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Research Article

Influence of biologics on the productivity of winter wheat varieties under irrigation conditions

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Abstract

The aim of the research was to determine the influence of varietal characteristics, pre-sowing seed treatment and irrigation on the yield of winter wheat (*Triticum aestivum* L.). Experimental studies were carried out in the conditions of Mykolayiv National Agrarian University (Ukraine) during 2019-2022 yrs. It was found that among the studied variety of winter wheat, the highest grain yield was distinguished by the variety 'Ozerna' and 'Duma Odes'ka'. On average, for pre – sowing seed treatment and irrigation options, these variety formed yields at the level of 6.78 and 6.95 tha^{-1}, which was higher than the grain yield of 'Anatoliya' variety by 4.1 up to 6.5%, and then the yield of 'Ovidii' variety by 3.9 up to 6.3%. It was proved that preparations for pre-sowing seed treatment contributed to the formation of more productive stems and grain mass from one ear in winter wheat plants. So, on average, over the years of research, variety and irrigation options, for the use of Azotofit-R, the number of productive stems increased by 34-74 PCs./ m^2 compared to other seed treatment options. At the same time, the yield of winter wheat grain was also slightly higher with the use of Azotofit-R biologics. It was found that the use of irrigation provided an increase in grain yield by 1.66-2.19 tha^{-1} or 23.1-27.2%, depending on the studied winter wheat variety. At the same time, the 'Duma Odes'ka' variety had a higher grain yield under irrigation (8.06 tha^{-1}), while in conditions without irrigation, a slightly higher grain yield was formed by plants of the 'Ozerna' variety (5.87 tha^{-1}). On average, over the years of research, the highest yield of winter wheat grain was provided by the cultivation of the 'Duma Odes'ka' variety for pre-sowing seed treatment with Azotofit - R biologics and irrigation–8.38 tha^{-1}.

Keywords: biologics; irrigation; variety; winter wheat; yield

Introduction

Agrarian science has faced the problem of is the humanity provision with food, the major part of which is provided by grain crops. Today, grain production has a special place in the structure of the agro-industrial complex. It is the grain and products of its processing which are vital products that ensure the food security of the state, play an important role in the socio-economic development of the national economy, form the basis of agricultural exports and determine the degree of its participation in international cooperation (Panfilova and Mohylnytska, 2019).

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Wheat production and utilization accounts for 28% of the global cereal crops. Wheat consumption has been steadily increasing due to population expansion and urbanization. Consequently, wheat supplies approximately one-fifth of human calories in a variety of forms. Wheat will remain a crucial component of human nutrition, and increasing its production is therefore an important requirement for food security (Hongjie *et al*., 2019; Nazarenko *et al*., 2020).

Winter wheat makes the fullest use of the existing bioclimatic potential of the regions of Ukraine. The highest productivity of this crop can be obtained if modern adapted variety with a high genetic potential of productivity are used, taking into account the soil and climatic conditions of the zone, improving and developing highly effective, scientifically based nutrition and protection systems against harmful organisms (Markovska and Hrechyshkina, 2020).

Due to the increase in the world's population, the decrease in acreage and gross crop yields due to military operations, the question arises of finding innovative methods to increase the yield of these crops and, as a result, increase the world's food reserves. Wheat yield varies from year to year under the influence of moisture availability of crops during the growing season, the variety grown and agricultural techniques for growing the crop, in particular the introduced nutrients (Suciu *et al*., 2018; Panfilova *et al*., 2020; Ma *et al*., 2022; Zhang *et al*., 2022). Wheat production in Europe countries is particularly dependent on synthetic fertilizers because the use of animal manure is very limited, many of the soils are naturally low in levels of soil organic matter and there are only a few legumes present in main crop rotations that could supply symbiotically fixe nitrogen (Biel *et al*., 2016). Research of many foreign and domestic scientists (Ying, 2019; Hashem *et al*., 2019; Gamayunova and Panfilova, 2020; Panfilova *et al*., 2020; Müller and Behrendt, 2021; Nemea *et al*., 2021; Holtappels *et al*., 2021; Panfilova, 2021; Panfilova *et al*., 2021) the most effect of biologics and growth-regulating drugs on the yield and quality of agricultural crops has been proven.

