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Productivity of winter wheat varieties depending on nutrition optimisation

Abstract. The purpose of the study was to establish the influence of optimisation of the nutrition system on the formation of productivity and quality indicators of winter wheat varieties in the conditions of the Southern Steppe of Ukraine. The study was conducted in the field in the Mykolaiv region of Ukraine, with a comparison of wheat varieties and nutrition systems and further determination of yield, protein, and gluten content in the grain. As a result, it was determined that the reaction of wheat varieties to nutrition systems had a pronounced differentiated character. In the control variants, the average yield was 3.75-4.19 t/ha, while with optimised nutrition it grew to 5.2 t/ha for the 'Blagodarka Odesa' variety, to 5.23 t/ha for the 'Astarta' variety, and to 5.41 t/ha for the 'Smuglyanka' variety. For the varieties 'Blagodarka Odesa', 'Astarta', and 'Smuglyanka', the highest average yield was provided by the option with Organic D2. According to grain quality indicators, the 'Astarta' variety exhibited the most balanced reaction: the average protein content increased to 12.67%, and gluten – up to 26.66% for the combination of Urea K1 and K2. The 'Blagodarka Odesa' variety had the highest average protein content of 12.35%, and gluten content of 25.57%. The 'Podolyanka' variety demonstrated the best quality indicators using Escort-Bio. The practical significance of the findings lies in the fact that agricultural enterprises, farms, and agronomic services can use them to make informed choices regarding fertilisation regimes for specific varieties of winter wheat, with the aim

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of increasing yields and improving the protein and gluten content of the grain under the conditions of the Southern Steppe of Ukraine

Keywords: grain; gluten; protein; yield; fertilisers

INTRODUCTION

The relevance of the study is due to the need to improve the efficiency of growing winter wheat in the Southern Steppe of Ukraine. The cultivation of this crop in the region is accompanied by a combination of several technologically significant restrictions: unstable moisture, high dependence on the flow of spring vegetation, a substantial difference between the potential and factually realised productivity of varieties, and the need to combine yield growth with an improvement in grain food indicators. Under such conditions, the nutrition system acquires not only the functions of compensating for the deficiency of mineral nutrition elements but also the role of a tool for regulating the varietal reaction, crop stability, and the formation of a protein-gluten complex of grain. In this regard, the definition of such approaches to nutrition optimisation that ensure the realisation of the productive potential of varieties and improve the quality of grain in specific agroecological conditions of the region becomes of scientific and practical importance.

During 2020-2022, A.V. Drobitko *et al.* (2025) investigated the influence of varietal characteristics and pre-sowing treatment of seeds with biological preparations on the productivity of winter wheat in the conditions of southern Ukraine. The work included a three-time field experiment with four varieties and four seed treatment options, and the highest yield was obtained with the combined use of Azotofit-R and Phytocide-R preparations, indicating the importance of combining the varietal factor with the biological elements of the technology. V.V. Gamayunova *et al.* (2024) summarised data on increasing the productivity of winter wheat with modern energy-saving technologies in the context of climate change and military conditions in Ukraine. The paper considered the role of resource-saving approaches, selection of adapted varieties, optimisation of nutrition, minimisation of tillage, and use of biologics as ways to reduce the gap between potential and actual crop yields in the steppe zone. The influence of different levels of nitrogen fertilisation on the productivity of common winter wheat varieties in the agroclimatic conditions of the southern region of Ukraine was examined by A.V. Shepel (2025). According to the results, for some varieties, average nitrogen doses were optimal, which provided high yields in conditions of moderate moisture and improved grain quality.

The influence of the method of placement of nitrogen fertiliser and the timing of its application on the yield and protein concentration in winter wheat grain was evaluated by B. Ballagh *et al.* (2025). The authors compared the surface application of urea and stabilised urea with the subsurface placement of fertiliser by disk systems in different calendar periods, and the increase in yield with subsurface application was recorded only in a part of the media, which emphasised the dependence of the effect on soil and weather conditions. Modified fertilisation strategies aimed at increasing the protein content in the grain of soft red winter wheat in the Mid-Atlantic region of the United States were evaluated by N.M. Fiorellino & L.A. Thorne (2025). The authors compared four nitrogen nutrition schemes, including the shift of part of the dose to later phases, post-flowering application, and increased total nitrogen dose, and evaluated the reaction of several wheat varieties, indicating a separate role of the variety and nutrition regime in the formation of grain protein content. I.M. Hernández-Ochoa *et al.* (2023) conducted a three-year field experiment in Germany to explore the interaction of genotype, nitrogen nutrition levels, and environmental conditions in old and modern winter wheat varieties. In the four-repeat experiment, three nitrogen levels and six varieties of different breeding periods were compared, after which the yield, mass of a thousand grains, number of grains, protein, and test weight were analysed; it was established that the intermediate nitrogen level provided an increase in yield, and the optimal norms for yield and protein did not coincide across varieties.

The reaction of winter wheat to a combination of sowing dates and different levels of nitrogen fertiliser in Poland was investigated by W. Jarecki (2024). In a three-year field experiment, delaying sowing for 30 days reduced the yield, but was partially compensated by an increase in nitrogen nutrition, while the best economic result was provided by the recommended sowing period in combination with the norm of 150 kilograms of nitrogen per hectare. Optimised winter wheat fertilisation strategies in the North China Plain, considering yield, quality, nutrient accumulation, economic impact, and environmental losses, were evaluated by X. Jiang *et al.* (2023). In a field experiment with a randomised block design and four repetitions, eight nutrition schemes were compared, resulting in an increase in yield and net profit simultaneously with a decrease in nitrate leaching and nitrous oxide emissions, which expanded the interpretation of nutrition optimisation from purely productive to complex production and ecological. The examination of the combined effect of nitrogen fertiliser and high-protein varieties on protein concentration and wheat grain yield was conducted by J. Kang *et al.* (2026). The study demonstrated that top dressing increased the concentration and yield of grain protein, high-protein varieties also enhanced this effect, and random forest modelling confirmed that the largest share of variation in the indicator was explained by nitrogen nutrition management and varietal characteristics. X. Lyu *et al.* (2022), in a two-year field study, evaluated the effect of various forms of foliar nitrogen applied during the flowering stage on protein accumulation and grain quality in winter wheat. It was determined that nitrogen forms had different effects on the accumulation of gluten proteins and quality indicators, and foliar application of nitrate and amide forms was more effective than ammonium, which is of direct importance for the choice of preparations in corrective feeding technologies.

