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EFFECTS OF OPTIMIZED MINERAL FERTILIZATION ON YIELD AND STRUCTURAL ELEMENTS OF WINTER WHEAT ON THE RETISOL OF WESTERN POLISSIA OF UKRAINE

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Abstract: The effects of mineral fertilizer rates, based on NPK removal by grain and by grain plus straw, compared with the recommended rate, on winter wheat crop productivity were studied. The treatments were applied against the background of different ameliorants, with plant residues returned to the soil. In Retisol, the highest winter wheat grain yield (4.98 t ha^{-1}) was obtained with the application of the 1.0 Hh (hydrolytic acidity) rate of dolomite lime (DL) with $N_{150}P_{50}K_{125}$ (the rate based on grain and straw NPK removal). This treatment led to the best indicators of yield structure elements. However, the harvest index was lower than with $N_{130}P_{25}K_{35}$ (the rate based on grain NPK removal). This suggests a higher grain-to-straw ratio with the grain-based NPK removal approach. Despite lower structural indicators, the average yield in the treatment with DL (1.0 Hh) + $N_{130}P_{25}K_{35}$ had no statistically significant difference compared to the $N_{120}P_{60}K_{90}$ (the recommended rate) at $P<0.05$. The absence of PK fertilizers in the treatment with N_{130} significantly decreased yield (19%) compared to the other NPK treatments. Applying 1.0 Hh limestone (LS) with the recommended NPK rate did not promote the formation of structural elements, and the yield decreased by 0.21 t ha^{-1} compared to DL (1.0 Hh) under similar conditions. Based on the results, applying mineral fertilizer rates calculated according to main product (grain) NPK removal, combined with 1.0 Hh DL and the return of plant residues to the soil, is recommended for optimal winter wheat productivity on Retisols.

Key words: grain, straw, yield structure, fertilizer rates, dolomite lime, limestone.

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Introduction

Winter wheat plays a vital role in ensuring the long-term food security for the ever-expanding global population. Achieving this requires balanced winter wheat nutrition management for sustainable agriculture. Crop productivity management should address the specific needs of each field and be based on production profitability and the ecological stability of ecosystems. Shah and Wu (2019) and Abdeta (2021) emphasize that it is crucial to consider both soil fertility and crop nutrient requirements. This targeted approach maximizes the impact of fertilization technologies, as fertilizers have a greater effect under such conditions than with blanket recommendation rates. Tailoring winter wheat fertilization to the specific needs of each field can improve nutrient use efficiency, increase yields, and enhance grain quality, ultimately contributing to a more sustainable and productive agricultural system (Sidyakina and Dvoretskyi, 2020).

There are many studies on winter wheat nutrition that offer different views on the optimal fertilization system. Some researchers recommend using high doses of mineral fertilizers to obtain maximum yield, while others believe that more economical and environmentally friendly methods, such as organic fertilizers and green manure, can be equally effective.

Yang et al. (2017) recommend N-application rates of 150–170 kg N ha^{-1} for wheat for obtaining high yields with low environmental risk. According to Panayotova et al. (2017), increasing nitrogen fertilizer application from N_{120} to N_{180} with P_{80} increased the yield of winter wheat by only 2%. Lykhochvor et al. (2022) noted that N_{180} increased the yield of winter wheat grain by 2.94 t ha^{-1}. However, the increase in yield from the additional application in the $P_{60}K_{90}S_{30}Mg_{20}$ plus microfertilizer complex was equivalent to the increase from nitrogen of 2.56 t ha^{-1} (70.3%), highlighting the importance of balanced nutrition in the crop productivity formation.

Under the eco-ecological scenario, the application of 144.7 N and 34.3 kg ha^{-1} P, plus 30 t ha^{-1} manure, provided a grain yield of 4.03 t ha^{-1} (Mohsen and Behzad, 2018). A positive effect on grain yield and components of the winter wheat harvest was obtained for the used NPK fertilizers (120 kg N ha^{-1}, 100 kg P_2O_5 ha^{-1}, 60 kg K_2O ha^{-1}), lime (5 t ha^{-1} $CaCO_3$) and manure (20 t ha^{-1}) (Jelic et al., 2015). Earlier studies by Polovyi and Yashchenko (2021) on light-textured podzolic soil have established that liming is a priority for improving winter wheat nutrition. Liming helps to neutralize soil acidity, while adding organic matter and mineral fertilizers improves nutrient availability.

