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OPTIMIZATION OF WINTER WHEAT NUTRITION WITH ZERO TILLAGE TECHNOLOGY IN THE RAINFED ZONES OF SOUTHERN KAZAKHSTAN

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SUMMARY

The promising research showcased the results of herbicides' uses, considering the quantitative composition of weeds with zero tillage technology of winter wheat cultivation. It revealed that when treating wheat seeds with the growth stimulator Vimpel (0.5 l/t) and micro-fertilization with Oracle (1.0 l/t) simultaneously etching with the fungicide Bunker (0.4 l/t), as well as, early spring treatment of crops in the tillering phase of winter wheat with the same stimulator (Vimpel, 0.5 l/ha) and micro-fertilization (Oracle multicomplex, 2.0 l/ha) simultaneous with the herbicide "Ballerina" (0.5 l/ha) application, the number of preserved plants before harvesting was 286.1 pcs./m^2, reaching a height of 88.9 cm, with a productive bushiness of 1.15 pcs., grains per spike (22.2), 1000-grain weight (34.8 g), and collected dry grains at a standard humidity (22.1 c/ha). It was also evident that the competitive productivity of winter wheat also emerged when treating wheat seeds with biological fertilizer Biobars–M (1.0 l/t), the crop at the tillering stage with Biobars–M (0.5 l/ha), and the earring phase (0.7 l/ha). Similarly, using growth stimulants Vimpel and micronutrient Oracle multicomplex enhanced the grain yield with reduced cost of production (USD 61.3–66.0/kg) compared with the control version (USD 78.6 /kg). On one hectare of winter wheat crop, the net income ranged from USD 289.55 to 443.56.

Keywords: Winter wheat (*Triticum aestivum* L.), zero technology, growth stimulator, biofertilizers, herbicides, productive moisture, economic efficiency, grain yield, net income

Key findings: In winter wheat, using growth regulators, micro- and biofertilizers significantly enhanced the yield variables and, eventually, the grain yield. In particular, applying growth stimulators combined with micro-fertilization increased grain yields by 2.0–2.1 times, giving winter wheat grain harvest of 1.4–2.2 t/ha, respectively.

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INTRODUCTION

In rainfed agriculture, soil moisture scarcity is one of the foremost constraints in crop production, which badly affects crop growth and development and, ultimately, the grain yield. Therefore, it becomes apparent that under such circumstances, improving the crop sector is achievable primarily through utilizing moisture, soil, energy, resources, and various nature-saving technologies. It is a conservation agriculture system that currently plays a crucial role in the survival of the farming community engaged with crop production in agriculture (Gusev *et al*., 2022; Utebayev *et al.,* 2022; Bugubaeva *et al*., 2023). The resource conservation agriculture technologies also include minimal and zero tillage (Kenenbayev and Bastaubayeva, 2016).

In Southern Kazakhstan, studying resource-saving technologies used in winter wheat cultivation with direct sowing ensued, with the experiments conducted since 2006 (Sydykov and Sydyk, 2015; Sydykov *et al.,* 2017). In these long-term studies in winter wheat, the highest grain yield occurred at the Bogar (4.3 t/ha), formed through direct sowing with the seeder SZS-2.1 with the background of mineral fertilizers (P30 N50 kg/ha) and systemic herbicide Target (1.0 l/ha). Over the years of research, the direct sowing of winter wheat reduced direct costs (36.5%–38.6%), fuel (28%–44%), and other costs (24.3%–26.3%), with an increase in net income (16.7%–31.5%).

Growth stimulants are effective organic compounds that enhance the grain yield of crops and improve their quality. Growth stimulants improve the regulatory mechanisms of growth after influencing the endocrine system. However, the precise manner in which hormones interact to control growth is yet to be fully understood. Developing new growth regulators requires their comparative study for their rational use in a publicly available setting since it is an economically profitable and environmentally friendly agricultural approach (Danilov, 2017). Using biological products formulated the varietal response of the winter wheat. Pre–sowing seed treatment with the Growth Matrix preparation increased the grain yield of winter wheat "Scepter 2" (0.65 t/ha), and processing one ton of seeds with 0.3 liters of the preparation gave an additional 3.25 tons of grains (Chernenkaya, 2021).

