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GRAIN CORN PRODUCT YIELD AND GROSS VALUE DEPENDING ON THE HYBRIDS AND APPLICATION OF BIOPREPARATIONS IN THE IRRIGATED CONDITIONS

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Abstract

Modern crop production is aimed to decrease anthropogenic loads on environment due to the replacement of chemical pesticides with biological preparations. The study on the efficiency of biological preparations Fluorescein BT, Trichopsin BT, and Biospectrum BT in corn hybrids of different ripeness groups (FAO 190, 290, and 420), cultivated in the conditions of irrigation in the Steppe zone of Ukraine, was conducted during 2018–2020. The goal of the study was to evaluate the level of technical efficiency of the biopreparations against common diseases (corn smut and fusarium of the cob) and insect (European corn borer), and their impact on the crop yield. It was determined that the studied biopreparations decreased corn smut infestation rate in the hybrids of corn by 1.7–4.2%, while the infestation rate of fusarium disease dropped by 1.6–3.9%. European corn borer infestation was reduced under the application of Trichopsin BT and Biospectrum BT, which possess insect-fungicidal and growth-promoting effects, by 2.7–4.6% depending on the genotype of the hybrids. High technical efficiency of the studied preparations was determined: Fluorescein BT against corn smut showed technical efficiency of 24.0–30.4%; Trichopsin BT – 38.2–57.9%; Biospectrum BT – 46.0–58.6%, respectively. Application of the biological preparation Fluorescein BT provides the formation of the highest grain yield of corn, which averaged to 14.89 t/ha. The maximum yield in the study was recorded for the hybrid Arabat (FAO 420) under the application of the biopreparation Fluorescein BT – 17.06 t/ha. At the same time, this variant provided the highest gross value of the grain product – 3,968 EUR/ha. The study results provide a proof of high efficiency of the studied biological preparations in the corn cultivation under irrigation.

Key words**:** *biological preparations, corn smut, European corn borer, fusarium, yield, gross value*

INTRODUCTION

The formation of highly productive crops of spring cereals, including corn, is strongly dependent on the soil-climatic zone of cultivation, the general level of agriculture, soil fertility and varietal traits. Therefore, the increase in grain yield is inextricably linked with the improvement and optimization of the basic elements of cultivation technology. One of the most important and effective among them is plant nutrition. Creating a favorable nutritional background plays an exceptional role for the growth and development of corn plants, the formation of their vegetative mass and significant increase in grain yield with high indices of quality [14].

The issue of preserving soil fertility and increasing crop yields has always been relevant to mankind. The chemicalization and intensification of agriculture have given us answers to all possible questions. However, significant side effects of these systems, in particular environmental aspects, have brought agricultural producers to a standstill. Intensive production, on the one hand, requires a scientifically sound system that would allow to obtain the highest yields at the lowest material and technical expenses without reduction of soil fertility, and, on the other hand, would be as environmentally friendly as possible. At the same time, the use of only organic fertilizers in production does not justify itself due to their high cost and significant volumes needed [15].

All these facts push modern farmers around the world to move to so-called alternative

technologies, which provide for the following goals:
-a more complete combination of production and natural processes;
-reduction of the use of preparations and fertilizers that are harmful to the health of agricultural workers;
-increase in the production use of biological and genetic potential of plants (selection of the most productive, disease-resistant varieties);
-improvement of production processes;
-obtaining environmentally friendly, safe for the consumers' health products;
-use of energy and environmental saving technologies.

Increasingly popular in agricultural production is the direction aimed at the increase in the environmental friendliness of agriculture. The biological method of plant protection (biological control or biocontrol) in its narrow classical sense is a method of controlling pests, weeds and plant diseases using natural enemies. It is based on natural mechanisms ("predator - victim", "parasite - host") and active human intervention in the process of regulation and suppression of pests and pathogens [2].

Increased attention is paid to plant protection in agricultural production because pests and plant diseases can significantly reduce crop yields and agricultural production. According to analysts, more than a third of the losses in the agricultural sector fall on the destruction of crops by pests and plant diseases. Every year, due to the influence of dangerous plant pests, 40% of crop yields are lost [24, 37].