The optimal fertilizer system for a planned yield of winter wheat should consider the biological features of the variety, and soil and weather conditions, the predecessor of the crop and other factors of agricultural technology (Hospodarenko et al., 2022).

A certain number of chemical fertilizers can ensure a high grain yield. However, when the chemical fertilizers are excessively applied, a decrease in crop response and a faster decline in grain yield than its initial growth can be observed. Inefficient use of fertilizers can also cause several negative effects on the environment (Yang et al., 2017; Jiang et al., 2023).

The possibility of changing approaches to crop fertilization in Ukraine is associated with the increased use of crop residues for fertilization. This practice is particularly widespread in the cultivation of winter wheat, which is the dominant crop in the country. The use of by-products of plants and siderates creates conditions for reducing the rates of mineral fertilizers by 30–50% without reducing the productivity of arable land (Degodiuk et al., 2014).

Consequently, there are theoretical grounds for adjusting recommendations regarding winter wheat fertilization by considering only the nutrient export through the harvested yield (Polovyi and Yashchenko, 2021). This approach would allow farmers to optimize fertilizer use, reducing costs and environmental impacts.

The hypothesis of this research is that winter wheat grown on ameliorated Retisols with straw incorporation will exhibit enhanced structural elements when fertilized at rates optimized based on NPK removal by grain or by both grain and straw, compared to the recommended fertilization rate. This approach could lead to more sustainable and cost-effective winter wheat production on these soils.

The aim was to investigate the possibility of reducing the recommended rate of mineral fertilizers in combination with ameliorants, when plant residuals return to the soil without decreasing the winter wheat crop.

Material and Methods

Study area

The research was conducted from 2021 to 2023 in a stationary field experiment on the lands of the Institute of Agriculture of the Western Polissia of the National Academy of Agrarian Sciences of Ukraine (50º70'81"N; 26º54'55"E). The soil of the experimental plots was sod-podzolic *Albic Retisol* (Arenic, Aric) (WRB, 2022). The experiment was conducted with the Astarta winter wheat variety (developed by the Institute of Plant Physiology and Genetics, NAS of Ukraine). The experimental plots were arranged sequentially with three replications. The sowing area of the plot was 99 m^2 (16.5 × 6 m), and the accounting area was 50 m^2 (12.5 × 4 m).

The recommended rate of mineral fertilizers for winter wheat in the Western Polissia zone was $N_{120}P_{60}K_{90}$. The calculated rates of mineral fertilizers were determined by the normative method, considering the uptake of NPK by one unit of yield and the level of soil nutrient supply: 1) for the formation of 5 t ha^{-1} of grain:

$N_{130}P_{25}K_{35}$; 2) for the formation of 5 t ha^{-1} of grain with a corresponding amount of straw: $N_{150}P_{50}K_{125}$.

The experiment included the following treatment options: V1) without fertilizers (control); V2) DL (1.0 Hh); V3) DL (1.0 Hh) + $N_{120}P_{60}K_{90}$ (recommended rate) + Microfertilizer Nutrivant universal (MF); V4) DL (1.0 Hh) + $N_{130}P_{25}K_{35}$ (normative rate for grain formation) + MF; V5) DL (1.0 Hh) + $N_{150}P_{50}K_{125}$ (normative rate for grain and straw formation) + MF; V6) DL (1.0 Hh) + N_{130} (normative rate for grain formation) + MF; V7) DL (1.5 Hh) + $N_{120}P_{60}K_{90}$ (recommended rate) + MF; V8) LS (1.0 Hh) + $N_{120}P_{60}K_{90}$ (recommended rate).