The winter wheat contamination decreased by 85% to 90% when using herbicides concerning control. Past studies revealed that herbicide application recorded the highest winter wheat grain yield (4.1 t/ha), 0.7 t/ha higher than the yield obtained in the control variant (Kotelnikova *et al*., 2021). A significant increase in crop yield also appeared with the vitoplane variant, compared with the control (by 0.3 t/ha) and azotovite and phosphatovite (0.4 t/ha) (Rezanova, 2013; Rezanova and Ivanchenko, 2021). The maximum values of the photosynthetic potential of the spring wheat were notable when engaging bacterial preparations of azotovite and phosphatovite (2.39 million m^2 day/ha) and their combinations with aquamix (2.54 million m^2 day/ha) (Stepanova *et al*., 2013).

Direct sowing, with herbicide applications, documented the effective release of alkaloids due to the decomposition of crop residues, which negatively affect the vital activity of weed vegetation. It resulted in a tendency toward decreasing the number of weeds in the variants using the direct seeding system, and the longer the period of its use, the more decrease occurred (Pleskachev and Sukhova, 2013). By moving at high speed, wavy discs that loosen relatively narrow strips of soil into which seeds are laid also preserve moisture more effectively and significantly affect the dynamics of seedlings and grain yield of spring barley (Syromyatnikov, 2021).

In direct-seeded wheat fields, the weed species were almost two times higher due to the broad presentation of biennial and wintering plants, as well as, strengthening the role of root-sprouting perennial plants (Vlasenko *et al*., 2014a, b). Therefore, it is impossible to solve the weeds' problem, primarily by developing no-till, without chemical weed control (Alekhin, 2014). In Russian regions (Central Non–Chernozem region and Western Siberia), direct seeding has proven to be an economically and environmentally beneficial technology in resource-saving agriculture (Vlasenko and Vlasenko, 2016; Nikitin *et al*., 2017; Zhelezova *et al*., 2017; Grebennikov *et al*., 2018). Profitable zero tillage crops are becoming popular and actively implemented in the CIS countries, i.e., in Ukraine (from 250,000 to 1 million ha) and Kazakhstan, up to 3 million ha (Derpsch *et al*., 2010). By cultivating crops with zero tillage, soil moisture preservation transpires due to the mulching layer of crop residues, along with an increase in suppressiveness and a decrease in soil erosion (Kumar *et al*., 2018).

Winter wheat, with one ton of prime products, absorbs about 35 kg of nitrogen, 10 kg of phosphorus, and 20 kg of potassium; therefore, nitrogen fertilizers are vital in plant growth and development and a leading factor in increasing the wheat grain yield by 30% to 60% (Yesaulko *et al*., 2020). By implementing zero technology, special attention is necessary to the soil's nitrogen content since winter wheat plants are ineffective in absorbing nitrogen fertilizers applied superficially (Menkina, 2019). The effectiveness of nitrogen fertilizers with zero technology depends on several factors, including soil and climatic conditions, cultivation technologies, the choice of fertilizer type, dose, time, application methods, and the biological characteristics of cultivated varieties (Shapovalova *et al*., 2019). In global agriculture, no-till technology became increasingly widespread by seeding with special seed drills in untreated soil with previous plants' residues on its surface (Sokolov *et al*., 2019; Arifa and Oleh, 2018). Recent years have seen zero technology's worldwide use in an area of more than 150 million ha (Kotoboitseva and Orlova, 2019).

An arid zone is the chief limiting factor in obtaining the optimum crop yield. Therefore, its accumulation, preservation, and economical use require thorough attention. By using zero tillage technology, the previous crops' residues located on the soil surface play an essential role (Perederieva *et al*., 2018; Gusev and Dzhogan, 2019), which contributed to higher accumulation of moisture in the soil (Dridiger *et al*., 2018) and accordingly, better provision of it to cultivated crops. In this regard, the research aimed to optimize the nutrition conditions of winter wheat with zero cultivation technology on the rainfed lands of South Kazakhstan, ensuring its consistently high yields and preserving and reproducing soil fertility.

