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Resistance of sunflower crops to harmful objects when using growth-stimulating bioproducts in their crops

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ABSTRACT

Sunflower is one of the most popular crops in the world, and its sown areas are growing rapidly in all countries of the world. Sunflower is one of the most common crops in the structure of sown areas in Ukraine. Thus, over the past two decades, the sown areas under sunflower have increased fourfold, and the total harvest has increased tenfold. Today, there is a wide range of biological products that can be used in sunflower cultivation to increase yield by reducing costs and improving the ecological condition of the crop. An experimental field study to study the impact of different fertilization regimes on the spread of diseases and weeds in sunflower crops was conducted from 2022 to 2024 at the experimental plots of the Scientific Research Farm «Agronomichne» of the Vinnytsia National Agrarian University, located in the village of Agronomichne, Vinnytsia region. It was found that the most common diseases in sunflower crops were white rot (*Sclerotinia sclerotiorum*), gray rot (*Botrytis cinerea*), Phomosis (*Photma oleracea*) and Alternaria alternata (*Alternaria alternata*). The greatest damage to the sunflower crop was caused by white rot (*Sclerotinia sclerotiorum*) in unfertilized control variants, where 50% of the plants were affected. The proportion of sunflowers affected by white rot (Sclerotinia sclerotiorum) varied depending on the fertilizer application. In particular, the greatest damage was detected when applying N_{60} – 35%, which is 15% less than in the control variant. The greatest proportion of sunflowers affected by white rot (Sclerotinia sclerotiorum) was detected in the variant N_{30} + Bionorm nitrogen (32%), as well as in the variants Bionorm nitrogen and Bionorm nitrogen + Bionorm phosphorus – 30% respectively. The lowest percentage of sunflowers affected by white rot (Sclerotinia sclerotiorum) was observed when Bionorm Phosphorus and P30 + Bionorm Phosphorus were applied – 10% each. The results of the survey show that the weed infestation of sunflower crops ranged from strong to medium. Thus, the variants of the experiment with fertilizer N_{60}, $N_{60}P_{60}K_{60}$, Bionorm Nitrogen and the variant without fertilizer (control) had strong weed infestation (score 3), and the remaining variants had a medium degree (score 2). Fertilizing sunflower crops with the biological preparation Bionorm Phosphorus allows to significantly reduce the spread of diseases in its crops. Bionorm Phosphorus exhibits a powerful preventive fungicidal effect. The greatest damage to sunflower diseases is observed in the absence of fertilizers and when mineral nitrogen N_{30} is applied. In the phase of the 8th leaf of sunflower, depending on the fertilizer, 5 types of weeds were detected in its crops: gray mouse grass (*Setaria* spp), white quinoa (*Chenopodium* spp), common buckwheat (*Capsella bursa-pastoris* L., *Capsella hyrcana* grosch.), common amaranth (*Amaranthus retroflexus*) and field bindweed (*Convolvulus arvensis*). In this phase, the options with mineral phosphorus fertilizer P_{60} had the fewest weeds – 20 pcs./m^2, Bionorm nitrogen + Bionorm phosphorus and N_{30} + Bionorm nitrogen – 25 pcs./m^2 each. The most weedy option was the option without fertilizer – 133 pcs./m^2. Subsequently, the number of weeds in crops decreases the most on the options with fertilizer N_{60} – by 73%, $N_{60}P_{60}K_{60}$ – by 53%.

Keywords: sunflower, weeds, diseases, biological products, marketing year.

INTRODUCTION

Today, sunflower is one of the most popular crops in the world. Its cultivated area is growing rapidly in all countries. For example, in the last 100 years alone, the global area of sunflower has more than doubled – from 12.4 million hectares to almost 29 million hectares (Domaratskiy et al., 2018; Bulgakov et al., 2024). As the area under sunflower increases, the negative impact of its cultivation on agroecosystems also increases. Total sunflower production in the 2021/2022 marketing year reached a record level worldwide, exceeding 57.2 million tonnes. The global sunflower area reached 28.75 million hectares, up 7% from the previous season and the highest since the beginning of cultivation (Didur et al., 2020). Sunflower is grown in 60 countries around the world, which indicates the high ecological adaptability of the crop: the main producers of sunflower in the world in the 2021/2022 marketing year are: Ukraine (17.5 million tons), the russian federation (15.57 million tons), Argentina (3.35 million tons) and China (2.9 million tons), EU countries (total 9.8 million tons) (Domaratskiy et al., 2021; Razanov et al., 2024; Mazur et al., 2021d; Hetman et al., 2024) (Table 1).

Sunflower is one of the most common crops in the structure of sown areas in Ukraine. Over the past two decades, the sown areas under sunflower have increased fourfold (from 1.6 million hectares to 7.1 million hectares), and the total yield has increased tenfold. In recent years alone, the production of this crop has increased from 9.02 million tons in the 2012/2013 marketing year to 17.5 million tons in the 2021/2022 marketing year (Mazur et al., 2021c). The prerequisites for mass production of sunflower in Ukraine are intensive technologies for growing sunflower, the potential of soil fertility, new adaptive varieties, improved fertilization systems, balanced plant protection systems, and modern effective means of mechanization (Table 2).

An important prerequisite for increasing agricultural productivity is a scientifically based composition of sown areas and rational crop rotation to ensure the optimal ratio of crops. The use of crop rotation does not require additional costs, but allows you to increase crop yield and profitability, preserve and improve soil fertility, regulate water and nutrient regimes and improve the phytosanitary condition of crops (Gamayunova et al., 2020; Hnatiuk et al., 2021; Honcharuk et al., 2022; Kaletnik et al., 2024; Didur et al., 2024; Okrushko, 2022; Vdovenko et al., 2024).