The analysis of the literature showed that the influence of pre-sowing seed treatment, sowing dates, nitrogen nutrition levels, fertiliser application methods, and individual foliar top dressing schemes on the yield or individual grain quality indicators is sufficiently covered. However, there was a lack of systematic analysis of the combined assessment of varietal characteristics, multi-variant fertilisation regimes, and simultaneous changes in yield, protein, and gluten content under the conditions of the Southern Steppe of Ukraine, where the effectiveness of the technology depended significantly on regional agro-ecological constraints. This study aimed to establish the specifics of the formation of productivity of winter wheat varieties in the conditions of the Southern Steppe of Ukraine. The following research objectives were defined to achieve this goal: establish the influence of various nutrition systems on the yield of winter wheat varieties; determine changes in protein and gluten content in grain depending on the variety and variant of nutrition; justify the most appropriate combinations of varieties and nutrition systems for simultaneous increase in yield and improvement of technological indicators of grain.

MATERIALS AND METHODS

The experimental part of the study was conducted during 2017-2020, and the results until the end of 2025 were summarised. The experiment was conducted on the experimental field of the Educational, Scientific, and Practical Centre of the Mykolaiv National Agrarian University (Ukraine). Territorial reference to the Mykolaiv region and the Southern Steppe of Ukraine determined the agroecological context of the study, in which nutrition technology was considered as a factor in regulating productivity in conditions of potential moisture deficiency, increased temperature load, and significant dependence of the crop on the spring growing season. The soil of the experimental site is Southern heavy loamy chernozem. In the arable soil layer (0-30 cm), the humus content was 2.9-3.2%, the pH of salt extract – 6.8-7.2, the content of easily hydrolysed nitrogen – 65 mg/kg of soil, nitrate nitrogen – 22-27 mg/kg, mobile phosphorus – 37-40 mg/kg, exchange potassium – 330-340 mg/kg of soil. Weather conditions in the years of research were characterised by unstable moisture, uneven distribution of precipitation during the growing season, and increased temperature background in the spring-summer period, which is typical for the conditions of the Southern Steppe of Ukraine. Meteorological data were obtained based on the materials of the Mykolaiv regional Hydrometeorology Centre (Ukrainian Hydrometeorological Centre, 2021). The object of the study was winter wheat varieties of Ukrainian selection: 'Blagodarka Odesa'; 'Astarta'; 'Smuglyanka'; 'Podolyanka', recommended for growing in the Southern Steppe of Ukraine and their nutrition systems. The subject of the study covered the specific features of yield formation, protein, and gluten content in grain, depending on the combination of varietal characteristics and fertiliser schemes.

The experiment was performed according to a two-factor scheme. The first factor was the variety, the second – the food system. This design allowed simultaneously assessing both the Independent Influence of each factor and the nature of the combination of varietal reaction with technological top dressing options. Factor A – winter wheat variety: 'Blagodarka Odesa'; 'Astarta'; 'Smuglyanka'; 'Podolyanka'. Factor B – nutrition system: control – without fertilisers, water treatment; $N_{30}P_{30}$ – application for pre-sowing cultivation, background option; Background + Urea K1 at a rate of 1 L/ha; Background + Urea K2 at a rate of 1 L/ha; background + Escort-Bio at a rate of 0.5 L/ha; Background + Urea K1+K2 at a rate of 0.5 L/ha of each preparation; Background + Organic D2 at a rate of 1 L/ha. For foliar feeding, preparations with different functions were used in the baseline mineral nutrition treatment: Urea K1, Urea K2, and Organic D2 – as organo-mineral fertilisers for foliar application, and Escort-Bio – as a biological preparation. This set of options enabled the comparison of the effectiveness of fertilising plants with the use of preparations of different types of action and evaluating the result of their combination. Application rates of 1 L/ha for Urea K1, Urea K2 and Organic D2 and 0.5 L/ha for Escort-Bio were selected as working standards for field foliar top dressing of grain crops. In the combined version of Urea K1+K2, preparations were introduced at 0.5 L/ha each to assess their combined effect without increasing the total volume of the preparation compared to single-component variants. Thus, the experiment included 28 combinations of factors. With three repetitions, the total number of considered options was 84 sites. This scheme allowed comparing both between varieties and between different technological approaches to nutrition within each variety. The total area of one experimental plot was 80 m², the accounting area – 30 m². The repetition of the experiment was threefold. The use of a smaller accounting area than the total was due to the need to minimise the marginal effect and ensure comparability of results between options. Threefold repetition allowed reducing the random influence of local heterogeneity of field conditions on the final indicators of grain yield and quality.

The basic element of the technology in the fertilised versions was the background application of $N_{30}P_{30}$ for pre-sowing cultivation. This method served as a basis upon which foliar feeding with various preparations was applied. The control version did not provide for the application of fertilisers; water was used to equalise the technological regime of crop treatment in these areas. Foliar treatment of crops with fertilisers was conducted twice. The first treatment was carried out at the start of the spring growing season, and the second during the stem elongation stage. It was these phases that were chosen as key for regulating plant nutrition, since during this period the main elements of the crop structure were laid and the prerequisites for further grain filling were formed. The working solution in all top dressing options was applied with a flow rate of 200 L/ha. The use of a two-time foliar top dressing scheme allowed assessing not a one-time, but a prolonged response of plants to technological adjustment of nutrition. This methodological construction corresponded to the task of establishing not only the fact of exposure to the preparations but also the stability of the varietal response when reintroduced into critical phases of plant development. The protein content of the grain was determined using the Kjeldahl method in accordance with ISO 20483:2013 (2013) on a FOSS Kjeltec™ 8400 automatic analyser (Denmark). The crude gluten content was determined mechanically in accordance with ISO 21415-2:2009 (2009) on the Perten Glutomatic® 2200 system (Sweden). Each sample was examined in three laboratory repetitions, and the tables show the average values of the indicators.

The research material was the crop and grain of winter wheat obtained in each version of the experiment. Yield, protein content, and gluten content were used to characterise the results of the experiment. Yield analysis was performed for the varieties 'Blagodarka Odesa', 'Astarta', and 'Smuglyanka', for which a complete array of accounting data was generated. Grain quality indicators, in particular, the protein and raw gluten content, were determined for all four varieties – 'Blagodarka Odesa', 'Astarta', 'Smuglyanka', and 'Podolyanka'. The 'Podolyanka' variety was not included in the yield analysis due to the lack of a complete set of experimental data on this indicator. The first group consisted of yield indicators expressed in tonnes per hectare. They were used to assess the quantitative effect of different nutrition systems in each variety and to compare varieties with each other. The second group consisted of indicators of protein content in grain, expressed as a percentage. This indicator was used to assess changes in the food value of grain under the influence of nutrition systems. The third group consisted of indicators of gluten content in grain, also expressed as a percentage. They were used to characterise the technological properties of grain and to determine whether the increase in yield was accompanied by an improvement in the quality of grain products. For each year of observations, the results were presented in two forms: as an absolute value of the indicator and as a deviation from the control. The use of an additional indicator "± to control" allowed determining the direction and magnitude of the response of plants to a specific food option within the same variety and year, which was important for further interpretation of the stability or instability of the technological effect.