Mineral fertilizers were applied in the form of ammonium nitrate, ammophos, and potassium chloride in accordance with the treatment option: PK fertilizers were applied during plowing, and N fertilizers were applied three times: N_{40} for cultivation fertilization, N_{60} in early spring at the stage of resumed plant growth, and the remainder at the stage of stem elongation before ear emergence. The Nutrivant universal microfertilizer (MF) was applied foliarly twice at a dose of 2 kg ha^{-1} in the phase of spring tillering (BBCH 25-27) and in the phase of stem elongation (BBCH 33-35) of winter wheat.

Ameliorants in the form of dolomite lime (DL) and limestone (LS) were applied according to the experimental scheme before sowing wheat. The application rates were determined based on the hydrolytic acidity (Hh, mol kg^{-1}) of the soil as follows: $D(1.0Hh) = Hh \times 1.5$. During the experiment, 3.0 t ha^{-1} of DL corresponded to a 1.0 Hh dose of $CaMg(CO_3)_2$, 4.5 t ha^{-1} to a 1.5 Hh dose of $CaMg(CO_3)_2$, and 3.5 t ha^{-1} of LS to a 1.0 Hh dose of $CaCO_3$.

Sampling procedure and measurements

Before initiating the experiment and at the end of winter wheat vegetation, soil samples were collected diagonally from five sampling points within the topsoil layer (0–20 cm) using a soil auger. For each experimental plot, the collected samples were combined and mixed thoroughly to create a representative sample. The samples were then dried, sieved through a 2-mm mesh, and analyzed using the following methods: pH in 1 M KCl by the potentiometric method, hydrolytic acidity by the Kappen's method, organic carbon by the Tjurin's method, alkaline hydrolyzable nitrogen by the Cornfield method, and available P_2O_5 and K_2O by the Kirsanov's method (a soil to 2.0 M HCl extract ratio of 1:5) (Horodnyi et al., 2007). Soil texture was determined in dry soil samples by the pipette method as modified by Kachinsky (Standards Ukraine, 2007).

At physiological maturity (BBCH 89), 20 plants were randomly collected from each treatment plot (three replicates) to determine: ear and straw length, plant density, total number of tillers, number of grains per ear, 1000-grain weight, grain yield, straw yield, and harvest index (Hrytsaienko, 2003).

Statistical analysis

The data was analyzed using one-way analysis of variance (ANOVA) followed by Fisher's LSD test to determine significant differences at $P<0.05$. The treatment results were analyzed using Statistica software, version 10.0 (StatSoft Inc.).

Results and Discussion

Physical and agrochemical properties of soil

Table 1 presents the results of the initial physical and agrochemical properties of the experimental site soil. This loamy sand soil has a high sand content (83.0%) and a very low clay content (1.8%).

Table 1. Initial physical and agrochemical properties of Albic Retisol.

Parameters	Value	Rating
Particle size distribution, %		
sand (>0.05 mm)	83.0	
silt (0.05–0.001 mm)	15.2	
clay (<0.001 mm)	1.80	
Textural class	loamy sand	
Physical and agrochemical properties		
pH_{KCl}	4.05	strongly acid
hydrolytic acidity (Hh) mol kg^{-1}	2.00	needs amelioration
organic carbon (C)%	0.37	low
alkaline hydrolyzable nitrogen (N) mg kg^{-1}	40.6	low
available phosphorus (P_2O_5) mg kg^{-1}	183.0	high
available potassium (K_2O) mg kg^{-1}	68.4	medium

With a soil pH of 4.1, falling within the very acidic range (4.1–4.5), and a high hydrolytic acidity of 2.0 mol kg^{-1} of soil, the experimental site requires significant liming. This is especially crucial as winter wheat is highly sensitive to soil acidity, with an optimal pH level of 6.0–7.0. Baquy et al. (2017) noted that the critical soil pHs at different locations for wheat were 5.29 and 4.66.

The soil analysis result shows low levels of OC and alkaline hydrolysable nitrogen, and a medium level of available potassium. The high rating of available phosphorus (P_2O_5) determined by the Kirsanov method can likely be attributed to previous practices applying phosphorus with fertilizer. Thus, the application of a low rate of P_2O_5 (25–50 kg ha^{-1}) is justifiable to satisfy the wheat crop needs.

