РОСЛИННИЦТВО ТА КОРМОВИРОБНИЦТВО

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FORMATION THE EFFICIENCY OF WINTER WHEAT UNDER INFLUENCE THE POLYFUNCTIONAL CHELATE FERTILIZERS

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Abstract. *Article highlights the results of research of the effect of pre-sowing seed treatment with polyfunctional chelate fertilizers on growth and development of winter wheat.*

The research was conducted in the research field of separated department "Agronomic research station" of National university of life and environmental sciences of Ukraine. Field and laboratory experiments were conducted due to approved methods.

Maximum grain yield was formed in variant of fertilization "Base (P90K120) + N30 (BBCH 25-26)+N30(BBCH 31-32)+N30 (BBCH 68-69) and pre-sowing seed treatment with mix of Avatar-1 and Jodis-concentrate. There are 7.37 t/ha in cultivar Samurai and 7.16 t/ha in cv. Bohemia of grain yield formed in average in 2018-2020. Significant effect on grain yield was observed under application of nitrogen fertilizers on BBCH 25-26, BBCH 31-32 and BBCH 68-69. Pre-sowing seed treatment with mix of Avatar-1 and Jodis-concentrate increased yield from 11-13 % on variants without nitrogen fertilizers till 15-20 % under combine application of fertilizers. Seed treatment by Avatar-1 increase yield on 8-10 %, but effect of Jodis-concentrate is slight lesser (2-4%).

Key words: *seed treatment, Avatar-1, Jodis-concentrate, Bohemia, Samurai, yield.*

Introduction.

Nano dispersive powders and colloidal solutions of biologically active metals are uses to increase resistance to abiotic and biotic environmental factors. Anti-stress preparations based on easily digestible forms of metals increase resistance to abiotic factors without increasing crop transpiration. They improve winter resistance of winter wheat, increase activity of root system, decrease infection of fungi diseases (Chhipa, 2017; Elmer & White, 2018). Nanoparticles of metals cause adaptive changes in the expression of the genome of seed cells in the early stages of germination, which are then transmitted epigenetically during cell division to all plant cells (Elsakhawy et al., 2018). When nanoparticles are introduced into water, it becomes an environment with certain features, which increases adaptability to the environment, there is a self-organization of structures that ensures optimal plant development in these specific conditions (Lopat`ko et al., 2011).

Plants are vulnerable to many stresses, which can significantly decrease in their productivity. Such adverse effects include low and high temperatures, lack of moisture and drought, exposure to phytopathogens, ultraviolet radiation, etc (Polishchuk et al., 2015). Application of chemicals causes stress in the plant body at the cellular level of the organization (Worrall et al., 2018). Preventive adaptation of plants to negative factors by accumulation of protectors allows them to prepare for extreme situations before the moment of collision with them (Frantijchuk, et al., 2012).

Analysis of recent research and publications.

Current trends in world agricultural production are aimed at greening the technology of crop production. There is an urgent need to reorient the agriculture of our country to the standards of the European Union, the comprehensive development and implementation of the paradigm of biologization of intensification processes in crop production is underway (Honchar & Shen, 2016).

Interest in the formation of ecologically balanced agrocenoses and increasing the adaptive potential of crops in existing systems of agricultural production has grown significantly in recent years. According to the global theory of organic farming, the created agroecosystems should be not only highly productive, but also ecologically steady, possess ability to reprogram ontogenetic processes of plants according to sharp fluctuations of weather conditions and action of anthropogenic factors for production of ecologically pure products (Pruntseva, 2018). Systematic researches the responds of plants under conditions of changing climatic factors, transformation with the prevalence of degradation of soil and water systems, their pollution by various pollutants, indicate the feasibility of using nanoelements to optimize adaptive strategies of crops and ensure their sustainability (Honchar, 2016).