To increase the yield of agricultural products, modern nanotechnologies based on growth-regulating preparations containing carbon and cuprum are widely used in scientific research, which protect plants from pathogenic organisms and negative environmental factors (Jacob *et al*., 2020; Singh *et al*., 2021; Afreena *et al*., 2022). Research by Reda (2021) the positive effect of biostimulants and bioprotectors based on seaweed extracts, humic substances, protein hydrolysates, amino acids, and plant extracts on increasing crop productivity has been proven.

No less important in increasing the productivity of agricultural crops is the choice of variety (Visioli *et al*., 2018). Replacing old variety with new, more productive, competitive ones with wide agroecological plasticity and increased adaptive properties to adverse environmental conditions, better adapted to the soil and climatic conditions of a certain area and an increased level of agricultural technology is one of the most rational and economic means of increasing the grain yield of winter grain crops with high quality indicators (Krivenko and Pochkolina, 2019; Hudzenko *et al*., 2021). Research by Bazalii *et al*. (2019) it is established that when identifying variety and forms of various types of high-yielding wheat, which has an increased adaptive potential, it is necessary to conduct a step-by-step assessment under different growing conditions.

Nowadays in the State Register of Plant Varieties, there are more than 460 cultivars of winter wheat. For effective breeding work, the initial material must be studied in detail to meet specific parameters and requirements (Wu and Zhatova, 2022). Obtaining a comparative assessment of new variety and selecting promising ones for further study and introduction into production is impossible without ecological variety testing, so the study of new promising variety of winter wheat in production conditions using modern biologics and irrigation is relevant.

Materials and Methods

Experimental researches were carried out during 2019-2022 yrs on the experimental field of the Mykolayiv National Agrarian University, Ukraine. The object of research was *Triticum aestivum* L. – variety 'Ovidii', 'Duma Odes'ka', 'Ozerna' and 'Anatoliya'. The technology of its cultivation, except for the studied factors, was generally accepted to the existing zonal recommendations for the southern steppe of Ukraine.

The soil of the experimental field was a typical southern chernozem of residual-slightly saline heavy loess on Loess with a humus content (0-30 cm) from 3.1 up to 3.3% and a neutral reaction of the soil solution (pH – 6.8-7.2). The arable soil layer contained an average of 15-25 mobile forms of nitrates (by Grandval Lyagu), 41-46 mobile phosphorus (by Machigin) and 389-425 mg/kg of exchange potassium (on a semi-lamp photometer). Agricultural techniques for growing winter wheat of various species were generally accepted for the zone, with the exception of variants that were studied according to the experimental scheme. Its predecessor was sown peas.

The scheme of experience included the following variants:

Factor A - variety: 1. 'Ovidii'; 2. 'Duma Odes'ka'; 3. 'Ozerna'; 4. 'Anatoliya'.

Factor B – seed treatment: 1. water treatment (control); 2. Azotofit–R (0.3 l/t); 3. Phytocide (1.5 l/t); 4. Mycophrend-R (1.0 l/t); 5. Organic-Balance Monophosphorus (0.5 l/t).

Factor C - humidification conditions: 1. without irrigation; 2. irrigation (1 water-charging irrigation before sowing 800-1000 m^3 ha^{-1}, 2 vegetation irrigation of 400-500 m^3 ha^{-1}).

The total area of the experimental plot is 50 m^2, the accounting plot is 26 m^2, the repetition rate is four times.

Records and observations, the number of productive stems, the mass of grain from one ear and grain yield were determined by the method of State Variety testing (Tkachyk *et al*., 2017).

Mathematical and statistical processing of research results was performed using variance analysis using the STATISTICA 10.0 program (Ushkarenko *et al*., 2020).

Results and Discussion

The productivity of winter wheat varies from year to year under the influence of moisture availability of crops during the growing season, the variety grown and agricultural techniques for growing the crop, in particular the use of biologics for pre-sowing seed treatment. It is possible to get a guaranteed high yield of winter wheat grain in the southern steppe zone of Ukraine, regardless of climatic conditions, only on irrigated land.

The productivity of winter wheat plants mainly depends on the density of the productive stem and the mass of grain from one ear. The largest number of productive stems is 917 PCs./m^2 under irrigation conditions was formed in the variety 'Duma Odes'ka' with the use of pre-sowing seed treatment with Azotofit-R. Slightly lower indicators were observed in all the studied variety in conditions without irrigation, but the trend regarding the use of drugs remained the same (Table 1).

