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The influence of moistening conditions and seed treatment with biological preparations on the growth and yield of winter wheat varieties

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Purpose. To determine the influence of the moistening conditions and treatment of seeds with biological preparations Azotofit-r, Fitotsyd, Mycofriend-r, Orhanik-balans Monofosfor on growth processes at the initial plant life stages, formation of stand density and grain yield of winter wheat varieties. **Methods.** General scientific, special, field, mathematical-statistical and calculation-comparative methods were used for research. **Results.** The key to a high yield of winter wheat is in obtaining even stands, forming the optimal density of plant stands at the time of harvesting, taking into account their survival rates, the coefficient of productive tillering, and the study of new varieties adapted to climate changes. According to the research results, it was determined that, on average, for 2020–2022, the highest grain yield among the studied varieties of winter wheat was recorded in plants of the variety 'Duma Odeska' (8.38 t/ha) under irrigation in the variant with pre-sowing treatment of seeds with the biopreparation Azotofit-r, which was 0.78 t/ha more compared to the control (treatment with water). In the variant without irrigation, the yield was 6.08 t/ha, which was less than the control by 2.3 t/ha or 27.4%. **Conclusions.** The developed elements of the technology of winter wheat varieties growing make it possible to form the optimal plant density and significantly increase grain yield in the conditions of the Southern Steppe of Ukraine.

Keywords: *Triticum aestivum L.; field germination; number of plants; productive tillering; survival; yield.*

Introduction

Hamaiunova and others claim that winter wheat has always been and will continue to be the most important grain crop in Ukraine [1]. According to the State Statistics Service of Ukraine, the sown area of winter wheat in our country amounted to 6.5 million hectares in 2022, which is 6.1% (0.4 million hectares) more than in 2021. As of August 26, 2022, it was possible to collect wheat from only 4.6 million hectares of land area, with a gross harvest of 18.8 million tons of grain against 32 million tons collected in 2021, which is associated with hostilities in Ukraine, in particular, mining of territories, destruction of fields, late implementation elements of crop care and harvesting technology, etc. [2].

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According to the Ministry of Agrarian Policy and Food of Ukraine, it is predicted that the area planted with winter wheat for the harvest in 2023 will decrease by a third from last year, so the main reserve for increasing the gross harvest of this crop remains the increase in its yield. According to V. V. Hamaiunova and A. V. Panfilova, in order to obtain large yields of grain that would correspond to bread-making quality, it is necessary to apply scientifically based doses of nitrogen fertilizers, the prices of which are constantly increasing. Therefore, the authors recommend looking for new ways to increase yield and preserve grain quality [3].

The studies of J. R. Lamichhane, V. V. Bezpalko, O. Voloschuk and others determined that the use of biological preparations (mycorrhizal agents, biostimulants, biofungicides, etc.) for pre-sowing seed treatment is one of the reserves for increasing the yield of winter wheat grain [4–6]. Thus, according to O. O. Viniukov and co-authors [7], the use of biological preparations promotes the development of winter wheat plants during the growing season. The highest coefficients of tillering in the au-

thors' experiments were obtained in variants with seed treatment, namely: on the background of $N_{60}P_{60}$ and the use of Rost-concentrate, on the background of $N_{60}P_{60}$ and the use of microfertilizer Sizam, which contains trace elements (manganese, zinc, iron, copper, cobalt); at the same time, seed treatment contributed to the formation of high yields.

The studies of Kovalenko and others [8] established that seed treatment with the biological preparation Agat-25, which contains in its composition inactivated bacteria *Pseudomonas aureofaciens* strain H16 titer 3-6X10 10 cells/ml, biologically active substances with a total amino acid content of 38% and Biocomplex-BTU on the basis of nitrogen-fixing, phosphorus- and potassium-mobilizing bacteria, microorganisms with fungicidal properties, macro- and microelements, increased the field germination of seeds and contributed to the formation of a 10–15% higher coefficient of tillering of winter wheat plants of the 'Podolianka' variety.

Voloschuk and co-authors [9] confirmed the high stimulating effect of Vympel-K biological preparation (plant growth stimulator, which contains polyethylene oxides – 770 g/l and amber-humate complex – 30 g/l) at the application rate of 500 g/t, compared to the control, which provided high seed germination energy and laboratory germination (92 and 96%).

The authors of the publication [10] claim that the use of the biological preparation Help Rost for pre-sowing treatment of seeds contributed to an increase in the coefficient of the total tillering of plants by 0.2 stems per plant, compared to the control, and in the version with the biological preparation Azotofit, this indicator was correspondingly higher by 0.3 stems per plant.

According to S. O. Pryplavko and V. M. Havii [11], the field germination of seeds of the 'Yuvivata' soft winter wheat variety in the control plots was on average 85%, and in the experimental variants (the use of Vympel, Azotofit, Succinic acid) ranged from 74.3 to 83.3% and was the lowest under the condition of using succinic acid. According to the authors, growth regulators do not affect the indicator of field germination of plants.

Siroshtan and others [12] found a positive effect of the Vimpel K growth stimulator on seed germination and increase in germination activity by 4–5%, compared to the control.

