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The demand of modern varieties of winter wheat to mineral nutrition

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Goal. *Generalization of the results of experimental studies of the content of nutrients in grain and straw of winter wheat varieties currently grown in Ukraine.* ***Methods.*** *The research was carried out during 2016-2020 at two objects of variety testing in the forest-steppe zone of Ukraine, on production fields in Western Polissya, Right-Bank and Left-Bank of Forest-Steppe, with statistical analysis of chemical-analytical data.* ***Results.*** *According to the generalization of data on 167 plots of winter wheat cultivation of modern varieties, accumulation of nutrients in grain and straw differs from parameters that were revealed before. Modern varieties are characterized by a narrower ratio of N: P2O5 in the grain (1: 0.30), which differs from the previously developed standards (1: 0.34-0.35), as well as a much higher accumulation of potassium in straw. The content of nutrients in grain has more stable parameters than in straw. High variability of micronutrient composition of grain and straw, especially cobalt and iron, has been found. It is proposed to use as normative not arithmetic means, but geometric means. Similar features of the chemical composition of grain and straw were at all objects of the study.* ***Conclusions.*** *Average parameters of nutrient uptake in winter wheat modern varieties are (kg/t): for grain N - 21.6, P_2O_5 - 6.5, K_2O - 4.6, for straw - 4.9, 1.1 and 17.5 respectively. Average parameters of micronutrient uptake in winter wheat modern varieties are (mg/kg): for grain - Zn 19, Co 0.51, Fe 37, Mn 30, Cu 2.1, for straw - Zn 1.8, Co 0.52, Fe 27, Mn 12, Cu 0.6.*

Key words: *NPK, microelements, grain, straw, remote standards, variability, variety specificity, strain testing plots.*
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Winter wheat is the most demanding crop among cereals in terms of mineral nutrition. Due to breeding progress, modern varieties of winter wheat have a high level of nitrogen uptake and its reutilization in plants, that is often accompanied by increased concentrations of other nutrients [1-2]. It is proved that these properties of modern varieties are occurred mainly under the high fertilizing, while old varieties show more stable yield on the lack of nutrients [3]. However, due to lack of information, the peculiarities of the nutrition of new varieties of wheat are not taken into account when agronomists design a fertilizer system, as suggested by E. Klimashevsky 30 years ago [4]. Genetic features of enzymatic systems, absorption and photosynthesis in different varieties of winter wheat require appropriate forms and doses of fertilizers [3, 5-6], but also lead to different resilience to the acid pH [7], salinization [8-9] and other affecting factors in terms of nutrients uptake. Therefore, it is necessary to periodically update the regulatory framework for the development of adaptive farming systems, including fertilizer systems.

In 2014, a draft of Resolution of the Cabinet of Ministers of Ukraine "Regulatory indicators of nutrient removal by crops" [10] was developed in accordance with Articles 30 and 32 of the Law of Ukraine "On Land Protection" and the action plan of the Ministry of Agrarian Policy of Ukraine. This regulatory act provides standards of NPK content per unit of crop yield by nature zones (Table 1).

1. Standards for nutrient removal with the harvest of winter wheat (according [10])

Nature zones	NPK content per 1 ton of crop yield, kg					
	grain			straw		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O
Forest (Polissya)	22,0	7,7	5,1	5,0	1,7	9,8
Forest-Steppe	23,5	7,9	6,3	5,4	1,9	10,9
Steppe	21,7	7,9	5,7	4,8	1,8	11,5
Average	22,4	7,8	5,7	5,1	1,8	10,7

Due to the fact that the abovementioned project has not yet been approved, researchers use other values of NPK removal with grain and straw of winter wheat. In particular, G. Hospodarenko gives the following values of removal per 1 ton of grain: N – 22.7 kg, P_2O_5 – 8.0 kg, K_2O – 5.5 kg, and per 1 ton of straw – 5.7 kg, 1.9 kg and 10.7 kg, respectively [11]. The method of calculating the balance of NPK by NSC "ISSAR named after ON Sokolovsky" uses slightly different standard parameters in a straw: N – 5.1 kg, P_2O_5 – 1.6 kg, K_2O – 9.9 kg [12]. M. Gorodnyi et al. have mentioned higher nutrient content in grain, namely: N – 2.50%, P_2O_5 – 0.85%, K_2O – 0.65%, and for straw – 0.50%, 0.20% and 0.90%, respectively [13]. Unfortunately, all the above indicators refer mainly to varieties that were in crop production more than 20-30 years ago, and it is currently unknown to what extent they coincide with the requirements of modern wheat varieties.

