UDC:633.11 https://doi.org/10.31867/2523-4544/0263

FORMATION OF THE WINTER WHEAT YIELD DEPENDING ON THE ELEMENTS OF CULTIVATION TECHNOLOGY IN THE CONDITIONS OF THE RIGHT BANK FOREST STEPPE OF UKRAINE

L. S .Kvasnitska, H. P. Voitova
Khmelnitsky State Agricultural Experimental Station of Institute of Feed Research and Agriculture Podillia of NAAS, Samchyky village, Khmelnytsky district, Khmelnytskyi region, 31182, Ukraine

Topicality. *In eco-friendly farming systems, the biologicals help to increase winter wheat productivity and improve grain quality. These include both stubble biodestructors that accelerate the return of nutrients from by-products to the soil and multifunctional biologicals with fertilising, growth-regulating and protective properties.* ***Purpose.*** *To determine the influence of the stubble biodestructors and multifunctional biologicals under different fertilization backgrounds on the formation of individual plant productivity, yield and grain quality of winter wheat in the conditions of the Right-Bank Forest-Steppe.* ***Methods.*** *Field method was used to study the interaction of the investigated factors on the plant growth and development, as well as and the winter wheat yield; quantitative-weight method – to determine the structure of the yield; mathematical and statistical method – to analyse the reliability of the obtained results.* ***Results.*** *It was established that the application of stubble biodestructors and multifunctional biologicals had an impact on the formation of the winter wheat yield and provided an increase in the number of productive stems by 4–9 %, grain weight per spike by 3–7 %, and yield by 8–17 % against the background without fertilizers. The application of $N_{90}P_{60}K_{60}$ resulted in an increase in the number of productive stems by 10%, the grain weight per spike by 14 %, and the yield by 31 % compared to the background without fertiliser. The use of biological preparations against this background provided an additional increase in productivity in the range of 9–15 %, which was accompanied by an increase in the number of productive stems and the weight of the ear of grain by 3–6 % and 5–8 %, respectively. On this background, the application of biologicals provided an additional increase in yield within 9–15 %, as well as an increase in the number of productive stems and grain weight per spike by 3–6 % and 5–8 %, respectively. The highest yield of winter wheat was provided by the combination of the stubble biodestructor Organic-Balance with the seed and crop treatment with a multifunctional biologicals Organic-Balance on a non-fertilised background – 5.27 t/ha and on a mineral background – 6.79 t/ha due to high productive stem density and the highest grain weight per spike.* ***Conclusions****. In the Right-Bank Forest-Steppe on the non-fertilised background and mineral background with $N_{90}P_{60}K_{60}$, the maximum grain yield of winter wheat grown after sunflower was obtained due to the combination of technological elements, including the application of stubble biodestructors and multifunctional biologicals for seed and crop treatment. These eco-friendly elements have the potential to improve the winter wheat cultivation technology.*

Key words: *winter wheat, fertilizer background, stubble biodestructor, multifunctional biologicals, productivity, grain quality*

Introduction. The key task of Ukrainian agriculture is to increase the production of winter wheat (*Triticum aestivum* L.), which is the most valuable food crop in the country. The growing demand for wheat grain on the global market raises the question of the prospects for increasing export supplies, which is impossible without increasing the yield of this crop [1–3]. Agrarian science has long been conducting research to develop cultivation technologies to reduce the negative impact of abiotic and biotic factors on winter wheat. The biotic factors significantly reduce yields and deteriorate grain quality [4]. Among the priorities of the modern strategy is the use of biologicals as an integral technological link in the cultivation of grain crops in ecological farming systems [5]. The main advantages of microbiologicals are their low cost per unit of incremental output, low consumption rate, and environmental safety, which creates broad prerequisites for their implementation in biological agriculture [6].

Among agricultural plant protection products, the greatest preference is given to biologicals with multifunctional action, i.e. products with a complex effect (simultaneously exhibiting fertilising, growth-regulating and

Author information:
Larysa S. Kvasnitska, *Candidate of Agricultural Sciences, Senior Researcher*, e-mail: larusa7215@ukr.net, https://orcid.org/ 0000-0002-7925-2299
Halyna P. Voitova, *Researcher*, e-mail: larusa7215@ukr.net, https://orcid.org/0000-0001-6152-5677

protective properties) [7, 8]. Microbial plant residue destructors play an important role among biologicals in land preparation technologies for sowing winter crops. They reduce the rate of decomposition of humus substances, improve soil structure, and reduce soil moisture evaporation, soil density and water erosion. In addition, they suppress many diseases and reduce the number of certain pests that are localised on plant residues [9–11]. Chemicalisation causes a signifycant suppression of soil biological activity due to a decrease in the diversity and quantity of microflora, including the decomposition of plant residues [12–14]. These factors necessitate the application of biodestructors.