At the end of the winter wheat growing season, studies revealed changes in the content of mobile nitrogen, phosphorus, and potassium compounds within the 0–20-cm soil layer. These changes depended on the fertilization options applied (Figure 1).

The most significant changes compared to initial values were observed, on average over three years, in the control plot (no fertilizer) and the DL (1.0 Hh) variant that is due to the absence of additional nutrient input in these treatments. The deficit of hydrolyzable nitrogen and available potassium for subsequent crops will be partially compensated by incorporating the wheat straw into the soil. Interestingly, no decrease in the content of mobile phosphorus was observed compared to initial levels.

It was also found that applying phosphorus (P_{80}) as part of the recommended mineral fertilizer rate, compared to the counted rates (P_{25} and P_{50}), did not significantly increase the content of available phosphorus in the arable soil layer for growing wheat (LSD = ±10.4).

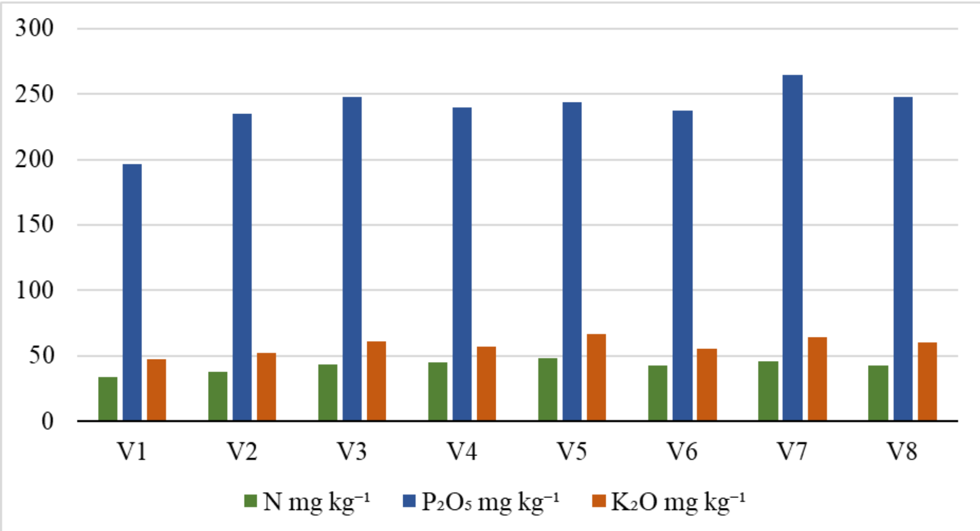
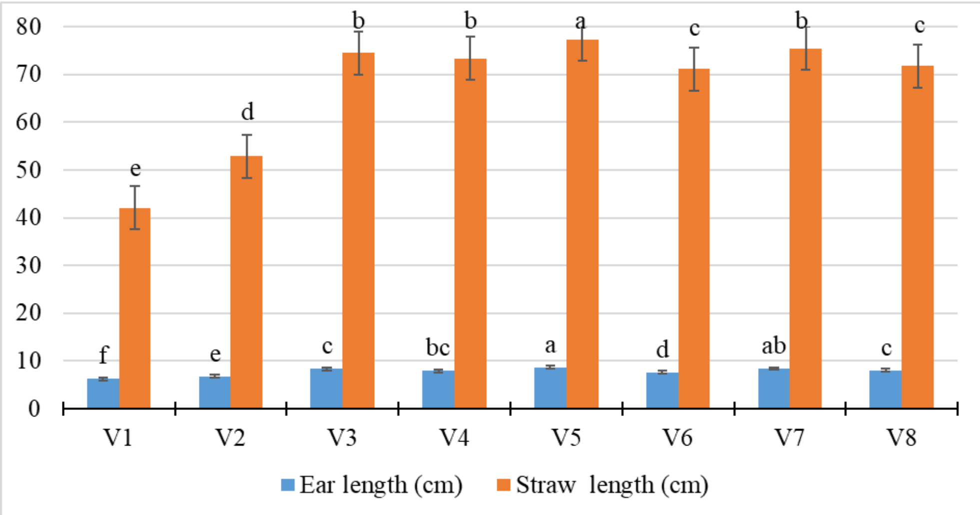


Figure 1. The content of alkaline hydrolyzable nitrogen (N), available phosphorus (P_2O_5) and potassium (K_2O) in the 0–20-cm layer of Retisol at the end of winter wheat vegetation (average for 2021–2023).