Table 1. Number of productive stems of winter wheat variety depending on pre-sowing seed treatment and irrigation, PCs./m^2 (average for 2020-2022 yrs)

Variety (Factor A)	Seed treatment (factor B)				
	water treatment (control)	Azotofit-R	Phytocyde	Mycophrend-R	Organic-balance mono-phosphorus
Without irrigation (Factor C)					
‘Ovidii’	566	619	570	619	630
‘Duma Odes’ka’	609	651	638	657	649
‘Ozerna’	598	656	639	654	649
‘Anatoliya’	581	647	640	735	625
Irrigation (Factor C)					
‘Ovidii’	714	826	758	816	776
‘Duma Odes’ka’	801	917	877	889	842
‘Ozerna’	758	844	787	816	805
‘Anatoliya’	708	764	745	755	757

$LSD_{0.5}$: factor A: 17-36; factor B: 43-48; factor C: 22 - 30

The most productive stems of winter wheat plants were noted for growing the crop on irrigation and using Azotofit-R biologics for pre-sowing seed treatment. Thus, on average over the years of research, in this version of the experiment, 764 PCs./m^2 of productive stems were formed in plants of the Anatolia variety, and 826 and 844 PCs./m^2 in the ‘Ovidii’ and ‘Ozerna’ variety, respectively. Best of all, the ‘Duma Odes’ka’ variety responded to seed treatment before sowing with Azotofit-R, which had 917 PCs./m^2 of productive stems.

It should be noted that the variety react differently to irrigation conditions. So, on average, over the years of research and according to the factor of pre - sowing seed treatment, plants of the ‘Ozerna’ and ‘Duma Odes’ka’ variety formed the most productive stems under irrigation conditions - 802 and 865 PCs./m^2 respectively. While in conditions without irrigation, the most productive stems were found in the variety ‘Duma Odes’ka’ and ‘Anatoliya’ - 641 and 646 PCs./m^2 respectively.

The factors studied by us also affected the mass of grain from one ear of winter wheat, which, depending on the experiment option, fluctuated on average over the years of research from 0.90 to 0.98 g. At the same time, it should be noted that this indicator was highest for growing the studied variety of winter wheat under irrigation conditions and conducting pre-sowing seed treatment with Azotofit–R biologics, which exceeded the indicators of other experiment options by 1.0-8.2%.

In the conditions of the Southern Steppe of Ukraine, precipitation in the summer period falls extremely unevenly, mainly has a storm character, is lost to runoff and evaporation, especially with a low content of organic substances in the soil, so irrigation is the only way to provide plants with moisture during this period (Drobitko *et al*., 2022). On average, over the years of our research and according to the options for pre-sowing seed treatment, the yield of winter wheat grain on the options without irrigation was 5.53-5.87 tha^{-1}, depending on the variety under study (Figure 1). The use of irrigation provided an increase in grain yield by 1.66-2.19 tha^{-1} or 23.1-27.2%.