The nanoscale state of matter is characterized by a significant change and the appearance of new properties that are not inherent in the material in a compact state. The specificity of the nanostructured state of matter is reflected in particular in thermodynamic characteristics, when with decreasing size the difference between the solid phase model adopted in classical thermodynamics and the real nanoparticle increases significantly, and the division into bulk and surface components becomes conditional. Increasing in the free Gibbs energy of nanoparticles occurs due to a significant increase in the surface area, or the phase distribution surface in the nanostructured material under conditions of constant temperature and pressure. Due to the large surface area, all nanomaterials have a significant surface energy - increased by at least three orders of magnitude relative to the compact material, thus being in an unstable or metastable state and prone to the formation of agglomerates (Lopat`ko et al, 2011).

None of the known methods and methods of obtaining nanomaterials is universal, but only allows to solve certain technical problems. The development of new and improvement of existing methods and methods of obtaining nanomaterials remains relevant, especially when it comes to their application in biotechnology. Biological effects of nanomaterials, their toxicity or ability to positively affect metabolic processes and the physiological state of the body as a whole, remains key in fundamental studies of the interaction of nanoparticles with the biological environment (Babaei et al., 2017).

The implementation of pre-sowing treatment of seeds with various factors has a positive effect on the processes of its germination, plant vegetation, and as a result improves the formation of ears, fruits, increases yields. There are a number of technologies for pre-sowing treatment of seed material, which include chemical, biological, physical factors influencing the condition of the seed in order to stimulate the physiological processes of germination and development (Singh et al., 2015).

Nanometallic solutions are used for pre-sowing treatment of crop seeds, which causes to increase yields by up to 20-35%. There is an increase in plant adaptation to stressors during the growing season and improve the quality of agricultural products in additional (Gonchar & Tschubenko, 2013).

Nanometals affect biological objects at the cellular level, increase the efficiency of processes in plants and participate in the formation of micronutrient balance, namely, are bioactive. The study of important properties of nanometals is carried out simultaneously with the detection of negative effects and prevention of risks from their use (Polishchuk et al. 2015).

Aim of our research was to establish the influence of multifunctional chelated fertilizers on the growth and development of winter wheat plants, especially yield.

Materials and methods of research.

Field experiments were conducted in stationary research field of Department of Plant Science in separated department "Agronomic research station" of National university of life and environmental sciences of Ukraine in 2018-2020. Soil of research field is chernozem typical low-humic. Previous crop is peas. Each variant has four replications. The research scheme provided for different options for seed treatment with polyfunctional chelate fertilizers and different variants of fertilization. Poly-factorial field experiment includes: ***factor A*** – cultivar: Samurai, Bohemia; ***factor B*** – fertilization: 1. $P_{90}K_{120}$ (base); 2. base + $N_{30(BBCH\ 25\text{-}26)}$+$N_{30(BBCH\ 31\text{-}32)}$; 3. base + $N_{30(BBCH\ 25\text{-}26)}$+$N_{30(BBCH\ 31\text{-}32)}$+ $N_{30(BBCH\ 68\text{-}69)}$; ***factor C*** – pre-sowing seed treatment with liquid chelate nanofertilizers: 1. control (water 10 L/t); Avatar-1 (600 mL/t); Jodis-concentrate (600 mL/t); mix Avatar-1 and Jodis-concentrate (300 + 300 mL/t).

Avatar-1 is a multicomponent microelement preparation that improve nitrogen-phosphorus nutrition, increase stress resistance and productivity. Avatar-1 contains the necessary micro and ultra-micronutrients, chelated natural organic acids - citric, succinic, malic, tartaric and mixtures thereof. Jodis-concentrate is an immunomodulatory preparation that has pronounced antiviral, antifungal and antibacterial properties and is now widely used in animal husbandry and crop production.

Yield per hectare was calculated to 14% moisture. Assess the influence of factors on the yield used *ANOVA* at the level of significance of 5%. Difference between the options within the factor was established by the post-hoc *Tukey`s HSD* test, the *Fisher`s LSD* test was auxiliary.

Results.

Winter wheat yield is the amount of grain obtained from one hectare as a result of the interaction with the plant, which includes the absorption of nutrients and water from the soil and the synthesis of organic matter under the action of solar energy.

