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EFFICIENCY OF THE APPLICATION OF HUMIC PREPARATIONS IN FORMING THE YIELD OF WINTER WHEAT

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The relevance of the use of nitrogen inhibitors is determined by three main aspects, namely, reducing the amount of nitrogen fertilizers and, therefore, the chemical load on the environment, increasing the yield of agricultural crops, and economic feasibility. There is some information about the positive effect of the combined use of a nitrogen inhibitor and fulvic acid preparations, but there is no data on the role of humic substances such as nitrogen inhibitors. The results of the research showed a significant impact of the use of humic preparations on the formation of the yield of winter wheat. The use of UltraBoost for seed for pre-sowing treatment in the amount of 1 kg/t of seeds contributed to an increase in productivity by 0.22–0.29 t/ha, which was 4.4–6.4%. The norm of 1 kg/ha ensured a statistically significant increase in yield by 5–7.9%, which was 0.23–0.4 t/ha. In the variants of the experiment with a rate of 3 l/ha, the increase was 8.8–11% or 0.38–0.51 t/ha. The use of UltraBoost for NH₃ and pre-sowing seed treatment contributed to an increase in yield by 7.1–7.5%. The rate of UltraBoost for NH₃ of 1 l/ha provided an increase in yield by 0.25–0.4 t/ha, which in relative terms amounted to 3.9–7%. Twice as much rate led to an increase in productivity by 0.31–0.69 t/ha or by 10.4%. The use of nitrogen inhibitor UltraBoost for NH₃ leads to an increase in the content of total nitrogen in the soil. In the variants with the application of 1 l/ha, an increase in the content was noted on average by 2.06 g/m³, which was 14.3%, and in the case of application of 2 kg/ha, the content of total nitrogen in the soil was higher on average by 3.28%, which was 22.7%. The rate of alkaline hydrolyzed nitrogen in these variants was higher by 3.5–8.8%. In variants with a rate of 1 l/ha of UltraBoost for NH₃, the content of total nitrogen increased by 11.5%, and on variants with a rate of 3 l/ha – by 12.7%. The similar trend was also noted for the content of alkaline hydrolyzed nitrogen as the increase was 13.4 and 14.1%, respectively.

Key words: wheat, nitrogen, inhibitors, nutrients, productivity, humic preparations.

ЕФЕКТИВНІСТЬ ЗАСТОСУВАННЯ ГУМІНОВИХ ПРЕПАРАТІВ У ФОРМУВАННІ УРОЖАЙНОСТІ ПШЕНИЦІ ОЗИМОЇ

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Актуальність застосування інгібіторів азоту обумовлюється трьома головними аспектами – зменшення кількості азотних добрив, а отже, хімічного навантаження на довкілля, підвищення врожайності сільськогосподарських ку-



льтур, економічною доцільністю. Існує інформація про позитивний ефект від сумісного застосування інгібітора азоту та препаратів фульвових кислот, але не зустрічається даних про роль гумінових речовин як інгібіторів азоту. Результати досліджень показали в цілому істотний вплив застосування гумінових препаратів на формування врожайності пшениці озимої. Використання для передпосівної обробки препарату UltraBoost for seed в кількості 1 кг/т насіння сприяло збільшенню урожайності на 0,22–0,29 т/га, що становило 4,4–6,4 %. Норма в 1 кг/га забезпечила статистично достовірну прибавку врожайності на 5–7,9 %, що становило 0,23–0,4 т/га. На варіантах досліду з нормою 3 л/га прибавка становила 8,8–11 % або 0,38–0,51 т/га. Застосування UltraBoost for NH₃ та передпосівної обробки насіння сприяло збільшенню врожайності на 7,1–7,5 %. Норма UltraBoost for NH₃ в 1 л/га забезпечила зростання врожайності на 0,25–0,4 т/га, що у відносному значенні становило 3,9–7 %. Удвічі більша норма призвела до збільшення урожайності на 0,31–0,69 т/га або ж на 10,4 %. застосування інгібітора азоту UltraBoost for NH₃ призводить до збільшення вмісту загального азоту в ґрунті. У варіантах із застосуванням 1 л/га відмічалось збільшення вмісту в середньому на 2,06 г/м³, що становило 14,3 %, а в разі застосування 2 кг/га вміст загального азоту в ґрунті був більшим у середньому на 3,28 %, що становило 22,7 %. Показник лужногідролізованого азоту в цих варіантах був вищим на 3,5–8,8 %. На варіантах з нормою 1 л/га UltraBoost for NH₃ вміст загального азоту збільшився на 11,5 %, а на варіантах з нормою 3 л/га – на 12,7 %. Подібна тенденція також була відмічена й для вмісту лужногідролізованого азоту – збільшення становило відповідно 13,4 та 14,1 %.