Plant height and yield components of winter wheat

Plant height plays a critical role in both wheat development and grain yield. The mean comparison for ear and straw length is presented in Figure 2.



Values with the same letters do not differ statistically at $P = 0.05$.

Figure 2. Indicators of the ear and straw lengths of winter wheat in the experiment, the average for 2021–2023.

The results showed that the application of DL (1.0 Hh) provided a statistically significant increase in plant height compared to the control. In addition, the application of N_{130} against the background of DL (1.0 Hh) statistically increased the length of both ear and straw compared to these treatments at $P<0.05$. However, the greatest increase in plant height was observed with the combination of ameliorants and complete mineral fertilizer. Interestingly, the variant with the recommended rate (DL [1.0 Hh] + $N_{120}P_{60}K_{90}$ [recommended] + MF) resulted in the maximum ear length (8.69 cm) and straw length (77.4 cm). This treatment showed statistically significant differences (LSD = ±0.25) for ear length and (LSD = ±1.61) for straw length compared to other treatments. These results are consistent with the findings of Malghani et al. (2010), who reported a linear response in wheat growth and yield to NPK fertilization. Vishwakarma et al. (2023) suggest that the high solubility of mineral fertilizers allows for the quick release of nutrients into the soil solution, promoting optimal nutrient uptake by plants and consequently enhancing growth and yield.

In the variant with the recommended rate DL (1.0 Hh) + $N_{120}P_{60}K_{90}$ (recommended) + MF, compared to the DL (1.0 Hh) + $N_{130}P_{25}K_{35}$ (normative rate for grain formation) + MF variant, a statistically significant increase in ear length was noted. In contrast, the difference in straw length was not statistically significant at $P<0.05$. Increasing the DL rate from 1.0 to 1.5 Hh in combination with the recommended rate also had no significant effect on plant height.

To create high-yielding crops, it is important to understand how elements of cultivation technology, including chemical soil amelioration and fertilization systems, affect the formation of yield components. For cereal crops, the most important of these are the number of productive tillers, the ear length, the number of grains per ear, and the grain mass per ear (Polishchuk and Konovalov, 2022).

The lowest values of yield structure indicators were obtained in the control plot without fertilizers (Table 2). The three-year average data for these indicators in the control plot were statistically comparable to the results from other experimental variants. The dolomite lime treatment DL (1.0 Hh) represents a dividing line between the unfertilized control and the treatment where the ameliorant was applied in combination with NPK fertilizer. The application of DL (1.0 Hh) led to a statistically significant result ($P<0.05$) for all yield structure indicators compared to the other variants.

Table 2. Elements of the structure of the winter wheat crop depending on fertilization and ameliorants (the average for 2021–2023).

Treatment	Plant density pcs. m^2	Total number of tillers pcs. m^2	Number of grains per ear pcs.	1000-grain weight, g
V1	248^{e}	289^{e}	25.8^{f}	27.4^{d}
V2	287^{d}	339^{d}	27.0^{e}	29.3^{c}
V3	322^{ab}	390^{b}	33.9^{bc}	34.1^{a}
V4	320^{ab}	387^{b}	33.6^{bc}	33.7^{a}
V5	329^{a}	405^{a}	35.0^{a}	35.1^{a}
V6	307^{c}	362^{c}	31.4^{d}	32.2^{b}
V7	324^{ab}	396^{ab}	34.1^{ab}	34.4^{a}
V8	319^{b}	386^{b}	32.9^{c}	33.9^{a}
LSD_{05}	9.29	13.5	1.02	1.43

Means within each column with the same letters do not differ statistically at $P<0.05$.