The consequence of excessive fascination with chemical methods of plant protection is an increase in biocenoses and, especially in agrocenoses, threatening phenomena associated with contamination of plants, soils, water, and food by chemical pesticide residues, reduced resistance of pests to pesticides, impaired ecosystem resilience due to the loss of a part of biota as a result of the action of chemicals. This adversely affects human health and environment [3].

The study of the impact of biological preparations with growth-regulating properties is promising and relevant, especially in the context of climate change. Analysis of the literature indicates that the use of biopreparations promotes opening of the potential inherent in the body, including certain immune responses, increases plant productivity and promotes the implementation of genotypic traits of varieties and hybrids. The issue of widespread use of biological preparations in agriculture is given considerable attention in most economically developed countries: France, Great Britain, Germany, Switzerland, the United States, and others [13, 16].

A particular interest in the biological method as a means of wide production application in agricultural production appeared in the 60s of the last century. This gave impetus to new studies of the bio method in plant protection, in particular the conditions of inclusion in the general processes of greening of agriculture, the development of new technological solutions to improve the efficiency of biocontrol and integrated methods of its application [11, 12, 26, 27]. Practical industrial production and use of biological preparations have been studied by numerous foreign and Ukrainian scientists [10, 19, 20, 25, 32, 33, 34].

In Ukraine and abroad, post-industrial agricultural production is being developed using biotechnological alternatives for fertilization and biological protection of plants, precision agriculture, minimization of soil structure degradation. The use of biological preparations allows to reduce the anthropogenic load of agricultural production on the environment with a simultaneous reduction of energy and material costs and increase the quality of the obtained products [1, 22, 23].

The Institute of Genetics, Physiology and Plant Protection of Moldova has found that in the plant body of corn with the use of bacterial strains *Pseudomonas putida* and *Bacillus subtilis* photosynthetic activity is increased, the aging of the leaf surface is delayed, biological potential is enhanced, immune system is strengthened, the level of damage by diseases and insects decreases. Under the influence of biologically active substances, the mass of the root system

increases and the biometric parameters of the cob increase, which leads to higher yields [21].

Along with chemical and biological methods of plant protection, plant breeding methods to increase plant resistance to adverse environmental conditions have become more important. The primary tasks of modern plant breeding are to create a source material resistant to adverse bio- and abiotic factors [4].

Corn is affected by pathogens of many infectious diseases, especially in the Southern Steppe of Ukraine under irrigation, where optimal conditions are created for their development.

Each of the pathogens has its own biological characteristics, a certain cycle of development and causes specific symptoms of a disease. The most dangerous are mold fungi of the genera: *Aspergillus, Penicillium, Fusarium, Trichoderma lignorum* (Tode) Harz. The following metabolites cause great damage to grain: aflatoxins, ochratoxins, zearalenone, cayic, penicilic, fusaric acid [31]. The predominance of one or another species of fungus in the complex of pathogens does not always indicate that it poses a major threat. Fungi with severe toxicity in the studied sample could be present in small quantities. Since cereals suffer from the action of common pests, in the experiments of Edel-Hermann, Lecomte devoted to determination of the effect of fusarium wilt on germination and seedling growth it was found out that at 100% infection at the time of seed germination provided the germination rate of 90-94% compared to control, while wheat and rye grain was severely affected by fungi and lost germination by 10-15 % [9]. Some species of *Fusarium* do not reduce the germination of infected grain but inhibit the growth and development of sprouts and roots [5]. Thus, according to Dudka, if the incidence of seedling mold is 20–25% (in some years it can go up to 70%), then the field germination decreases by 3–9%, which leads to a strong thinning of crops [8]. Surviving plants are characterized by inhibition of growth processes and have low productivity. The loss of corn yield from diseases because of mold-infected seeds and sprouts is 0.9–6.5 cwt/ha [17]. With severe fusarium wilt, the weight of 1000 grains are halved [36]. A highly effective measure of protection against pathogenic microflora is the treatment of corn seeds with fungicides. In terms of efficiency, the chemical measure outperforms all others and requires consideration of phytosanitary status and environmental safety [7, 35].