In the publication [13], the authors also note the positive effect of the Ekostim biostimulant on the germination energy and field germination of seed.

Studies with the 'Vidrada' variety conducted by T. O. Hrabovska and H. H. Melnyk [14] showed that the use of the preparations Fito-Help, MikoHelp and Biokompleks BTU, Biokompleks zernovi, Riverm affects the increase in the yield of winter wheat grain by 17.1–26.1%. At the same time, P. Juozas and S. Jolanta [15] did not find significant differences between the effect of different biological preparations on the germination energy of winter wheat seeds.

Moisture is the limiting factor for obtaining significant harvests in the southern Steppe of Ukraine, so improving moistening conditions is a task facing agricultural producers and scientists [16–18]. It is also important to find ways to increase productivity, improve the elements of the crop structure of new varieties of winter wheat thanks to the use of biological preparations.

The purpose of the research is to establish the influence of seed treatment and moistening conditions on the growth processes of winter wheat varieties in the autumn-spring period and in general during the growing season and the formation of their productivity.

Materials and methods

The research was conducted during 2020–2022 at the Educational-Scientific-Practical Center of Mykolaiv State Agrarian University, located in the village of Blagodarivka, Mykolaiv district, Mykolaiv region, belonging to the Southern Steppe zone of Ukraine.

In a three-factor field experiment, the following varieties (factor A) were studied: 'Ovidii', 'Duma Odeska', 'Ozerna', 'Anatoliia'; seed treatment (factor B) – treatment with water (control) and biological preparations Azotofit-r (0,3 l/t), Fitotsyd (1,5 l/t), Mycofriend-r (1,0 l/t), Orhanik-balans Monofosfor (0.5 l/t); moisture conditions (factor C) – without irrigation, with irrigation. The varieties most common in the steppe zone of Ukraine were used as material for research, the owners of which are the Institute of Irrigated Agriculture of the National Academy of Sciences of Ukraine, the Plant Breeding and Genetic Institute – National Center of Seed and Cultivar Investigation of the National Academy of Sciences of Ukraine and PABRE "Bor". All studied varieties are recommended for distribution in the steppe zone of Ukraine: 'Ovidii' and 'Anatoliia' – intensive type, universal use; 'Duma Odeska' is characterized by high drought resistance and, according to the owner, a positive reaction to nitrogen fertilizers; 'Ozerna' is characterized by 9-point drought resistance.

For the pre-sowing treatment of seeds, biological preparations of the Ukrainian manufacturer of microbial and enzyme preparations "BTU-center" were used. Namely: Azotofit-r is a biostimulant for increasing plant growth and nutrition, based on the nitrogen-fixing bacterium *Azotobacter chroococcum*; biofungicide Fitotsyd – based on living cells and spores of the natural bacterium *Bacillus subtilis*; Mycofriend-r is a mycorrhiza-forming biopreparation for plant nutrition and protection based on fungi of the genus *Glomus*, *Trichoderma harzianum*, as well as a complex of soil rhizosphere bacteria; Orhanik-balans Monofosfor for growth stimulation, protection and phosphorus nutrition of plants based on phosphorus-mobilizing bacteria. The seeds were processed on the day of sowing in the shade, avoiding direct sunlight.

The total experimental area is 50 m^2, the accounting area is 26 m^2, with four-fold repetition. The soils of the experimental site are southern chernozems, residual-slightly saline, heavy loamy soils on loess.

The predecessor in all the years of research was peas. Before sowing, winter wheat seeds were treated with the fungicide Insure Perform at the rate of 0.5 l/t. In order to increase the effectiveness of seed treatment with biological preparations, Liposam bioadhesive was used at the rate of 0.3 l/t for all experimental options. Soft winter wheat was sown in the first decade of October with a seed sowing rate of 4.5 million seed/ha to the seeding depth of 5–6 cm with simultaneous application of the complex mineral fertilizer nitroamophoska ($N_{16}P_{16}K_{16}$) in norm of 175 kg/ha. The experimental plots were fertilized three times: first – on the frozen soil with ammonium nitrate in the amount of 145 kg/ha (N_{50}); then – in stem extension phase with urea in the amount of 130 kg/ha (N_{60}); then – in the earing phase with urea in the amount of 22 kg/ha (N_{10}). The crops were cared for by spraying against weeds with Quelex 200 herbicide at the rate of 50 g/ha in the stem extension phase, against diseases and pests with the insecticide Decis 100 ES KE (0.1–0.15 kg/ha) in combination with Impact C fungicide at a rate of 0.5 l/ha. In the irrigation options, moisture loading watering was carried out before sowing 800–1000 m^3/ha and 2 vegetation irrigations of 400–500 m^3/ha.

Weather conditions differed between years of research: 2020 was dry in terms of moisture and temperature conditions, 2021 was wet, and 2022 was moderately wet.

Results and discussion

It was determined that the growth and development of *Triticum aestivum* L. plants depended on many factors, in particular pre-sowing treatment of seeds with biological preparations and moistening conditions, which affected their vital activity from the seedling to the ripening stage.