Wheat yield potential is heavily influenced by the number of tillers a plant produces. Estimating tiller numbers serves as a valuable tool for monitoring wheat growth and ultimately forecasting final yield (Wu et al., 2022). Improving mineral nutrition through fertilization on a limed background promoted the growth of plant density and total number of productive stems. However, neither the types of ameliorants (DL or LS) nor the rates (1.0 or 1.5 DL), in combination with $N_{120}P_{60}K_{90}$ (recommended) + MF, had a statistically significant effect on tillering. Iljkić et al. (2011) found that the liming with dolomite meal significantly increased the number of spikes at all liming treatments compared with the control, but no significant difference was observed between rates of 5–15 t ha^{-1} of dolomite.

On the positive side, in the variant DL (1.0 Hh) + $N_{130}P_{25}K_{35}$ (normative rate for grain formation) + MF, the decrease in phosphorus and potassium compared to the recommended rate did not cause a significant decrease in the total number of shoots per m^2, but the difference was significant compared to the variant DL (1.0 Hh) + $N_{150}P_{50}K_{125}$ (normative rate for grain and straw formation) + MF. According to Brennan and Bolland (2008), the effectiveness of potassium fertilizer application depends heavily on the level of nitrogen available to the plant. In general, applying increasing rates of K increased the rate of N required to achieve 90% of the maximum grain yield. The absence of phosphorus and potassium in the winter wheat nutrition scheme in the DL (1.0 Hh) + N_{130} (normative rate for grain formation) + MF variant caused a decrease in plant density by 13–22 pcs. m^2 and in the total number of tillers by 24–43 pcs. m^2 compared to other NPK rates in the treatments.

The highest total number of tillers (405 pcs. m^2) was obtained in the DL (1.0 Hh) + $N_{150}P_{50}K_{125}$ (normative rate for grain and straw formation) + MF variant. The lowest among the fertilized variants was 362 pcs. m^2 in DL (1.0 Hh) + N_{130} (normative rate for grain formation) + MF.

The number of grains per ear (ranging from 25.8 to 35.0 pcs.) and thousand-grain weight (from 27.4 to 35.1 g), both important yield parameters affecting wheat grain yield, varied across the three-year treatments. The highest average values for both parameters were recorded with the application of DL (1.0 Hh) + $N_{150}P_{50}K_{125}$ (normative rate for grain and straw formation) + MF, while the unfertilized treatment resulted in the lowest values. According to Usman et al. (2020), a balanced nutrient supply promotes ear elongation, leading to more spikelets per spike and ultimately, heavier, and fuller grains.

The application of the fertilizer rate calculated based on the nutrient removal by the main product (DL [1.0 Hh] + $N_{130}P_{25}K_{35}$ [normative rate for grain formation] + MF) did not cause a significant decrease in the number of grains per ear compared to the application of the recommended NPK rate on different backgrounds of dolomite lime and limestone.

The weight of 1000 grains did not change significantly with the application of different NPK rates together with ameliorants and microfertilizers (LSD = ±1.43).

Yield and harvest index

This soil is characterized by low natural fertility, especially in terms of organic matter and nitrogen content. This resulted in an average winter wheat yield of 2.04 t ha^{-1} in the unfertilized control variant from 2021 to 2023 (Table 3).

The application of ameliorants created the preconditions for increasing the efficiency of mineral fertilizers. Applying DL (1.0 Hh) under winter wheat increased grain yield by 0.64 t ha^{-1} and straw yield by 0.65 t ha^{-1} compared to the control. The combination of DL (1.0 Hh) and the recommended rate of $N_{120}P_{60}K_{90}$ (recommended) + MF resulted in the average grain yield increase for 2021–2023 of 122.1 and 69.0% compared to the control and DL (1.0 Hh), respectively. However, increasing the DL rate to 1.5 Hh did not significantly affect the grain or straw yield compared to the previous variant at $P<0.05$.

Table 3. The influence of fertilization systems and chemical melioration on the productivity of winter wheat.