The need to preserve the environment and improve the hygiene of production determines the need to find safe measures to protect corn crops, to study the possibility of using biological preparations. We have worked to identify preparations of biological origin for the treatment of corn, which would reliably protect seeds and plants from soil microflora after sowing in the field.

The goal of the study is to improve the existing technology of cultivation innovative corn hybrids on the irrigated lands by determining the impact of new biological preparations on the plant disease and pest infestation and seed yield under irrigation in the Southern Steppe of Ukraine. The goal is achieved through the selection and scientific substantiation of the most effective preparations for the relevant groups of ripeness of hybrids under drip irrigation, which will increase the yield of corn hybrids using environmentally friendly biological preparations.

MATERIALS AND METHODS

The study was conducted in 2018–2020 at the experimental field of the Institute of Irrigated Agriculture of NAAS. Factor A studied different ripeness groups of the corn hybrids Stepovyi, Kakhovskyi, Arabat, Chongar, and selections of the Institute of Irrigated Agriculture of NAAS. Factor B - treatment of parental components of corn with innovative Ukrainian biological preparations Fluorescein BT, Trichopsin BT, Biospectrum BT. Biopreparations were used to treat seeds before sowing and plants during the growing season according to the recommendations of the Engineering and Technological Institute "Biotechnics" NAAS (Odesa).

Trichopsin BT. Microbiological preparation of insect-fungicidal and growth-stimulating action. The active formulation of the drug is mycelium, fungal spores of the genus *Trichoderma* and rhizosphere bacteria of the genus *Pseudomonas* with a titer of not less than 2.0×10^{10} CFU/cm^3, as well as biologically active substances produced by producer strains.

Fluorescein BT. Microbiological preparation with fungicidal and growth-stimulating action. Contains rhizosphere bacteria of the genus Pseudomonas with a titer of not less than 5.0×10^{9} CFU/cm^3, as well as biologically active substances (BAS): phenazine-carboxylic acids, siderophores, cytokinin.

Biospectrum BT. Microbiological preparation of insect-fungicidal action. Contains rhizosphere bacteria of the genus Pseudomonas with a titer of not less than 5.0×10^{9} CFU/cm^3, biologically active substances (BAS): acids of the genus phenazine-carboxylic, a complex of active pigments that are active factors in the preparation.

The cultivation technology of corn was generally accepted for irrigated conditions and met the requirements of corn production technologies for agroecological conditions of the Steppe zone of Ukraine [30].

During the growing season, phenological observations and biometric records were performed according to appropriate methods. After harvesting a structural analysis of the cobs was performed in the laboratory of the Institute.

The experiments were performed under irrigation. The main criterion for planning the irrigation regime was the level of pre-irrigation soil moisture (LPSM).

The biologically optimal regime of corn irrigation is the regime in which at all the stages of the plant organogenesis LPSM is maintained at the level of 80% FC.

The methodology of the study is generally accepted for field experiments in the conditions of irrigation and plant breeding studies with corn plant [29]. The technical efficiency of the preparations was calculated according to the method of Tribel et al. [28].

RESULTS AND DISCUSSIONS

Corn smut (*Ustilago zeae* (Beckm) Unger.). The disease is widespread but causes the greatest damage in the semi-arid central regions of the Steppe zone, especially on susceptible hybrids, affecting 10-25% of plants.

Harmfulness of corn smut depends on the place and time of the infestation, the intensity of spreading. High temperatures and periodic droughts, as well as damage to plants by Swedish flies, *Phyllotreta*, European corn borer and other insects, and mechanical trauma during tillage and sandstorms are the most favorable conditions for the development of corn smut [6].

Fusarium wilt is one of the most difficult diseases of corn, as there are many species of Fusarium that cause the disease. Fusarium wilt is the most common and dangerous disease in the irrigated lands of southern Ukraine. Irrigation and high air temperature contribute to the development of the disease. Harmfulness of fusarium root and stem rot is manifested in the thinning of crops, reduction in the productivity of infested plants. Severe damage to corn cobs leads to a decrease in cob length, grain weight, loss of seed germination capacity [18].

