

Influence of environmental fertilizer systems on yield formation and grain quality of winter wheat

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Goal. To study the formation of productivity and grain quality of winter wheat in environmental fertilizer systems.

Methods. Field, laboratory, and statistical research. **Results.** The data are given of research in the influence of environmental fertilizer systems on the productivity of winter wheat. Use of environmental fertilizer systems allowed to increase the number of productive stems to 379 – 462 picks/m², the productivity of the ear — to 1.26 – 1.48 g, the mass of 1000 seeds — to 33.5 – 41 g, and to get the yield of winter wheat at the level of 4,46 – 5.92 t/ha. The highest content of macronutrients (N, P, K) in the grain of winter wheat was fixed for fertilizer systems based on N₆₀P₉₀K₉₀. The level of potassium and magnesium in the grain was higher than at use in the compositions of fertilizer of straw of peas + N₃₀P₄₅K₄₅. Efficiency and perspective were revealed of the use of alternative fertilizers based on by-products with the addition of mineral fertilizers N₃₀P₄₅K₄₅ + organic component (humus or microbiological fertilizer) and treatment of plants with a biostimulator. Due to that grain was yielded with optimal gluten content — 25.6 – 27.6%, protein — 11 – 11.9%, a slight amount of nitrates — 55.8 – 56 mg/kg, and the maximum allowable concentration of micro-elements. **Conclusions.** It was found that the use of the straw of peas as a by-product at entering N₃₀P₄₅K₄₅ with humus or microbial fertilizer and plant treatment with biostimulant increased winter wheat yield by 52.3 – 59.4%, compared to the variants without fertilization. At the use of mineral (N₆₀P₉₀K₉₀) and organo-mineral fertilizer systems, such an increase made 77.7 – 87.8%, which slightly increased the nitrate content in the grain. Application of natural fertilizer systems revealed a complex positive impact on the field of safe production of winter wheat according to ecological quality indicators.

Key words: *mineral fertilizer, organic component, yield, biostimulant, microelements, content of gluten and protein.*

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The task of modern and future agriculture is the simultaneous solution of three important problems – increasing the profitability of technologies in crop production, environmental protection and increasing the productivity of cultural agrocenoses and product quality [1, 2]. The latter is especially important for winter wheat, which has a leading place in providing humanity with balanced food.

One of the factors in the formation of optimal yields and environmentally friendly products is the use of environmentally friendly fertilizer systems. They are conceptually characterized by the principle of alternativeness through the use of secondary plant products, appropriate humus, microbiological and chelated fertilizers, treatment of plants with biostimulants, etc. [3, 4].

Components of green manure systems, including the introduction of secondary crop products, micronutrients, humus and microbiological fertilizers, include compliance with natural biological laws, namely the accumulation of organic matter, increased microbiological activity, and thus pave the way for increasing the availability of nutrients for crops [5, 6].

The use of biostimulants increases the productivity of crops, due to the intensification of cell life of plant organisms, acceleration of biochemical processes, which in turn enhances the processes of nutrition, respiration and photosynthesis and, as a result, better realization of plant genetic potential [7]. In the conditions of modern agricultural production for practical use it is necessary to estimate comprehensively quality of the grown production [8], especially it concerns ecological indicators of grain [9]. The nutritional quality of grain, and especially its elemental composition is of considerable interest to both agronomists and nutritionists. The autecological reaction of plants to changes in the content of macro- and microelements in ecological fertilizer systems requires research on the definition of the system "soil-plant" [10].

The purpose of the research is to study the formation of productivity and quality of winter wheat grain under ecological fertilizer systems.

Materials and methods. The research was carried out in the field of winter wheat (*Triticum aestivum* L.), variety Poliska 90, sown after peas for grain (*Pisum Sativum* L.). The scheme of the experiment includes 8 options: 1). Control (without fertilizers); 2). Straw peas (g.); 3). Straw g. + N₃₀R₄₅K₄₅ + biostimulator (BS); 4). Straw + N₃₀R₄₅K₄₅ + BS + humus fertilizer (GD); 5). Straw g. + N₃₀R₄₅K₄₅ + BS + microbiological fertilizer (MD), 6). N₆₀P₉₀K₉₀ + BS; 7). N₆₀P₉₀K₉₀+ BC + GD; 8). N₆₀P₉₀K₉₀ + BS + MD. Pea straw was plowed in the amount of 2.5 t/ha, GD – eco-impulse was applied in the pre-sowing period (3 l/ha). BS - terra sorb - twice during the growing season (tillering, tube exit)

– dose 0.5 l/ha; MD – eco-soil was applied at the end of tillering – 3.0 l/ha. The object of study – plants and grains of winter wheat. Agrochemical characteristics of gray forest surface-gleyed soil are as follows: rNKSI – 4,85 (DSTU ISO 10390:2007); hydrolytic acidity of 2,4 mg-eq/100 g of soil (DSTU 7537:2014), content of easily hydrolyzed nitrogen – 9.8 (DSTU 7863:2015), mobile forms of phosphorus and potassium according to Kirsanov (0.2 n HCl) 10.6 and 8.6 mg/100 g of soil (DSTU 4405:2005), total humus – 2,1% (DSTU 4289:2004).