Sunflower in Ukraine is grown on unreasonably large areas, contrary to scientifically based requirements and in violation of technology, without taking into account the impact on the yield of subsequent crops, with a negative impact on the agroecological condition of the soil and the ecological safety of products (Petrychenko, et. al., 2018). In particular, there are significant deviations from the recommended terms of return to

Table 1. Dynamics of sunflower production in the world for the 2012/2013–2021/2022 marketing years, million tons

Countries	Marketing years									
	2012/ 2013	2013/ 2014	2014/ 2015	2015/ 2016	2016/ 2017	2017/ 2018	2018/ 2019	2019/ 2020	2020/ 2021	2021/ 2022
Ukraine	9.02	11.58	10.23	11.95	15.18	13.71	15.02	16.47	14.14	17.50
Russian Federation	7.52	9.81	8.38	9.20	10.85	10.36	12.74	15.29	13.29	15.57
Argentina	3.09	2.09	3.16	3.01	3.55	3.54	3.82	3.24	3.43	3.35
China	2.32	2.42	2.50	2.88	3.20	3.15	2.49	2.66	2.57	2.90
Romania	1.48	2.15	2.00	1.75	2.04	2.70	2.70	2.89	2.11	2.90
Bulgaria	1.40	1.97	2.00	1.70	1.85	2.08	1.94	1.94	1.66	2.00
Hungary	1.30	1.48	1.60	1.57	1.88	2.02	1.83	1.71	1.70	1.82
France	1.57	1.54	1.57	1.19	1.20	1.60	1.24	1.30	1.61	1.92
Turkey	1.13	1.40	1.20	1.10	1.32	1.55	1.80	1.75	1.56	1.75

Table 2. The share of sunflower in the structure of sown areas of the world in the 2021/2022 marketing year

Countries	Sunflower sown area. million hectares	Arable land area. million hectares	Share of sunflower in the structure of sown areas. %
Russian Federation	9.61	121.6	7.9
Ukraine	7.10	32.9	21.6
Argentina	1.96	32.6	6.1
China	0.89	119.5	0.7
USA	0.50	157.7	0.3

previously cultivated lands. In some cases, sunflower is a repeated or permanent crop sown after an unfavorable predecessor (Mazur and Kolisnyk, 2021; Tkachuk et al., 2025; Tkach et al., 2024; Lohosha et al., 2024; Mazur et al., 2021b; (Petrychenko et al., 2024).

In a 10-field crop rotation with 10% sunflower, the average crop yield was 2.6 t/ha, at 20% saturation – 1.3 t/ha and 1.1 t/ha when sunflower was returned to the crop rotation after four years. Such violations of the rules of the sunflower growing cycle lead to crop losses of up to 40% (Mazur et al., 2021a).

The increase in sunflower sown areas significantly worsens the phytosanitary condition of agrocenoses. The contamination of crops, including the parasitic weed sunflower wolfberry, increases 7–8 times both in sunflower crops and in neighboring fields, the spread of diseases such as sclerotinia and downy mildew increases significantly, and the water and nutrient balance of the soil is disturbed. If the share of sunflower in the sown areas exceeds 15%, the soils, including the deeper layers, may dry out, which will negatively affect the yield of subsequent crops (Petrychenko, et. al., 2022).

The optimal composition of the sown areas and rational crop rotation should be based on the basic position of the balanced use of biological and natural resources and conditions for the restoration of soil fertility. In addition, the oversaturation of crop rotations with late spring crops (corn and sunflower) has reached its maximum impact on the environment. As a result, there is a chronic deficit of soil moisture. The saturation of crop rotations with crops that consume more nutrients and water and increase phytosanitary risks will lead either to a decrease in the productivity of arable land, or to additional production costs to compensate for the negative consequences of crop rotation violations (Bakhmat et al., 2023).

As the crop industry has adapted to the demands of modern agricultural markets and producers have become highly dependent on the results of their commercial activities, the range of agricultural crops has narrowed, and it is necessary to take into account the economics of production activities based on environmental requirements, effective plant protection systems, modern agricultural technologies and crop varieties (Pantsyreva et al., 2023).

In farms with limited livestock resources, the use of biopreparations, including humic substances, nitrogen-fixing and phosphorus-mobilizing bacteria, fungi and other agronomically beneficial bacteria that improve soil fertility, as well as other biopreparations based on organic microfertilizers, can increase sunflower yields in an environmentally friendly way (Panfilova et al., 2021; Pantsyreva et al., 2024).

Depending on the type of hybrid, soil cultivation and climatic conditions, approximately 40–50 kg of nitrogen, 25–30 kg of phosphorus, 100–150 kg of potassium, 14 kg of calcium and 12 kg of magnesium are required to form 1 ton of seeds and the corresponding amount of sunflower by-products. However, given that sunflower by-products (stem, leaves and root system) are returned to the soil, sunflower removes only 28 kg of nitrogen, 16 kg of phosphorus and 24 kg of potassium per ton of seeds (Tkachuk et al., 2024; Dubik et al., 2024).

The largest source of nitrogen is the atmosphere, which contains 78%. However, this nitrogen is unavailable to most crops, except for legumes. Only nitrogen-fixing microorganisms can convert atmospheric nitrogen into a form available to plants. When using biological preparations based on free-living and aggregating nitrogen-fixing microorganisms, 20–50 kg of nitrogen per hectare is introduced into the soil. In addition, these microorganisms synthesize a number of biologically active substances that stimulate plant growth (Honcharuk et al., 2024).

The phosphorus content in the upper soil layer is quite high. However, phosphorus is contained in the soil in a form unavailable to plants. In this case, only phosphate-immobilizing microorganisms can convert phosphate into a form that can be absorbed by plants. In addition, only 25% of the phosphorus contained in phosphate fertilizers passes into the soil solution and is immediately absorbed by plants, while the remaining 75% is unavailable to them. Thus, phosphate-immobilizing bacteria can reduce the application of phosphorus fertilizers by 25–50% (Tkach, et. al., 2024).

Today, there is a wide range of biological products that can be used in sunflower cultivation to increase yield by reducing costs and improving the ecological state of the crop. In addition to nitrogen and phosphorus fixers, these are salts of humic acids, destructors, anti-stress agents, mycorrhizal fungi and protective agents (for example, Trichoderma, Pseudomonas). These are preparations of beneficial soil microorganisms, the use of which contributes to improving plant nutrition, active growth and development of plants, protection against diseases and pests, and restoration of soil fertility (Mazur et al., 2023).