Intensive cultivation technologies have reached critical limits in terms of environmental, energy and productivity [15]. Therefore, the realisation of the maximum productivity potential of winter wheat requires a rational fertilisation system that would fully meet the requirements of plants to growing conditions [16].

The purpose of the research is to determine the effect of the application of stubble biodestructor Organic-Balance and multifunctional biological product Organic-Balance against different fertilizer backgrounds on the formation of individual plant productivity, yield and quality of winter wheat grain in the conditions of the Right-Bank Forest-Steppe.

Materials and Methods. The object of research was the processes in the formation of yield and quality of winter wheat grain depending on the studied technological elements in the period 2021–2022. The research was conducted in a temporary field trial by the Khmelnytskyi State Agricultural Experimental Station of Institute of Feed Research and Agriculture Podillia of NAAS.

The soil of the experimental plot is a slightly podzolized medium loamy moderately deep low-humus chernozem on loess loam of brownish-pale colour. Accounting plot area is 32 m^2; replication is four times; plots are placed systematically. Humus content (according to Tyurin) is 2.8–3.0 %, pH is 5.8–6.2; hydrolytic acidity is 1.9–2.3 mg/equiv. per 100 g of soil; gross nitrogen reserves are 0.153–0.163 %, phosphorus reserves are 0.136–0.149 %; alkaline hydrolysed nitrogen is 17–19.3 mg, mobile forms of phosphorus and potassium (according to Chirikov) are 20.8–22.6 and 8–12 mg per 100 g of soil, respectively. The experiment studied the elements of cultivation technology, such as the application of two biologicals with the same name Organic-Balance produced by BTU-Center: stubble biodestructor (1.0 l/ha) and multifunctional biological product for treatment of seeds (1.0 l/t) and crops (0.5 l/ha) on a fertiliser-free background and mineral background with $N_{90}P_{60}K_{60}$. Before ploughing the plant residues of the predecessor (sunflower), N_{10}/t of by-products was introduced. The seeding rate was 4.5 million/ha. Accounting and observations were carried out according to generally accepted methods in agriculture [17–19]. It was sown Bohdana variety of winter wheat; sowing dates were on October 05, 2021 and on September 30, 2022.

The main research method was field, which included the study of the interaction of the studied factors on the plant growth and development and yield of winter wheat; quantitative and weight method – to determine the yield structure; mathematical and statistical method – to analyse and establish the reliability of the results.

Results and Discussion. The formation of a crop yield is the result of the complex interaction of productivity elements, the main of which are the number of productive stems in the crop, the grain weight per spike, the grain content of the spike and the 1000 grain weight.

For the years of research, the main factors that formed the productive stem stand of winter wheat were biologicals applied independently and in combination on two fertilisation backgrounds. Higher plant density was observed under mineral fertilisation, with a productive tillering coefficient of 1.87 compared to 1.70 (no fertilisation), and a lower percentage of unproductive stems in the crop – 7 compared to 9 %. Biologicals application resulted in an increase in the values on the background without fertilizers and with the application of mineral fertilizers in the average range of 1.72–1.77 and 1.89–1.92 stems per plant and 5–7 and 5–6 %, respectively (Table 1).