Complex seed treatment with Avatar-1 and Jodis-concentrate allowed to form the highest level of yield in cultivars Samurai and Bohemia on each variant of the fertilizer system (table 1–2).

High grain yields of winter wheat can be achieved only by creating optimal conditions for plant growth and development, grain formation and filling, it is possible to achieve by providing plants with all the elements of mineral nutrition. Significant impact on the yield of winter wheat was observed under fertilization with nitrogen fertilizers. The most effective variant is application of nitrogen fertilizers at BBCH 25-26, BBCH 31-32 and BBCH 68-69. Maximum grain yield was formed in variant of fertilization “Base ($P_{90}K_{120}$) + $N_{30\ (BBCH\ 25\text{-}26)}$+$N_{30(BBCH\ 31\text{-}32)}$+$N_{30\ (BBCH\ 68\text{-}69)}$ and pre-sowing seed treatment with mix of Avatar-1 and Jodis-concentrate in both cultivars. There are 7.37 t/ha in cultivar Samurai (table 2) and 7.16 t/ha in cv. Bohemia (table 1) of grain yield formed in average in 2018-2020.

Average yield of winter wheat was 5.70 t/ha in the variety Bohemia and 5.93 t/ha in cv. Samurai in the control variants of fertilization. Seed treatment with Avatar-1 contributed to an increase in wheat yield by 0.52 t/ha in cv. Bohemia and by 0.55 t/ha in cv. Samurai on this variant of fertilization.

Carrying out two nitrogen fertilizations cause to increase the yield, but the seed treatment with Avatar-1 increased in yield by 9.6% compared to the control. The maximum yields were achieved during the third nitrogen fertilization and pre-sowing seed treatment, which increased the yield by 0.82 t/ha.

It was found that the use for pre-sowing seed treatment with Avatar-1 increased the productivity of winter wheat in both cultivars, and it should be noted that the use of this preparation increased plant resistance to stress factors, which in turn affected plant survival and their number per hectare. Pre-sowing seed treatment with Jodis-concentrate insignificantly increased the productivity on the studied cultivars (2-4%), this is due to the peculiarity of the preparation (decontamination of seed, non-regulatory function). However, the use of Avatar-1 and Jodis-concentrate in the complex was achieved in their highest efficiency, as evidenced by the obtained research data.

The highest yield was formed in cultivar Samurai (7.4 t/ha) under option of fertilization “Base ($P_{90}K_{120}$) + $N_{30\ (BBCH\ 25\text{-}26)}$+$N_{30(BBCH\ 31\text{-}32)}$+$N_{30\ (BBCH\ 68\text{-}69)}$ and complex pre-sowing treatment with Avatar-1 and Jodis-concentrate.

1. Grain yield of winter wheat cv. Bohemia depends on fertilization and pre-sowing seed treatment

Fertilization (A)	Pre-sowing seed treatment (B)	Yield, t/ha				Increase in yield to control	
		2018	2019	2020	μ	t/ha	%
$P_{90}K_{120}$ (Base)	Control(water)	5.77	6.13	5.20	5.70	-	-
	Avatar-1	6.48	6.54	5.63	6.22	0.52	9.06
	Jodis-concentrate	5.89	6.28	5.31	5.83	0.13	2.22
	Avatar-1 +Jodis-concentrate	6.40	6.95	5.88	6.41	0.71	12.46
Base + $N_{30(BBCH\ 25\text{-}26)}+N_{30(BBCH31\text{-}32)}$	Control(water)	6.12	6.64	5.46	6.07	-	-
	Avatar-1	6.73	7.11	5.84	6.56	0.49	8.01
	Jodis-concentrate	6.34	6.84	5.66	6.28	0.21	3.40
	Avatar-1 +Jodis-concentrate	6.85	7.53	6.06	6.81	0.74	12.18
Base + $N_{30(BBCH\ 25\text{-}26)}+N_{30(BBCH\ 31\text{-}32)}+N_{30(BBCH\ 68\text{-}69)}$	Control(water)	6.55	6.71	5.79	6.35	-	-
	Avatar-1	7.21	7.25	6.30	6.92	0.57	8.98
	Jodis-concentrate	6.68	6.98	5.90	6.52	0.17	2.68
	Avatar-1 +Jodis-concentrate	7.34	7.61	6.53	7.16	0.81	12.76
LSD_{05} A, t/ha	–	0.25	0.24	0.22	0.13	–	–
LSD_{05} B, t/ha	–	0.29	0.28	0.25	0.15	–	–
LSD_{05} AB, t/ha	–	0.50	0.48	0.44	0.27	–	–