MATERIALS AND METHODS

An experimental field study to study the impact of different fertilization regimes on the spread of diseases and weeds in sunflower crops was conducted from 2022 to 2024 at the experimental plots of the Scientific Research Farm «Agronomichne» of Vinnytsia National Agrarian University, located in the village of Agronomichne, Vinnytsia region. The experimental plots were located on medium loamy gray podzolized soils, and the agrochemical parameters were as follows: humus content – 2.22% (according to Tyurin); saline pH – 5.7–5.9; hydrolytic acidity – 2.4–2.8 mg-eq./100 g; sum of absorbed bases – 14 mg-eq./100 g; degree of saturation with bases – 80–86%; content of easily hydrolyzed nitrogen – 82–89 mg/kg of soil (according to Kornfield); mobile phosphorus – 200–245 mg/kg of soil (according to Chirikov); exchangeable potassium – 81–88 mg/kg of soil (according to Chirikov), which is favorable for the growth and development of sunflower plants in this region.

The predecessor of sunflower was winter wheat. Soil cultivation included stubble peeling and autumn plowing to a depth of 27 cm. Sunflower was sown in mid-April. The medium-sized linoleum hybrid of French selection MAS 87.A was grown, recommended for the forest-steppe and steppe zones of Ukraine. The declared yield was 5.7 t/ha. Morphological characteristics: grass height – 170–180 cm, basket diameter 20–22 cm, slightly convex. Oil content – 47–50%; 1000 seeds weighing 60–65 g. Approximate vegetation period – 112–116 days.

Fertilizers in sunflower crops on the experimental plot were applied in variants according to the experimental scheme using the following forms of nutrition: ammonium nitrate (N_{60}); double superphosphate (P_{60}); nitroammofoska ($N_{60}P_{60}K_{60}$); Bionorm Nitrogen (biological preparation of nitrogen-fixing action); Bionorm Phosphorus (biological preparation of phosphorus-mobilizing action); Bionorm Nitrogen + Bionorm Phosphorus; N_{30} + Bionorm nitrogen; P_{30} + Bionorm phosphorus; N_{30} + Bionorm nitrogen + P_{30}+Bionorm phosphorus. The experiment also included the option of growing sunflower without fertilizer (control) (Table 3). Bionorm Nitrogen contains free-aggregate bacteria Azotobacter croococcum, Azotobacter vinelandii and aggregate nitrogen-fixing bacteria Azospirillum brasiliense and Azospirillum lipoferrum, which improve nitrogen nutrition of plants and allow them to achieve their natural growth potential. Consumption rate – 10 l/ha. Application rate – 10 l/ha.

Bionorm Phosphorus is soil spore bacteria, Bacillus megaterium, Bacillus amyloliquefaciens, Trichoderma harzianum micromycetes, which provide full phosphorus nutrition and increase the degree of phosphorus absorption from the soil and mineral fertilizers. The components of the drug synthesize organic and mineral acids, and phosphatase enzymes convert insoluble phosphorus compounds into a soil solution that can be absorbed by the root system. The application rate is 10 l/ha.

Table 3. Experimental design

Experiment option	Fertilizer, application rate
N_{60}	Ammonium nitrate, 60 kg/ha of mineral nitrogen in the active substance
P_{60}	Double superphosphate, 60 kg/ha of mineral phosphorus in the active ingredient
$N_{60}P_{60}K_{60}$	Nitroammophoska, 60 kg/ha of mineral nitrogen, phosphorus and potassium in the active substance
Bionorm nitrogen	10 l/ha
Bionorm phosphorus	10 l/ha
Bionorm nitrogen + Bionorm phosphorus	10 l/ha + 10 l/ha
N_{30}+ Bionorm nitrogen	Ammonium nitrate, 30 kg/ha of mineral nitrogen in active ingredient + 10 l/ha
P_{30}+ Bionorm phosphorus	Double superphosphate, 30 kg/ha of mineral phosphorus in the active ingredient + 10 l/ha
$N_{30}P_{30}$+ Bionorm nitrogen + Bionorm phosphorus	Ammonium nitrate, 30 kg/ha of mineral nitrogen in active ingredient, double superphosphate, 30 kg/ha of mineral phosphorus in active ingredient + 10 l/ha + 10 l/ha
Without fertilizer (control)	–

Mineral fertilizers were applied by scattering, and biological products were applied to the soil at a rate of working fluid loss of 200 l/ha for pre-sowing cultivation. Sunflower cultivation technologies were generally accepted in the growing areas.

The area of sowing plots was 300 m^2, accounting – 30 m^2. The experiment was repeated four times, the variants were placed systematically.

Phytopathological studies were carried out in each variant of the experiment by direct inspection of 20 sunflower plants at an equidistant distance from each other and by visual method. The degree of damage and spread of the disease on the stems, leaves and baskets of plants was measured in percentage. The intensity of disease development and spread was measured. Pests found on sunflower were identified and classified using reference books and atlases. Weed counts were conducted quantitatively in the 8-leaf sunflower phase and at the beginning of sunflower wilting; after counting the number of weeds per m^2, weed infestation of the crop was assessed using scores (Table 4).

Observations of sunflower growth and development phenology were conducted visually. Calculations of weed abundance were performed at two phenological stages: V8 – when the eighth true leaf blooms, and R9 – when the sunflower plant dies.

Table 4. Scale of weed infestation of crops

Score	Weed count, pcs./m^2	Degree of weediness
1	Up to 10	Weak
2	10–50	Average
3	Over 50	Strong

RESULTS AND DISCUSSION

In Ukraine, there are more than 30 pathogens of sunflower diseases of fungal, bacterial and viral origin. However, only a fifth of them lead not only to a significant decrease in sunflower yield, but also to the complete destruction of the crop. The types of pathogens and the economic losses they cause depend on environmental conditions. The most common fungal diseases of sunflower are: sclerotinia or white rot (*Sclerotinia sclerotiorum*), alternaria (*Alternaria alternata*), powdery mildew (*Erysiphe cichoracearum* f. helianthi Jacz.), downy mildew or downy mildew (*Plasmopara helianthi* Novot), verticillium wilt (*Verticillium longisporum*), coal rot (*Macrophomina phaseolina* (Tassi) Goid.), embellisia or black spot (*Embellisia helianthi Hansf.*), rust (*Puccinia helianthi*), rhizopus or dry rot (*Rhizopus nodosus* Nam. and *Rhizopus nigricans* Her.), septoria (*Septoria helianthi* Ell. et Kell), gray rot (*Botrytis cinerea*), phomosis (*Photma oleracea*), phomopsis (*Phomopsis helianthi*); bacterial – bacterial stem and basket rot (*Pectobacterium carotovorum*), bacterial blight of sunflower (synonyms: bacterial wilt, bacterial rot, bacterial necrosis) (*Xanthomonas arboricola*), brown angular spot (*Pseudomonas syringae* pv. Helianthi), small necrotic leaf spot (*Pseudomonas syringae* pv. Mellea); viral – viral mosaic of sunflower leaves (*Tobacco rattle virus*).