The parameters of formation of plant productivity elements depending on fertilisation backgrounds were determined on winter wheat crops, and their differences were established. Among the variants with biological treatments in the full grain maturity, higher plant height was reached by application of the multifunc-

Table 1. Average plant density of winter wheat under the application of biologicals on different fertilisation backgrounds, (average for 2021–2022)

Background	Variants of experiment	Plant density, ths. plants/ha			Density of productive stems, ths. pcs/ha	Coefficient of productive tillering	Unproductive stems in the crop, %	Plant survival rate, %		
		seedling	resumption of growth season	harvest				seedling – resumption of growth season	resumption of growth season – harvest	total
No fertilisation	no treatment – control	3753	3432	2867	4877	1.70	9	93	84	78
	stubble biodestructor	3774	3496	2958	5101	1.72	7	94	85	80
	treatment of seeds and crops with a multifunctional biologicals	3814	3568	3004	5289	1.76	6	95	85	81
	stubble biodestructor + treatment of seeds and crops with a multifunctional biologicals	3832	3583	3001	5300	1.77	5	94	85	80
Mineral ($N_{90}P_{60}K_{60}$)	no treatment – control	3766	3448	2879	5375	1.87	7	93	84	78
	stubble biodestructor	3782	3512	2925	5519	1.89	6	94	84	79
	treatment of seeds and crops with a multifunctional biologicals	3828	3586	2945	5609	1.91	5	95	83	79
	stubble biodestructor + treatment of seeds and crops with a multifunctional biologicals	3839	3601	2993	5720	1.92	5	95	84	80

tional biologicals (Table 2).

There was an improvement in individual productivity and yield quality of the crop due to the treatment of seeds and crops with this product: on the background without fertilisation, the spike length varied within 6.9–7.8 cm, on the mineral background – 7.7–8.3 cm, respectively, the number of grains in the spike – from 24.6 to 25.6 and from 26.2 to 26.9 pcs, grain weight per spike – from 1.04 to 1.09 and from 1.19 to 1.28 g, 1000 grain weight – from 42.4 to 42.6 and from 46.0 to 47.4 g, gluten content – from 15.0 to 17.9 and from 18.9 to 22.2 %, grain hardness – from 49 to 53 and from 66 to 71 % and grain volume weight – from 765 to 807 and from 785 to 818 g/l. The maximum increase in the values of indicators was noted in the variants with a combination of stubble biodestructor and a multifunctional biological product, which were: 1000 grain weight – 42.9 g on the background without fertilisation and 47.5 g – on the mineral background, in accordance with these backgrounds, gluten content – 18 and 22.3 %, grain hardness – 54 and 72 %.

Our studies also showed that the grain yield of winter wheat varied depending on the fertilisation backgrounds and biological products applied (Table 3).

Its lowest value (4.54 t/ha) was obtained on the background without fertilizers, where the application of stubble biodestructor provided a grain increase of 0.37 t/ha (or 8 %), treatment of seeds and crops with a multifunctional biologicals – 0.65 t/ha (15 %), and their combined application – 0.73 t/ha (17 %). The variant without fertilisers was characterised by the lowest number of productive stems (4,877 thousand stems/ha) and grain weight per spike (1.04 g), as well as the highest percentage of unproductive stems in the crop (9 %).

Improvement of these indicators was achieved with the application of the studied bio-

Table 2. Average indicators of yield structure and grain quality of winter wheat under the application of biologicals on different fertilisation backgrounds, (average for 2021–2022)

Background	Variants of experiment	Plant height, cm	Spike length, cm	Number of kernels per spike, pcs	Grain weight per a spike, g	1000 grain weight, g	Straw to grain ratio	Gluten content in the grain, %	Grain hardness, %	Grain volume weight, g/l
No fertilisation	no treatment – control	91	6,9	24.6	1.04	42.4	1.13	15.0	49	765
	stubble biodestructor	98	7.3	25.2	1.07	42.5	1.12	16.1	52	775
	treatment of seeds and crops with a multifunctional biologicals	101	7.8	25.6	1.09	42.6	1.00	17.9	53	807
	stubble biodestructor + treatment of seeds and crops with a multifunctional biologicals	103	7.9	25.7	1.11	42.9	1.00	18.0	54	803
Mineral ($N_{90}P_{60}K_{60}$)	no treatment – control	97	7.7	26.2	1.19	46.0	1.01	18.9	66	785
	stubble biodestructor	101	8.0	26.7	1.25	46.8	0.99	20.7	67	801
	treatment of seeds and crops with a multifunctional biologicals	103	8.3	26.9	1.28	47.4	0.97	22.2	71	818
	stubble biodestructor + treatment of seeds and crops with a multifunctional biologicals	104	8.5	26.9	1.28	47.5	0.93	22.3	72	817

Table 3. Winter wheat yield under the application of biologicals on different fertilisation backgrounds, t/ha, (average for 2021–2022)