Structural analysis of winter wheat plants was performed according to Maisuryan, gluten content according to DSTU 3768: 2019, protein content according to Lowry, nitrate content by ionometric method, trace element content (ME) by atomic absorption spectrophotometry 116-M method, potassium content, macroelements, macroelements MVV ashing – 31-497058-024-2005, calcium and magnesium content by trilonometric method.

Research results. To obtain high and stable yields of winter wheat, it is important to form an appropriate morphostructure of plants and the structure of crops, which would effectively use the optimal conditions of nutrient supply created by the technology of cultivation. The efficiency of ecological fertilizer systems on the formation of productivity of winter agrophytocenosis of winter wheat Poliska 90, grain yield and its quality were evaluated.

One of the main elements of highly productive agrophytocenoses is the formation of the optimal value of productive stems. The number of productive stalks of winter wheat in 2017–2018 under the conditions of plowing pea straw was 316 pcs/m² against 265 in the control (Table 1).

1. Influence of ecological fertilizer systems on elements of productivity and yield of winter wheat (average 2017–2018)

№ var.	Systems fertilization	Number of productive stems pcs. per 1m ²	Mass 1000 grains, g	Weight of grain from the ear, g	Harvest, t / ha	Yield increase to control	
						t / ha	%
1	Control (without fertilizers)	265	28,8	0,97	3,15		
2	Pea straw (g.)	316	29,3	1,05	3,44	0,29	9,2
3	Straw r. + N ₃₀ R ₄₅ K ₄₅ + BS	379	33,5	1,26	4,46	1,31	41,6
4	Straw r. + N ₃₀ R ₄₅ K ₄₅ + BS + GD	409	36,7	1,32	5,02	1,87	59,4
5	Straw r. + N ₃₀ R ₄₅ K ₄₅ + BS + MD	390	34,8	1,29	4,90	1,65	52,3
6	N ₆₀ P ₉₀ K ₉₀ + BS	415	39,1	1,44	5,60	2,45	77,7
7	N ₆₀ P ₉₀ K ₉₀ + BS + GD	462	41,0	1,48	5,92	2,77	87,8
8	N ₆₀ P ₉₀ K ₉₀ + BS + MD	428	40,2	1,46	5,76	2,61	82,5
NIR 0,5		40,7	3,1	0,15	0,17		

The introduction of N₃₀R₄₅K₄₅ on the background of pea straw in combination with the treatment of plants with a biostimulator led to an increase in the density of productive stems to the level of 379 pcs/m². The positive effect was manifested when applying humus or microbiological fertilizer both on the background of pea straw + N₃₀R₄₅K₄₅ + BS and on the basis of N₆₀P₉₀K₉₀ + BS. Productivity of winter wheat is characterized by weight of grains from one ear, weight of 1000 grains, productivity. The largest mass of grain from the ear was found on the background of pea straw + N₃₀R₄₅K₄₅ + BS with the addition of humus fertilizer (1,32 g) and on the basis of N₆₀P₉₀K₉₀ + BS compatible with GD (1,48 g), respectively, as shown in table 1. The highest weight of 1000 grains (36.7–41.0 g) were obtained under similar conditions, which had a positive effect on the yield of winter wheat. The maximum realization of productivity of winter wheat was provided by the ecological fertilization systems. Thus, the largest increase in yield relative to absolute control was obtained by applying fertilizers at the rate of N₆₀P₉₀K₉₀ + BS with the addition of MD or GD 2,61 – 2,77 t/ha. Slightly lower yields were formed by winter wheat with the introduction of pea straw + N₃₀R₄₅K₄₅ + BS + GD. The effect of the fertilizer system on the basis of secondary crop products relative to control was – 1,87 t/ha. When plowing only pea straw, the yield of winter wheat decreased to the level of 3.44 t/ha, and at the control – to 3.15 t/ha, respectively.

The use of environmentally friendly fertilizer systems has led to changes in the accumulation of macronutrients in the grain of winter wheat. It was found that in the variant without fertilizers (control) the nitrogen content in the grain was 1.68%. In the variants of the experiment composed on the basis of pea straw, an increase in its content to 1.80–1.90% was noted. Compositions based on N₆₀P₉₀K₉₀ provided a nitrogen level of 1.98–2.01%. The content of phosphorus and potassium depending on the ecological fertilizer systems varied similarly. The content of calcium and magnesium was higher than fertilizer systems based on pea straw 0.08–0.09% and 0.14–0.15%, and on the

control 0.05–0.09%, respectively. The decrease in the content of calcium and magnesium in the compositions against the background of $N_{60}P_{90}K_{90}$ (0.06–0.07 and 0.011–0.12%), in relation to the variants with secondary plant products is due to the acidification of the soil solution, and therefore a decrease in their mobility and availability.