MATERIALS AND METHODS

The experiment transpired at the rainfed zone of the Southwestern Research Institute of Animal Husbandry and Crop Production (SRIAHCP), Shymkent, Kazakhstan. The soil cover of the stationary site has a southern ordinary black soil, and based on the composition, the soil belonged to medium loess consisting mainly of coarse, powdered, and clay fractions.

The initial content of the effective fertility elements were characteristics of the following: When cultivating winter wheat after safflower in the arable horizon (0–7.5 cm), the observed components were humus (2.13%), mobile form of nitrate nitrogen (5.5 mg/kg), phosphorus (14.7 mg/kg), potassium (347 mg/kg), and pH (8.61). With a depth of 15.0–22.5 cm, the above indicators were significantly lower, amounting to 2.04%, 4.7 mg/kg, 7.7 mg/kg, 268 mg/kg, and 8.76, respectively.

Winter wheat cultivar 'Steklovidnaya 24,' plant growth stimulator 'Vimpel,' micronutrient 'Oracle' seeds, an 'Oracle' multicomplex, and biofertilizers 'Biobars M' were basic materials used in the presented study. Biofertilizer Biobars M with trace elements is complex-mixed – created based on macro- and microelements, contains seven macro- (nitrogen, phosphorus, potassium, calcium, magnesium, iron, and sulfur) and nine trace elements (copper, zinc, molybdenum, manganese, boron, cobalt, iodine, silicon, and chlorine).

Field experiments using growth stimulators of micro-fertilizers and fertilizers with zero tillage technology of winter wheat cultivation on the rainfed lands of South Kazakhstan began on November 1, 2021, on a stationary plot with an area of two hectares. In autumn, before sowing, the seeds of winter wheat cultivar 'Steklovidnaya 24' attained soaking with a Hopper protectant (0.4 l/t) and simultaneous seed treatment with growth stimulator (Vimpel [0.5 l/t] + micronutrients Oracle seeds [1.0 l/ha]) as per the experiments' scheme.

RESULTS AND DISCUSSION

In 2022, March month markedly had abundant rainfall (231.2 mm), 2.9 times more than the long-term average. The soil analysis, based on productive moisture indicators, revealed that, in soil, the plentiful moisture reserves at the beginning of March (03/08/2022) at a depth of 0–100 cm was 206 mm, at the end of March 18, at 227.0 mm, and at the end of the month (03/28/2022) at 225 mm. (Figure 1, Table 1). The excellent moisture reserves during the spring contributed much to the intensive development of winter wheat in fertilized versions of the experiment and the rapid growth of weeds in quantitative terms per unit area. Therefore, after nine days in April (04/09/2022), winter wheat crops received the herbicide Ballerina (0.5 l/ha) treatment. By analyzing the species composition and number of weeds on the seventh day of herbicidal treatment, most annual and perennial dicotyledonous weeds twisted and had an unhealthy appearance, suspended growth and development. Aiming to eradicate wild barley, oatmeal, and other weeds, winter wheat crops' simultaneous treatment with the herbicide Eraser Top (0.4 l/ha) ensued (04/09/2022). The biological effectiveness of these herbicides was very high (85.1%–90.7%).

With heavy rains in March and sufficient temperature, massive weeds were visible, contributing to the high contamination of winter wheat crops with annual and perennial dicotyledonous and cereal weeds. In this regard, timely treatment of crops against weeds is highly imperative for improving crop growth and development, further determining crop height. In Southern Kazakhstan, more than 30 weed species occur in winter grain crops. Moreover, in recent years, the agricultural sector's reform of the economy with the formation of various small and medium-sized economic entities led to the significant deterioration of the grain crops' phytosanitary conditions due to violations of previously recommended farming systems.