Background	Variants of experiment	Yield	Increase in yield, ±					
			to control		to background		interaction of factors	
			t/ha	%	t/ha	%	t/ha	%
No fertilisation	no treatment – control	4.54	0	0	0	0	0	0
	stubble biodestructor	4.91	0.37	8	0.37	8	0	0
	treatment of seeds and crops with a multifunctional biologicals	5.18	0.65	15	0.65	15	0	0
	stubble biodestructor + treatment of seeds and crops with a multifunctional biologicals	5.27	0.73	17	0.73	17	0	0
Mineral ($N_{90}P_{60}K_{60}$)	no treatment – control	5.90	1.37	31	0	0	1.37	31
	stubble biodestructor	6.39	1.85	42	0.49	9	1.48	31
	treatment of seeds and crops with a multifunctional biologicals	6.63	2.10	47	0.73	13	1.45	29
	stubble biodestructor + treatment of seeds and crops with a multifunctional biologicals	6.79	2.26	51	0.89	15	1.53	30
$LSD_{0.05}$			0.11		0.15		0.21	
			0.12		0.16		0.23	

logicals: increase in the number of productive stems in the crop by 5–9 % and grain weight per spike by 3–7 %, decrease in the number of unproductive stems by 2–4 %.

On the mineral background with $N_{90}P_{60}K_{60}$, a significantly higher yield (5.90 t/ha) was obtained with a grain increase of 1.37 t/ha (31 %) and an increased number of productive stems by 10 % in the crop and grain weight per spike by 14 % compared to the variant without fertilisation. Against the background of mineral fertilisation with the application of biologicals, an additional increase in grain yield was obtained: 0.49 t/ha (9 %) due to the application of stubble biodestructor, 0.73 t/ha (13 %) due to the treatment of seeds and crops with a multifunctional biologicals, and 0.89 t/ha (15 %) due to their combined application, which was accompanied by an increase in the number of productive stems in the crop by 3–6 % and grain weight per spike by 5–8 %. The highest values of these indicators were obtained in variants with the application of multifunctional biologicals.

It was found that the application of a stubble biodestructor in combination with the treatment of seeds and crops with a multifunctional biological product provided the highest yield of winter wheat on a background without fertilizers – 5.27 t/ha and a mineral background – 6.79 t/ha, this resulted from the formation of a denser productive stem stand and the largest grain weight per spike.

Conclusions. According to the preliminary results of the research, it was found that the application of a multifunctional biological product and a stubble biodestructor influenced the formation of winter wheat yield with a significant increase in the following indicators: the number of productive stems by 5–9 % on the background without fertilizers and by 3–6 % on the mineral background ($N_{90}P_{60}K_{60}$), the grain weight per spike by 3–7 and 5–8 %, which ensured an increase in yield by 8–17 and 9–15 %, respectively.

The highest yield of winter wheat was in the variant with the combination of stubble biodestructor with treatments of seeds and crops with a multifunctional biologicals on the background without fertilizers – 5.27 t/ha and on the mineral background – 6.79 t/ha, due to the formation of a denser productive stem stand and the largest grain weight per spike.

The above environmentally friendly biologicals can be used to improve the winter wheat cultivation technology.

