



INFLUENCE OF FERTILIZING WITH MODERN COMPLEX ORGANIC-MINERAL FERTILIZERS TO GRAIN YIELD AND QUALITY OF WINTER WHEAT IN THE SOUTHERN STEPPE OF UKRAINE

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ABSTRACT. This article presents the results of using different varieties, variants of nutrition and their impact on the yield and grain quality of winter wheat. Experimental studies were conducted during 2011–2016 on the experimental field of the Mykolayiv National Agrarian University, Ukraine. The technology of growing winter wheat in the experiment, except the studied factors, was generally accepted to the existing zonal recommendations for the southern steppe of Ukraine. The predecessor was peas (*Pisum sativum* L.) It was determined that the higher grain yield and slightly better quality indicators differed grain of the studied winter wheat varieties with the joint use of pre-sowing application of $N_{30}P_{30}$ and foliar fertilizing of winter wheat crops twice during the vegetation season by Escort-bio. Thus, for this variant of nutrition, the crude gluten content of winter wheat grain was 24.2 up to 25.1%, the protein content was 12.9 up to 13.2%, and the conditional protein yield of from 1 ha of sowing area was 0.58–0.66 t depending on the studied variety. At the same time, on average, according to the nutrition factor, plants of the 'Zamozhnist' variety in comparison with the 'Kolchuga' variety formed more by 9.3% of the grain, which had the best quality indicators.

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Introduction

For millennia, human beings have been aware of the importance of agricultural products in their life and have benefited from plants and their different parts like fruits, leaves, and seeds, for food, clothing, medicine, and animal feed (Erturk *et al.*, 2010; Canan *et al.*, 2016; Hricova *et al.*, 2016). Wheat is an important cereal crop, because of its high productivity and diverse usage possibilities (Filipcev *et al.*, 2017; Erben *et al.*, 2017; Abera *et al.*, 2017; Adams *et al.*, 2016; Altinel, Unal, 2017; Antov, Dordevic, 2017; Barber *et al.*, 2017; García-Molina *et al.*, 2019). The main purpose of wheat is to provide people with bread, bakery products, cereals and other grain processing products. The value of wheat bread is determined by the favourable chemical composition of the grain, in particular, a combination of proteins, carbohydrates, fats, amino acids, minerals and other preparations (Ulich *et al.*, 2014; Janić Hajnal *et al.*, 2019). Wheat provides about 20% of the calories and it is an important protein source for a large portion of the world's population (FAO,

2018). Therefore, global wheat production needs for increasing in the upcoming decades to cover the rising demand for this grain (Hernández-Espinosa *et al.*, 2018).

Wheat production in Europe countries is particularly dependent on synthetic fertilizers because the use of animal manure is very limited, many of the soils are naturally low in levels of soil organic matter and there are only a few legumes present in main crop rotations that could supply symbiotically fixed nitrogen (Biel *et al.*, 2016).

Mineral fertilizers are an important element for achieving stable high grain yields with high-quality indicators (Delogu *et al.*, 1998; Pan *et al.*, 2006; Panfilova *et al.*, 2019; Shi *et al.*, 2012).

According to some studies, mineral fertilizers are better absorbed by plants in certain periods of growth and development.

Nitrogen fertilizers have been a key factor in the increased yields achieved by modern agriculture and the last 30 years, the use of mineral nitrogen to fertilize crops has widely increased (Marinciu *et al.*, 2018).



According to Sommer and Scherer (2009), the nitrogen fertilizer should not be applied using the CULTAN (Controlled Uptake Long Term Ammonium Nutrition) system to cereals until the end of tillering. However, according to the findings of Kozlovsky *et al.* (2010) the nitrogen injection just at the end of tillering leads, under conditions of the Czech Republic, to the deterioration of baking quality of grain of CULTAN-treated winter wheat compared to the winter wheat treated with nitrogen split into three doses. Therefore, according to the findings of Kozlovsky *et al.* (2010), the nitrogen fertilization by the CULTAN system should be carried out at an earlier date in spring.

There is a growing global interest in the use of organic farming and in increasing grain production using low levels of mineral fertilizers (Petrenko *et al.*, 2018). Reducing the dose of mineral fertilizers, especially nitrogen, is possible with the use of growth-regulating preparations.

Modern intensification of crop production in the conditions of acute deficiency of organic fertilizers and too high prices for mineral fertilizers involves the development of alternative measures of technology of crop cultivating, including growth-regulating preparations (Panfilova *et al.*, 2020). That is why the research presented in this article is relevant.