Yield assessment took place separately for each variety and variant of the nutrition system. Within each year, the results were compared primarily with the control, which allowed establishing an absolute and relative increase or decrease in productivity under the influence of background and foliar top dressing. In addition, interannual mapping was performed to determine the stability of the variety's response to each feeding variant. During the stage of analytical generalisation, the average yield values for the entire presented time series were also used. This approach helped separate one-time reactions caused by the conditions of a particular year from more stable patterns associated with the variety or nutrition scheme. Grain quality was characterised by two main indicators – protein content and gluten content. The assessment was carried out according to the same principle as the yield assessment: separately for each variety, food option and year, followed by the determination of deviations from the control. This approach helped trace whether the increase in yield was accompanied by a simultaneous improvement in the protein-gluten complex, or whether a compromise was formed between the quantitative and qualitative characteristics of the crop. Both annual values and averaging over the entire observation period were used to interpret the data. The combination of these two levels of analysis was fundamentally important, as protein and gluten are indicators that are sensitive to the conditions of the year and to the characteristics of the redistribution of plastic substances in the plant. Statistical processing of experimental data was conducted by methods of variance analysis for a two-factor field experiment, where factor A was the winter wheat variety, and factor B – the nutrition system. The analysis of indicators was performed separately by year of research. The arithmetic mean was determined for each variant of the indicator. The reliability of differences between variants was evaluated by LSD05. In the tables, the results are presented separately by variety, which allowed tracking the response of each variety to food options in different years of research. The reliability of differences between the average values was estimated by the method of variance analysis at the significance level $p \leq 0.05$. The results were processed in the IBM SPSS Statistics programme.

Experimental plant studies, including the collection of plant material, were in accordance with institutional, national, and international guidelines. The authors adhered to the Convention on Biological Diversity (1992) standards, which are the basis for ensuring the sustainable use of bioresources and the conservation of biodiversity.

RESULTS

Formation of the yield of winter wheat varieties depending on the nutrition system. Yield indicators showed that the control options formed a lower level of realisation of productive potential compared to most fertilised schemes. The reaction of varieties to different food options varied. The difference between the effect of a simple mineral background and combined schemes with foliar preparations turned out to be fundamental since it was the combined variants that most often provided the transition to a consistently higher level of yield (Table 1).

Table 1. Yield of the variety 'Blagodarka Odesa' depending on the food system, t/ha

Fertilisation system	2017	± to control, %	2018	± to control, %	2019	± to control, %	2020	± to control, %
Control	3.87	–	4.09	–	3.59	–	3.81	–
Background (N30P30)	4.65	0.78	3.75	-0.34	3.9	0.31	4.03	0.22
Background + Urea K1	4.63	0.76	4.51	0.42	3.95	0.36	4.63	0.82
Background + Urea K2	4.7	0.83	4.27	0.18	4.43	0.84	4.74	0.93
Background + Escort-Bio	4.46	0.59	4.37	0.28	4.69	1.1	5.19	1.38
Background + Urea K1+K2	4.66	0.79	5.45	1.36	4.77	1.18	4.97	1.16
Background + Organic D2	4.76	0.89	5.67	1.58	5.53	1.94	4.82	1.01
LSD05, t/ha	0.32		0.36		0.38		0.31	

Source: compiled by the authors

Analysis of the presented data showed that for the 'Blagodarka Odesa' variety, the most pronounced productive effect was provided by variants with Organic D2 and the combined application of Urea K1 and K2. The simple background of $N_{30}P_{30}$ did not have a stable advantage over the control over all years, while the combined schemes maintained a higher level of yield over the entire observation period. Such dynamics indicated that for this variety, basic mineral nutrition created only initial conditions, and additional provision of plants in the phases of active stem growth and the formation of generative organs was crucial for the realisation of productive potential. The consequence of this type of reaction was a shift in yield in the range of consistently higher values and a decrease in the dependence of the final result on the variability of individual years.

For the 'Astarta' variety, the reaction to nutrition systems was more selective. A relatively higher control level indicated good basic productivity of the variety, but not every fertiliser option equally enhanced this advantage. The most effective schemes were Organic D2, Escort-Bio and the combined use of Urea K1 + K2. In turn, a simple mineral background and individual monosyllabic top dressing in certain years not only did not provide additional growth but also deviated from the control in the direction of decrease. This ratio of results showed that the 'Astarta' variety needed not just an increased background of nutrition, but its better synchronisation with the phases of active consumption of elements. In practical terms, this meant the need for more accurate technological selection of the fertilisation system since the universal scheme did not guarantee the same return (Table 2).

Table 2. Yield of the 'Astarta' variety, depending on the fertilisation system, t/ha

Fertilisation system	2017	± to control, %	2018	± to control, %	2019	± to control, %	2020	± to control, %
Control	4.37	–	4.31	–	3.86	–	4.21	–
Background (N30P30)	4.3	-0.07	4	-0.31	3.98	0.12	4.46	0.25
Background + Urea K1	4.61	0.24	4	-0.31	4.44	0.58	4.46	0.25
Background + Urea K2	4.12	-0.25	4.78	0.47	4.24	0.38	4.87	0.66
Background + Escort-Bio	5.27	0.9	4.74	0.43	5.1	1.24	4.79	0.58
Background + Urea K1+K2	5.33	0.96	4.62	0.31	4.57	0.71	5.02	0.81

Table 2, Continued

Fertilisation system	2017	± to control, %	2018	± to control, %	2019	± to control, %	2020	± to control, %
Background + Organic D2	4.91	0.54	5.2	0.89	5.69	1.83	5.13	0.92
LSD05, t/ha	0.34		0.35		0.39		0.33	

Source: compiled by the authors

The most contrasting reaction to nutrition optimisation was formed in the 'Smuglyanka' variety. Under the control conditions, this variety showed the lowest yield among the varieties listed; however, it was found to have the greatest potential for yield increase. Organic D2 consistently produced the highest or one of the highest results throughout the entire period, and the Urea K1 + K2 variant occupied the second position or approached it. This nature of changes indicated a high reactivity of the variety to improved feeding conditions. Presumably, with limited nutrition, some of its potential remained unfulfilled, while additional treatments provided faster compensation for the deficit at critical stages of crop formation (Table 3). Table 4 presents the average yield of varieties for 2017-2020.