Ключові слова: пшениця, азот, інгібітори, поживні елементи, урожайність, гумінові препарати.

Introduction. The problem of nitrogen losses in agriculture has a multifaceted nature, being felt in both of its main branches – crop and animal husbandry. If in animal husbandry it has, for the most part, an ecological nature, then in the field of plant breeding it also entails a significant economic aspect. First of all, it is related to nitrogen nutrition of plants. The greatest losses of nitrogen are observed, as a rule, in the case of the use of liquid nitrogen fertilizers, anhydrous ammonia, manure, organic fertilizers such as biochar, siderates, etc. Thus, there is a need to develop and implement techniques for the rational use of nitrogen fertilizers. Forms, norms, terms, methods of application of nitrogen fertilizers represent a complex of factors and their interactions, which is complicated by the unpredictability of growing conditions, particularly weather conditions.

The use of biochar in combination with nitrogen inhibitors reduced the emissions of N₂O and NO by 49.1–49.7% and 51.7–55.2%, and NH₃ by 33.4–35.2%, and also increased the yield of wheat by 13–22%, and the biomass of wheat plants – by 38% (Li Q. et al., 2015, He T. et al., 2018, Dawar K. et al., 2021). In other studies, nitrogen emissions decreased by 23–45% and wheat yield increased by 12% (Li Y. et al., 2015).

The yield increase, depending on the timing of nitrogen application and the use of urease inhibitors, can reach up to 29% if fertilizers are applied in the spring (Mohammed Y. A. et al. 2016, Owens J. L. et al., 2022). However, there are also data on the high efficiency of application at different temperature regimes (13–15 °C) and the frequency of treatments (Wang Y. et al., 2018). The type of soil can also be a significant factor as larger increases at the level of 7.5–12.9% were obtained on soils with a heavy structure that have an alkaline reaction (Abalos D. et al., 2014). On different soils, the agronomic efficiency of inhibitors can be 8.4–31.5%, and grain weight can increase by 9.1% (Kiani S. et al., 2014).



The use of nitrogen inhibitors also affects the assimilation of other nutrients, in particular phosphorus (Bronson K. F. et al., 1991; Ehsanpour F. et al., 2013; Polychronaki E. et al., 2013), which contributes to the increase in yield and the ratio of main and secondary products. In addition to increasing yield, the use of nitrogen inhibitors, in particular nitrapyrin, is considered as an alternative to repeated application of nitrogen fertilizers, and can also develop the effect of nitrogen fertilizers for the next crop in the crop rotation (Huber D. M. et al., 1980, Owens J. et al., 2019).

Nitrogen inhibitors can have a different chemical structure and origin, and therefore are not always equally effective. In studies with such inhibitors as trichloroethylphosphodiamidate, diethylphosphoniumtriamide, dimethylphosphoniumtriamide, N-(diaminophosphinyl) cyclohexylamine, N-benzyl-N-methylphosphoniumtriamide and phenylphosphorodiamide, the effectiveness of urea fertilizers was not noted (Schlegel A.J., Nelson D.W., Sommers L.E., 1987), and DMPP inhibitors (3,4-dimethylpyrazole phosphate) and DMPSA (3,4-dimethylpyrazoluccinic acid) reducing N₂O emissions to a minimum do not affect yield reduction (Huerfano X. et al., 2016). In arid conditions, inhibitors also play a role, which consists mainly of reducing emissions into the atmosphere, rather than significantly increasing yield or grain quality (McKenzie R. H. et al., 2010). It is also necessary to take into account the stages of plant development, since the inhibitor may not affect even the content of mineral nitrogen, if it is applied in the initial phases of grain formation (Poškus K. et al., 2021).