Materials and methods

Experimental studies were conducted during 2011–2016 on the experimental field of the Mykolayiv NAU, Ukraine. We studied the following varieties of winter wheat – 'Kolchuga' and 'Zamozhnist'. The variety 'Kolchuga' (variety-lutescens) refers to the early maturing varieties, its vegetation period is 275–278 days. The height of the plant is medium-sized (96 cm). In the field conditions during the testing years, winter hardiness was 8.8 points, resistance to lodging was 8.7 points, resistance to shedding was 8.9 points, and drought resistance was 8.1 points. It is the variety of intensive type, universal use. The variety 'Zamozhnist' (variety – erythrospermum) is mid-ripening. The vegetation period is 282–287 days. Plant height is 94–104 cm, the variety is highly resistant to lodging and shatter, frost and winter hardiness above average, it is characterized by high drought and heat resistance. It is the variety of high-intensity type and universal use on different agricultural backgrounds.

The technology of growing winter wheat in the experiment, except the studied factors, was generally accepted to the existing zonal recommendations for the southern steppe of Ukraine, which has a temperate continental climate and chernozem soils (black soil of the South, light clay-loam soil on loess).

The experiment scheme included the following variants:

Factor A – variety: 1. 'Kolchuga'; 2. 'Zamozhnist'.

Factor B – nutrition: 1. Control (without fertilizers); 2. $N_{30}P_{30}$ for pre-sowing cultivation; 3. $N_{30}P_{30}$ and urea

K1 (1 l ha⁻¹); 4. $N_{30}P_{30}$ and urea K2 (1 l ha⁻¹); 5. $N_{30}P_{30}$ and Escort-bio (0.5 l ha⁻¹); 6. $N_{30}P_{30}$ and urea K1 and urea K2 (0.5 l ha⁻¹); 7. $N_{30}P_{30}$ and organic D2 (1 l ha⁻¹). Fertilizing of crops with preparations was carried out at the beginning of the resumption of spring vegetation (BBCH 21) and the beginning of the winter wheat stooling (BBCH 31).

Preparations to be used for foliar application of barley crops were listed in the list of pesticides and agrochemicals authorized for use in Ukraine. Preparations of Urea K1 and Urea K2 are registered as fertilizers containing respectively N as 11–13%, P₂O₅ as 0.1–0.3%, K₂O as 0.05–0.15%, micronutrients as 0.1%, succinic acid as 0.1% and N as 9–11%, P₂O₅ as 0.5–0.7%, K₂O as 0.05–0.15%, sodium humate as 3 g L⁻¹, potassium humate as 1 g L⁻¹, trace elements as 1 g L⁻¹. Organic D2 is organo-mineral fertilizer containing N as 2.0–3.0%, P₂O₅ as 1.7–2.8%, K₂O as 1.3–2.0%, total calcium as 2.0–6.0%, organic matter as 65–70% (in terms of carbon). Escort-bio is a natural microbial complex that contains strains of microorganisms of genera Azotobacter, Pseudomonas, Rhizobium, Lactobacillus, Bacillus, and biologically active substances produced by them.

In the process of research the method it was used the state variety testing of crops (Volkodav *et al.*, 2001). The crop structure was analyzed by the sheaves, which were taken before harvesting from the sites of 1 m². The yield was determined by the method of continuous harvesting of each registration area (Sampo - 130 combine harvester).

Technological and biochemical indicators of quality of soft wheat grain intended for food needs use were established by DSTU 3768:2010 "Wheat. Technical conditions", regarding the standards: the crude gluten content by a manual method according to DSTU ISO 21415-1:2009, "Wheat and wheat flour"; the protein content of grain according to DSTU 4117:2007; the nature of grain according to DSTU 4234:2003 "Crops".

The statistical analysis (repetition was three times during 5 years of growing grain) of the research were processed using the method of multivariate disperse analysis. The obtained data were compared using analysis of variance. All statistical analyses were performed with Agrostat New and Microsoft Excel.

Results and discussion

Wheat yields vary from year to year under the influence of climatic conditions, the grown variety, introduced nutrients, the presence of pests and pathogens (Suciu *et al.*, 2018; Panfilova, Mohylnytska, 2019).

Our research also found the yield of winter wheat grain varied under the influence of varietal characteristics, background nutrition and climatic conditions of the cultivation year, in particular, the provision of plants with moisture during the vegetation season (Table. 1).

Table 1. The yield of winter wheat depending on the variety and nutrition, t ha⁻¹