Table 3. Yield of the 'Smuglyanka' variety depending on the fertilisation system, t/ha

Fertilisation system	2017	± to control, %	2018	± to control, %	2019	± to control, %	2020	± to control, %
Control	3.68	–	3.53	–	4.27	–	3.53	–
Background (N30P30)	3.88	0.2	4.61	1.08	3.9	-0.37	3.81	0.28
Background + Urea K1	4.2	0.52	4.16	0.63	3.91	-0.36	3.93	0.4
Background + Urea K2	4.62	0.94	4.76	1.23	4.92	0.65	4.74	1.21
Background + Escort-Bio	4.73	1.05	4.61	1.08	5.01	0.74	4.61	1.08
Background + Urea K1+K2	4.79	1.11	5.02	1.49	5.23	0.96	5.01	1.48
Background + Organic D2	5.31	1.63	5.25	1.72	5.47	1.2	5.61	2.08
LSD05, t/ha	0.35		0.38		0.4		0.37	

Source: compiled by the authors

Table 4. Average yield of varieties for 2017-2020, t/ha

Variety	Control	Background ($N_{30}P_{30}$)	Background + Urea K1	Background + Urea K2	Background + Escort-Bio	Background + Urea K1+K2	Background + Organic D2
'Blagodarka Odesa'	3.84	4.08	4.43	4.54	4.68	4.96	5.2
'Astarta'	4.19	4.19	4.38	4.5	4.98	4.89	5.23
'Smuglyanka'	3.75	4.05	4.05	4.76	4.74	5.01	5.41
LSD05, t/ha							
A	0.13						
B	0.21						
AB	0.36						

Note: LSD05, t/ha – the smallest significant difference for each of the factors, with a significance level of $p \leq 0.05$: a – factor "variety"; B – factor "nutrition system"; AB – interaction of factors
Source: compiled by the authors

Generalisation of average yield indicators showed that in all three varieties, the lowest level of productivity was formed at the control, and the highest – for systems with Organic D2 or for combined application of Urea K1 and K2. The obtained pattern showed that the effectiveness of nutrition was determined not only by the introduction of a basic dose of mineral elements but also by the presence of a technological mechanism for supporting plants during periods when soil assimilation could be limited. The conditions of the Southern Steppe, which are characterised by fluctuations in humidity and temperature stress in the spring-summer period, caused an increased importance of those schemes that supplemented soil nutrition with foliar treatments. That is why combined systems often provided not only an increase in yield but also its better stabilisation over the years.

Formation of protein content in grain depending on the variety and nutrition system

In contrast to the yield, the protein content varied less unambiguously. The increase in productivity was not always accompanied by a proportional increase in grain protein content. This indicated a different nature of the formation of quantitative and qualitative components of the crop: while the yield increased as a result of improving the overall supply of plants and better implementation of the assimilation apparatus, the protein content depended on the redistribution of nitrogen in the plant and the intensity of synthesis of spare proteins during the grain filling period (Table 5).

Table 5. Protein content in the grain of the 'Blagodarka Odesa' variety for the period 2017-2020, %

Fertilisation system	2017	± to control, %	2018	± to control, %	2019	± to control, %	2020	± to control, %
Control	12.39	–	11.06	–	11.4	–	12.34	–
Background ($N_{30}P_{30}$)	12.05	-0.34	12.12	+1.06	12.56	+1.16	11.66	-0.68
Background + Urea K1	12.41	+0.02	11.97	+0.91	12.54	+1.14	12.07	-0.27
Background + Urea K2	12.64	+0.25	12.27	+1.21	12.49	+1.09	12	-0.34
Background + Escort-Bio	12.61	+0.22	12.44	+1.38	12.27	+0.87	11.83	-0.51
Background + Urea K1+K2	11.98	-0.41	12.91	+1.85	11.79	+0.39	11.55	-0.79
Background + Organic D2	11.94	-0.45	12.11	+1.05	12.02	+0.62	12.83	+0.49

Source: compiled by the authors

The protein content of the grain of the 'Blagodarka Odesa' variety increased more evenly than that of other varieties. The most consistent effect was provided by variants with urea K2, Escort-Bio, and Organic D2. The maximum one-time indicator was formed not on a more stable version, but on a combined application of Urea K1+K2, which indicated a strong dependence of protein content on the weather background of a particular year. Therefore, for this variety, additional nutrition affected not only the gross yield but also the redistribution of nitrogen compounds in the grain. The result was a combination of higher productivity with improved food parameters, although the degree of this combination varied depending on the nutrition scheme.

For the 'Astarta' variety, the most consistent positive protein response was observed in the Urea K1+K2 variant. This scheme provided the highest average protein content over the years and was combined with one of the highest yield levels. This indicated that there was no strong contradiction between the increase in crop mass and the accumulation of protein in the grain. Probably, in this case, there was a better agreement between the formation of the yield mass and the supply of nitrogen to plants in the grain filling phase. For industrial practice, this result was of particular importance, as it testified to the possibility of simultaneously achieving a quantitative and qualitative effect (Table 6).

Table 6. Protein content in 'Astarta' grain for the period 2017-2020, %

Fertilisation system	2017	± to control, %	2018	± to control, %	2019	± to control, %	2020	± to control, %
Control	12.23	–	12.39	–	11.97	–	11.19	–
Background ($N_{30}P_{30}$)	11.11	-1.12	11.49	-0.9	12.51	+0.54	12.25	+1.06
Background + Urea K1	11.83	-0.4	12.43	+0.04	12.57	+0.6	12.13	+0.94
Background + Urea K2	11.48	-0.75	12.09	-0.3	11.32	-0.65	11.38	+0.19
Background + Escort-Bio	12.81	+0.58	11.54	-0.85	12.04	+0.07	12.21	+1.02
Background + Urea K1+K2	12.28	+0.05	12.85	+0.46	12.95	+0.98	12.59	+1.4
Background + Organic D2	12.15	-0.08	12.11	-0.28	12.04	+0.07	12.37	+1.18

Source: compiled by the authors

The 'Smuglyanka' variety reacted differently to protein nutrition. On average, the control level remained one of the highest over the years, and most of the fertilised options did not show a stable advantage. Some years were accompanied by a short-term increase in protein content, but the overall picture remained uneven. This indicated that for this variety, the improvement of nutrition was primarily aimed at increasing yields, and not at systematically increasing the protein concentration. A likely consequence of this ratio was a partial "dilution" of the protein component against the background of an increase in crop mass, which is typical for varieties with a high response to the intensification of the production process (Table 7).

Table 7. Protein content in 'Smuglyanka' grain for the period 2017-2020, %

Fertilisation system	2017	± to control, %	2018	± to control, %	2019	± to control, %	2020	± to control, %
Control	12.44	–	12.09	–	12.28	–	12.19	–
Background ($N_{30}P_{30}$)	11.85	-0.59	12.43	+0.34	11.35	-0.93	11.76	-0.43
Background + Urea K1	11.63	-0.81	12.16	+0.07	12.6	+0.32	11.24	-0.95
Background + Urea K2	12.21	-0.23	11.54	-0.55	12.16	-0.12	12.55	+0.36
Background + Escort-Bio	11.48	-0.96	12.31	+0.22	12.32	+0.04	12.01	-0.18
Background + Urea K1+K2	12.86	+0.42	11.65	-0.44	11.71	-0.57	11.73	-0.46
Background + Organic D2	11.82	-0.62	11.61	-0.48	12.92	+0.64	12.42	+0.23

Source: compiled by the authors

For the 'Podolyanka' variety, the most noticeable improvement in protein content was provided by Escort-Bio and the combined version of Urea K1 + K2. Despite the relatively moderate amplitude of changes, the results showed the orientation of the variety to a positive reaction, precisely for the qualitative component of the grain. Such dynamics indicated that for 'Podolyanka', nutrition optimisation could be particularly important not so much in the aspect of gross harvest, but in the aspect of increasing the suitability of grain for food use (Table 8).