Fertilization systems and the type of fertilizers applied have a significant impact on the level of disease. It is known that nitrogen fertilizers applied to cultivated plants increase the spread of diseases, while the use of mainly phosphorus and potassium fertilizers increases plant immunity to diseases and slows down their development. Foliar fertilizers have become increasingly popular in recent years and are used together with conventional mineral fertilizers or independently.

Sunflower crop disease monitoring was conducted in the R6 – flowering and R8 – seed ripening phases. Disease monitoring during flowering included Septoria (*Septoria helianthi Ell.* et Kell), Verticillium (*Verticillium longisporum*), Sclerotinia (white rot) (*Sclerotinia sclerotiorum*), dry rot (*Rhizopus nodosus* Nam. and *Rhizopus nigricans* Her.), gray rot (*Botrytis cinerea*), powdery mildew (*Erysiphe cichoracearum* f. helianthi Jacz.), Phomosis (*Photma oleracea*) and Alternaria alternata.

The most common diseases in sunflower crops were White rot (*Sclerotinia sclerotiorum*), Gray rot (*Botrytis cinerea*), Phomosis (*Photma oleracea*) and Alternaria alternata. The greatest damage to the sunflower crop was caused by white rot (Sclerotinia sclerotiorum) on unfertilized control variants, where 50% of the plants were affected. The proportion of sunflowers affected by white rot (Sclerotinia sclerotiorum) varied depending on the fertilizer application. In particular, the greatest damage was found when N_{60} was applied – 35%, which is 15% less than in the control variant. The greatest proportion of sunflowers affected by white rot (*Sclerotinia sclerotiorum*) was found in the variant N_{30} + Bionorm nitrogen (32%), as well as in the variants Bionorm nitrogen and Bionorm nitrogen

+ Bionorm phosphorus – 30% each, respectively. The lowest percentage of sunflowers affected by white rot (*Sclerotinia sclerotiorum*) was observed when applying Bionorm Phosphorus and P_{30} + Bionorm Phosphorus – 10% each (Table 5). Thus, it was established that the greatest damage to sunflower plants by white rot (*Sclerotinia sclerotiorum*) was observed in the control variant without fertilizer application, where the plants were characterized by the least resistance. Sunflower fertilization reduced the damage to its crops by white rot (*Sclerotinia sclerotiorum*) by 15–40% due to increased plant resistance. The most increased the resistance of sunflowers to white rot (*Sclerotinia sclerotiorum*) was the application of the biological preparation Bionorm Phosphorus and the combined application of P_{30} + Bionorm Phosphorus. The least positive effect on inhibiting the development of white rot (Sclerotinia sclerotiorum) on sunflower plants was observed with the application of mineral nitrogen at a rate of 60 kg/ha.

The damage of sunflower plants by Photma oleracea (*Photma oleracea*) ranged from 10 to 35%. The highest percentage of damage was observed with mineral fertilizer for sunflower N_{60} – 35% of plants, P_{60}, $N_{60}P_{60}K_{60}$, Bionorma nitrogen and in the control – 30% of plants. In general, no damage of sunflower plants by Photma oleracea (*Photma oleracea*) was detected with the application of the biological preparation Bionorma phosphorus. Thus, the biological preparation Bionorma phosphorus exhibits a fungicidal effect on the prevention of damage to sunflower plants by Photma oleracea (*Photma oleracea*). The use of different types of mineral fertilizers stimulated the development of Photma oleracea (*Photma oleracea*) in sunflower.

The damage of sunflower plants by Alternaria alternata (*Alternaria alternata*) was 10–35%. The plants were most affected with the option of applying mineral fertilizer N_{60} – 35% of plants. In the control variant without fertilizers, 30% of sunflower plants were affected. And the least damage to sunflower by Alternaria alternata (*Alternaria alternata*) was observed with the application of Bionorm Phosphorus – 10% of plants.

Thus, it was established that the biopreparation Bionorm Phosphorus exhibits a preventive fungicidal effect on Alternaria alternata (*Alternaria alternata*) of sunflower. While nitrogen mineral fertilizer and the variant without the use of fertilizers were the most favorable for Alternaria alternata (*Alternaria alternata*).

The damage to sunflower plants by gray rot (*Botrytis cinerea*) was 10–40%. The highest percentage of damage was observed with the application of nitrogen mineral fertilizer N_{60}. Sunflower plants were not affected by gray rot (*Botrytis cinerea*) at all in the variants of application Bionorm Phosphorus and P_{30} + Bionorm Phosphorus.