References

1. Kozak, O. A., & Hryshchenko, O. Yu. (2016). Development of the grain industry of Ukraine at the current stage. *Ekonomika APK* [Economy of agroindustrial complex], *1*. 38–47. [in Ukrainian].
2. Prokopenko, O. M. (2019). Agriculture of Ukraine. *Statystychnyi zbirnyk* [Statistical collection]. Kyiv: N. p. [in Ukrainian].
3. Kernasiuk, Yu. V. (2020). Global wheat market: situation and trends. *Ahrobiznes sohodni* [Agribusiness today], *22 (437).* 12–16. [in Ukrainian].
4. Mudrak, A. A., Filatov, V. O., & Nestor, S. M. (2015). *Optymizatsiia pryiomiv vyroshchuvannia pshenytsi ozymoi za riznykh poperednykiv u vyrobnychykh posivakh v umovakh Stepu Ukrainy* [Optimization of methods of growing winter wheat under different predecessors in production crops in the conditions of the Steppe of Ukraine]. *Problemy konstruiuvannia, vyrobnytstva ta ekspluatatsii silskohospodarskoi tekhniky: materialy X mizhnar. nauk.-prakt. konf*, Proceedings of the *Problems of design, production and operation of agricultural machinery:* X intern. sci. pract. conf. (pp.26−28). November 5−6, 2015, Kirovohrad, Ukraine. [in Ukrainian].
5. The concept of organic farming (soil and agrochemical supply) (2017). *Posibnyk ukrainskoho khliboroba* [Manual of the Ukrainian farmer]. *1*, 63–80. [in Ukrainian].
6. Kaminskyi, V. F. (2017). Biologization of agriculture as a component of the biosphere. *Posibnyk ukrainskoho khliboroba* [Manual of the Ukrainian farmer], *1*. 28–31. [in Ukrainian].
7. Saiko, V. F., Lobas, M. H., Yashovskyi, I. V. (Ed). et al. (1994). *Naukovi osnovy vedennia zernovoho hospodarstva* [Scientific foundations of grain management]. Kyiv: Urozhai. [in Ukrainian].
8. Nesterets, V. H., Pykhtin, M. I., Solodushko, M. M. et al. (2006). Agrometeorological conditions for growing winter wheat in the north-eastern part of the Steppe during 2001–2005. *Biuleten Instytutu zernovoho hospodarstva UAAN* [Bulletin of the Institute of grain farming of the UAAN], *28–29*. 124–132. [in Ukrainian].
9. Shaharooma, B., Naveed, M., Arshad, M. & Zahir, Z. A. (2008). Fertilizer-dependent efficiency of *Pseudomonads* for improving growth, yield, and nutrient use efficiency of wheat (*Triticum aestivum* L.). *Appl. Microbiol. Biotechnol., 79.* 147–155. doi: 10.1007/s00253-008-1419-0.
10. Tokmakova, L. M. & Trepach, A. O. (2022). Microbiological destruction of organic matter in agrocenoses. *Visnyk ahrarnoi nauky* [Bulletin of Agricultural Science], *2*. 19–26. doi: 10.31073/agrovisnyk202202-03. [in Ukrainian].
11. Kovalenko, A. M., Novokhyzhnii, M. V., Tymoshenko H. Z. & Serhieieva, Yu. O. (2020). Peculiarities of the use of stubble destructors in the conditions of the steppe zone. *Visnyk ahrarnoi nauky* [Bulletin of Agricultural Science], *2*. 44–51. doi: 10.31073/agrovisnyk

202002-07. [in Ukrainian].
12. Baliuk, S. A., Nosko, B. S. & Vorotyntseva, L. I. (2018). Regulation of soil fertility and fertilizer efficiency in climate change. *Visnyk ahrarnoi nauky* [Bulletin of Agricultural Science], *4.* 5–12. doi: 10.31073/agrovisnyk201804-01 [in Ukrainian].
13. Dubytska, A. O., Kachmar, O. Y., Dubytskyi, O. L. & Vavrynovych, O. V. (2019). Influence of ecologically safe fertilization systems of winter wheat on the biological activity of the soil under conditions of climate change. *Zernovi kultury* [Grain Crops], *3 (2),* 331–336. doi: 10.31867/2523-4544/0093 [in Ukrainian].
14. Berdnikov, O. M., Volkohon, V. V., Potapenko, L. V., & Kozar, S. F. (2020). Agrochemical evaluation of the effectiveness of biological products in specialized crop rotation. *Silskohospodarska mikrobiolohiia* [Agricultural microbiology], *31.* 44–50. doi: 10.35868/1997-3004.31.44-50 [in Ukrainian].
15. Lykhochvor, V. V. (2004). *Biolohichne roslynnytstvo* [Biological crop production]. Lviv: NVF Ukrainski tekhnolohii. [in Ukrainian].
16. Drozd, M. O.(2015). Effectiveness of elements of spring wheat cultivation technology in the Northern Forest Steppe. *Zbirnyk naukovykh prats NNTs IZ UAAN* [Collection of scientific works of the National Science Center Institute of Agriculture UAAN], *4.* 53–57. [in Ukrainian].
17. Volkohon, V. V., Zaryshniak, A. S., Hrynyk, I. V., Berdnikov, O. N., Tsentylo, L. V., Nadkernychna, O. V. Murach, O. M. (2011). *Metodolohiia i praktyka vykorystannia mikrobnykh preparativ u tekhnolohiiakh vyroshchuvannia silskohospodarskykh kultur* [Methodology and practice of using microbial preparations in technologies of growing crops]. Volkohon V. V. (Ed.). Kyiv: Ahrarna nauka. [in Ukrainian].
18. Tsykova, V. S. & Pykush, H. R. (Ed.). (1983). *Metodicheskiye rekomendacii po provedeniyu polevyh opytov s zernovymi, zernobobovymi i kormovymi kulturami (issledovaniya, uchety i nablyudeniya).* [Methodological recommendations for conducting field experiments with grain, leguminous and fodder crops (research, records and observations)]. Dnepropetrovsk: VNIIK. [In Russian].
19. Dospekhov, B. A. (1985). *Metodika polevogo opyta: s osnovami statisticheskoy obrabotki rezultatov issledovaniy.* [Field experiment methodology: with the basics of statistical processing of research results]. (5^{ht}, enl. rev.). Moskva: Kolos. [In Russian].