The emergence of timely and even stands largely depended on the conditions of moisture supply and pre-sowing treatment of seeds with biopreparations Azotofit-r, Fitotsyd, Mycofriend-r and Orhanik-balans Monofosfor.

Field germination of seeds for all studied varieties was higher in the variant with irrigation and in the control variant (treatment with water) – 84.5–87.2%, which is 7.1–9.1% more than in the variants without irrigation (Table 1).

Table 1

Field seed germination (%) of winter wheat varieties under the conditions of treatment with biological preparations and moistening conditions (average for 2020–2022)

Variety (factor A)	Seed treatment (factor B)				
	control (treatment with water)	Azotofit-r (0,3 l/t)	Fitotsyd (1,5 l/t)	Mycofriend-r (1,0 l/t)	Orhanik-balans Monofosfor (0,5 l/t)
without irrigation (factor C)					
'Ovidii'	76.9	75.8	72.8	75.8	77.4
'Duma Odeska'	78.1	76.3	75.4	76.3	77.6
'Ozerna'	78.6	77.5	77.7	77.6	77.6
'Anatoliia'	77.6	77.0	76.5	76.6	76.5
with irrigation (factor C)					
'Ovidii'	84.5	82.8	83.0	85.6	84.8
'Duma Odeska'	87.2	86.0	85.7	83.9	86.9
'Ozerna'	85.7	84.6	84.2	85.3	85.1
'Anatoliia'	85.5	84.7	84.8	84.7	84.9
$LCD_{0,05}$ by factor A (%) – 1.9–2.6 $LCD_{0,05}$ by factor B (%) – 2.7–4.2 $LCD_{0,05}$ by factor C (%) – 1.9–2.2					

Pre-sowing treatment of seeds with biological preparations, both in the variants without irrigation and under irrigation conditions, affected the decrease in the field germination of winter wheat seeds of the investigated varieties, except for the variety 'Ovidii'. Thus, on average during 2020–2022, under the conditions of seed treatment with biopreparations Azotofit-r, Fitotsyd, Mycofriend-r and Orhanik-balans Monofosfor, the field seed germination of all studied varieties decreased by 0.5–4.1% (option without irrigation) and by 0.3–1.7% (option with irrigation).

It was established that the pre-sowing treatment of winter wheat seeds of the 'Ovidii' variety with the biopreparation Orhanik-balans Monofosfor insignificantly increased the field germination of seeds by 0.3–0.5%, compared to the control option.

Using the method of dispersion analysis, it was determined that factor C (moistening conditions) had the greatest influence on the field germination of seeds (65–85%).

As a result of this study, it was found that the number of seedlings per 1 m^2 depended both on varietal characteristics and on the factors used (Table 2). Thus, on average for 2020–2022, this indicator was the highest for the variety 'Duma Odeska' under irrigation conditions on the control option (treatment with water) – 392 pcs./m^2, and was close to the options using Mycofriend-r and Orhanik-balans Monofosfor and was 390 and 391 pcs./m^2, respectively.

The smallest number of plants – 386 pcs./m^2, was formed when using the biopreparation Fitotsyd (by 6 pcs./m^2 less than the control indicator). Such a regularity was also observed under the condition of using the biopreparation Azotofit-r – 387 pcs./m^2, which is 7 pcs./m^2 less than the control.

Table 2

Plant density of winter wheat varieties in the seedling phase depending on seed treatment with biological preparations and moistening conditions, psc./m^2 (average for 2020–2022)

Variety (factor A)	Seed treatment (factor B)				
	control (treatment with water)	Azotofit-r (0,3 l/t)	Fitotsyd (1,5 l/t)	Mycofriend-r (1,0 l/t)	Orhanik-balans Monofosfor (0,5 l/t)
without irrigation (factor C)					
'Ovidii'	346	341	328	341	348
'Duma Odeska'	351	347	340	345	349
'Ozerna'	354	349	350	349	349
'Anatoliia'	349	346	344	345	344
with irrigation (factor C)					
'Ovidii'	380	373	364	387	382
'Duma Odeska'	392	387	386	390	391
'Ozerna'	386	381	379	384	383
'Anatoliia'	385	381	381	381	382
	$LCD_{0,05}$ by factor A (pcs./m^2) – 4.0–9.2				
	$LCD_{0,05}$ by factor B (pcs./m^2) – 6.4–9.2				
	$LCD_{0,05}$ by factor C (pcs./m^2) – 3.9–5.2				

Moistening conditions had a significant effect on plant stand formation. Thus, in the version without irrigation for the control variety 'Duma Odeska', the number of plants was 351 pcs./m^2, which was 41 pcs./m^2 or 10.6% less than in the version with irrigation. A smaller number of plants – 328 pcs./m^2, was produced by plants of the 'Ovidii' variety in rainy conditions with the use of Fitotsyd biopreparation for seed treatment, which is 18 pcs./m^2, or 5.2% less than the control. In the version without irrigation, a larger number of plants were produced by plants of the 'Ozerna' variety – 354 pcs./m^2, which is 8 pcs./m^2 more than in the plants of the 'Ovidii' variety, by 6 pcs./m^2 – than in the 'Anatoliia' variety and by 3 pcs./m^2 – than in the 'Duma Odeska' variety.