Damage to sunflower crops by dry rot (*Rhizopus nodosus* Nam. and *Rhizopus nigricans* Her.) was detected only in three variants – in the control, where 50% of plants were damaged,

Table 5. Spread of diseases in sunflower crops depending on fertilizer, % of plant damage, M ± m

Diseases	Sunflower fertilization system									
	$_{N6}$0	$_{P6}$0	$N_{60}P_{60K6}$0	Bionorm nitrogen	Bionorm phosphorus	Bionorm nitrogen + Bionorm phosphorus	N_{30}+ Bionorm nitrogen	P_{30}+ Bionorm phosphorus	$N_{30}P_{30}$+ Bionorm nitrogen + Bionorm phosphorus	Without fertilizer (control)
Sclerotinia sclerotiorum	35±4	20±2	20±2	30±2	10±2	30±3	32±3	10±1	20±3	50±5
Rhizopus nodosus Nam. and *Rhizopus nigricans* Her.	5±1	-	-	-	-	-	5±1	-	-	50±6
Botrytis cinerea	40±5	10±2	10±2	20±3	-	17±3	30±4	-	10±2	10±2
Erysiphe cichoracearum f. helianthi Jacz.	5±1	-	-	-	-	-	-	-	-	-
Photma oleracea	35±3	30±3	30±3	30±3	-	15±1	25±2	15±2	10±1	30±4
Alternaria alternata	35±3	15±2	20±2	25±3	10±2	15±2	20±3	15±2	15±2	30±3
Septoria helianthi Ell. et Kell	5±1	5±1	5±1	5±1	3±1	8±2	3±1	10±2	10±2	15±2

with the application of N_{60} and N_{30} + Bionorm nitrogen – 5% of plants each. Powdery mildew (*Erysiphe cichoracearum* f. helianthi Jacz.) was detected only in the variant with the application of mineral nitrogen fertilizer N_{60} in an amount of 5% of plants.

Septoria blight (*Septoria helianthi* Ell. et Kell) was widespread in 3–15% of sunflower plants. The highest percentage of damage was observed in the control variant without fertilizer application, and the lowest – with the application of Bionorm phosphorus and N_{30} + Bionorm nitrogen.

Figure 1 shows the cumulative effect of damage to sunflower crops by a complex of diseases depending on the fertilizer system. The greatest prevalence of sunflower diseases was found in the control variant without fertilizer application. 7 diseases were widespread here, with the greatest development of white (*Sclerotinia sclerotiorum*) and dry rot (*Rhizopus nodosus* Nam. and *Rhizopus nigricans* Her.), as well as phomosis (*Photma oleracea*) and alternariosis (*Alternaria alternata*). Also, a significant percentage of sunflower crop disease damage was observed in the variant of nitrogen mineral fertilizer N_{60}, where 8 diseases were found with the greatest prevalence of gray (*Botrytis cinerea*), white (*Sclerotinia sclerotiorum*), dry rot (*Rhizopus nodosus* Nam. and *Rhizopus nigricans* Her.), as well as phomosis (*Photma oleracea*).

When combining mineral nitrogen fertilizer N_{30} with the biopreparation Bionorma nitrogen, 6 diseases were spread on sunflower crops, with the most widespread white rot (*Sclerotinia sclerotiorum*) and gray rot (*Botrytis cinerea*). Fertilizing sunflower with the biopreparation Bionorma nitrogen allowed only five diseases to develop, with the most widespread white rot (*Sclerotinia sclerotiorum*) and Phomosis (*Photma oleracea*). Variants with the application of mineral phosphorus P_{60}, $N_{60}P_{60}K_{60}$, biopreparations Bionorma nitrogen + Bionorma phosphorus were affected by five diseases. Phomosis (*Photma oleracea*) prevailed among them. The application of $N_{30}P_{30}$ + Bionorma nitrogen + Bionorma phosphorus allows reducing the incidence of diseases. Among them, white rot (*Sclerotinia sclerotiorum*) prevails.

The application of mineral phosphorus P_{30} + Bionorma Phosphorus significantly reduces the spread of diseases with a predominance of Phomosis (*Photma oleracea*) and Alternaria (*Alternaria alternata*). The lowest spread of diseases on sunflower crops was observed with the application of the biopreparation Bionorma Phosphorus. Only three diseases with a slight spread were detected in this variant.

The species composition of the most common weedy vegetation growing in sunflower agrocenoses includes: ragweed (*ambrosia artemisiifolia*), field bindweed (*convolvulus arvensis*), purple nettle (*lamium purpureum*), stinging nettle (*urtica urens*), quinoa (*species*) (*chenopodium* spp), mouse (*species*) (*setaria* spp), common nettle (*xanthium strumarium*), common buckwheat (*capsella bursa-pastoris* l.,

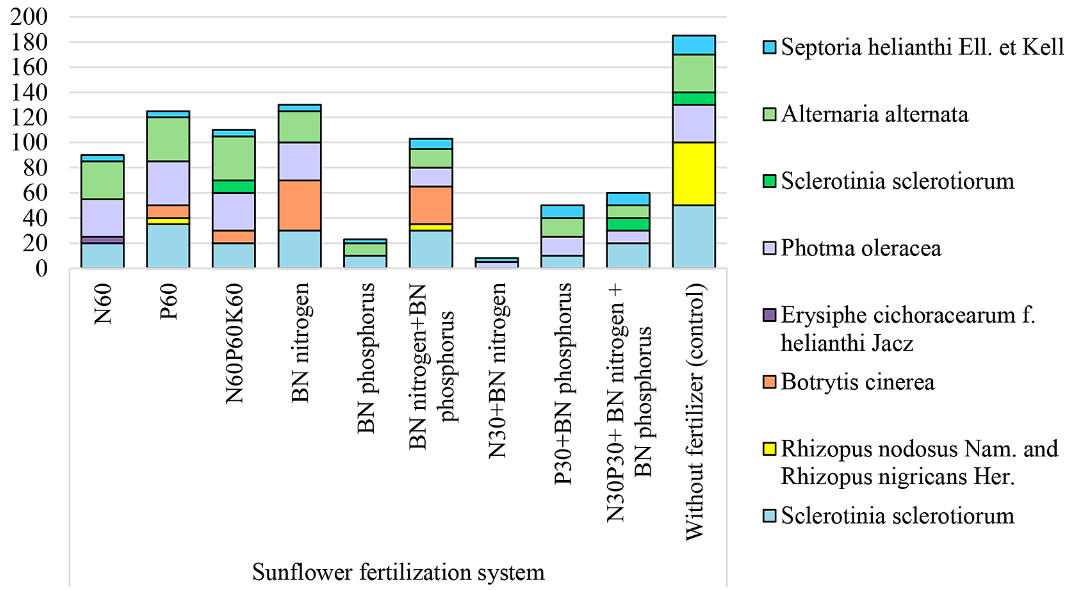

Figure 1. Cumulative damage to sunflower plants by diseases depending on the fertilization system, %

capsella hyrcana grosch.), garden thistle (*sonchus oleraceus*), yellow thistle (*sonchus arvensis*), common amaranth (*amaranthus retroflexus*), common knotweed (*polygonum aviculare*), common ragweed (*barbarea vulgaris*), sunflower wolfberry (*orobanche cumana*) and others.