Little is known about the micronutrient composition of grain products. Modern farming systems in Ukraine are usually deficient in the balance of micronutrients [14]. According to D. Garvin and R. Welch, genetic improvements in the United States have led to a decrease in the concentration of Fe, Zn Se in grain, although yields are increasing [15]. On the other hand, the study of K. Hamner et al. [2], as well as Z. Svecnjak et al. [16] show that the increase in nitrogen uptake during the wheat growing season is also accompanied by a greater accumulation of Fe, Zn, Mn, Cu and B in plants.

The purpose of this article is to generalize results of experimental research regarding nutrients content in grain and straw of winter wheat varieties currently grown in Ukraine.

Methods. The research was carried out during 2016-2020 at two objects of variety testing in the forest-steppe zone of Ukraine and by expeditionary research on crop production fields in Western Polissya, Right-Bank and Left-Bank Forest-Steppe.

24 winter wheat varieties in 2016 and 36 winter wheat varieties in 2017 were studied at the demonstration and research field of LLC "PRF "Urozhay" (Korsun-Shevchenkivskyi district of Cherkasy region), where Phaeozems predominate in soil cover. Particularly, it were studied varieties by German breeding - Etana, Patras, Matrix, Kombin, Arctis (Deutsche Saatveredelung AG), Skagen, Torild (SAATEN UNION); Austrian breeeding - Panonicus, Tacitus, Fidenius, Balitus (Saatzucht Donau); Czech breeding - Bodicek, Bordotka, Daria (RAGT Semences), Croatian breeding - Annica, Mandica (Zagreb Bc Institute), and Ukrainian breeding - Svitanok Myronivsky (Myronivsky Wheat Institute named after V.M. Remesla), Chorniava (Institute of Plant Physiology and Genetics of the National Academy of Sciences of Ukraine) .

Four varieties that are a national standards of Ukraine - Rozkishna (V. Yuriev Institute of Plant Breeding). Yuriev), Bunchuk (Breeding and Genetics Institute), Smuglyanka and Podolyanka (Institute of Plant Physiology and Genetics of the National Academy of Sciences of Ukraine), as well as 8 varieties of foreign breeeding - the above-mentioned Balitus, Arctis, Matrix, Annitsa, Manditsa, Bodicek and Daria were studied at the research field of the Plant Production Institute named after V.Ya. Yuriev NAAS (Kharkiv district of Kharkiv region, 2018-2020) on Chernozem haplic.

The peculiarities of winter wheat nutrient uptake were studied during the expeditionary research in Western Polissya on Luvisols and Phaeozem, in the Right-Bank Forest-Steppe - on Phaeozems, Chernozem luvic, in the Left-Bank Forest-Steppe - on Phaeozems, Chernozem luvic and haplic. Samples were taken random, and the agrochemical properties of soils differed greatly in some cases.

Samples of grain and straw were taken before harvest in 3 repetitions, each sample consisted of 15-20 plants. The content of nitrogen, phosphorus and potassium in grain and straw was determined by the method of wet chemistry ashing with analytical ending on the spectrophotometer SF-4 and flame photometer CL-22D, the content of trace elements - on atomic absorption spectrophotometers AANALYST 400 and Saturn-76. During 2016-2020, grain and straw were analyzed in 167 plots, which differed in soil type, level of nutrient supply and fertilizer. Data analysis was performed by Statistica 10.

Results. Generalization of all data on the content of macro- and microelements in grain and straw of winter wheat in 2016-2020 allows to take into account not only genetically determined features of modern varieties, but also due to soil-climatic, weather conditions and fertilizers, which differed significantly in some cases. The sample met the criteria of Shapiro-Wilkes normality in terms of NPK content in grain (W = 0.98-0.99; p = 0.16-0.56). The main statistical characteristics of NPK content are shown in the table 2.