The studied biological preparations had a positive effect on increasing resistance to fungal diseases. In the early-ripening hybrid Stepovyi, all the biological preparations had a positive effect on the reduction of the intensity of infestation of with corn smut (Ustilago zeae Beckm.).

The biological preparation Fluorescein BT reduced the manifestation of the disease compared to untreated control by 1.7%, the biological preparation Trichopsin BT – by 3.0%, the biological preparation Biospectrum BT – by 2.9%, respectively (Table 1).

There was a decrease in the incidence of corn smut (*Ustilago zeae* Beckm.) on the plants of middle-ripening hybrid Kakhovskyi due to the use of the biological preparation Fluorescein BT by 1.7%, the biological preparation Trichopsin BT reduced the incidence by 2.1%, while the biological preparation Biospectrum BT provided the reduction of 4.0%.

Table 1. Effect of treatment with biopreparations on the intensity of corn hybrids infestation, % (average for 2018–2020)

Hybrid (Factor A)	Treatment with biopreparations (Factor B)	Intensity of infestation, %		
		Corn smut (*Ustilago zeae Beckm.*)	Fusarium of the cob (*Fusarium moniliforme Scheld.*)	European corn borer (*Ostrinia nubilalis*)
Stepovyi (FAO 190)	Control, no treatment	6.3	9.3	15.4
	Fluorescein BT	4.6	7.3	15.4
	Trichopsin BT	3.3	7.5	11.8
	Biospectrum BT	3.4	6.4	10.8
Kakhovskyi (FAO 290)	Control, no treatment	7.6	7.7	15.8
	Fluorescein BT	5.9	5.9	15.8
	Trichopsin BT	5.5	4.7	11.3
	Biospectrum BT	3.6	3.6	11.4
Chongar (FAO 420)	Control, no treatment	7.5	8.8	10.7
	Fluorescein BT	5.7	6.6	10.7
	Trichopsin BT	3.4	5.9	9.9
	Biospectrum BT	3.3	5.8	9.7
Arabat (FAO 420)	Control, no treatment	6.9	8.3	11.4
	Fluorescein BT	4.8	6.6	11.4
	Trichopsin BT	2.9	5.9	9.9
	Biospectrum BT	2.9	5.7	8.7
LSD		0.33	0.31	0.37

Source: Own study.

The studies have shown that in the middle-late hybrid Chongar, the reduction in disease from the use of the biological preparation Fluorescein BT was 1.8%, the biological preparation Trichopsin BT reduced the manifestation of the disease by 4.1%, and the biological preparation Biospectrum BT – by 4.2%.

In the middle-late hybrid Arabat, biopreparations also reduced the development of corn smut (*Ustilago zeae* Beckm.). The biological preparation Fluorescein BT reduced the incidence of the disease by 2.1%, the biological preparation Trichopsin BT and the Biospectrum BT did it by 4.0%.

The incidence of fusarium cob blight also decreased with the use of biological preparations (Table 1). The most effective preparation was Biospectrum BT. Incidence of fusarium cob blight in the hybrids decreased by 1.6–2.9%. The hybrid Kakhovskyi was characterized by the lowest incidence of cob fusarium with the use of the preparation Biospectrum BT – 3.9%.

Infestation with European corn borer was reduced with the use of biological preparations Trichopsin BT and Biospectrum BT, which possess insect-fungicidal and growth-stimulating effects. The reduction in the incidence was 2.7–4.6% depending on the genotype of the hybrids.

The studied biological preparations showed high technical efficiency in the studied diseases. Biopreparation Fluorescein BT showed technical efficiency against corn smut ranging within 24.0% to 30.4%. The biological preparation Trichopsin BT showed a technical efficiency of 38.2% to 57.9%. A biopreparation Biospectrum BT showed technical efficiency from 46.0% to 58.6%, respectively (Table 2).

Technical efficiency of the biological preparation Fluorescein BT against the disease of fusarium cob blight (*Fusarium moniliforme* Scheld.) ranged from 20.5 to 25.0%, the biological preparation Trichopsin BT showed technical efficiency of 19.4 to 38.9%. The biopreparation Biospectrum BT showed technical efficiency from 31.3 to 53.2%.