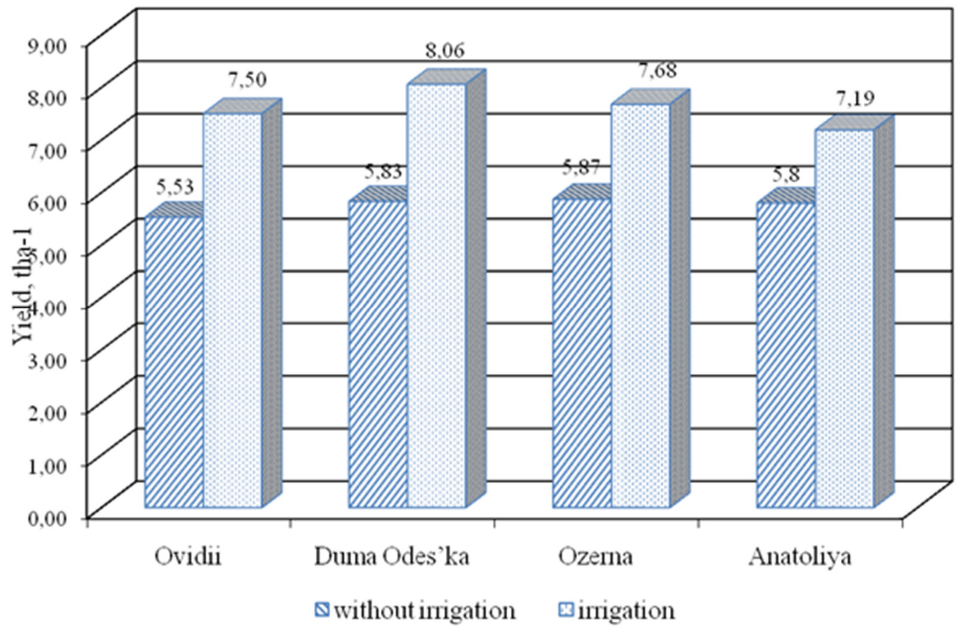

Figure 1. Influence of varietal characteristics and irrigation on the yield of winter wheat grain, tha^{-1} (average for 2020-2022 yrs)

It should be noted that the 'Duma Odes'ka' variety responded better to irrigation in all the years of research, while on average for 2020-2022 yrs the grain yield of this variety was 8.06 tha^{-1}, while in conditions without irrigation, plants of the 'Ozerna' variety formed a slightly higher grain yield – 5.87 tha^{-1}.

Irrigation is one of the means of sustainable development of regions with a lack of moisture supply for the growing season of plants and increasing crop productivity (Ghane *et al*., 2009).

Research by Martínez *at al*. (2020) irrigation sheet reductions of 1 to 0.8, 0.6 and 0.4 m decreased grain yield by 14.4, 37.6 and 76.8%, respectively. In limiting humidity (0.4 m) the number of spikes and biological yield decreased 63.7 and 73.3%.

The data by Zhou *et al*. (2018) the simulated grain yield based on different growing season rainfall categories was more affected by irrigation when the growing season precipitation was below 100 mm. Two irrigations (75 mm each at the jointing stage and a thesis stage) resulted in the highest grain yield.

The choice of variety plays an important role in increasing the productivity of agricultural crops, including winter wheat. We found that on average over the years of research, options for pre – sowing seed treatment and moistening conditions, slightly higher grain yields were formed by plants of the 'Duma Odes'ka' variety – 6.95 tha^{-1}, which exceeded the indicators for the 'Ozerna' variety by 0.17 tha^{-1} or 2.4%, the 'Ovidii' variety by 0.44 tha^{-1} or 6.3%, and for the 'Anatoliya' variety by 0.45 tha^{-1} or 6.5% (Table 2).

Table 2. Winter wheat grain yield depending on varietal characteristics, pre-sowing seed treatment and moistening conditions, tha^{-1} (average for 2020-2022 yrs)

Variety (factor A)	Seed treatment (factor B)				
	water treatment (control)	Azotofit-R	Phytocyde	Mycophrend-R	Organic-balance monophosphorus
Without irrigation (Factor C)					
'Ovidii'	5.10	5.71	5.29	5.71	5.84
'Duma Odes'ka'	5.46	6.08	5.76	5.95	5.90
'Ozerna'	5.37	6.07	5.81	5.94	6.16
'Anatoliya'	5.29	6.04	5.98	5.90	5.80
Irrigation (Factor C)					
'Ovidii'	6.73	8.15	7.31	7.85	7.44
'Duma Odes'ka'	7.60	8.38	8.28	8.11	7.94
'Ozerna'	7.04	8.20	7.60	7.85	7.72
'Anatoliya'	6.77	7.48	7.21	7.21	7.29

$LSD_{0.5}$: factor A: 3 – 11; factor B: 4 – 13; factor C: 67-87

Research by Djaman *at al*. (2018) it was found the grain yield was dependent on winter wheat variety, decreased with years, and varied from 1.84 to 7.09 tha^{-1}. 'TAM107' obtained the highest grain yield.

Based on the research results of Wu and Zhatova (2022) identified wheat variety that have high productivity parameters. These are variety such as 'Okhtyrchanka Yuvileina', 'Svitanok Myronivskiy', 'Melody Odes'ka', 'Kubok', 'Zorepad', 'Ovidii', 'Shchedra Niva', 'Octave Odes'ka' and 'Slaven'.

Our studies determined that the use of biologics for pre-sowing seed treatment increased the yield of winter wheat grain compared to the control. Thus, the use of the biological product Azotofit-R provided the highest grain yield, which on average over the years of research, by variety and irrigation options amounted up to 7.01 tha^{-1}, which was more than the control by 0.84 tha^{-1} or 12.0%. The yield of winter wheat grain was slightly lower when using phytocide, mycophrend-r and organic-balance monophosphorus biologics for pre – sowing seed treatment such as 6.66; 6.82 and 6.76 tha^{-1}, which was respectively higher than the control by 0.49; 0.65 and 0.59 tha^{-1} or 7.4; 9.5 and 8.7%.