Some scientific works emphasize the use of nitrogen inhibitors as a means that reduces environmental risks and does not affect economic efficiency (Kong D. et al., 2021, Mirkhani R. et al., 2021, Hu Y. et al., 2014), and sometimes such an effect may be absent, especially in arid conditions (An H. et al., 2020).

There is some information about the positive effect of the combined use of the nitrogen inhibitor DMPP and fulvic acid preparations (Elsaka M. S., Abo Elsoud H., 2019), but there is no data in the literature on the role of such humic substances as nitrogen inhibitors, so the purpose of this work was to determine the effectiveness of humic preparations, which are food sources for microbes that feed on nitrogen and bacteria, break down stubble residues in the soil, which becomes mineralized and then assimilated by the plant. Instead of reducing bacteria as other inhibitors do, the UltraBoost for NH₃ formula allows nitrogen to bind to soil colloids within the top 8-10 inches of soil.

Relevance and purpose of research. It can be seen from the given material that the relevance of using nitrogen inhibitors is determined by three main aspects such as reducing the amount of nitrogen fertilizers and, therefore, the chemical load on the environment, increasing the yield of agricultural crops, and the economic expediency arising from the previous two factors. At the same time, a scientific and industrial discussion continues on each of the mentioned issues. In Ukraine, the economic aspect is most acutely felt, as the cost of fertilizers has increased sharply, and the prices of agricultural products have reacted negatively as a result of hostilities. The purpose of the research was to determine the effectiveness of using nitrogen inhibitors UltraBoost for NH₃ to increase the yield of winter wheat.

Research materials and methods. UltraBoost for seed is a liquid preparation for pre-sowing seed treatment with a recommended application rate of 0.5–1 kg/t for grain crops, which contains 10% humic, 3% fulvic and 1% ulmic acids. According to the manufacturer, the drug has a local inhibitory effect on the development of *Nitrosomonas* bacteria and stimulates an increase in the content of cytokinins in seedlings. UltraBoost for NH₃ is a liquid preparation intended for simultaneous use with KAS or anhydrous ammonia and is declared a nitrogen inhibitor. It contains 17.8% humic, 4.77% fulvic and 1.19% ulmic acids.



In the first experiment, the influence of varietal properties, drugs and inhibitor application rates on the yield of winter wheat was determined, in the second one, the effectiveness of UltraBoost for NH_3 nitrogen inhibitor application rates in the conditions of farms in the Poltava region was researched. UltraBoost for NH_3 is a CAS inhibitor that contains 16% humic, 3% fulvic and 1% ulmic acids and 7% oligomerized mixture of N-cyanoguanidine.

The experiments were conducted in the production conditions of farms that are in conditions of unstable moisture in the Left Bank Forest Steppe of Ukraine during 2020–2021 (factor A). In one of the experiments, the effectiveness of the nitrogen inhibitor UltraBoost for NH_3 (factor C) was established in the process of growing wheat varieties Boria and Postat (factor B). The cultivation technology used in the farm was taken as control. Methods of application were investigated. In the second experiment with the Smuglyanka wheat variety, the multifactorial complex consisted of year conditions (factor A), farming technology (factor B) and also the rate of application of the humic nitrogen inhibitor UltraBoost for NH_3 (factor C). Factor B combined agrotechnical methods typical for enterprises such as selection of a predecessor, fertilizers, features of crop protection.