Table 2. Technical efficiency of the used biopreparations on the corn hybrids, %

Hybrid (Factor A)	Treatment with biopreparations (Factor B)	Technical efficiency, %		
		Corn smut (*Ustilago zeae Beckm.*)	Fusarium of the cob (*Fusarium moniliforme Scheld*.)	European corn borer (*Ostrinia nubilalis*)
Stepovyi (FAO 190)	Control, no treatment	-	-	-
	Fluorescein BT	27.0	21.5	-
	Trichopsin BT	47.6	19.4	23.4
	Biospectrum BT	46.0	31.2	29.8
Kakhovskyi (FAO 290)	Control, no treatment	-	-	-
	Fluorescein BT	28.8	23.4	-
	Trichopsin BT	38.2	38.9	28.4
	Biospectrum BT	58.6	53.2	27.8
Chongar (FAO 420)	Control, no treatment	-	-	-
	Fluorescein BT	24.0	25.0	-
	Trichopsin BT	54.7	32.9	7.5
	Biospectrum BT	56.0	34.1	10.3
Arabat (FAO 420)	Control, no treatment	-	-	-
	Fluorescein BT	30.4	20.5	-
	Trichopsin BT	57.9	28.9	15.1
	Biospectrum BT	57.9	31.3	23.7

Source: Own study.

Technical efficiency of the biological preparation Trichopsin BT under the infestation of corn plants with European corn borer (*Ostrinia nubilalis*) ranged from 7.5 to 28.4%, the biological preparation Biospectrum BT showed technical efficiency of 10.3 to 29.8%. The biological preparation Fluorescein BT is not an insecticide, so it had no effect on European corn borer (*Ostrinia nubilalis*).

Productivity formation of any crop depends on many factors. First, soil and climatic conditions of the cultivation area, varietal or hybrid composition, seed quality, sowing dates, application of pesticides, strict adherence to all methods of cultivation technology is of great importance [18].

The results of the corn hybrids yield estimation showed that under the influence of agrotechnical elements in the conditions of irrigation, the productivity of the studied corn hybrids, on average, ranged from 11.69 to 17.06 t/ha (Table 3).

It was found that the treatment with the biological preparation Fluorescein BT promotes the formation of the highest grain yield of corn, which averaged to 14.89 t/ha. At treatment with Trichopsin BT, the grain yield of corn was slightly lower – 14.78 t/ha. At treatment with Biospectrum BT, the grain yield of corn was 14.45 t/ha.

In comparison with the control, the increase in the yield from the application of the preparation Fluorescein BT was 1.34 t/ha or 9.9%. The increase in the yield from the application of the preparation Trichopsin BT was 1.23 t/ha or 9.1%, the increase in the yield from the application of the preparation Biospectrum BT was 0.90 t/ha or 6.6%.

The hybrid Arabat, on average during the period of the study, turned out to be the most productive – the average grain yield was 16.74 t/ha.

The maximum yield of the hybrid Arabat was obtained under treatment with Fluorescin BT – 17.06 t/ha, slightly lower yield was obtained in the variants with the hybrid Chongar – 16.74 t/ha.

The maximum yield of the hybrid Stepovyi of 12.27 t/ha was obtained under treatment with the preparation Fluorescein BT, the yield increase is 0.88 t/ha or 4.9%.

The hybrid Kakhovskyi provided the maximum yield under treatment with the

preparation Fluorescein BT – 13.65 t/ha, the increase from the use of the preparation was 0.78 t/ha or 6.1%.

The highest gross value of the grain product was provided by the hybrid Arabat (FAO 430) AND on the variants with the biopreparation Fluorescein BT. Early-ripening hybrid Stepovyi (FAO 190) and the biopreparation Biospectrum together with the control (no treatment with biopreparation) provided the lowest gross value of the corn grain product per hectare.