УДК: 633.11

Квасніцька Л. С., Войтова Г. П. Формування врожаю пшениці озимої залежно від елементів технології вирощування в умовах Правобережного Лісостепу. *Зернові культури. 2023. 7 (1). 86–91.*

Хмельницька державна сільськогосподарська дослідна станція Інституту кормів та сільського господарства Поділля НААН, с. Самчики, Хмельницький р-н, Хмельницька обл., 31182, Україна

Актуальність. В екологізованих системах землеробства підвищенню урожайності та поліпшенню показників якості зерна пшениці озимої сприяє застосування біопрепаратів. Серед них – деструктори рослинних решток, які пришвидшують повернення поживних речовин з побічної продукції у ґрунт та біологічні препарати поліфункціональної дії з проявом удобрювальних, рістрегулюючих і захисних властивостей. **Мета.** Визначення впливу застосування біодеструктора рослинних решток та біопрепарату поліфункціональної дії за різних фонів удобрення на формування показників індивідуальної продуктивності рослин, урожайності та якості зерна пшениці озимої в умовах Правобережного Лісостепу. **Методи**. Польовий метод – для вивчення взаємодії досліджуваних факторів на ріст і розвиток рослин та урожайність пшениці озимої; кількісно-ваговий метод – визначення структури врожаю; математично-статистичний – аналіз і встановлення достовірності отриманих результатів. **Результати.** Встановлено, що застосування біодеструктора рослинних решток і біопрепарату поліфункціональної дії мало вплив на формування врожаю пшениці озимої та забезпечило на фоні без добрив збільшення кількості продуктивних стебел на 4–9 %, маси зерна з колоса – на 3–7 %, урожайності – на 8–17 %. За рахунок внесення $N_{90}P_{60}K_{60}$ на мінеральному фоні відбулося зростання кількості продуктивних стебел – на 10 %, маси зерна колоса – на 14 %, урожайності – на 31 % порівняно з фоном без застосування добрив. Використання біопрепаратів на даному фоні забезпечило додатковий приріст урожайності в межах 9–15 %, що супроводжувалось збільшенням кількості продуктивних стебел та маси зерна з колоса на 3–6 % і 5–8 % відповідно. Найвищу врожайність пшениці озимої забезпечило поєднання біодеструктора рослинних решток Органік-баланс з обробкою насіння і посівів біопрепаратом поліфункціональної дії Органік-баланс на фоні без добрив – 5,27 т/га та мінеральному фоні – 6,79 т/га – як наслідок щільного продуктивного стеблостою рослин і найбільшої маси зерна колосу. **Висновки.** В умовах Правобережного Лісостепу на фоні без добрив та мінеральному фоні з $N_{90}P_{60}K_{60}$ максимальну урожайність зерна пшениці озимої, за вирощування після соняшнику, отримано від поєднання технологічних елементів, що включали застосування біодеструктора рослинних решток та біопрепарату поліфункціональної дії для обробки насіння і посівів. Зазначені екологічнобезпечні елементи можуть бути використані для вдосконалення технології вирощування пшениці озимої.

Ключові слова: *пшениця озима, фон удобрення, біодеструктор рослинних решток, біопрепа-*

рат поліфункціональної дії, урожайність, якість зерна