All studied factors had their influence (table 3) on the formation of yield, but their interaction did not have a significant impact on yield, except for "fertilization– year". The greatest influence on yield had weather conditions (year) with a share of 54.6%, much lower was fertilization (21.0 %) and pre-sowing seed treatment (15.0 %), and the smallest was the influence of cultivar (8.1 %). $p > 0.001$ indicates a high reliability of the influence of individual factors on yield.

According to post-hoc analysis *Tukey`s HSD* noted the difference between all variants within each factor (Fig. 1).

In particular, cv. Samurai (fig. 1a) was more productive and formed 6.65 t/ha on average in 2018-2020, while cv. Bohemia forms lesser – 6.40 t/ha. Influence of weather conditions (year) differed significantly (fig. 1b): grain yield was 6.68 t/ha in 2018, 6.98 t/ha in 2019 and it was 5.90 t/ha under adverse conditions in 2020. Impact of fertilization was characterized by an almost linear increase in yield with increasing the norm of nitrogen fertilizers, but the applied fertilizer rate did not give the expected increase (fig. 1c). However, the difference between options of fertilization was significant. Response to fertilization with nitrogen fertilizers, may be lower than expected in some cultivars, especially in the late BBCH-stages (Mazurenko et al., 2020).

(a) The use of pre-sowing seed treatment with nanomaterial solutions showed a significant increase in yield (fig. 1d) compared to the control in general in

2. Grain yield of winter wheat cv. Samurai depends on fertilization and pre-sowing seed treatment

Fertilization (A)	Pre-sowing seed treatment (B)	Yield, t/ha				Increase in yield to control	
		2018	2019	2020	μ	t/ha	%
$P_{90}K_{120}$ (Base)	Control(water)	6.00	6.43	5.35	5.93	-	-
	Avatar-1	6.79	6.93	5.72	6.48	0.55	9.34
	Jodis-concentrate	6.13	6.55	5.46	6.05	0.12	2.02
	Avatar-1 +Jodis-concentrate	6.84	7.14	5.94	6.64	0.71	12.04
Base + $N_{30(BBCH\ 25\text{-}26)}$ + $N_{30(BBCH31\text{-}32)}$	Control(water)	6.36	6.78	5.64	6.26	-	-
	Avatar-1	7.08	7.34	6.16	6.86	0.60	9.58
	Jodis-concentrate	6.49	7.06	5.88	6.48	0.22	3.46
	Avatar-1 +Jodis-concentrate	7.25	7.41	6.36	7.01	0.75	11.93
Base + $N_{30(BBCH\ 25\text{-}26)}$ + $N_{30(BBCH\ 31\text{-}32)}$ + $N_{30(BBCH\ 68\text{-}69)}$	Control(water)	6.81	6.86	5.98	6.55	-	-
	Avatar-1	7.59	7.43	6.50	7.17	0.62	9.52
	Jodis-concentrate	6.95	7.10	6.11	6.72	0.17	2.60
	Avatar-1 +Jodis-concentrate	7.73	7.53	6.84	7.37	0.82	12.47
LSD_{05} A, t/ha	–	0.26	0.50	0.23	0.14	–	–
LSD_{05} B, t/ha	–	0.30	0.29	0.26	0.16	–	–
LSD_{05} AB, t/ha	–	0.52	0.50	0.46	0.28	–	–