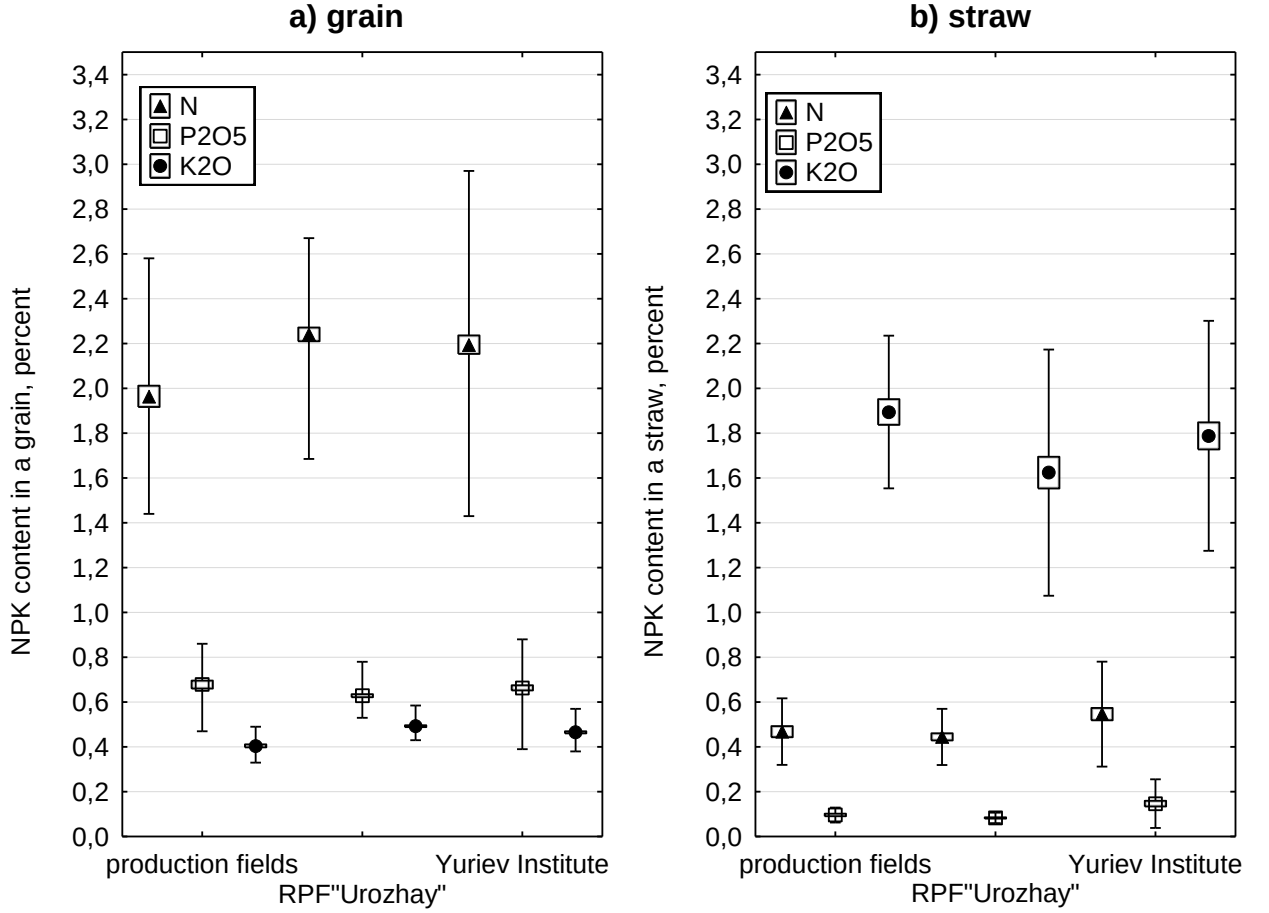
2. Main statistics of NPK content in grain and straw in 2016-2020 (n=167)

Part of yield	Nutrients	Nutrients content, %				Coefficient of variation
		mean	minimum	maximum	standard error	
Grain	N	2,16	1,43	2,97	0,32	15
	P_2O_5	0,65	0,39	0,88	0,09	13
	K_2O	0,46	0,33	0,58	0,05	11
Straw	N	0,49	0,16	1,29	0,19	38
	P_2O_5	0,11	0,04	0,53	0,08	70
	K_2O	1,75	0,49	2,94	0,50	29

According to experimental data, modern varieties of winter wheat are characterized by average parameters of nutrients uptake from 1 ton of grain: N – 21.6 kg, P_2O_5 – 6.5 kg, K_2O – 4.6 kg, and from 1 ton of straw – 4.9 kg, 1.1 kg and 17.5 kg, respectively. With the exception of potassium in straw, these values are lower than those given in [10-13], but very well coincide with the data of recent studies [17-18]. In our opinion, the lower

content of nutrients in the final product is due to their more efficient use in modern varieties of wheat and a high level of their yield. Another feature of modern varieties is a narrower ratio of N : P_2O_5=1 : 0.30 that differ from 1:0.34-0.35, as previously envisaged.

The content of nutrients in straw is less stable, because it depends more on the completeness of remobilization and other influencing factors. The highest variation was for phosphorus, its content in straw varied from 0.04% to 0.53%. On average, straw of modern varieties also contains less nitrogen and phosphorus but much more potassium, probably due to the peculiarity of varieties of European breeding [19]. The fact that the differences in the chemical composition of grain and straw is not a random phenomenon, confirmed by statistical analysis of subordinate data samples based on the results of surveys of production fields in 2016-2017 (n = 72), demonstration and research field of LLC "RPF Urozhay" in 2016-2017 (n = 60), and the research field of the Plant Production Institute named after V.Ya. Yuriev NAAS in 2018-2020 (n = 35).