Table 8. Protein content in 'Podolyanka' grain for the period 2017-2020, %

Fertilisation system	2017	± to control, %	2018	± to control, %	2019	± to control, %	2020	± to control, %
Control	12.48	–	11.82	–	12.05	–	11.99	–
Background ($N_{30}P_{30}$)	12.11	-0.37	12.08	+0.26	11.64	-0.41	12.53	+0.54
Background + Urea K1	11.56	-0.92	12.27	+0.45	12.41	+0.36	12.03	+0.04
Background + Urea K2	11.85	-0.63	11.79	-0.03	12.6	+0.55	11.93	-0.06
Background + Escort-Bio	12.35	-0.13	12.37	+0.55	12.17	+0.12	11.93	-0.06
Background + Urea K1+K2	11.64	-0.84	12.49	+0.67	12.7	+0.65	11.52	-0.47
Background + Organic D2	12.08	-0.4	11.74	-0.08	12.65	+0.6	11.67	-0.32

Source: compiled by the authors

Overall, the protein block showed that the varieties' response to fertilisation systems was clearly variety-specific. Whilst certain variants resulted in a significant improvement in protein content for 'Astarta' and 'Blagodarka Odesa', this effect proved to be weaker and less consistent for 'Smuglyanka'. Therefore, the protein content of grain could not be considered as an automatic consequence of increased nutrition; its changes depended on the extent to which the variety was able to transform the additional intake of elements into the accumulation of protein substances in the grain.

Formation of gluten content in grain depending on the variety and nutrition system

In terms of gluten content, the effect of nutrition systems was more pronounced than in terms of protein. In most varieties, it was the combined nutrition options that provided a more stable improvement in this indicator. This demonstrated that the structural characteristics of the protein complex were more sensitive to the technological support of sowing in the phases of spring vegetation restoration and the stem elongation stage (Table 9).

Table 9. Gluten content in grain varieties 'Blagodarka Odesa' for the period 2017-2020, %

Fertilisation system	2017	± to control, %	2018	± to control, %	2019	± to control, %	2020	± to control, %
Control	25.23	–	24.36	–	22.98	–	23.35	–
Background ($N_{30}P_{30}$)	25.79	0.56	22.37	-1.99	23.87	0.89	22.68	-0.67
Background + Urea K1	23.35	-2.44	23.51	-0.85	25.12	2.14	22.74	-0.61
Background + Urea K2	25.06	1.71	23.6	-0.76	24.91	1.93	25.07	1.72
Background + Escort-Bio	26.78	1.72	24.75	0.39	25.17	2.19	25.56	2.21
Background + Urea K1+K2	23.94	-2.84	24.05	-0.31	26.39	3.41	23.65	0.3
Background + Organic D2	25.51	1.57	24.25	-0.11	23.9	0.92	25.24	1.89

Source: compiled by the authors

For 'Blagodarka Odesa', the most clear increase in gluten was provided by Escort-Bio. This option held higher values for most years and had a better average score. The introduction of Urea K2 and Organic D2 also had a positive effect on gluten, but less consistently. This distribution clarified that for this variety, the improvement of the structural properties of the protein complex depended not only on nitrogen intake but also on the general physiological state of the plant during grain formation. The consequence was that the nutrition technology had to be selected separately for the task of improving gluten to obtain both a high yield and the best baking performance.

In the 'Astarta' variety, the most pronounced gluten effect was formed on the Urea K1+K2 variant, while Escort-Bio and Organic D2 also provided consistently high indicators. A special feature of this variety was the combination of a high level of yield with the simultaneous growth of gluten. That is why 'Astarta' showed the most balanced type of reaction among the presented varieties. From a practical standpoint, this meant that a properly selected fertilisation system scheme allowed obtaining grain with higher technological characteristics without losing productivity. This response model was most favourable for directing the technology not only to gross yield but also to food quality (Table 10).

Table 10. Gluten content in 'Astarta' grain for the period 2017-2020 %

Fertilisation system	2017	± to control, %	2018	± to control, %	2019	± to control, %	2020	± to control, %
Control	25.44	–	25.51	–	22.71	–	24.09	–
Background ($N_{30}P_{30}$)	24.34	-1.1	24.94	-0.57	26.12	3.41	23.16	-0.93
Background + Urea K1	23.49	-1.95	24.82	-0.69	24.08	1.37	22.94	-1.15
Background + Urea K2	24.25	-1.19	23.87	-1.64	26.61	3.9	25.03	0.94
Background + Escort-Bio	24.49	-0.95	26.79	1.28	27.07	4.36	25.75	1.66
Background + Urea K1+K2	26.31	0.87	26.03	0.52	26.91	4.2	27.4	3.31
Background + Organic D2	27.69	2.25	25.2	-0.31	25.34	2.63	25.09	1

Source: compiled by the authors

In the 'Smuglyanka' variety, the increase in gluten was more pronounced than the increase in protein. Organic D2 provided the best average results, while Urea K2 and Urea K1+K2 formed similar values. This meant that with the intensification of nutrition in this variety, the improvement in the technological properties of grain occurred primarily due to changes in the gluten complex, and not due to a stable increase in total protein content. The consequence was the possibility of a simultaneous increase in yield and a partial improvement in the technological suitability of grain, although the direct relationship between these two effects remained less unambiguous than in the 'Astarta' variety (Table 11).

Table 11. Gluten content in 'Smuglyanka' grain for the period 2017-2020, %

Fertilisation system	2017	± to control, %	2018	± to control, %	2019	± to control, %	2020	± to control, %
Control	23.01	–	25.59	–	23.27	–	23.08	–
Background ($N_{30}P_{30}$)	23.5	0.49	25.42	-0.17	24.53	1.26	22.61	-0.47
Background + Urea K1	22.75	-0.26	22.94	-2.65	25.38	2.11	26.45	3.37
Background + Urea K2	24.91	1.9	26.49	0.9	23.29	0.02	25.68	2.6
Background + Escort-Bio	24.31	1.3	23.24	-2.35	27.16	3.89	23.89	0.81
Background + Urea K1+K2	24.46	1.45	26.15	0.56	25.57	2.3	24.5	1.42
Background + Organic D2	25.76	2.75	24.44	-1.15	26.76	3.49	26.66	3.58

Source: compiled by the authors

For the 'Podolyanka' variety, Escort-Bio provided the highest average gluten level, and Urea K1+K2 and Urea K2 also formed similar results. This reaction indicated a good sensitivity of the variety to foliar top dressing precisely in the aspect of improving the rheological properties of grain. Since there are no data on the yield of this variety in the provided array, the qualitative reaction acquired an independent value. It showed that even without an estimate of the gross harvest, it was possible to trace a clear increase in the food parameters of grain against the background of nutrition optimisation (Table 12).