The microelement composition of grain is an important indicator of its biological value. According to MN Kuleshov [11] the content of trace elements in the grain of winter wheat, which is used as food should contain: Zn – 25.0, Cu – 5.0, Fe – 50.0, Mn – 44.5 mg / kg.

The need of plants for manganese under the conditions of the experiment is fully satisfied by the soil itself at rNKSI – 4.87–5.28, which determines the accumulation of manganese in the grain in optimal quantities (Table 2).

2. Content of microelements and heavy metals in winter wheat grain under ecological fertilizer systems, mg/kg (average 2018–2019)

№ var	Fertilizer systems	Cu	Zn	Mn	Fe	Cd
1	Control	3,04	10,00	12,6	13,9	0,06
2	Pea straw (g.)	3,10	10,30	11,9	14,3	0,04
3	Straw r. + $N_{30}R_{45}K_{45}$ + BS	3,38	11,42	13,8	17,8	0,05
4	Straw r. + $N_{30}R_{45}K_{45}$ + BS + GD	3,46	11,02	12,7	16,4	0,05
5	Straw r. + $N_{30}R_{45}K_{45}$ + BS + МД	3,49	10,76	12,8	16,5	0,05
6	$N_{60}P_{90}K_{90}$ + BS	3,60	12,28	13,5	19,4	0,09
7	$N_{60}P_{90}K_{90}$ + BS + GD	3,49	11,42	13,2	18,0	0,09
8	$N_{60}P_{90}K_{90}$ + BS + MD	3,42	11,22	13,2	17,8	0,09

Our experiments were characterized by an increase in the content of iron, zinc and copper in green fertilizer systems, compared with the control (Table 2). Such accumulation of trace elements of iron, zinc and copper may be due to increased efficiency of their use by wheat plants. Under the conditions of application of fertilizer systems against the background of $N_{60}P_{90}K_{90}$ there was an increase in the content of ME in the grain, due to increased mobility and mobility, against the background of acidification of the soil solution. Under these conditions, there is also a tendency to increase the cadmium content. By quantitative characteristics, the microelement composition of grain can be represented as a series: Fe > Mn > Zn > Cu > Cd. At the same time, this distribution of elements is a consequence of unequal lyophilicity and the specificity of their functional purpose.

We emphasize that the microelement composition of winter wheat grain is an important diagnostic indicator that characterizes not only the provision of plants with vital IU, but also determines the environmental friendliness of winter wheat cenoses. Under the conditions of the experiment, the amount of ME in the grain is within the MPC (maximum allowable concentrations).

The content of gluten, protein and nitrates is an important indicator of the qualitative characteristics of the winter wheat harvest. The content of crude gluten under control for an average of three years was 22%. The introduction of green fertilizer systems increased its number in different variants by 0.4–6.8%.

Studies have shown that fertilizing winter wheat for plowing straw peas + $N_{30}R_{45}K_{45}$ and the introduction of BS and GD increased the gluten content in the grain to 25.6 and 27.6%. The highest level of gluten was provided by fertilizer systems based on $N_{60}P_{90}K_{90}$. The protein content in the grain of winter wheat in the control was 9.3%. Most of it was in the variants of organo-mineral fertilizer systems arranged on the background of $N_{60}P_{90}K_{90}$.

As a result of research it was noted that in the variants of control and plowing only pea straw the content of nitrates was – 51.6–51.2 mg/kg. Against the background of fertilizer using pea straw + $N_{30}R_{45}K_{45}$ + BS and the addition of GD or MD, an increase in nitrate content by 8.0–8.5% was obtained. In the conditions of compositions based on $N_{60}P_{90}K_{90}$, this increase was found at the level of 18.0–19.5%. Application of mineral fertilizers $N_{60}P_{90}K_{90}$ + BS to the greatest extent increased the content of nitrates in the grain to 66.8 mg/kg, but the results are much lower than the maximum allowable norms (GDN-300 mg/kg).

It should be noted that under the conditions of using pea straw + $N_{30}R_{45}K_{45}$ + BS + GD, the payback of one hryvnia cost UAH 2.2, and profitability – 120%, which determined the highest economic efficiency of this fertilizer system.

Conclusions

It was found that the use of by-products as pea straw + $N_{30}R_{45}K_{45}$ + BS in combination with humus or microbiological fertilizer and treatment of plants with biostimulants increased the yield of winter wheat by 52.3–59.4%, compared to options without fertilizers. Under the conditions of projects with mineral ($N_{60}P_{90}K_{90}$) and organo-mineral fertilizer systems, this increase was 77.7–87.8%, which was accompanied by a slight increase in the content of nitrates in the grain. The application of ecological fertilizer systems has revealed a complex positive impact on the production of safe winter wheat products in terms of environmental quality indicators.

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