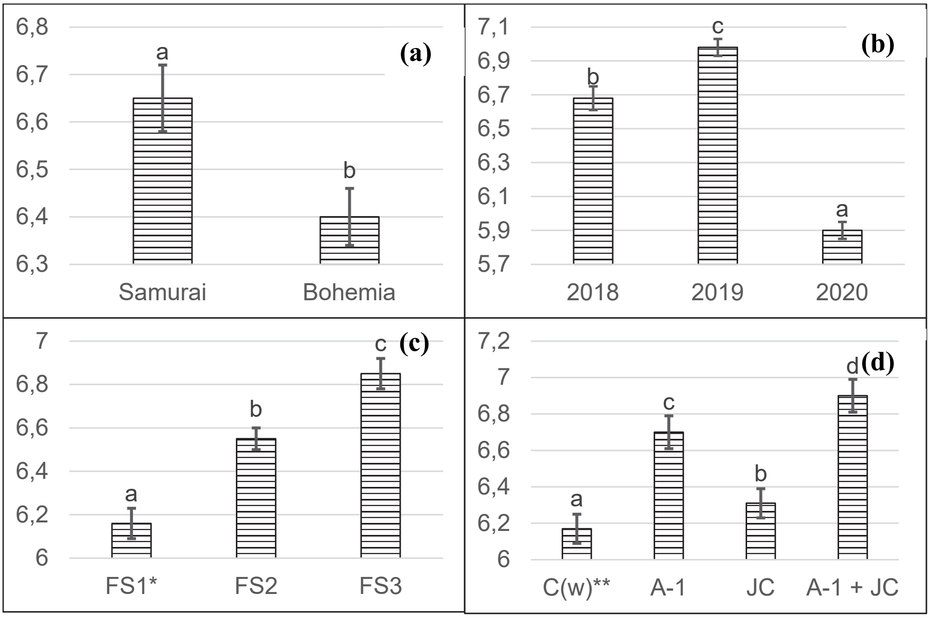
the experiment. In the control variant, the average yield was 6.17 t / ha. Grain yield was 6.31 t/ha in the variants with Jodis-concentrate treatment, and the largest yield was in the variants with treatment by Avatar-1 with independent and compatible with Jodis-concentrate (6.70 and 6.90 t/ha, respectively).

Cultivar sensitivity (fig. 2) to pre-sowing treatment differed significantly compared with the general experiment on Tukey`s HSD test.

There was no significant difference in yield between seed treatment with Jodis-concentrate and the control variant in both cultivars, but when using the Fisher`s

3. Analysis of variance of yield in cv. Bohemia and Samurai

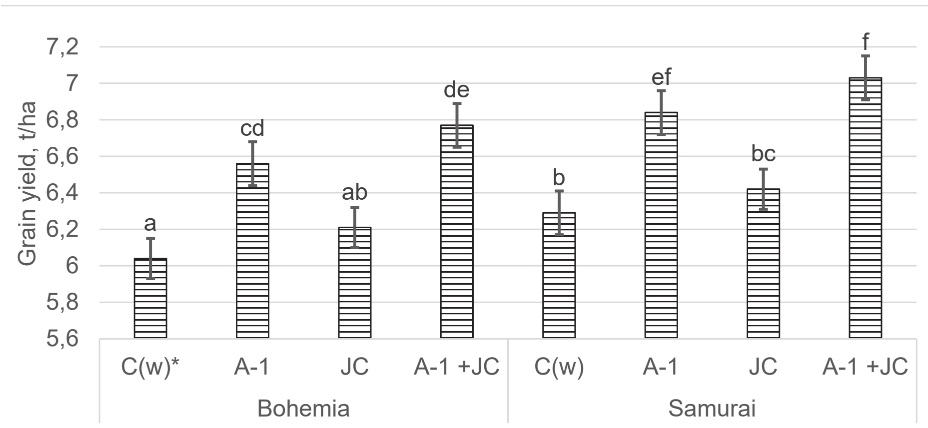
Effect	df	MS	p	Participance, %
Cultivar (A)	1	3.353	>0.001	8.1
Fertilization (B)	2	8.722	>0.001	21.0
Pre-sowing seed treatment (C)	3	6.201	>0.001	15.0
Year (Y)	2	22.607	>0.001	54.6
B x Y		0.232	0.029	0.6
Other interactions, summary		0.325	<0.05 (no significant)	0.7