Table 12. Gluten content in 'Podolyanka' grain for the period 2017-2020, %

Fertilisation system	2017	± to control, %	2018	± to contr ol, %	2019	± to control, %	2020	± to control, %
Control	22.97	–	24.77	–	24.81	–	23.12	–
Background ($N_{30}P_{30}$)	25.35	2.38	23.2	-1.57	23.47	-1.34	25.25	2.13
Background + Urea K1	25.51	2.54	23.55	-1.22	25.84	1.03	25.05	1.93
Background + Urea K2	25.43	2.46	25.89	1.12	26.55	1.74	23.89	0.77
Background + Escort-Bio	25.34	2.37	26.6	1.83	25.21	0.4	26.23	3.11
Background + Urea K1+K2	26.84	3.87	25.77	1	26.1	1.29	23.96	0.84
Background + Organic D2	24.55	1.58	25.27	0.5	26.98	2.17	23.96	0.84

Source: compiled by the authors

A generalisation of this block of results showed that gluten was more sensitive to nutrition systems than protein. For most varieties, it was not merely a case of an increase in performance being recorded; rather, a consistent advantage was established for certain hybrid combinations. This demonstrated that the technological adjustment of nutrition affected both the concentration of nitrogen compounds and the qualitative structure of the protein complex. In the applied aspect, this pattern was of direct importance for the choice of fertiliser system in the production of food grain.

Summary of inter-varietal differences based on average grain quality indicators

The average values of protein and gluten for the entire observation period were calculated to compare the reaction of varieties by qualitative indicators. This comparison made it possible to separate varieties in which nutrition optimisation mainly affected protein content from varieties in which the main effect was manifested through gluten or through a combination of qualitative and quantitative effects (Table 13). Comparison of average values showed the presence of at least three types of varietal response to nutrition optimisation. The first type was inherent in 'Astarta', for which the same combined scheme provided an increase in yield, protein, and gluten. The second type was typical of 'Blagodarka Odesa', where productivity and quality indicators also improved, but the best options for protein and gluten did not coincide. The third type was typical for 'Smuglyanka', where the strongest effect was observed for yield and gluten, while the average protein content remained close to the control. 'Podolyanka', according to available data, tended to the option with a predominant qualitative effect, especially for gluten. This differentiation of varieties was of direct technological importance. It showed that the fertilisation system could not reach according to a single universal principle. If the goal was to maximise the increase in gross yield, the priority was primarily options with Organic D2 and Urea K1+K2. If the emphasis shifted to improving baking characteristics, the structure of preferences changed, and Escort-Bio or separate combined schemes were taken to the leading positions, depending on the variety. Thus, the results demonstrated the need for a variety-differentiated approach to nutrition optimisation.

Table 13. Summary of average grain quality indicators for 2017-2020

Variety	Average protein in the control, %	The option with the highest average protein content	Average protein in the best variant, %	Average gluten in control variant, %	Variant with the highest average gluten content	Medium gluten in the best variant, %
'Blagodarka Odesa'	11.8	Background + Urea K2	12.35	23.98	Background + Escort-Bio	25.57
'Astarta'	11.95	Background + Urea K1+K2	12.67	24.44	Background + Urea K1+K2	26.66
'Smuglyanka'	12.25	Control	12.25	23.74	Background + Organic D2	25.91
'Podolyanka'	12.09	Background + Escort-Bio	12.21	23.92	Background + Escort-Bio	25.85

Source: compiled by the authors

The totality of these data showed that the productivity of winter wheat varieties in the conditions of the Southern Steppe of Ukraine was formed under the influence of not only the genetic characteristics of the variety but also the structure of the nutrition system. A simple mineral background did not ensure the maximum realisation of the potential of any of the analysed varieties. The advantage shifted to those schemes in which the basic fertiliser was supplemented with foliar treatments that can support plants in the phases of intensive growth and grain formation. That is why combined systems often provided a more stable increase in yield. Grain quality indicators were characterised by more complex dynamics. In contrast to yield, where the preference for combined schemes was almost universal, protein, and gluten reacted differently depending on the variety. This meant that the increase in nutrition did not always automatically translate into an increase in all quality indicators. The reaction of varieties to food options was heterogeneous: in 'Blagodarka Odesa', 'Astarta', and 'Smuglyanka', changes were primarily manifested in the yield level, while in 'Podolyanka', shifts in protein and raw gluten content were more pronounced. Along with this, for individual varieties, nutrition optimisation was combined with positive changes in both productivity and grain quality indicators. This pattern showed that the quantitative and qualitative components of the crop had different mechanisms of formation and reacted differently to technological intervention. The most balanced reaction was typical for the 'Astarta' variety, where one of the combined schemes provided not only a high yield but also an improvement in protein and gluten. 'Blagodarka Odesa' was characterised by high plasticity in terms of yield and manageability of quality parameters, but the optimal options for protein and gluten did not coincide. The 'Smuglyanka' variety demonstrated the largest reserve of yield growth, which indicated a high response to the intensification of nutrition, but the qualitative reaction of this variety was less uniform. For 'Podolyanka', the presented data showed that the effect is primarily aimed at improving grain quality indicators.

The results showed that nutrition optimisation should not be considered solely as a means of increasing yields. Its significance also consisted in changing the structure of grain productivity, increasing or weakening protein content, forming a gluten complex, and changing the ratio between quantitative and qualitative characteristics of the crop. As a result, there was a need to choose a fertilisation system not only for the expected gross harvest but also for the final direction of grain use. As a result, the results of the experiment showed that the greatest effect in increasing the yield was provided by systems with Organic D2 and with a combination of Urea K1+K2, while in improving the quality indicators of grain, the leading role was played by variety-specific reactions to Escort-Bio, Urea K2, or combined variants. This confirmed the expediency of a differentiated approach to optimising the nutrition of winter wheat varieties in the conditions of the Southern Steppe of Ukraine.