The spread of weeds is influenced by the crop fertilization system. Some types of fertilizers promote better weed germination, while others, on the contrary, promote intensive initial growth of the crop and its greater competitiveness with weeds. In this context, the response of vegetation to the application of biofertilizers is important.

In sunflower crops in the 8th leaf phase (V8), depending on the fertilizer, 5 types of weeds were detected: blue mouse grass (*setaria* spp), white quinoa (*chenopodium* spp), common buckwheat (*capsella bursa-pastoris* l., *capsella hyrcana* grosch.), common amaranth (*amaranthus retroflexus*) and field bindweed (*convolvulus arvensis*). The most numerous of the weeds was blue mouse grass (*setaria* spp). It prevailed in all variants. The largest number of blue mouse grass (*setaria* spp) plants was detected in the control variant – without fertilizer – 78 pcs./m^2. A significant number of gray mouse (*setaria* spp) was detected on the variants of application of the biological preparation Bionorma nitrogen – 52 pcs./m^2, $N_{60}P_{60}K_{60}$ – 50 pcs./m^2 and mineral fertilizer N_{60} – 45 pcs./m^2. The least number of gray mouse (setaria spp) plants was detected on the variants of mineral phosphorus fertilizer P_{60} and biofertilizers Bionorma nitrogen + Bionorma phosphorus – 15 pcs./m^2 each, which was 80.8% less than on the control. Also, a small number of gray mouse (setaria spp) was detected on the variants of fertilizer P_{30} + Bionorma phosphorus and N30P30+ Bionorma nitrogen + Bionorma phosphorus – 17 pcs./m^2 each (Table 6).

The highest number of white quinoa (chenopodium spp) was found on the control variant – 27 pcs./m^2. 10 pcs./m^2 of this weed were found on the variants N_{60}, P_{30}+Bionorma phosphorus and $N_{30}P_{30}$+Bionorma nitrogen + Bionorma phosphorus, which was 63% less than on the control. Common amaranthus (*amaranthus retroflexus*) was also found most on the control variant – 28 pcs./m^2. Almost the same number of amaranthus (*amaranthus retroflexus*) was found on the variant of fertilizer Bionorma nitrogen. The least number of this weed was on the variant $N_{30}P_{30}$+Bionorma nitrogen + Bionorma phosphorus – 12 pcs./m^2, which was 57.1% less than on the control. Common buckwheat (capsella bursa-pastoris l., capsella hyrcana grosch.) in the amount of 23 pcs./m^2 were found

Table 6. Species composition of weeds in the agrophytocenosis of sunflower in the V8 phase, M±m

Sunflower fertilization system	Number of weeds, pcs./m^2						
	Small weeds				Perennial		Total
	Monocotyledons		Dicotyledons		Dicotyledons		
	Species	Number	Species	Number	Species	Number	
N_60	*Setaria spp*	45±6	*Chenopodium spp*	10±2	-	-	78±8
			Capsella bursa-pastoris l., *capsella hyrcana* grosch	23±3			
P_60	*Setaria spp*	15±2	-	-	*Convolvulus arvensis*	5±1	20±3
$N_{60}P_{60K6}0$	*Setaria spp*	50±4	*Chenopodium spp*	14±2	-	-	64±7
Bionorma nitrogen	*Setaria spp*	52±4	*Amaranthus retroflexus*	26±3	-	-	78±8
Bionorm phosphorus	*Setaria spp*	25±3	*Amaranthus retroflexus*	15±2	*Convolvulus arvensis*	4±1	44±5
Bionorma nitrogen + Bionorm phosphorus	*Setaria spp*	15±2	*Amaranthus retroflexus*	5±1	*Convolvulus arvensis*	5±1	25±3
N_{30}+ Bionorma nitrogen	*Setaria spp*	20±2		-	*Convolvulus arvensis*	5±1	25±3
P_{30}+ Bionorm phosphorus	*Setaria spp*	17±2	*Chenopodium spp*	10±2	-	-	40±4
			Amaranthus retroflexus	13±2			
$N_{30}P_{30}$+ Bionorma nitrogen + Bionorm phosphorus	*Setaria spp*	17±2	*Chenopodium spp*	10±2	-	-	39±4
			Amaranthus retroflexus	12±2			
Without fertilizer (control)	*Setaria spp*	78±8	*Chenopodium spp*	27±3	-	-	133±13
			amaranthus retroflexus	28±3			

only on the N_{60} variant. Among perennial weeds, only field bindweed (*convolvulus arvensis*) was found in the amount of 4–5 pcs./m^2 on the P_{60}, Bionorm phosphorus, Bionorm nitrogen + Bionorm phosphorus and N_{30}+Bionorm nitrogen variants. The total number of all weeds on the fertilizer variants ranged from 20 pcs./m^2 on the P_{60} variant to 133 pcs./m^2 on the control. Among the sunflower fertilization variants, N_{60} and Bionorm nitrogen had significant weed infestation – 78 pcs./m^2 each, which was 41.4% less than on the control variant. Thus, it was established that the application of mineral and biofertilizers contributes to the reduction of weediness of sunflower crops due to its more intensive growth and better competition with weed plants. The assessment of weediness of sunflower crops by point score is given in Table 7.