With zero tillage technology of winter wheat cultivation, the chemical weed control applications used different herbicides. The biological effectiveness of the herbicide 'Ballerina' (0.5 l/ha) was evident, which reached 90.0% to 92.3% against annual dicotyledons, up to 82.5% against the perennial root (creeping mustard), and 93.1% against other weeds. Against annual narrow leaf weeds, winter wheat crops' treatment with the herbicide 'Lastik Top' (0.4–0.5 l/ha) in the early weeds stage (2-3 leaf stage) proceeded. Results further revealed that at both consumption rates, this herbicide showed the best biological efficiency, at the consumption rate of 0.4 l/ha, and their efficiency was 85.0%–90.0%. At 0.5 l/ha, it reached the highest values, ranging from 90.0% to 92.5%, depending on the biological characteristics of the cereal weeds. Notably, the use of said herbicides was in the tank mixture with simultaneous treatment of crops with growth stimulants 'Vimpel,' micronutrients 'Oracle' multicomplex, and biofertilizers 'Biobars-M' according to the experiment scheme (Figure 2). Consequently, with the zero tillage technology in winter wheat cultivation, the herbicide selection depended on the weed species and quantitative composition of weeds, playing a decisive role in timely combating them.

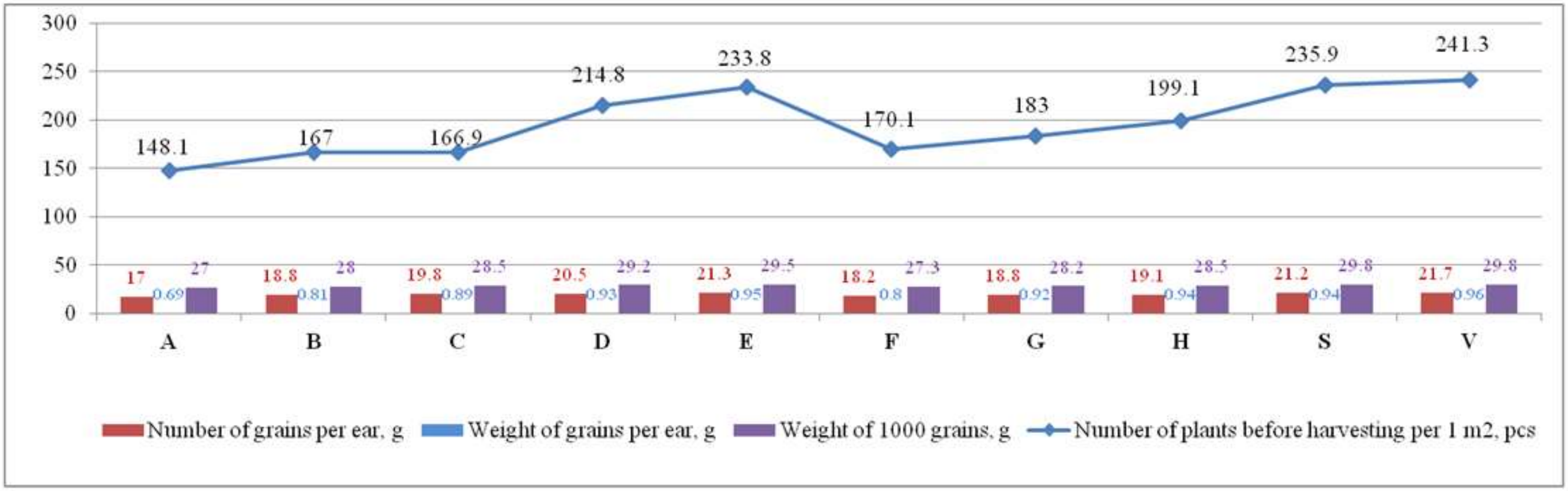

Figure 1. Productivity of winter wheat with zero cultivation technologies depending on the use of growth stimulants, micro-fertilizers, biofertilizers, and calculated norms of mineral fertilizers 2021.

Options of experiments	
A – Control	F - Seed treatment with bio-fertilizers "Biobars-M" - 1.0 l/t
B- Seed treatment with a growth stimulator "Vimpel" 0.5 l/t	G - Processing of crops in the phase of sowing "Biobars-M" 0.5 l/ha
C - Seed treatment with growth stimulators "Vimpel" - 0.5 l/t and micro-fertilizer "Oracle" seeds - 1.0 l/t	H - Processing of crops during the flowering period "Biobars-M" 0.5 l/ha and in the earring phase 0.7 l/ha
D- Processing of crops in the phase of winter wheat sowing with preparations "Vimpel" - 0.5 l/ha and "Oracle" multicomplex - 2.0 l/ha	S– Application of mineral fertilizers $P_{45}N_{70}$
E - Processing of crops in the tillering and flag-leaf phase of winter wheat with preparations "Vimpel" - 0.5 l/ha and "Oracle" multicomplex - 1.0 l/ha	V - The estimated rate of mineral fertilizers for the planned grain harvest