The soil of the experimental plots is leached chernozem with a humus content of 3.96%; the depth of the humus horizon is 52–96 cm; pH – 6.0; hydrogen content – 105.6; P_2O_5 – 118.7; K_2O – 119.3 mg/kg. The seed sowing rate was 5 million seeds/ha, fertilizer – 100 kg/ha of KAS in physical volume. Winter wheat varieties studied were Boriya, Postat and Smuglyanka.

The area of the experimental site is 3.08 hectares, the repetition is three times, the placement is randomized. Statistical processing of the results of the experiment was carried out using the methods of dispersion and correlation analysis using the STATISTICA 10.0 program.

The research results showed a significant effect of inhibitor application on the formation of winter wheat yield. The use for pre-sowing treatment of the drug of the same name UltraBoost for seed in the amount of 1 l/t of seeds contributed to an increase in productivity by 0.22–0.29 t/ha, which was 4.4–6.4% (Table 1). The use of the nitrogen inhibitor UltraBoost for NH_3 turned out to be somewhat more effective. The norm of 1 l/ha ensured a statistically significant increase in yield by 5–7.9%, which was 0.23–0.4 t/ha. In the variants of the experiment with an inhibitor rate of 3 l/ha, the increase was 8.8–11% or 0.38–0.51 t/ha.

The obtained results indicate the prospect of using a nitrogen inhibitor in the economic conditions of a significant increase in the price of nitrogen fertilizers. From an economic point of view, it can be assumed that the use of UltraBoost for NH_3 can provide a 10% reduction in fertilizer application rates. However, in further programs, it is necessary to investigate the effect of this inhibitor on different types of soil and moisture conditions, because depending on these factors, the dynamics of changes in the amount and form of nitrogen may be different.

Dispersion analysis made it possible to single out the main factors that had the greatest impact on yield formation (Fig. 1). The largest share was the factor of selection of the variety for cultivation, which was almost 60%, the year conditions played a smaller role during the research period, only 36%.

It is significant that the use of humic preparations had a statistically significant value ($p \leq 0.01$), although it is small, but it is also important for yield management and forecasting – almost 4%. On average, the use of a nitrogen inhibitor and pre-sowing seed treatment contributed to an increase in yield by 7.5%. In the conditions of intensive crop production, such an effect deserves attention, as it has the prospect of not only an



increase in yield, but also a significant economic effect due to the use of lower rates of nitrogen fertilizer application. The total impact of regulated factors in the experiment was 64%. This is quite a high indicator for managing the formation of wheat yield.

Table 1

Yield depending on varietal properties and inhibitor application (2020-2021)

Variety	Way of application	Yield, t/ha	Increase, %
Boria	St (without treatment)	4.54	
	UltraBoost for seed (1 l/t)	4.83	6.4
	t	4.77	5.0
	UltraBoost for NH ₃ (3 l/ha)	4.95	9.0
Postat	St(without treatment)	3.86	-
	UltraBoost for seed (1 l/t)	4.19	8.6
	UltraBoost for NH ₃ (1 l/ha)	4.12	6.6
	UltraBoost for NH ₃ (3 l/ha)	4.28	11.0
Boria	St (without treatment)	5.07	-
	UltraBoost for seed (1 l/t)	5.29	4.4
	UltraBoost for NH ₃ (1 l/ha)	5.47	7.9
	UltraBoost for NH ₃ (3 l/ha)	5.58	10.1
Postat	St(without treatment)	4.38	-
	UltraBoost for seed (1 l/t)	4.68	6.8
	UltraBoost for NH ₃ (1 l/ha)	4.64	5.9
	UltraBoost for NH ₃ (3 l/ha)	4.76	8.8
HIP ₀₁ Conditions of growing years (factor A)		0.05	7.5
HIP ₀₁ Variety (factor B)		0.04	
HIP ₀₁ Method of application (factor C)		0.07	