DISCUSSION

The results obtained indicate that in the conditions of the Southern Steppe of Ukraine, optimisation of winter wheat nutrition affected the yield and quality indicators of grain, but the nature of this effect was determined by the variety and composition of the nutrition system. The highest average yield indicators in the experiment were formed mainly with the application of Organic D2 and a combination of Urea K1 and K2, while the reaction for protein and gluten was more differentiated: the 'Astarta' variety had a combination of high yield with an improvement in both qualitative parameters, the 'Blagodarka Odesa' variety – a distinction between optimal options for protein and gluten, and the 'Smuglyanka' – a predominance of the yield effect over the protein one. Integrated cultivation systems that differed in sowing time, standing density, fertiliser, and irrigation regimes were compared by H. Xu *et al.* (2023). The authors stressed that integrated management provided almost the same level of yield as a high-cost system, but with a better nitrogen balance and higher water productivity. This interpretation of the optimisation of the technology was consonant with the results obtained since even in the experiment with winter wheat, the decisive factor was not the fact of increasing the dose of nutrients, but the combination of elements of the technology, which ensured a more complete realisation of varietal potential without losing the quality indicators of grain. A. Burton *et al.* (2024) conducted an experiment at three sites in Switzerland involving five varieties and six nitrogen application regimes, showing that the yield and nitrogen content in grain were determined mainly by the total nitrogen dose, and not by the options for its distribution by application time. The results obtained in the experiment partially coincide with this conclusion, since in the conditions of the Southern Steppe, combined nutrition schemes with foliar top dressing were more effective, which indicated a stronger role of phase adjustment of nutrition in an arid and more stressful agroecological environment. The interaction of winter wheat varieties with different norms and terms of nitrogen application was examined by D. Ghimire *et al.* (2021). Researchers determined that increasing the nitrogen background steadily increased the protein content, while the increase in yield was more dependent on the year and water supply conditions; at the risk of nitrogen loss, spring, or fractional application gave better results. This corresponded to the results obtained in the part that the quality indicators of grain were more closely related to the nutrition scheme than the yield itself, and the varietal response to top dressing was not linear and the same in all variants.

Five levels of nitrogen nutrition combined with sprinkler irrigation under the influence of dry stress were examined by D. He *et al.* (2026). The authors determined that with an increase in the nitrogen background, the yield, water, and nitrogen efficiency increased only to a certain optimum, after which excess nitrogen nutrition reduced the return on the resource. This pattern was consistent with the results of this experiment, since the highest performance indicators were formed not on the simplest or most intense variant in terms of load, but on balanced combined schemes that provided the best implementation of the production process without a pronounced deterioration in protein-gluten characteristics. A.K.M. Hamani *et al.* (2025), in a two-year field study, combined two irrigation regimes with six methods of nitrogen distribution by drip fertigation and showed that the 50:50 scheme between basic application and top dressing after the resumption of vegetation provided the highest yield and contributed to improved grain quality. This was close to the results obtained, in which the preference also shifted to options with distributed and combined nutrition, while a single or simplified supply of nutrients did not provide the same pronounced effect. J. Chang *et al.* (2026) examined four nitrogen norms in combination with two sowing methods and found that the norm of 180 kg of nitrogen per hectare provided the best balance between yield, water efficiency and acceptable quality in the arid conditions of the Loess Plateau of China, while the higher norm increased individual quality characteristics, but increased the consumption of soil moisture. This coincided with the logic of the results obtained, according to which quality maximisation and yield maximisation did not always coincide in the same technological version, and the choice of the fertilisation system should be conducted considering which component of productivity was a priority.

Various combinations of granular nitrogen application dates and foliar top dressing were evaluated by L. Drenjančević *et al.* (2026). The results obtained by the researchers showed that the response of grain yield and quality depended on the conditions of the year, while nitrogen efficiency indicators were more sensitive to changes in the variant than absolute yield parameters. Similar seasonal heterogeneity was observed in this experiment, where the same fertilisation system could affect protein, gluten, and yield differently depending on the variety and year, which confirmed the need to evaluate the effectiveness of nutrition not only by absolute yield but also by the stability of the qualitative and quantitative response. Y. Wang *et al.* (2023), in a global meta-analysis, summarised the effects of nitrogen nutrition on wheat yield, protein content, and water productivity, and showed that nitrogen application on average increased all three indicators, while the best effect was provided by higher standards, fractional application, post-flowering top dressing, and the use of controlled forms of fertilisers. This is consistent with the results obtained, since in the experiment, the most pronounced effect was observed not with a simplified nutrition background, but with combined schemes in which additional top dressing supported both grain yield and quality. M. Li *et al.* (2026), in a two-year field trial involving ten varieties of rain-fed wheat, classified genotypes according to their combination of yield and nitrogen use efficiency, and the best results were linked to the coordinated functioning of the root system and the aboveground parts, more active post-anthesis photosynthesis, and more efficient remobilisation of assimilates and nitrogen. This was consistent with the results of the experiment, where an unequal response to the same nutrition schemes was also identified between varieties, which indicated the decisive role of intra-variety physiological mechanisms in the implementation of the effect of nutrition optimisation.

The hypothesis that effective management of nitrogen nutrition requires determining the dose of nitrogen and a balanced supply of potassium, magnesium, and sulphur was tested on winter wheat by A. Andrzejewska *et al.* (2025). This expansion of the interpretation of nutrition corresponded to the results obtained since the advantage in the experiment was also formed not by isolated nitrogen solutions, but by combined systems in which nutrition acted as a multicomponent regulator of grain productivity and quality. The results obtained are consistent with the data of R. Wang *et al.* (2025), which showed that the combination of irrigation and nitrogen nutrition in winter wheat contributes to an increase in yield and protein yield, but the impact on individual grain quality indicators is less clear. This confirms that it is advisable to consider nutrition optimisation not only as a means of increasing yields but also as a tool for achieving a balance between quantitative and qualitative indicators of grain. C. Li *et al.* (2025), in a field experiment, showed that the norm of N210 provided the highest yield for two seasons, while a further increase in the nitrogen dose increased the number of ears, but limited the mass of grain from the ear and the mass of a thousand grains. This was consistent with the results of the experiment, since it also confirmed that the productive effect was determined not by maximising the intensity of nutrition as such, but by achieving a balanced scheme in which grain filling improved and the balance between quantitative and qualitative characteristics of the crop was not disturbed.

The APSIM Next Generation model for reproducing winter wheat growth, nitrogen yield response, and nitrogen dynamics was evaluated by J.G. Pinto *et al.* (2026). The authors determined that the model accurately predicted the overall response of yield to nitrogen levels, particularly at high fertilisation rates, although its accuracy declined when nitrogen levels were zero. This was important in the context of the results obtained, as it confirmed the possibility of further modelling the variety-specific response to fertilisation systems and predicting their effectiveness in various agroecological scenarios. The dynamics of protein and starch in winter wheat grain, depending on irrigation regimes and nitrogen nutrition, were examined by B. Zib *et al.* (2025). The researchers established that protein components responded positively to nitrogen application, but were suppressed by irrigation, while starch accumulation was increased by both water and nitrogen. This enabled the explanation of the results of the experiment by the fact that a linear relationship was not always formed between the yield and protein content of grain, and changes in the nutrition system could affect individual components of grain quality in different ways, depending on environmental conditions and varieties. S. Liu *et al.* (2022) indicated that moderate supplemental irrigation increased yields, water productivity, and nitrogen efficiency by improving the nitrogen status of plants, whereas excessive water supply did not provide a corresponding crop increase. This was tangential to the results obtained since it also confirmed that the implementation of the effect of nutrition was determined by the general physiological state of sowing, and not just by the dose of fertilisers itself, that is, the optimisation of the technology should account for the interaction of nutrition with the water regime.