The formation of the number of plants per unit area during harvesting is influenced by the survival rate, which shows the number of saved plants during the harvesting period, expressed as a percentage of the number of sown germinating seeds. The research results confirmed the influence of moistening conditions and treatment of seeds with biological preparations on the survival of the varieties 'Ovidii', 'Duma Odeska', 'Ozerna' and 'Anatoliia'.

During 2020–2022, the highest survival – an average of 89.4%, which is 2.1% more than the 'Ovidii' variety, was in the variant with irrigation in the 'Ozerna' variety (Fig. 1).

Under irrigation conditions, seed treatment with Azotofit-r biopreparation had the greatest effect on this indicator. Thus, for the variety

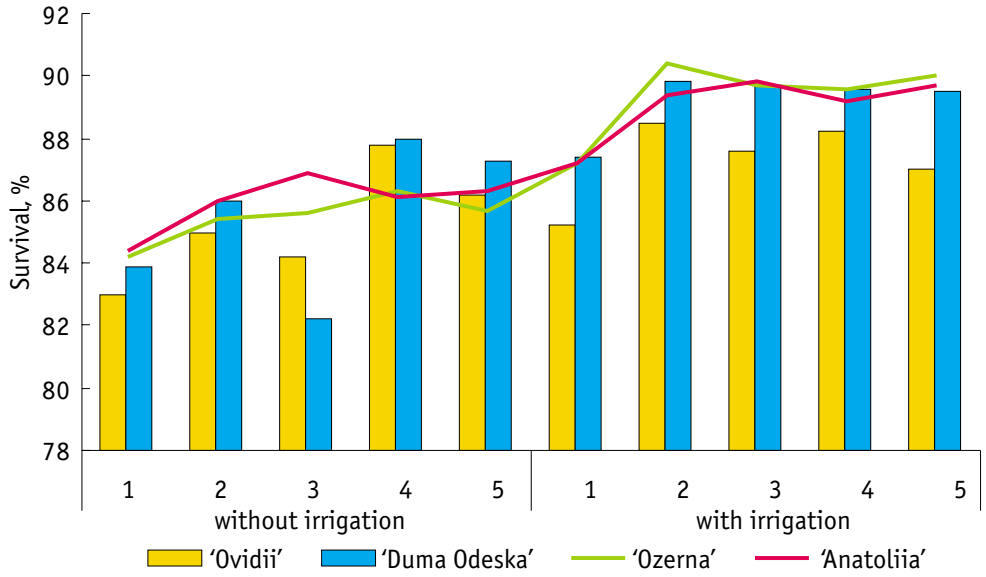

Fig. 1. Survival of winter wheat variety plants depending on seed treatment and moistening conditions for 2020–2022

Note. Seed treatment: 1. Treatment with water (control); 2. Azotofit-r (0.3 l/t); 3. Fitocide (1.5 l/t); 4. Mycofriend-r (1.0 l/t); 5. Orhanik-balans Monofosfor (0.5 l/t)

'Ozerna', plant survival was 90.4%, which is 3.2% more than the control (treatment with water). Under conditions without irrigation, the treatment of seeds of all varieties with the mycorrhizal preparation Mycofriend was more effective. Thus, their survival rate for 2020–2022 was 87.1% on average.

The coefficient of productive tillering and the number of plants at the time of harvesting are important elements of the crop structure and at the same time indicators of the structural formula for calculating the biological yield of grain crops.

On average, over the years of research, the main number of plants remained in the variants with irrigation for plants of the 'Duma Odeska' variety using the biopreparation Orhanik-balans Monofosfor – 350 pcs./m² with a survival rate of 89.5%, which is more than the control (treatment with water) by 7 pcs./m² and 2.1%, respectively. The same pattern was observed in other studied varieties (Table 3).

Table 3

The number of plants at the time of winter wheat harvesting depending on seed treatment and moistening conditions, pcs./m² (average for 2020–2022)

Variety (factor A)	Seed treatment (factor B)				
	Control (treatment with water)	Azotofit-r (0,3 l/t)	Fitotsyd (1,5 l/t)	Mycofriend-r (1,0 l/t)	Orhanik-balans Monofosfor (0,5 l/t)
without irrigation (factor C)					
'Ovidii'	287	291	276	299	305
'Duma Odeska'	295	299	292	303	304
'Ozerna'	294	298	299	301	299
'Anatoliia'	295	298	299	297	297
with irrigation (factor C)					
'Ovidii'	324	330	319	340	332
'Duma Odeska'	343	348	346	349	350
'Ozerna'	336	346	342	344	344
'Anatoliia'	336	347	342	340	343
$LCD_{0,05}$ by factor A (pcs./m²) – 6.2–7.1 $LCD_{0,05}$ by factor B (pcs./m²) – 6.7–13.5 $LCD_{0,05}$ by factor C (pcs./m²) – 5.5–8.8					

This indicator was the lowest for the variety 'Ovidii' under the condition of using the biopreparation Fitotsyd – 319 pcs./m², which is less than the control by 5 pcs./m². In non-irrigated options, the number of plants per 1 m² at harvest was on average 37 plants/m² or 9.7% lower compared to irrigated options. It was established that the coefficient of productive tillering in

plants of the variety 'Duma Odeska' was the largest among all studied varieties (Fig. 2).