Variety	Nutrition variant	Years				Average for 2012–2016	
		2012	2013	2014	2015		2016
'Kolchuga'	Control	1.71	1.85	2.71	4.02	4.15	2.89
	N ₃₀ P ₃₀	2.23	2.36	3.13	4.71	4.78	3.44
	N ₃₀ P ₃₀ and Urea K1	2.73	3.29	3.78	5.64	5.69	4.23
	N ₃₀ P ₃₀ and Urea K2	2.79	3.37	3.90	5.78	5.82	4.33
	N ₃₀ P ₃₀ and Escort-bio	3.04	3.49	3.97	5.93	5.99	4.48
	N ₃₀ P ₃₀ and Urea K1 and Urea K2	2.91	3.44	3.94	5.82	5.77	4.38
	N ₃₀ P ₃₀ and Organic D2	2.97	3.42	3.98	5.74	5.98	4.42
'Zamozhnist'	Control	1.86	1.99	2.90	4.20	4.28	3.05
	N ₃₀ P ₃₀	2.35	2.47	3.35	4.86	4.89	3.58
	N ₃₀ P ₃₀ and Urea K1	3.32	3.74	4.21	5.96	5.99	4.64
	N ₃₀ P ₃₀ and Urea K2	3.54	3.95	4.42	6.09	6.13	4.83
	N ₃₀ P ₃₀ and Escort-bio	3.76	4.14	4.55	6.24	6.28	4.99
	N ₃₀ P ₃₀ and Urea K1 and Urea K2	3.71	4.11	4.46	6.21	6.25	4.95
	N ₃₀ P ₃₀ and Organic D2	3.72	4.20	4.39	6.20	6.31	4.96
LSD 05	Factor A	0.07	0.10	0.11	0.09	0.11	
	Factor B	0.13	0.12	0.14	0.13	0.14	
	Factor AB	0.15	0.14	0.16	0.17	0.18	

For all years of cultivation, the increase in grain yield under the influence of fertilizers in the context of varieties was determined by statistical analysis to be reliable.

Thus, the lowest grain yield of winter wheat was formed in 2012 – 1.71 up to 3.04 t ha⁻¹ by 'Kolchuga' variety and it was 1.86 up to 3.76 t ha⁻¹ by a variety of 'Zamozhnist' depending on the nutrition. Favourable weather conditions in 2015 and 2016 during the vegetation season provided the highest yield of winter wheat, regardless of the studied factors. Thus, on average, for both varieties and nutrition variants, in 2015, it was formed grain yield as 5.53 t ha⁻¹, and in 2016 was 5.59 t ha⁻¹, which exceeded the level of 2012, which was the least favourable, by 2.63 up to 2.69 t ha⁻¹ or by 90.7 up to 92.8%.

The level of grain yield varied depending on the variety taken for study. According to our studies, on average over the cultivation years on the nutrition factor, slightly higher yields were formed by plants of the 'Zamozhnist' variety as 4.43 t ha⁻¹, which exceeded the yields of the 'Kolchuga' variety by 0.41 t ha⁻¹ or 10.2%.

In all the years of research, it was observed a positive effect of the main pre-sowing application of moderate doses of mineral fertilizers and foliar application in the main periods of vegetation of winter wheat varieties. Thus, on average, over the years of research, the winter wheat grain yield as 3.44 up to 3.58 t ha⁻¹ was obtained on the background of N₃₀P₃₀ depending on the variety, which exceeded the control by 0.53 up to 0.55 t ha⁻¹ or 17.4 up to 19.0%. The use of N₃₀P₃₀ contributed to a slight increasing of the winter wheat grain yield in all years of research, regardless of the variety. At the same time research (Ammanullah, 2014; Sedlar *et al.*, 2017) showed that moderate doses of nitrogen fertilizers had little effect on grain yield.

The maximum grain yield in the experiment was formed by winter wheat plants of the variety 'Zamozhnist' in the background + Escort – bio nutrition variant in the range from 3.76 to 6.28 t ha⁻¹ depending on the weather conditions of the year.

The quality of wheat grain is influenced by the interaction of several factors, including variety, soil, climate, grain cultivation practices and grain storage conditions (Buráňová *et al.*, 2016).

As a result of our research, it was found that the quality indicators of winter wheat grain depended on the variety and the plant nutrition variant (Table 2).

Table 2. Influence of nutrition optimization on grain quality of winter wheat varieties (average for 2012–2016)

Variety	Nutrition variant	Crude gluten content, %	Protein content, %	Conditional protein content, t ha ⁻¹
'Kolchuga'	Control	21.4	11.2	0.32
	N ₃₀ P ₃₀	22.8	12.0	0.41
	N ₃₀ P ₃₀ and Urea K1	23.0	12.2	0.52
	N ₃₀ P ₃₀ and Urea K2	23.2	12.3	0.53
	N ₃₀ P ₃₀ and Escort-bio	24.2	12.9	0.58
	N ₃₀ P ₃₀ and Urea K1 and Urea K2	23.6	12.5	0.55
	N ₃₀ P ₃₀ and Organic D2	23.9	12.7	0.56
'Zamozhnist'	Control	22.0	11.6	0.35
	N ₃₀ P ₃₀	23.4	12.4	0.44
	N ₃₀ P ₃₀ and Urea K1	23.7	12.6	0.58
	N ₃₀ P ₃₀ and Urea K2	24.1	12.6	0.61
	N ₃₀ P ₃₀ and Escort-bio	25.1	13.2	0.66
	N ₃₀ P ₃₀ and Urea K1 and Urea K2	24.6	12.8	0.63
	N ₃₀ P ₃₀ and Organic D2	24.9	13.0	0.64
LSD 0.05	factor A	0.18	0.12	
	factor B	0.24	0.14	
	factor AB	0.27	0.18	

When optimizing nutrition in the grain of the studied varieties the content of raw gluten, protein, and conditional protein collection from the conditional area significantly increased.