Treatment	Grain, t ha^{-1}		Straw, t ha^{-1}		Harvest index, %
	yield	increase compared to control	yield	increase compared to control	
V1	2.04^{g}	-	2.39^{f}	-	46^{d}
V2	2.68^{f}	0.64	3.04^{e}	0.65	47^{cd}
V3	4.52^{bc}	2.48	4.78^{b}	2.39	49^{b}
V4	4.38^{dc}	2.34	4.15^{d}	1.76	51^{a}
V5	4.97^{a}	2.93	5.21^{a}	2.91	46^{bc}
V6	3.66^{e}	1.62	4.40^{c}	2.01	45^{d}
V7	4.64^{b}	2.60	4.89^{b}	2.50	49^{b}
V8	4.31^{d}	2.27	4.77^{b}	2.38	47^{cd}
LSD_{05}	0.17		0.23		1.85

Means within each column with the same letters are not statistically different at $P = 0.05$.

Replacing DL (1.0 Hh) with LS (1.0 Hh) in combination with $N_{120}P_{60}K_{90}$ (recommended) + MF resulted in a significant decrease in the average grain yield by 0.21 t ha^{-1} but did not affect the straw yield. The advantage of DL is probably due to the improvement of not only the physical and chemical properties of the soil but also the plant nutrition with magnesium, which is very important due to its light granulometric composition.

The application of DL (1.0 Hh) + $N_{130}P_{25}K_{35}$ (normative rate for grain formation) + MF provided an average grain yield of 4.38 t ha^{-1} over the years of research. The difference in grain yield for this variant, compared to the recommended rate of $N_{120}P_{60}K_{90}$ (recommended) + MF with 1.0 Hh of ameliorant, regardless of its type, did not exceed the LSD = ±0.17 of the experiment. However, the difference in straw yield was significant (LSD = ±0.21). This means that the application of the recommended rates of $P_{60}K_{90}$ in the NPK nutrition increases the total plant biomass. Mojid et al. (2012) note that the treatment with 40 kg P ha^{-1} produced the longest plant height and the maximum biomass yield, but not the highest grain yield or harvest index.

The complete exclusion of PK from the winter wheat fertilization system in the variant DL (1.0 Hh) + N_{130} (normative rate for grain formation) + MF, which is sometimes practiced in production conditions, led to a statistically significant decrease in grain yield to 3.66 t ha^{-1} and straw yield to 4.40 t ha^{-1} compared to other fertilized variants at P<0.05. At the same time, a harvest index of 45 indicates an increase in straw with the unilateral application of nitrogen fertilizers.

The highest average yields of winter wheat grain (4.97 t ha^{-1}) and straw (5.21 t ha^{-1}) over the research years were determined in the DL (1.0 Hh) + $N_{150}P_{50}K_{125}$ (normative rate for grain and straw formation) + MF variant. However, the yield index of 48 units was lower than that of the DL (1.0 Hh) + $N_{130}P_{25}K_{35}$ (normative rate for grain formation) + MF variant (51 units), indicating a more significant increase in straw within the crop biomass. To assess the relationship between grain yield and its structural elements, the Pearson's correlation coefficient was calculated (Table 4).

Table 4. The Pearson's correlation between winter wheat grain yield and structural elements of the harvest.

Parameter	Grain yield, t ha^{-1}	Ear length, cm	Straw Length, cm	Plant density, pcs. m^2	Total number of tillers, pcs. m^2	Number of grains per ear, pcs.	1000 grain weight, g
Grain yield, t ha^{-1}	1						
Ear length, cm	0.994	1.000					
Straw length, cm	0.972	0.968	1.000				
Plant density, pcs. m^2	0.967	0.959*	0.979	1.000			
Total number of tillers, pcs. m^2	0.982	0.975	0.972	0.995	1.000		
Number of grains per ear, pcs.	0.994	0.987	0.978	0.953*	0.965	1.000	
1000-grain weight, g	0.997	0.990	0.981	0.975	0.985	0.993	1

The correlation is significant at the probability levels of $P<0.001$, $^*P<0.01$.