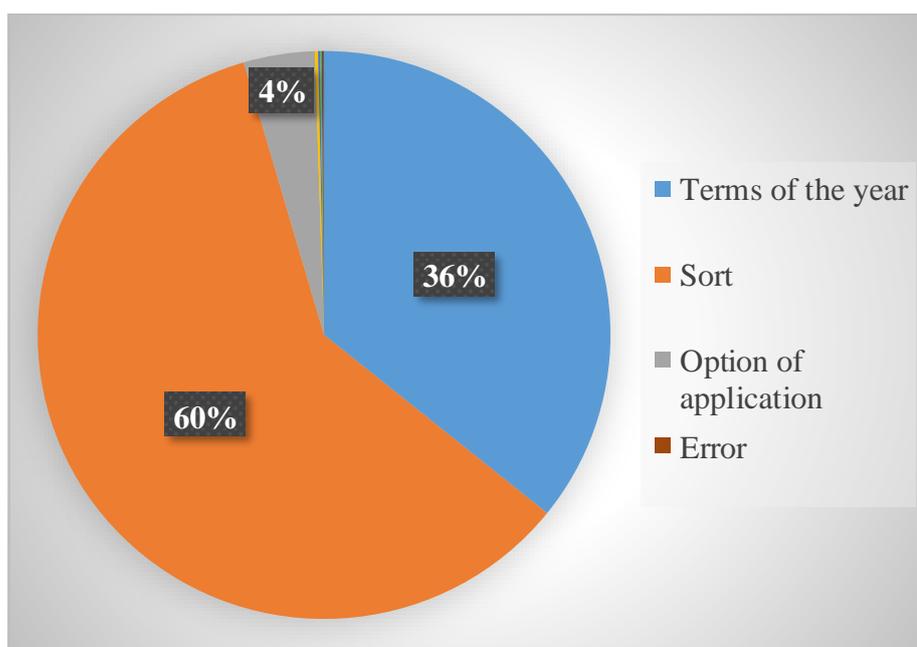


Fig. 1. The share of the influence of the factors forming the yield of winter wheat varieties depending on the method of application of the nitrogen inhibitor



In a parallel experiment in different farms of the region with the Smuglyanka wheat variety, where only a nitrogen inhibitor was used, regular increases in yield were also established. And although they were small in relative terms, they were statistically reliable. During the two-year research period, the use of a nitrogen inhibitor made it possible to increase the yield, on average, by 7.1% (Table 2). The rate of UltraBoost for NH₃ of 1 l/ha provided an increase in yield by 0.25–0.4 t/ha, which in relative terms amounted to 3.9–7%. Twice the rate led to an increase in productivity by 0.31–0.69 t/ha or by 10.4%, depending on the cultivation technologies used in the individual farm.

Dispersion analysis of the results of the experiment made it possible to identify the main factors of productivity formation. Cultivation technologies, which differed in the system of fertilization, protection, selection of a predecessor, etc., had the largest share, depending on the cultivation system adopted in each farm separately. Nevertheless, the inhibitor application factor was 8%, which is quite comparable to the previously described experiment. The conditions of the year also had a significant influence, which amounted to 19% (Fig. 2).

Of course, in the case of longer experiments, the conditions of the year can have a much greater influence, especially in years with extreme manifestations of growing factors. Further studies of the effectiveness of nitrogen inhibitors under conditions of temperature, water or salt stress are necessary. It is also advisable to conduct a study on the effectiveness of using this nitrogen inhibitor in combination with anhydrous ammonia.

Table 2

The productivity of the Smuglyanka variety depends on farm conditions and nitrogen inhibitor