The results of the inventory show that the weed infestation of sunflower crops ranged from strong to medium. Thus, the variants of the experiment with fertilizer N60, N60P60K60, Bionorm nitrogen and the variant without fertilizer (control) had strong weed infestation (score 3), and the remaining variants had a medium degree (score 2). A similar species-quantitative inventory of weeds was carried out in the phase of the beginning of the dying off of sunflower plants (R9) (Table 8). In this phase, the most common among cereal weeds was *setaria* spp. in the amount of 48 pcs./m^2 on the control variant without fertilizer application and

Table 7. Weediness of sunflower crops by three-point scale in phase V8

Fertilizer system	Weediness score	Crop weediness
N_{60}	3	Strong
$_{P6}$0	2	Average
$N_{60}P_{60K6}$0	3	Strong
Bionorm nitrogen	3	Strong
Bionorm phosphorus	2	Average
Bionorm nitrogen + Bionorm phosphorus	2	Average
N_{30}+ Bionorm nitrogen	2	Average
P_{30}+ Bionorm phosphoruѕ	2	Average
$N_{30}P_{30}$+ Bionorm nitrogen + Bionorm phosphoruѕ	2	Average
Without fertilizer (control)	3	Strong

Table 8. Species composition of weeds in the sunflower agrophytocenosis in the R9 phase, M ± m

Fertilizer system	Number of weeds, pcs./m^2						
	Small weeds				Perennial		Total
	Monocotyledons		Dicotyledons		Dicotyledons		
	Species	Number	Species	Number	Species	Number	
N_{60}	*Setaria spp*	16±2	*Chenopodium spp*	5±1	-	-	21±3
P_{60}	*Setaria spp*	15±2	*Chenopodium spp*	4±1	-	-	19±3
$N_{60}P_{60}K_{60}$	*Setaria spp*	19±3	*Chenopodium spp*	5±1	-	-	30±4
			Amaranthus retroflexus	6±2			
Bionorma nitrogen	*Setaria spp*	36±4	-	-	-	-	36±5
Bionorm phosphorus Bionorma nitrogen + Bionorm phosphorus	*Setaria spp*	32±3	*Chenopodium spp*	9±2	-	-	52±6
			Amaranthus retroflexus	11±2			
N_{30}+ Bionorma nitrogen	*Setaria spp*	34±3	*Amaranthus retroflexus*	8±2	*Convolvulus arvensis*	8±2	50±5
P_{30}+ Bionorm phosphorus	*Setaria spp*	52±6	*Chenopodium spp*	18±3	-	-	70±7
P_{30}+ Bionorm phosphorus	*Setaria spp*	17±2	*Amaranthus retroflexus*	13±2	-	-	30±4
$N_{30}P_{30}$+ Bionorma nitrogen + Bionorm phosphorus	*Setaria spp*	20±2	*Chenopodium spp*	9±2	-	-	29±4
Without fertilizer (control)	*Setaria spp*	48±5	*Chenopodium spp*	11±2	*Convolvulus arvensis*	9±2	80±8
			Amaranthus retroflexus	12±2			

with N_{30} + Bionorm nitrogen application – 52 pcs./m². The least amount of setaria spp. was found on the variants of fertilizer N_{60} – 16 pcs./m² and P_{60} – 15 pcs./m².

Among dicotyledonous weeds in sunflower crops, white chenopodium (*chenopodium* spp) and common amaranthus (*amaranthus retroflexus*) prevailed. The largest number of white chenopodium (*chenopodium* spp) was found on the N_{30} + Bionorma nitrogen variant – 18 pcs./m², and the smallest number – when applying N_{60} – 5 pcs./m² and P_{60} – 4 pcs./m². Common amaranthus (*amaranthus retroflexus*) was found on the P_{30} + Bionorma phosphorus variant – 13 pcs./m² and on the control – 12 pcs./m². When fertilizing sunflower with Bionorma nitrogen, common amaranthus (*amaranthus retroflexus*) was not found at all. Among perennial weeds, only field bindweed (*convolvulus arvensis*) was detected in the Bionorm nitrogen + Bionorm phosphorus variant in the amount of 8 pcs./m² and in the control – in the amount of 9 pcs./m².

The total number of weeds in sunflower crops in this phase of growth and development was 19–80 pcs./m². The fewest weeds were detected in the P_{60} variants – 19 pcs./m² and N_{60} – 21 pcs./m², and the most – in the control – 80 pcs./m² and with the application of N_{30} + Bionorm nitrogen – 70 pcs./m². Table 9 shows the degree of weed infestation of sunflower crops according to the fertilization system in points in the context of the experiment variants in the phase of plant death. These indicators were formed based on the total number of weedy vegetation in each variant separately.

The results of the three-point scale show that the weediness of sunflower crops in the experiment ranged from strong to medium. Thus, the experiment variants with Bionorm phosphorus fertilizer, N_{30} + Bionorm nitrogen and the variant without fertilizer (control) had strong weediness (score 3), and the remaining variants had a medium degree (score 2). Figure 2. shows the species-quantitative dynamics of weediness of sunflower crops according to plant fertilization in the V8 (8-true leaf opened) and R9 (plant death) phases in the context of the experiment variants

Comparison of the number of blue setaria (*setaria* spp) in the 8th leaf phase and at the beginning of the dying off of sunflower plants showed that the number of blue setaria decreased the most on the $N_{60}P_{60}K_{60}$ variant – by 62%. The number of blue setaria (*setaria* spp) also decreased on the N60, Bionorm nitrogen fertilizer variants and on the control. At the same time, the number of blue setaria (*setaria* spp) increased from the 8th leaf phase to the beginning of the dying off of sunflower plants on the Bionorm phosphorus, Bionorm nitrogen + Binorm phosphorus, N_{30} + Binorm nitrogen, $N_{30}P_{30}$ + Binorm nitrogen + Binorm phosphorus variants. The number of blue setaria (*setaria* spp) increased the most on the Bionorm nitrogen + Binorm phosphorus variant – by 61.5%.