NPK content in winter wheat grain (a) and straw (b) at the study sites in 2016-2020 (mean values, standard error and standard deviation are indicated)

According to the graph, the average nitrogen content in grain was the highest at the demonstration and research field of LLC "RPF "Urozhay", where varieties of foreign breeding have dominated, and the lowest content was at the research field of the Plant Production Institute named after V.Ya. Yuriev NAAS, where a third of all studied varieties had a domestic origin. The average potassium content in straw in all samples exceeded the parameters mentioned in [10 – 13]. These differences in the content and ratio of NPK in winter wheat are quite conditional, as it is clear how much it depends on the environment conditions and technology. The information from various sources have confirmed above conclusion (table 3).

3. The content of NPK in grain and straw of winter wheat according to different sources

Researches	Content in dry material, %					
	grain			straw		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O
J.M. Clarke et al., 1990 [20]*	1,94-2,90	0,69-0,96	-	-	-	-
P. Khan et al., 2008 [21]*	1,44-2,73	0,34-0,70	-	0,16-0,61	0,021-0,089	--
V.V. Ivanina, 2013 [22]	2,40-2,59	0,80-1,00	0,55-0,81	0,55-0,74	0,21-0,24	1,04-1,33

V. Kovačević et al., 2013 [23]*	-	0,90-1,00	0,55-0,58	-	-	
Y.A. Rangel et al., 2013 [24]*	1,66-1,90	0,71-0,85	-	0,43-0,70	0,22-0,73	-
Ya.S. Filimonchuk, 2014 [25]	1,8-2,4	0,61-0,81	0,44-0,51	0,40-0,64	0,04-0,11	0,86-0,95
W. Yan et al., 2015 [26]*	1,70-2,10	0,93-1,50	-	0,45-0,50	0,04-0,18	
K.J. Jankowski et al., 2016 [17]	2,26-2,29	0,60-0,68	0,54-0,57	0,39-0,61	0,17-0,18	1,49-1,67
S.I. Lastochkina, 2017 [27]	1,63-2,44	-	-	0,36-0,56	-	-
I. Jaskulska et al., 2018 [28]	-	0,69-0,73	0,77-0,81	-	-	-
X.-X. Chen et al., 2019 [29]*	-	0,55-0,94	-	-	0,47-1,44	--
L.M. Mikhalska et al., 2019 [18]*	-	0,56-0,73	0,38-0,50	-	-	-

Note. *Recalculated from P to P_2O_5 by a factor of 2.29, from K to K_2O by a factor of 1.20.*

The variability of the micronutrient composition of grain and straw was higher than the variability of NPK (Table 4). Zinc, iron and manganese accumulation in grain were the most stable indicators, and their data distribution was closest to normal. The content of cobalt in grain and iron in straw were the least stable, with a significant asymmetry of histograms of distribution towards smaller values. Given the significant fluctuations in the content of micronutrients and the rather asymmetric data distribution, we consider it more correct to use as normative not arithmetic mean, but geometric means, which are (mg/kg): for grain – Zn 19, Co 0.51, Fe 37, Mn 30, Cu 2.1, for straw – Zn 1.8, Co 0.52, Fe 27, Mn 12, Cu 0.6.

4. Main statistics of NPK content in grain and straw in 2016-2020 (n=167)

Part of yield	Micronutrients	Micronutrients content, %				Coefficient of variation
		mean	minimum	maximum	standard error	
Grain	Zn	19,59	11,58	31,34	3,80	19
	Co	0,76	0,04	3,36	0,67	88
	Fe	38,19	18,64	63,63	8,82	23
	Mn	30,76	6,13	49,22	6,76	22
	Cu	2,30	0,36	5,80	1,05	46
Straw	Zn	2,31	0,09	9,46	1,63	70
	Co	0,76	0,01	2,67	0,60	78
	Fe	49,55	3,21	251,54	57,73	117
	Mn	17,73	0,86	78,32	13,78	78
	Cu	0,79	0,01	3,47	0,57	73

Conclusions

The content and ratio of nutrients in grain and straw of winter wheat of modern varieties differ from those that were in production before.

For growing winter wheat of modern foreign and Ukrainian breeding during 2016-2020 on soils of different genesis and level of nutrient supply, the average nutrients uptake from 1 ton of grain are: N – 21.6 kg, P_2O_5 – 6.5 kg, K_2O – 4.6 kg, and from 1 ton of straw – 4.9 kg, 1.1 kg and 17.5 kg, respectively.

The average values of micronutrients content in the final production of winter wheat are (mg/kg): for grain – Zn 19, Co 0.51, Fe 37, Mn 30, Cu 2.1, for straw – Zn 1.8, Co 0.52, Fe 27, Mn 12, Cu 0.6.

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