Table 3. Effect of the biopreparations on the grain yield of the corn hybrids of different ripening groups, t/ha (average for 2018–2020)

Hybrid (Factor A)	Treatment with biopreparations (Factor B)				Average for the Factor A
	Control, no treatment	Fluorescein BT	Trichopsin BT	Biospectrum BT	
Stepovyi (FAO 190)	11.69	12.27	12.19	11.64	11.95
Kakhovskyi (FAO 290)	12.87	13.65	13.38	13.08	13.25
Chongar (FAO 420)	16.05	16.74	16.58	16.35	16.43
Arabat (FAO 430)	16.45	17.06	16.78	16.67	16.74
Average for the Factor B	13.55	14.89	14.78	14.45	14.42
Partial differences significance LSD_{05}: A = 0.24; B = 0.16					
Major effects differences significance LSD_{05}: A = 0.15; B = 0.14					

Source: Own study.

Table 4. Gross value of the grain corn yield in different hybrids under the treatment with biopreparations (average for 2018–2020), EUR/ha

Hybrid (Factor A)	Treatment with biopreparations (Factor B)				Average for the Factor A
	Control, no treatment	Fluorescein BT	Trichopsin BT	Biospectrum BT	
Stepovyi (FAO 190)	2,719	2,854	2,835	2,707	2,779
Kakhovskyi (FAO 290)	2,994	3,175	3,112	3,042	3,081
Chongar (FAO 420)	3,733	3,894	3,857	3,803	3,822
Arabat (FAO 430)	3,826	3,968	3,903	3,877	3,894
Average for the Factor B	3,318	3,473	3,427	3,357	

Source: Own study. The gross value of the product was calculated using the prices on FOB Ukraine dated for July, 02, 2021.

CONCLUSIONS

The biopreparations had a positive effect on the resistance to fungal diseases. In the early-ripening hybrid Stepovyi, all the biopreparations reduced the intensity of corn smut infestation (*Ustilago zeae* Beckm.): the biopreparation Fluorescein BT reduced the manifestation of the disease in comparison with the untreated control by 1.7%, the biopreparation Trichopsin BT by 3.0%, and the biopreparation Biospectrum BT – by 2.9%. On the middle-ripening hybrid Kakhovskyi, the application of the biological preparation Fluorescein BT decreased the infestation by 1.7%, the biological preparation Trichopsin BT reduced the manifestation of the disease by 2.1%, the biological preparation Biospectrum BT – by 4.0%. On the middle-late ripening hybrid Chongar, the manifestation of the disease decreased due to the application of the biological preparation Fluorescein BT by 1.8%, the biological preparation Trichopsin BT reduced the manifestation of the disease by 4.1%, the biological preparation Biospectrum BT – by

4.2%. On the middle-late ripening hybrid Arabat, the biological preparation Fluorescein BT reduced the incidence of the disease by 2.1%, the biological preparation Trichopsin BT and the Biospectrum BT – by 4.0%, respectively.

The infestation with fusarium cob blight has also decreased under the use of biological preparations - the most effective one was Biospectrum BT. The infestation with fusarium cob blight in the hybrids decreased by 1.6–2.9%. The hybrid Kakhovskyi had the lowest infestation rate with cob fusariosis under the application of the preparation Biospectrum BT – the infestation decreased by 3.9%.

European corn borer infestation was reduced under the application of Trichopsin BT and Biospectrum BT, which have insect-fungicidal and growth-promoting effects. The reduction in the infestation was 2.7–4.6% depending on the genotype of the hybrids.

High technical efficiency of the biological preparations was determined: Fluorescein BT against corn smut showed technical efficiency of 24.0% to 30.4%. Trichopsin BT showed technical efficiency of 38.2% to 57.9%, Biospectrum BT showed technical efficiency of 46.0% to 58.6% against corn smut.

Treatment with the biological preparation Fluorescein BT favors to the formation of the highest grain yield of corn, which averaged to 14.89 t/ha. At treatment with Trichopsin BT, the grain yield of corn was slightly lower – 14.78 t/ha. At treatment with Biospectrum BT, the grain yield of corn was 14.45 t/ha.

The maximum yield in the study was recorded for the hybrid of the middle-late ripening group Arabat under treatment with the preparation Fluorescein BT – 17.06 t/ha. This variant provided the highest gross grain product value of 3,968 EUR/ha.

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