June temperatures (r = 0.33–0.59).

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ЗАСТОСУВАННЯ БАКТЕРІАЛЬНИХ ПРЕПАРАТІВ ПРИ ВИРОЩУВАННІ СОНЯШНИКУ

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Метою дослідження було вивчити вплив застосування бактеріальних препаратів за двох фонів мінерального живлення на рівень урожайності соняшнику.

Матеріали і методи. Основні польові дослідження проводили в період 2016−2018 рр. у відділі рослинництва та сортовивчення Інституту рослинництва ім. В.Я. Юр'єва НААН. Ґрунт – глибокий слабковилугуваний чорнозем із зернистою структурою.Вінхарактеризується: вмістом гумусу (за Тюріним) 5,8 %; pH 5,8; гідролітичною кислотністю 3,29 мг/екв. на 100 г ґрунту. Запаси поживних речовин на контролі без добрив: азот – 132 мг/кг, фосфор – 104 мг/кг, калій – 128 мг/кг; на фонах із застосуванням мінеральних добрив ($N_{30}P_{30}K_{30}$): азот – 130−140 мг/кг, фосфор – 180−200 мг/кг, калій – 170−190 мг/кг ґрунту.

Статистичну обробку проводили методом дисперсійного та кореляційного аналізу.

Обговорення результатів.Ріст і розвиток соняшнику в умовах 2016−2018 рр. проходив у контрастних погодних умовах. Характерною була недостатня вологозабезпеченість в критичний період (цвітіння, формування і налив зерна), особливо на фоні підвищених температур повітря.

В умовах періоду досліджень найбільш ефективним було комплексне застосування біодобрива Граундфікс та бактеріального препарату Хелп рост. При застосуванні препарату Граундфікс в дозі 5 л/га надбавка урожайності, в порівнянні до контролю, склала на фоні без добрив 0,33 т/га, а при застосуванні в основне внесення $N_{30}P_{30}K_{30}$ – 0,36 т/га, при використанні Граунд фікс 5 л/га + Хелп рост – по 0,30 та 0,32 т/га відповідно. Ефективність застосування 3 л/га препарату Хелп рост у фазу 5−6 пар листків культури склала -0,03 та -0,04 т/га відповідно фонів мінерального живлення. При збільшені дози біодобрива до 8 л/га надбавка урожайності становила 0,32 та 0,30 т/га, а при спільному застосуванні з Хелп рост – 0,42 та 0,58 т/га.

Відмічено високий позитивний вплив температур квітня на урожайність, коефіцієнт кореляції r= від 0,36 до 0,72 та червня – r= від 0,33 до 0,59, за виключенням варіанту Граундфікс 5 л/га + Хелп рост 3 л/га на фоні $N_{30}P_{30}K_{30}$ r= мінус 0,25 та мінус 0,07.

Висновки. При застосуванні препарату Граундфікс в дозі 5 л/га надбавка врожайності в порівнянні з контролем склала на фоні без добрив 0,33 т/га, а при $N_{30}P_{30}K_{30}$ – 0,36 т/га, при спільному використанні Граунд фікс 5 л/га + Хелп рост − по 0,30 та 0,32 т/га відповідно. При збільшенні дози біодобрива до 8 л/га надбавка врожайності становила 0,32 та 0,30 т/га, а при спільному застосуванні з Хелп рост – 0,42 та 0,58 т/га.

Встановлено позитивну кореляцію (r= від 0,37 до 1,00) рівня врожайності із сумою опадів за вегетаційний період. Відмічено високий позитивний вплив температур квітня, коефіцієнт кореляції r= від 0,36 до 0,72 та червня – r= від 0,33 до 0,59.

Ключові слова: *соняшник, урожайність, бактеріальний препарат, коефіцієнт кореляції, прибавка врожайності.*

APPLICATION OF BACTERIAL AGENTS ON SUNFLOWER

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The study was aimed to examine the effects of bacterial agents combined with two variants of mineral fertilization on the sunflower yield.

Materials and methods. The main field experiments were carried out in Department of Plant Production and Variety Investigations of the Plant Production Institute named after V.Ya. Yuriev of NAAS of Ukraine in 2016−2018.

The soil was deep granular slightly leached chernozem. It had the following agrochemical parameters: humus content (Tyurin's method) 5.8%; pH 5.8; hydrolytic acidity 3.29 mg/eq per 100 g of soil. The nutrient reserves in the control (no fertilizer): nitrogen – 132 mg/kg; phosphorus – 104 mg/kg; potassium – 128 mg/kg. The nutrient amounts with mineral fertilizer ($N_{30}P_{30}K_{30}$): nitrogen – 130-140 mg/kg; phosphorus – 180−200 mg/kg; potassium – 170−190 mg/kg of soil.

Data were statistically processed by variance and correlation analyses.

Results and discussion. In2016-2018, sunflower plants grew and developed under very contrasting weather conditions compared to the multi-year averages. There was a water deficit during the critical periods (anthesis, seed setting and filling), especially at elevated air temperatures.

In the study, biofertilizer GroundFix + bacterial agent HelpRost turned out to be the most effective combination. When GroundFix was used at a dose of 5 L/ha without fertilizer, the yield increased by 0.33 t/ha compared to the control; when it was used with $N_{30}P_{30}K_{30}$ as basic fertilizer, the gain in the yield amounted to 0.36 t/ha. When the 'GroundFix 5 L/ha + HelpRost' combination was applied, the gain was 0.30 and 0.32 t/ha, respectively. The efficiency of HelpRost 3 L/ha in the "5−6 leaf pair" phase of the crop was -0.03 and -0.04 t/ha on the respective mineral fertilization. When the biofertilizer dose was increased to 8 L/ha, the yield was raised by 0.32 and 0.30 t/ha, respectively; when the increased dose was co-applied with HelpRost, the increment was 0.42 and 0.58 t/ha, respectively.

There was a strong positive effect of April temperatures on the yield, with correlation coefficient of 0.36− 0.72, and of June temperatures (r = 0.33−0.59), except for the 'GroundFix 5 L/ha + HelpRost 3 L/ha' combination on basic fertilization with $N_{30}P_{30}K_{30}$ (r = - 0.25 and r = - 0.07, respectively).

Conclusions. When GroundFix was used at a dose of 5 L/ha without fertilizer, the yield increment was 0.33 t/ha compared to the control; when GroundFix was used at the same dose with $N_{30}P_{30}K_{30,}$ the increment amounted to 0.36 t/ha. By combining GroundFix 5 L/ha with HelpRost, we obtained the yield increments of 0.30 and 0.32 t/ha, respectively. Increasing the biofertilizer dose to 8 L/ha gave the yield gain of 0.32 and 0.30 t/ha, respectively. When the increased dose was co-applied with HelpRost, the gain was 0.42 and 0.58 t/ha, respectively.

There was a positive correlation (r = 0.37−1.00) between the yield and precipitation amount during the growing period. We noted a strong positive effect of April temperatures, with correlation coefficient of 0.36−0.72, and of June temperatures (r = 0.33−0.59).

Key words: *sunflower, yield, bioagents, correlation coefficients, yield increments*