Year	Farms	Way of application	Yield, t/ha	Increase, %
2020	FE "Agrosvit SV"	St (without treatment)	6.42	-
		UltraBoost for NH ₃ (1 l/ha)	6.67	3.9
		UltraBoost for NH ₃ (2 l/ha)	6.73	4.8
	LLC "Karlivske FE "LOS"	St (without treatment)	5.76	-
		UltraBoost for NH ₃ (1 l/ha)	6.16	7.0
		UltraBoost for NH ₃ (2 l/ha)	6.37	10.6
	FE "Zlatopil"	St (without treatment)	4.95	-
		UltraBoost for NH ₃ (1 l/ha)	5.26	6.3
		UltraBoost for NH ₃ (2 l/ha)	5.42	9.5
2021	FE "Agrosvit SV"	St (without treatment)	6.90	-
		UltraBoost for NH ₃ (1 l/ha)	7.21	4.5
		UltraBoost for NH ₃ (2 l/ha)	7.59	10.0
	LLC "Karlivske FE "LOS"	St (without treatment)	6.15	-
		UltraBoost for NH ₃ (1 l/ha)	6.47	5.1
		UltraBoost for NH ₃ (2 l/ha)	6.79	10.4
	FE "Zlatopil"	St (without treatment)	5.36	-
		UltraBoost for NH ₃ (1 l/ha)	5.63	5.0
		UltraBoost for NH ₃ (2 l/ha)	5.78	7.8
HIP ₀₁ Conditions of growing years			0.08	
HIP ₀₁ Variety			0.09	
HIP ₀₁ Method of application			0.11	
HIP ₀₁ Conditions of years* Conditions of the farm			0.14	

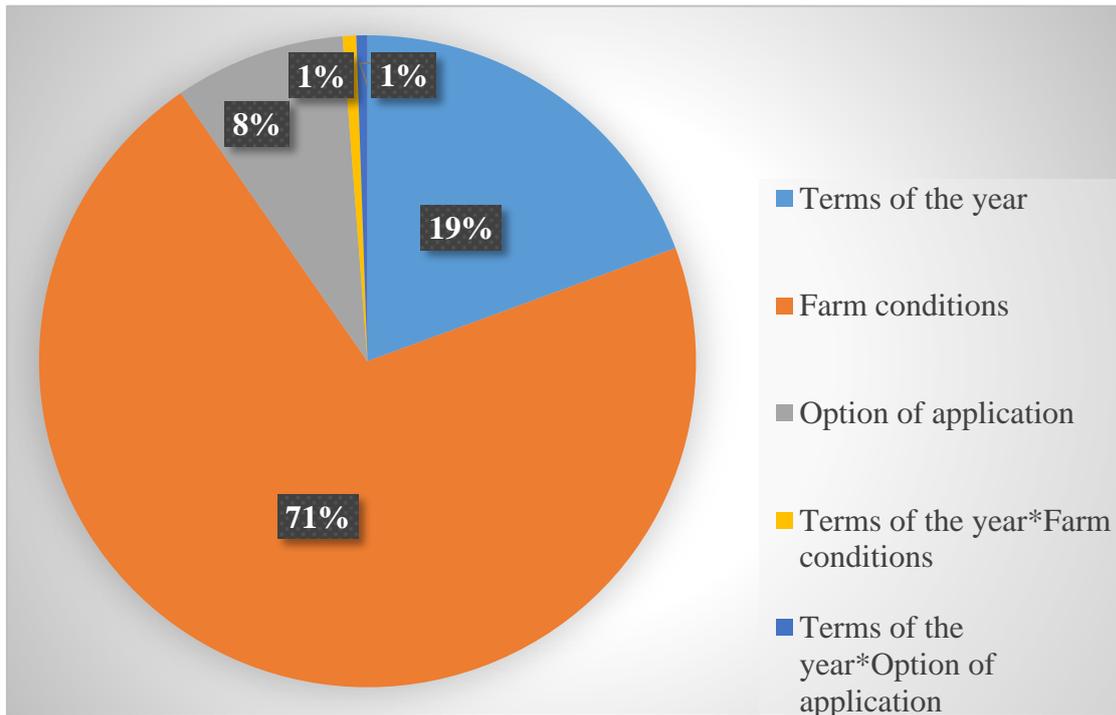


Fig. 2. The share of the influence of factors forming the yield of winter wheat varieties depending on the use of a nitrogen inhibitor.

Correlation analysis made it possible to establish a relationship between the nitrogen content in the soil and productivity. which may not always be present. In the first experiment. productivity correlated with the content of total nitrogen $r = 0.64$ and the content of alkaline hydrolyzed nitrogen $r = 0.57$ (Fig. 3). In the second experiment, such a dependence was not established although the productivity indicator naturally increased depending on the use of a nitrogen inhibitor.