Moistening conditions also had a significant impact on this indicator, namely: the higher coefficient of productive tillering – 2.6, was in the variety 'Duma Odeska' with irrigation under the condition of seed treatment with the biopreparation Fitotsyd, which was 0.4 more than in the variants without irrigation. A slightly smaller regularity was observed in other varieties: in the variety 'Ovidii' – by 0.3; in the variety 'Ozerna' – by 0.2; in the variety 'Anatoliia' – by 0.1.

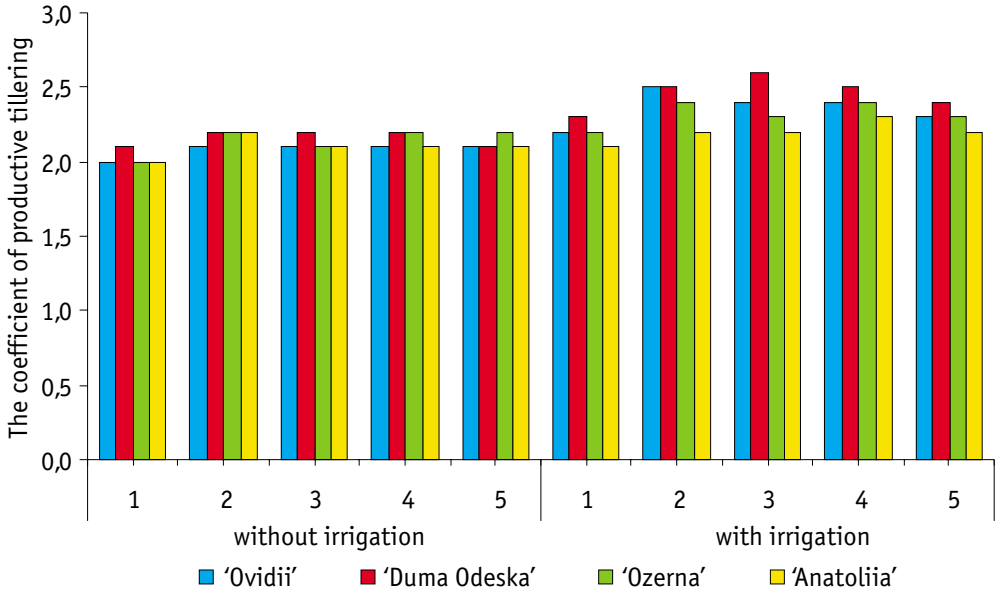

Fig. 2. The coefficient of productive tillering of winter wheat varieties depending on seed treatment and moistening conditions (2020–2022)

Note. Seed treatment: 1. Treatment with water (control); 2. Azotofit-r (0.3 l/t); 3. Fitotsyd (1.5 l/t); 4. Mycofriend-r (1.0 l/t); 5. Orhanik-balans Monofosfor (0.5 l/t)

Treatment of seeds with biological preparations before sowing had the following effect on productive tillering: for all varieties in conditions without irrigation, treatment with Azotofit-r and Mycofriend-r preparations was the most effective [coefficient of tillering – 2.2, which is 0.2 more than the control (treatment with water)]; under the condition of treatment with Fitotsyd and Orhanik-balans Monofosfor – 2.1, which is 0.1 more than the control.

The response of the 'Ovidii', 'Duma Odeska', 'Ozerna', 'Anatoliia' varieties to the growing conditions and the studied factors is one of the main elements in the formation of their productivity.

Table 4

Yield of winter wheat varieties under the conditions of seed treatment with biological preparations and moistening conditions, t/ha (average for 2020–2022)

Variety (factor A)	Seed treatment (factor B)				
	Control (treatment with water)	Azotofit-r (0,3 l/t)	Fitotsyd (1,5 l/t)	Mycofriend (1,0 l/t)	Orhanik-balans Monofosfor (0,5 l/t)
without irrigation (factor C)					
'Ovidii'	5.10	5.71	5.29	5.71	5.84
'Duma Odeska'	5.46	6.08	5.76	5.95	5.90
'Ozerna'	5.37	6.07	5.81	5.94	6.16
'Anatoliia'	5.29	6.04	5.98	5.90	5.80
with irrigation (factor C)					
'Ovidii'	6.73	8.15	7.31	7.85	7.44
'Duma Odeska'	7.60	8.38	8.28	8.11	7.94
'Ozerna'	7.04	8.20	7.60	7.85	7.72
'Anatoliia'	6.77	7.48	7.21	7.21	7.29
$LCD_{0,05}$ by factor A (t/ha) – 0.15–0.26 $LCD_{0,05}$ by factor B (t/ha) – 0.19–0.38 $LCD_{0,05}$ by factor C (t/ha) – 0.20–0.21					

On average, for 2020–2022, the highest grain yield (8.38 t/ha) was provided by the 'Duma Odeska' variety under the conditions of irrigation and seed treatment with Azotofit-r (Table 4).