Different nitrogen doses and ratios during the development phases of winter wheat were studied by M.S. Kubar *et al.* (2022). The researchers established that the optimal application was 225 kg of nitrogen per hectare with a distribution of 60+40%, which provided higher rates of photosynthesis, nitrogen efficiency, biomass accumulation, and yield. This was consistent with the results of an experiment in which the best outcomes were also linked not to a single application of nutrients, but to a controlled-release fertiliser system that supported the plants during key stages of crop development. L. Rempelos *et al.* (2023) stressed that varieties created for high-cost intensive systems did not always combine the productivity, sustainability, resource efficiency, and quality required for alternative growing systems. This was consistent with the results of the experiment, as different varieties reacted differently to the same nutrition schemes, which confirmed the need to consider the variety not as a neutral background of technology, but rather an active factor in the formation of grain yield and quality. Researchers H. Heinemann *et al.* (2025) in a multi-site study conducted along the European climatic gradient showed that pedoclimatic conditions had a greater influence on root biomass and yield than variety, although varietal differences in yield and the ratio of root to above-ground biomass were also significant. This also explained the results of the experiment, where the same fertilisation system did not give an identical response in all varieties, and its effectiveness had to be considered as a result of the interaction of the genotype with specific soil and climatic conditions of the steppe zone. A. Yousefi *et al.* (2025) compared facultative, winter, and spring wheat at four levels of nitrogen nutrition and showed that facultative wheat provided higher yields at traditional nitrogen rates of 100-200 kg/ha, while increasing nitrogen nutrition further increased the protein and nutrient content of the grain. This was close to the results obtained, as it also confirmed that optimal food standards and regimes are not universal for all genotypes, but are determined by a combination of the type of variety, environment, and production goal.

Strategies to create high-quality wheat varieties with increased nutritional value, combining genetic approaches, biofortification breeding and improved agronomic practices, including soil management, irrigation, and post-harvest technologies, were generalised by X. Zhang & X.M. Liu (2025). This expanded perspective on grain quality facilitated the interpretation of the results, considering both the effects of individual nutrition schemes and their role within a broader system where nutrient technology interacted with the variety to determine protein content, gluten parameters, and overall nutritional value. Comparison of sources confirmed that the results obtained are consistent with the modern idea of the need for combined consideration of the variety, nitrogen nutrition regime, foliar top dressing, water regime, and associated mineral supply when evaluating the productivity of winter wheat. The experiment specified that in the conditions of the Southern Steppe of Ukraine, the most appropriate technological solutions should be obtained not only by the average yield but also by the nature of the varietal reaction to individual fertilisation systems, since this interaction determined the final combination of yield, protein, and gluten.

CONCLUSIONS

As a result of the study, it was established that the productivity of winter wheat varieties in the conditions of the Southern Steppe of Ukraine significantly depended on the combination of varietal characteristics and nutrition system. It was confirmed that the use of only a mineral background did not ensure the maximum realisation of productive potential, while the combination of the background with foliar top dressing formed higher yield indicators and, in some cases, improved grain quality. In terms of yield, the lowest average values were recorded at the control: 3.84 t/ha for the 'Blagodarka Odesa' variety, 4.19 t/ha for the 'Astarta' variety, and 3.75 t/ha for the 'Smuglyanka' variety. The highest average values were obtained for the application of Organic D2 – 5.2, 5.23, and 5.41 t/ha, respectively. Consequently, the greatest reserve of productivity growth was associated with the use of combined nutrition systems, primarily due to the inclusion of Organic D2 and the combination of Urea K1 and K2. According to the qualitative indicators of grain, the variety-specific nature of the reaction was established. The most balanced effect was characteristic of the 'Astarta' variety, in which the average protein content increased to 12.67% by combining Urea K1 and K2, and gluten – up to 26.66%. The 'Blagodarka Odesa' variety had the highest average protein content of 12.35% when using Urea K2, and gluten – 25.57% for the use of Escort-Bio. In the 'Smuglyanka' variety, the most pronounced effect was observed in terms of yield and gluten content, whilst the average protein content remained highest in the control treatment, at 12.25%. For the 'Podolyanka' variety, the best protein and gluten values were formed mainly using Escort-Bio and amounted to 12.21% and 25.85%, respectively. A limitation of the study was that the dataset provided did not include yield data for the 'Podolyanka' variety, which meant it was not possible to perform a comprehensive comparison of this variety with others across all productivity indicators. Further research should focus on expanding the range of varieties, achieving a balance between yield and quality for all genotypes, and conducting an economic assessment of the effectiveness of fertilisation systems depending on the weather conditions of the year.

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Продуктивність сортів пшениці озимої залежно від оптимізації живлення

Анотація. Метою дослідження було встановити вплив оптимізації системи живлення на формування продуктивності та показників якості зерна сортів пшениці озимої в умовах Південного Степу України. Дослідження проводилося у польових умовах у Миколаївській області України з порівнянням сортів пшениці і систем живлення та подальшим визначенням врожайності, вмісту білка і клейковини в зерні. У результаті було встановлено, що реакція сортів пшениці на системи живлення мала виражений диференційований характер. На контрольних варіантах середня врожайність становила 3,75-4,19 т/га, тоді як за оптимізованого живлення зростала до 5,2 т/га у сорту ‘Благодарка Одеська’, до 5,23 т/га у сорту ‘Астарта’ і до 5,41 т/га у сорту ‘Смуглянка’. Для сортів ‘Благодарка Одеська’, ‘Астарта’ і ‘Смуглянка’ найвищу середню врожайність забезпечував варіант з Органік D2. За показниками якості зерна найбільш збалансовану реакцію виявив сорт ‘Астарта’: середній вміст білка підвищувався до 12,67 %, а клейковини – до 26,66 % за поєднання Мочевина К1 і К2. У сорту ‘Благодарка Одеська’ найвищий середній вміст білка становив 12,35 %, а клейковини – 25,57 %. У сорту ‘Подолянка’ найкращі показники якості формувалися за використання Ескорт-Біо. Практична значимість одержаних результатів полягає в тому, що аграрні підприємства, фермерські господарства та агрономічні служби можуть використати їх для обґрунтованого добору систем живлення під конкретні сорти пшениці озимої з метою підвищення врожайності, покращення білково-клейковинних показників зерна в умовах Південного Степу України

Ключові слова: зерно; клейковина; білок; врожайність; добрива