The results of the study revealed strong positive correlations between grain yield and several structural elements, with significance levels of P<0.001 and in some cases P<0.01. The correlation coefficients between grain yield and ear length, number of grains per ear, and 1000-grain weight were particularly high, exceeding 0.95 in all cases. These findings indicate that increasing these structural elements through breeding or agronomic practices could lead to significant gains in crop productivity.

Conclusion

The study reveals that the return of winter wheat plant residues into the Retisoil with high available phosphorus and average potassium enables a reduction in phosphorus and potassium fertilizer rates for winter wheat, matching the amounts removed by the main products, without significantly affecting the yield. This practice also improves the harvest index ratio. In the DL (1.0 Hh) + $N_{130}P_{25}K_{35}$ (normative rate for grain formation) + MF variant, yield structure indicators were comparable to those achieved with the recommended dose of

$N_{120}P_{90}K_{90}$ mineral fertilizer, and grain yield differences were not statistically significant. Although the highest yield structure and crop indicators were observed in the DL (1.0 Hh) + $N_{150}P_{50}K_{125}$ (normative rate for grain and straw formation) + MF variant, the optimal harvest index (51.0) was attained with fertilizer doses tailored to winter wheat grain removal. Furthermore, the absence of phosphorus-potassium nutrition in the study led to a significant decrease in both grain yield and the yield index.

Given that the use of crop by-products as fertilizer is promising for reducing mineral fertilizer rates, further research in this area is needed to ensure the sustainable and productive functioning of agriculture.

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UTICAJ OPTIMIZOVANIH MINERALNIH ĐUBRIVA NA PRINOS I NJEGOVE KOMPONENTE OZIME PŠENICE NA RETISOLU ZAPADNOG POLESJA U UKRAJINI

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R e z i m e

Ispitivani su uticaji primene različitih doza mineralnih đubriva, zasnovanih na akumulaciji NPK u zrnu i zrnu i slami, u poređenju sa preporučenom dozom, na produktivnost useva ozime pšenice. Tretmani su primenjeni u odnosu na različite poboljšivače zemljišta, uz vraćanje biljnih ostataka u zemljište. Na retisolu je najviši prinos zrna ozime pšenice (4,98 t ha^{-1}) ostvaren primenom doze od 1,0 Hh (hidrolitička kiselost) dolomitnog kreča (DK) uz $N_{150}P_{50}K_{125}$ (doza zasnovana na akumulaciji NPK u zrnu i slami). Ovaj tretman je doveo do najboljih pokazatelja komponenti prinosa. Međutim, žetveni indeks bio je niži u poređenju sa $N_{130}P_{25}K_{35}$ (doza zasnovana na akumulaciji NPK u zrnu). Ovo ukazuje na veći odnos zrna i slame kod pristupa zasnovanog na akumulaciji NPK u zrnu. Uprkos slabijim pokazateljima komponenti prinosa, prosečan prinos u tretmanu sa DK (1,0 Hh) + $N_{130}P_{25}K_{35}$ nije pokazao statistički značajnu razliku u poređenju sa $N_{120}P_{60}K_{90}$ (preporučenom dozom) na nivou $P<0,05$. Izostanak đubriva PK u tretmanu sa N_{130} značajno je smanjio prinos (za 19%) u poređenju sa ostalim tretmanima u kojima je korišćeno đubrivo NPK. Primena krečnjaka u dozi od 1,0 Hh uz preporučenu dozu NPK nije poboljšala komponente prinosa, a prinos je bio manji za 0,21 t ha^{-1} u poređenju sa DK (1,0 Hh) u sličnim uslovima. Na osnovu rezultata, za optimalnu produktivnost ozime pšenice na retisolima preporučuje se primena doza mineralnih đubriva izračunatih prema iznošenju NPK glavnog proizvoda (zrna), u kombinaciji sa 1,0 Hh DK i vraćanjem biljnih ostataka u zemljište.

Ključne reči: zrno, slama, struktura prinosa, doze đubriva, dolomitni kreč, krečnjak.

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