A similar pattern was observed in other varieties. For plants of the 'Ovidii' variety, the yield was 8.15 t/ha, for the 'Ozerna' – 8.20, and for the 'Anatoliia' – 7.48 t/ha. Irrigation had a significant impact on productivity, the increase in yield from the use of which averaged 24.3%.

Depending on the seed treatment, the yield of the studied varieties changed as follows: on average, during 2020–2022, under irrigation conditions for all varieties in control (treatment with water), the yield was 7.04 t/ha, with the use of the biopreparation Azotofit-r, it was higher by 12.3%, when treated with the biological fungicide Fitotsyd – by 7.7%, when treated with the mycorrhiza-forming preparation Mycofriend-r – by 9.3%, and when treated with the Orhanik-balans Monofosfor biological preparation – by 7.4%.

In the variants without irrigation, the formation of the crop proceeded as follows: for all the studied varieties in the control (treatment with water), the yield was 5.31 t/ha; it was more by 10.9% when using the growth regulator Azotofit-r, subject to treatment with the biological fungicide Fitotsyd – by 7.0%, when treated with mycorrhiza-forming preparation Mycofriend-r – by 9.7%, and when using the biopreparation Orhanik-balans Monofosfor – by 10.5%.

Conclusions

A significant influence of moistening conditions and seed treatment with biological preparations on field germination, survival rate and elements of the plant yield structure of the studied soft winter wheat varieties was established. It was determined that the seed field germination and plant density in the germination phase of the studied winter wheat varieties increased depending on the variety and biological preparations in the options with irrigation by 6.5–10.3% and 8.3–13.5%, respectively, compared with the experimental plots without irrigation. Greater survival of winter wheat plants was observed when seeds were treated with biological preparations Azotofit-r (on irrigation) and Mycofriend (without irrigation). Plants of the 'Duma Odeska' variety had the highest yield during irrigation and seed treatment with Azotofit-r (0.3 l/t) – an average of 8.38 t/ha for 2020–2022, and it was the lowest (5.10 t/ha) in the 'Ovidii' variety in the control variant without irrigation and without seed treatment with biological preparations.

Використана література

1. Гамаюнова В. В., Корхова М. М., Панфілова А. В. та ін. Пшениця озима: ресурсний потенціал та технологія вирощування. Миколаїв : МНАУ, 2021. 300 с.
2. Рослинництво України 2021: статистичний збірник / за ред. О. Прокопенка. Київ : Державна служба статистики України, 2022. 184 с. URL: https://ukrstat.gov.ua/druk/publicat/kat_u/2022/zb/05/zb_rosl_2021.pdf
3. Гамаюнова В. В., Панфілова А. В. Окупність сумісного використання добрив та біопрепаратів на пшениці озимій в Південному Степу України. *Вісник Полтавської державної аграрної академії*. 2019. № 1. С. 41–48. doi: 10.31210/visnyk2019.01.05
4. Lamichhane J. R., Corrales D. C., Soltani E. Biological seed treatments promote crop establishment and yield: a global meta-analysis. *Agronomy for Sustainable Development*. 2022. Vol. 42, Iss. 3. Article 45. doi: 10.1007/s13593-022-00761-z
5. Bezpalko V. V., Stankevych S. V., Zhukova L. V. et al. Laboratory and field germination of wheat and spring barley depending on the mode of irradiation with MWF of EHF and pre-sowing seed treatment. *Ukrainian Journal of Ecology*. 2021. Vol. 11, Iss. 2. P. 382–391.
6. Voloschuk O., Voloschuk I., Stasiv O. et al. Regulation of winter wheat productivity. *Ukrainian Journal of Ecology*. 2021. Vol. 11, Iss. 9. P. 127–130.
7. Вінюков О. О., Бондарева О. Б., Коробова О. М., Чугрій Г. А. Вплив біопрепаратів на продуктивність пшениці озимої на різних фонах живлення в умовах Донецької області. *Вісник аграрної науки*. 2018. № 11. С. 41–47. doi: 10.31073/agrovisnyk201811-06
8. Коваленко О. А., Ключник М. А., Чебаненко К. С. Застосування біопрепаратів для обробки насіннєвого матеріалу пшениці озимої. *Наукові праці. Екологія*. 2015. Т. 256, Вип. 244. С. 74–77.
9. Voloschuk O., Voloschuk I., Hlyva V., Marukhnyak A. Biological mechanisms of regulation of winter wheat productivity in the conditions of the western forest-steppe of Ukraine. *Ştiinţa Agricolă*. 2020. Vol. 1. P. 3–11.
10. Пінчук Н. В., Вергелес П. М., Коваленко Т. М., Амонс С. Е. Ефективність застосування біопрепаратів в посівах пшениці озимої в умовах Правобережного Лісостепу. *Сільське господарство та лісництво*. 2022. № 24. С. 96–113.
11. Приплавко С. О., Гавій В. М. Порівняльний вплив регуляторів росту азотофіт, янтарна кислота та вимпел на динаміку процесів росту та продуктивність озимої пшениці сорту Ювівата. *Наукові записки Тернопільського національного педагогічного університету імені Володимира Гнатюка. Серія : Біологія*. 2019. Т. 76, № 2. С. 91–97. doi: 10.25128/2078-2357.19.2.15
12. Сіроштан А. А., Заїма О. А., Кавунець В. П. та ін. Вплив протруйників із стимулятором росту і мікродобривом на посівні якості та врожайність пшениці озимої. *Миронівський вісник*. 2019. Вип. 9. С. 63–67. doi: 10.31073/mvis201909-09
13. Василенко М. Г., Терновий Ю. В., Швиденко І. К., Душко П. М. Застосування біологічного стимулятора росту рослин «Екостим» у сільськогосподарському виробництві. *Агроекологічний журнал*. 2020. № 3. С. 96–101. doi: 10.33730/2077-4893.3.2020.211532
14. Грабовська Т. О., Мельник Г. Г. Вплив біопрепаратів на продуктивність пшениці озимої за органічного виробництва. *Агробіологія*. 2017. Вип. 1. С. 80–85.
15. Juozas P., Jolanta S. Effect of biopreparations on seed germination and fungal contamination of winter wheat. *Biologija*. 2015. Vol. 61, No. 1. P. 25–33.
16. Коваленко О. А., Корхова М. М., Панфілова А. В. Застосування біопрепаратів в технології вирощування зернових культур за умов природного зволоження та зрошення зони Південного Степу України. Миколаїв : МНАУ, 2019. 48 с.
17. Davarpanah R., Ahmadi S. H. Modeling the effects of irrigation management scenarios on winter wheat yield and water use indicators in response to climate variations and water delivery systems. *Journal of Hydrology*. 2021. Vol. 598. Article 126269. doi: 10.1016/j.jhydrol.2021.126269