On average, over the years of research, it was found that the highest yield was formed in all the variety we studied by combining the option of pre-sowing seed treatment with Azotofit-R and irrigation. Thus, the winter wheat variety 'Duma Odes'ka' on this variant of the experiment grain yield was 8.38 tha^{-1}, yield of the variety 'Ozerna' as 8.20 tha^{-1}, the yield of 'Ovidii' as 8.15, and yield of the variety 'Anatoliya' as 7.48 tha^{-1}, which was respectively more by 2.92; 2.83; 3.05 and 2.19 tha^{-1} or by 34.8; 34.5; 37.4 and 29.3% compared to the control version of the experiment (without seed treatment with biologics and without irrigation).

The use of biologics in the cultivation of winter wheat also had a positive impact on its productivity in the research of other scientists. Thus, Almashova and Skok (2022) found that the greatest increase in the yield of winter wheat grain was observed during three-time cultivation of crops with Grain active–C in the tillering phase, flag leaf, grain filling (0.32 tha^{-1}, 1.18%). At the same time, the greatest effect was observed when processing crops in the tillering phase, where the yield increase was 16% before the control. Processing of crops in the flag leaf phase contributed to an increase in yield by 4%, and in the grain filling phase – 4.5%.

Research by Markovska and Hrechyshkina (2020) it was found the highest level of productivity was formed by plants of winter wheat of the Maria variety against the background of applying mineral fertilizers at a dose of $N_{30}P_{30}$ for pre-sowing cultivation using foliar top dressing with Organo-mineral fertilizer ROST (2.0 l/ha) at the beginning of the spring vegetation recovery and in the flag leaf phase. So, on average over the years of research, the grain yield in this variant was 4.96 tha^{-1}, the number of productive stems was 411 PCs/m^2, number of grains in an ear was 27.6 PCs, the weight of 1000 grains were 51.5 g.

Research by Panfilova *et al.* (2020) it was determined that the higher grain yield and slightly better-quality indicators differed grain of the studied winter wheat variety with the joint use of pre-sowing application of $N_{30}P_{30}$ and foliar fertilizing of winter wheat crops twice during the vegetation season by Escort-bio. The maximum grain yield in the experiment was formed by winter wheat plants of the variety Zamozhnist in the background + Escort – bio nutrition variant in the range from 3.76 to 6.28 tha^{-1} depending on the weather conditions of the year.

Conclusions

Studies established that in all years of research, there is clearly a positive effect of using Azotofit-R biologics for pre–sowing treatment of winter wheat seeds and irrigation for growing the 'Duma Odes'ka' variety, where the average grain yield over the years of research was 8.38 tha^{-1}. Studies established the efficiency of irrigation for the cultivation of all the studied variety of winter wheat. Thus, on average, over the years of research and by the factor of pre – sowing seed treatment, the grain yield on irrigation applications was 7.19–8.06 tha^{-1}, which was higher than the indicators of options without irrigation by 1.66–2.19 tha^{-1} or 23.1-27.2%. The studied variety of winter wheat reacted differently to irrigation conditions. Thus, under the conditions of natural moisture, the highest grain yield was formed by plants of the 'Ozerna' variety (5.87 tha^{-1}), and on the irrigation option – 'Duma Odes'ka' (8.06 tha^{-1}). The optimal combination of elements of cultivation technology developed to increase the yield of winter wheat makes it possible to obtain a high grain yield in the conditions of the Southern Steppe of Ukraine, thus confirming the important scientific and practical significance of the work under study.

Authors' Contributions

Conceptualization, A.P. and M.K.; methodology, A.P., M.K. and N.M; validation, A.P. and M.K.; formal analysis, A.P. and M.K.; investigation, A.P., M.K. and N.M; resources, A.P. and M.K.; writing-original draft preparation, A.P.;writing-review and editing, A.P.; supervision, A.P., M.K. and N.M. All authors read and approved the final manuscript.

Ethical approval (for researches involving animals or humans)

Not applicable.

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Conflict of Interests

The authors declare that there are no conflicts of interest related to this article.

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