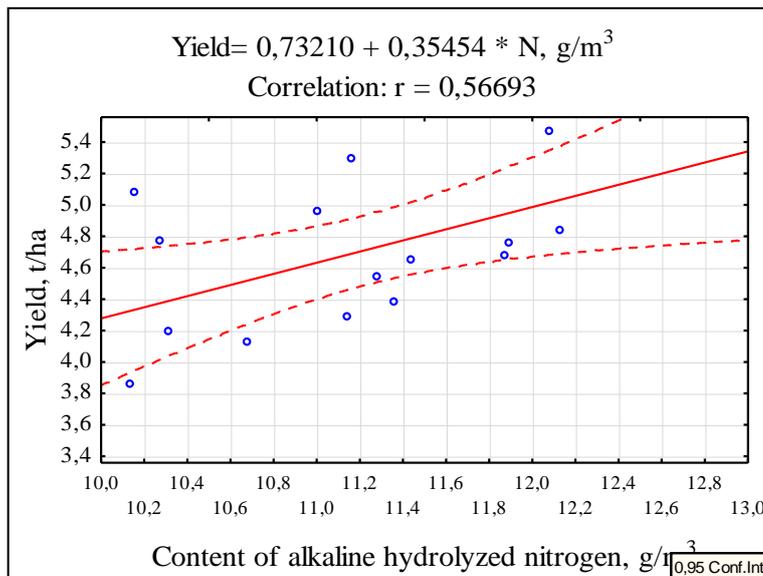


Fig. 3. Graph of yield dependence on the content of alkaline hydrolyzed nitrogen



As the results of the experiment showed, the use of the UltraBoost for NH₃ inhibitor leads to an increase in the content of total nitrogen in the soil (Fig. 4). In the first experiment, in the variants with the application of 1 l/ha, an increase in the content of 2.06 g/m³ was noted on average, which was 14.3%, and in the case of the application of 2 kg/ha, the content of total nitrogen in the soil was higher on average by 3.28%. which was 22.7%.

The rate of alkaline hydrolyzed nitrogen in these variants was higher by 3.5–8.8%. As it can be seen from the research data, a certain increase in nitrogen content was also recorded in the variants where the UltraBoost for seed processor was used. In this variant, the content of total nitrogen increased by almost 5%, and alkaline hydrolyzed nitrogen – by 5.8%.

In the second experiment, a natural increase in nitrogen content due to the use of a nitrogen inhibitor was also observed. On variants with a rate of 1 l/ha of UltraBoost for NH₃, the content of total nitrogen increased by 11.5%, and on variants with a rate of 3 l/ha – by 12.7%. The similar trend was also noted for the content of alkaline hydrolyzed nitrogen as the increase was 13.4 and 14.1%, respectively. Thus, the application of a higher rate did not lead to a proportional increase in nitrogen content and grain yield.