18. Zhao G., Zhou B., Mu Y. et al. Irrigation with activated water promotes root growth and improves water use of winter wheat. *Agronomy*. 2021. Vol. 11, Iss. 12. Article 2459. doi: 10.3390/agronomy11122459

References

1. Gamaiunova, V. V., Korkhova, M. M., Panfilova, A. V., Smirnova, I. V., Kovalenko, O. A., & Khonenko, L. H. (2021). *Pshenytsia ozyma: resursnyi potentsial ta tekhnolohiia vyroshchuvannia* [Winter wheat: resource potential and growing technology]. Mykolaiv: MNAU. [In Ukrainian]
2. State Statistics Service of Ukraine. (2022). *Plant Growing in Ukraine 2021: statistical publication*. Kyiv: State Statistics Service of Ukraine. Retrieved from https://ukrstat.gov.ua/druk/publicat/kat_u/2022/zb/05/zb_rosl_2021.pdf
3. Gamaiunova, V. V., & Panfilova, A. V. (2019). Repayment of co-using fertilizers and foliar nutrition biopreparations on crops of winter wheat in the Southern Steppe of Ukraine. *Bulletin of Poltava State Agrarian Academy*, *1*, 41–48. doi: 10.31210/visnyk2019.01.05
4. Lamichhane, J. R., Corrales, D. C., & Soltani, E. (2022). Biological seed treatments promote crop establishment and yield: a global meta-analysis. *Agronomy for Sustainable Development*, *42*(3), Article 45. doi: 10.1007/s13593-022-00761-z
5. Bezpalko, V. V., Stankevych, S. V., Zhukova, L. V., Lazarieva, O. V., Nemerytska, L. V., Popova, L. M., … Klymenko, I. I. (2021). Laboratory and field germination of wheat and spring barley depending on the mode of irradiation with MWF of EHF and pre-sowing seed treatment. *Ukrainian Journal of Ecology*, *11*(2), 382–391.
6. Voloschuk, O., Voloschuk, I., Stasiv, O., Hlyva, V., & Baistruk-Hlodan, L. (2021). Regulation of winter wheat productivity. *Ukrainian Journal of Ecology*, *11*(9), 127–130.
7. Viniukov, O. O., Bondareva, O. B., Korobova, O. M., & Chugrij, G. A. (2018). Effect of biological products on productivity of winter wheat on various backgrounds of nutrition in conditions of Donetsk oblast. *Bulletin of Agricultural Science*, *11*, 41–47. doi: 10.31073/agrovisnyk201811-06 [In Ukrainian]
8. Kovalenko, O. A., Kliuchnyk, M. A., & Chebanenko, K. S. (2015). Use of biological preparations for processing seed material of winter wheat. *Scientific Works. Series: Ecology*, *256*(244), 74–77. [In Ukrainian]
9. Voloschuk, O., Voloschuk, I., Hlyva, V., & Marukhnyak, A. (2020). Biological mechanisms of regulation of winter wheat productivity in the conditions of the western forest-steppe of Ukraine. *Ştiinţa Agricolă*, *1*, 3–11.
10. Pinchuk, N. V., Verheles, P. N., Kovalenko, T. M., & Amons, S. E. (2022). The effectiveness of the use of biological products in winter wheat crops in the conditions of the Right-Bank Forest-Steppe. *Agriculture and Forestry*, *1*, 96–113. [In Ukrainian]
11. Pryplavko, S. A., & Gaviy, V. M. (2019). Comparative effect of growth regulators of Azotofit, Amber acid and Vimpel on the dynamics of growth and productivity of winter wheat varieties of Yuvivata. *Scientific Issue Ternopil Volodymyr Hnatiuk National Pedagogical University. Series: Biology*, *76*(2), 91–97. doi: 10.25128/2078-2357.19.2.15 [In Ukrainian]
12. Siroshtan, A. A., Zaima, O. A., Kavunets, V. P., Dubovyk, D. Yu., Zabolotnii, V. I., & Olefirenko, B. A. (2019). The influence of protectants combined with growth stimulator and microfertilizer on seed quality and yield of winter wheat. *Myronivka Bulletin*, *9*, 63–67. doi: 10.31073/mvis201909-09 [In Ukrainian]