Variety selection is a key factor in obtaining high technological grain quality, although recently it is associated with a decrease in yield (Visioli *et al.*, 2018). In the 'Kolchuga' variety, the crude gluten content of non-fertilized plants was by 6.1 relative per cent less compared to the version of the main application of mineral fertilizers in the dose of N₃₀P₃₀. Carrying out foliar fertilizing of plants on the background of fertilizer contributed to the increase of this indicator by 7.0–11.5 relative per cent to the control.

The gluten content in the grain of 'Zamozhnist' variety plants also increased under the influence of optimization of nutrition. Thus, on average, over the years of research, the increasing of this quality indicator only from the background application of mineral fertilizers amounted to 6.0 relative per cent, and from the use of compatible with modern growth-regulating preparations, it was by 7.2–12.4 relative per cent compared to the control.

It is known that the protein content in the grain, is influenced by weather and climatic conditions, especially the provision of moisture during the grain loading, varietal characteristics, the presence and time of application of nutrients, especially nitrogen (Buránová *et al.*, 2016). This also was observed in our studies. Thus, the protein content in winter wheat grain of both varieties studied by us in 2012 was lower in comparison with its content in 2016, which was more favourable in terms of moisture content of crops. During the spring-summer period of winter wheat vegetation in 2016, precipitation was 173.0 mm, while in 2012 was only 73.3 mm, while in the interphase period "earing – full maturity of the grain" the amount of precipitation was 86.0 and 52.0 mm. Favourable weather and climatic conditions in 2012 for the formation of winter wheat grain quality indicators facilitated the conglomeration in the grain of 'Kolchuga' variety on average by a nutritional factor of 14.0% protein, and 'Zamozhnist' variety – 14.1%, which exceeded the indicators of 2016 by 20.6–21.4 relative points.

On average, over the years of research, in the control of the experiment, the grain of the 'Kolchuga' variety contained 11.2% protein, the grain of 'Zamozhnist' variety contained 11.6%, then the application of only mineral fertilizers before sowing ensured increasing of this indicator by 6.5–6.7%, and carrying out on their background foliar fertilizing increased by 8.2–13.2 and 7.9–12.1% depending on the variety.

It is established that the variants of the research affected both the protein content of winter wheat grain and its conditional yield from the sowing area. So, when introducing of moderate doses of mineral fertilizers under winter wheat the conditional protein yield of 'Kolchuga' variety compared to non-fertilized control increased by 22.0%, and the yield of 'Zamozhnist' variety increased by 20.5%. The foliar application increased this indicator of 'Kolchuga' variety by 38.5 up to 44.8% and it increased this indicator of 'Zamozhnist' variety by 39.7 and 47.0%.

It was determined that some better quality indicators were differed by the grain of both studied winter wheat varieties when used together with the pre-sowing application of N₃₀P₃₀ and foliar dressing of winter wheat crops twice during the vegetation season with Escort-bio. Thus, the crude gluten content in winter wheat grain for this variant of nutrition was 24.2–25.1%, the protein content was 12.9–13.2% and the conditional protein yield from 1 ha of sowing area was 0.58–0.66 t depending on the studied variety.

According to the research results, it was found that on average for 2012–2016, the cultivation of the 'Zamozhnist' variety contributed to the production of the grain of the highest quality compared to the 'Kolchuga' variety. So, on the average on nutrition variants, the gluten content in grain of winter wheat was 3.3% higher than 'Kolchuga' variety, and the protein content was higher by 2.4 relative per cent. In this case, the conditional protein yield from the sown area increased by 12.5%.

Conclusions

In the conditions of the South of Ukraine optimization of winter wheat plant nutrition on the principles of resource-saving, ensures the increase of grain yield and significantly improves its quality. It was established that double application of fertilizing with modern complex organic-mineral fertilizers (Organic D2 and Escort-bio) for foliar fertilizing of crops at the beginning of the resumption of spring vegetation and at the beginning of the winter wheat stooling on the background of N₃₀P₃₀ allowed optimizing the nutrition of this crop and due to this combination, it allowed to reduce (replace) a certain amount of nitrogen fertilizer.

Conflict of interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

Author contributions

AP – study conception and design, acquisition of data, analysis and interpretation of data, drafting of the manuscript;

VG – drafting of the manuscript, critical revision and approval of the final manuscript;

IS – analysis and interpretation of data.

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