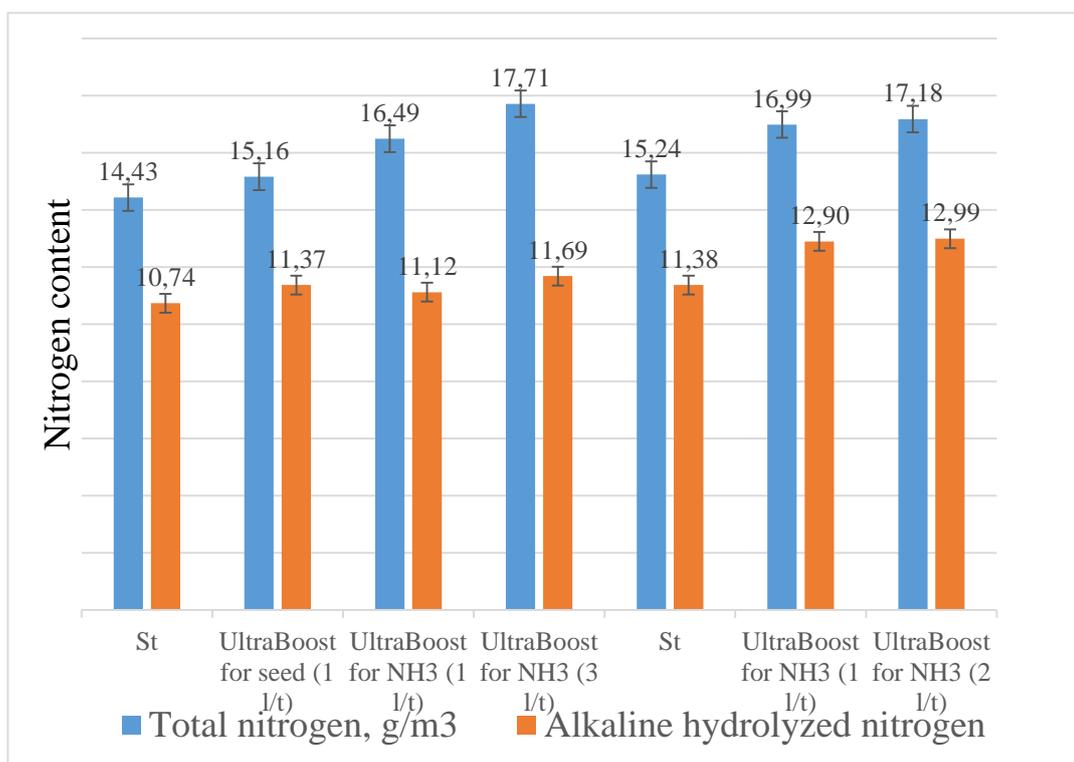


Fig. 4. The effect of nitrogen inhibitor on the content of total and alkaline hydrolyzed nitrogen in the soil

Discussion. The obtained research results indicate certain prospects for the use of humic nitrogen inhibitors on the example of UltraBoost for NH₃. The obtained yield increases are correlated with literature data (Mohammed Y. A. et al., 2016; Owens J. L. et al., 2022; Kiani, S. et al., 2014), and the increase in the content of total and alkaline hydrolyzed nitrogen – with other sources (Mirkhani R. et al., 2021; Hu Y. et al., 2014; An H. et al., 2020). Both research years were similar in terms of sufficient moisture and



slightly lower temperatures during the spring growing season but later were characterized by insufficient moisture.

Despite the fact that in arid conditions, nitrogen inhibitors may be ineffective (Elsaka M. S., Abo Elsoud H., 2019), in our experiments a statistically significant yield increase was obtained. Moreover, there is still a need for further research, as they also require accuracy and significant multiplicity of observations of different inhibitors under different environmental conditions.

Rather broad scientific discussion in literary sources should also be taken into account, which also notes the lack of direct influence of humic preparations and nitrogen inhibitors on yield formation. After analyzing a sufficient number of literary sources, it is possible to conclude that the research results obtained by scientists are ambiguous depending on the growing conditions and active substances of nitrogen inhibitors.

Conclusions. The main factors that shape the yield of wheat in conditions of unstable moisture are the selection of varieties for cultivation and agro-ecological conditions, the share of which can reach 60 and 71%, respectively. Furthermore, the annual conditions can be 19–36%, and the share of inhibitor use in the formation of yield ranged from 4–8%. The rate of UltraBoost for NH_3 of 1 l/ha provided an increase in yield by 0.25–0.4 t/ha, which in relative terms amounted to 3.9–7%. Twice as much rate led to an increase in productivity by 0.31–0.69 t/ha or by 10.4%. Application of the nitrogen inhibitor UltraBoost for NH_3 resulted in an average yield increase of about 7%, which was statistically significant. Thus, in conditions of unstable moisture, the use of nitrogen inhibitors may have a perspective for use in order to save nitrogen fertilizers and, possibly, increase the yield of winter wheat.

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