13. Vasylenko, M., Ternovyj, Yu., Shvidenko, I., & Dushko, P. (2020). Application of biological plant growth stimulator "Ecostym" in agricultural production. *Agroecological Journal*, *3*, 96–101. doi: 10.33730/2077-4893.3.2020.211532 [In Ukrainian]
14. Grabovska, T. O., & Melnyk, G. G. (2017). Effect of biological preparations on the productivity of winter wheat under organic farming. *Agrobiology*, *1*, 80–85. [In Ukrainian]
15. Juozas, P., & Jolanta, S. (2015). Effect of biopreparations on seed germination and fungal contamination of winter wheat. *Biologija*, *61*(1), 25–33.
16. Kovalenko, O. A., Korkhova, M. M., Panfilova, O. V., Gamaiunova, V. V., Khonenko, L. G., Fedorchuk, M. I., & Chernova, A. V. (2019). *Zastosuvannia biopreparativ v tekhnolohii vyroshchuvannia zernovykh kultur za umov pryrodnoho zvolozhennia ta zroshennia zony Pivdennoho Stepu Ukrainy* [The use of biological preparations in the technology of growing grain crops under the conditions of natural moistening and irrigation of the Southern Steppe zone of Ukraine]. Mykolaiv: MNAU. [In Ukrainian]
17. Davarpanah, R., & Ahmadi, S. H. (2021). Modeling the effects of irrigation management scenarios on winter wheat yield and water use indicators in response to climate variations and water delivery systems. *Journal of Hydrology*, *598*, Article 126269. doi: 10.1016/j.jhydrol.2021.126269
18. Zhao, G., Zhou, B., Mu, Y., Wang, Y., Liu, Y., & Wang, L. (2021). Irrigation with activated water promotes root growth and improves water use of winter wheat. *Agronomy*, *11*(12), Article 2459. doi: 10.3390/agronomy11122459

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Корхова М. М.*, Маркова Н. В., Панфілова А. В. Вплив умов зволоження та обробки насіння біопрепаратами на ріст і врожайність сортів пшениці озимої. *Plant Varieties Studying and Protection*. 2022. Т. 18, № 3. С. 201–208. https://doi.org/10.21498/2518-1017.18.3.2022.269001

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Мета. Визначити вплив умов зволоження та обробки насіння біологічними препаратами Азотофіт-р, Фітоцид, Мікофренд-р, Органік-баланс Монофосфор на ростові процеси на початкових етапах життя рослин, формування густоти стояння та урожайність зерна сортів пшениці озимої. **Методи.** Для досліджень використовували загальнонаукові, спеціальні, польові, математично-статистичні та розрахунково-порівняльні методи. **Результати.** Запорукою високої врожайності пшениці озимої є одержання дружних сходів, формування оптимальної густоти стояння рослин на час збирання з урахуванням показників їх виживаності, коефіцієнту продуктивної кущистості та вивчення нових сортів, адаптованих до змін клімату. За результатами досліджень визначено, що в середньому за 2020–2022 рр. більшу урожайність зерна серед досліджуваних сортів пшениці озимої сформовано у рослин сорту 'Дума одеська' (8,38 т/га) на зрошенні у варіанті з передпосівною обробкою насіння біопрепаратом Азотофіт-р, що на 0,78 т/га більше, порівнюючи з контролем (обробка водою). У варіанті без зрошення урожайність становила 6,08 т/га, що менше за контроль на 2,3 т/га або 27,4%. **Висновки.** Розроблені елементи технології вирощування сортів пшениці озимої дають можливість сформувати оптимальну густоту стояння рослин та значно підвищити урожайність зерна в умовах Південного Степу України.

Ключові слова: *Triticum aestivum L.; польова схожість; кількість рослин; продуктивна кущистість; виживаність; урожайність.*

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