*FS1 – $P_{90}K_{120}$ (Base); FS2 – Base + $N_{30(BBCH\ 25\text{-}26)}$ + $N_{30(BBCH25\text{-}26)}$;
FS3 – Base + $N_{30(BBCH\ 25\text{-}26)}$ + $N_{30(BBCH\ 31\text{-}32)}$ + $N_{30(BBCH\ 68\text{-}69)}$.
** C(w) – control(water); A-1 – Avatar-1; JC – Jodis-concentrate; A-1 + JC – mix

Figure 1. Grain yield (t/ha) of winter wheat depends on different factors:

LSD test (as an auxiliary) this difference was in the cultivar Bohemia. A similar situation was in the variants with treatment of Avatar-1 and its combine use with Jodis-concentrate. According to Tukey's HSD test, there was no significant difference between these options, but there was according to Fisher's LSD test in grain yield.



* C(w) – control(water); A-1 – Avatar-1; JC – Jodis-concentrate; A-1 + JC – mix

Conclusions and future perspectives.

Pre-sowing seed treatment with mix of Avatar-1 and Jodis-concentrate increased grain yield to 11-13 % in winter wheat, but its effect increases to 15-20 % under combine application of fertilizers. Seed treatment by Avatar-1 increase yield on 8-10 %, but effect of Jodis-concentrate treatment has a lesser effect on grain yield of wheat (2-4%).

According to a detailed analysis, pre-sowing seed treatment with Avatar-1 significantly increases the yield of winter wheat, regardless of variety. Effect of Jodis-concentrate on yields is controversial, as the significance of yield increases differs from one post-hoc test to another. Pre-sowing seed treatment with Jodis-concentrate according to Fisher's LSD_{05} gives a significant increase compared to the control(water), and when used in mix with Avatar-1 compared to the variant "Avatar-1". However, , this difference in yield in these variants was insignificant according to the Tukey`s HSD. Further research of the effect of pre-sowing seed treatments with nanomaterials and their solution are needed, especially to determine the mechanism of influence on production processes.

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Анотація. *У статті висвітлено результати досліджень щодо впливу передпосівної обробки насіння поліфункціональних хелатних нadoдобрив на ріст і розвиток рослин пшениці озимої.*

Дослідження проводили на дослідному полі відокремленого підрозділу «Агрономічна дослідна станція» Національного університету біоресурсів і природокористування України. Польові та лабораторні досліди виконувалися згідно з апробованими методиками.

Максимальний урожай за 2018 – 2020 рр. зерна пшениці озимої було отримано в сорту Самурай 7,37 т/га у варіанті Фон + $N_{30\ (BBCH\ 25\text{-}26)}$+$N_{30(BBCH\ 31\text{-}32)}$+$N_{30\ (BBCH\ 68\text{-}69)}$ та передпосівна обробка насіння Аватар-1+Йодис-концентрат, у сорту Богемія – 7,16 т/га. Істотний вплив на урожайність пшениці озимої спостерігали за підживлення азотними добривами, найефективніше вносити за стадіями росту та розвитку BBCH 25-26, BBCH 31-32 та BBCH 68-69. Встановлено, передпосівна обробка насіння Аватар-1+Йодис-концентрат сприяє отримання більшого урожаю на 11-13 %, у комплексі з підживленням – на 15-20 %. Обробка насіння Аватаром-1 з внесенням добрив дають змогу збільшити врожайність на 8-10 %, а обробки нанодобривом Йодис-концентрат урожайність зросла лише на 2-4 %.

Ключові слова: *обробка насіння, Аватар-1, Йодис-концентрат, Богемія, Самурай, урожайність.*