The number of white quinoa (*chenopodium* spp) from the 8th leaf phase of the sunflower to the death of the plants decreased on the variants N_{60}, $N_{60}P_{60}K_{60}$, P_{30}+ Bionorm phosphorus, $N_{30}P_{30}$ + Bionorm nitrogen + Bionorm phosphorus and on the control. And increased on the variants P_{60}, Bionorm phosphorus, N_{30} + Bionorm nitrogen. The number of common amaranth (*amaranthus retroflexus*) decreased on the variants Bionorm nitrogen, $N_{30}P_{30}$ + Bionorm nitrogen + Bionorm phosphorus and on the control, and increased on $N_{60}P_{60}K_{60}$,, Bionorm nitrogen + Bionorm phosphorus. The number of field bindweed

Table 9. Weed infestation of sunflower crops on a three-point scale in phase R9

Fertilizer system	Weediness score	Crop weediness
N_{60}	2	average
P_{60}	2	average
$N_{60}P_{60}K_{60}$	2	average
Bionorm nitrogen	2	average
Bionorm phosphorus	3	strong
Bionorm nitrogen + Bionorm phosphorus	2	average
N_{30}+ Bionorm nitrogen	3	strong
P_{30}+ Bionorm phosphorus	2	average
$N_{30}P_{30}$+ Bionorm nitrogen + Bionorm phosphorus	2	average
Without fertilizer (control)	3	strong

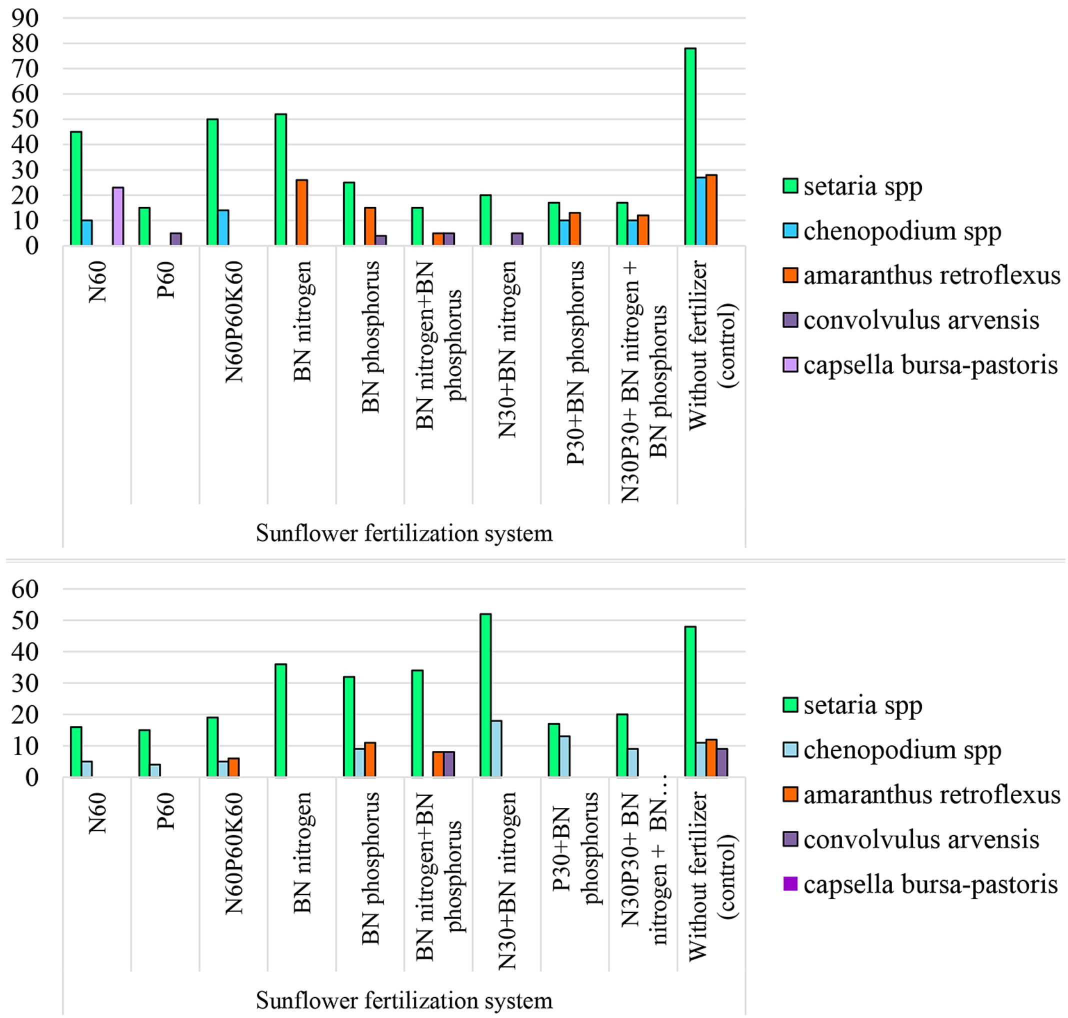

Figure 2. Comparative characteristics of the species and quantitative composition of weeds in sunflower crops in phases V8 (8th true leaf opened) and R9 (plant death)

(convolvulus arvensis) decreased on the variants P_{60}, Bionorm phosphorus, N_{30} + Bionorm nitrogen, and increased with the application of Bionorm nitrogen + Bionorm phosphorus and on the control.

In general, the total number of weeds in sunflower crops from the 8th leaf phase to the beginning of plant death decreased in the N_{60} variants by 73%, N_{60}, $N_{60}P_{60}K_{60}$, by 53%, control by 40%, P_{30} + Bionorm phosphorus by 25%, and $N_{30}P_{30}$ + Bionorm nitrogen + Bionorm phosphorus by 26%. The number of weeds increased in the N_{30} + Bionorm nitrogen variants by 64%, Bionorm nitrogen + Bionorm phosphorus by 50%, and P_{30} + Bionorm phosphorus by 15%.

CONCLUSIONS

Fertilizing sunflower crops with the biological preparation Bionorma phosphorus allows to significantly reduce the spread of diseases in its crops. Bionorma phosphorus exhibits a powerful preventive fungicidal effect. The greatest damage to sunflower diseases is observed in the absence of fertilizers and with the application of mineral nitrogen N_{30}. In the phase of the 8th leaf of sunflower, depending on the fertilizer, 5 types of weeds were found in its crops: gray mouse grass (*setaria* spp), white quinoa (*chenopodium* spp), common buckwheat (*capsella bursa-pastoris* L., *capsella hyrcana* Grosch.), common amaranth (amaranthus retroflexus) and field bindweed (*convolvulus arvensis*). In this phase, the options of mineral phosphorus fertilizer P_{60} – 20 pcs./m^2, Bionorma nitrogen + Bionorma phosphorus and N30 + Bionorma nitrogen –25 pcs./m^2 each. The most weedy option was the one without fertilizer application – 133 pcs./m^2. Subsequently, the number of weeds in crops decreases the most in the N_{60} fertilizer options – by 73%, N60P60K60 – by 53%.

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