Note: Seed treatment with growth stimulants, micro-fertilizers, biofertilizers proceeded before sowing together with grain protectants Bunker (fungicide), during tillering together in a tank mixture with herbicides Ballerina-0.5 l/ha and Eraser Top 0.4 l/ha.

Table 1. Results of studying the reserves of productive soil moisture on winter wheat crops in Bogara conditions for March–June, 2021–2022.

Terms of sampling	Moisture reserves (mm)						Average depth (cm)	
	2021	2022	2021	2022	2021	2022	2021	2022
	0-10	0-10	0-20	0-20	0-50	0-50	0-100	0-100
08.03.	-	24	-	47	-	111	-	206
18.03.	25	26	48	49	105	117	162	227
28.03.	22	24	45	47	102	114	196	225
08.04.	18	20	38	41	92	98	184	198
18.04.	9	2.5	20	7	61	43	141	148
28.04.	5	2.8	12	7	44	37	121	141
08.05.	7	5.4	16	10.5	46	51	116	150
18.05.	4	8.5	12	16.6	40	55	101	148
28.05.	1	5.5	6	11.6	32	48	100	142
08.06	3	0	8	0	28	23	83	160
18.06	1	0	3	0	19	34	68	161
28.06	1	1	2	2	11	33	49	155

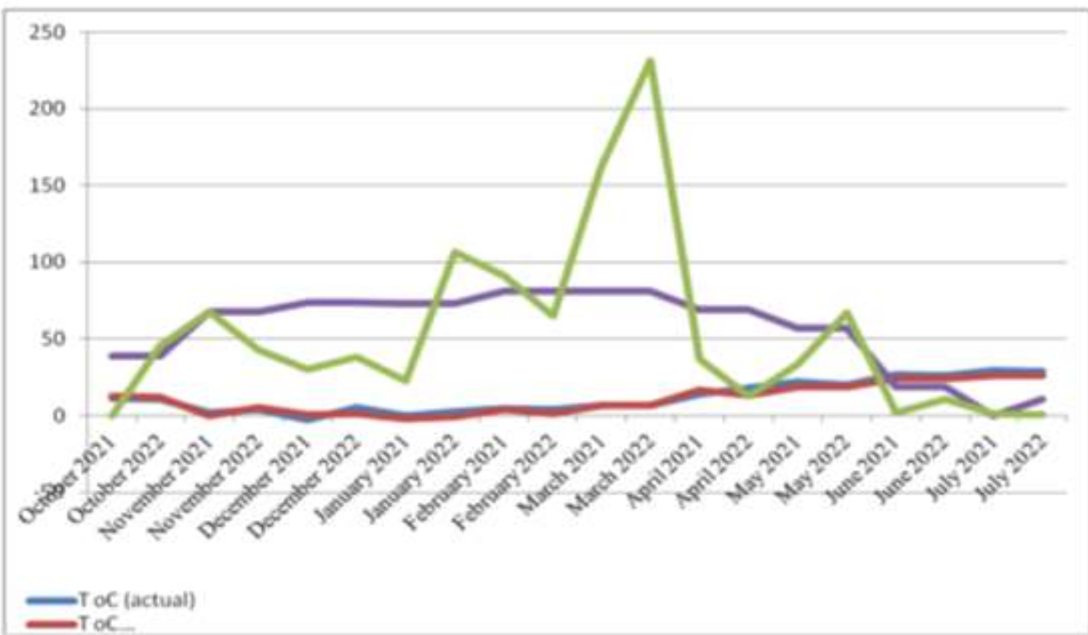

Figure 2. Average monthly air temperature and precipitation according to the branch of RSE "Kazhydromet" in Turkestan region for 2021–2022.

Treating winter wheat seeds with growth stimulator Vimpel (0.5 l/t) and micro-fertilization Oracle seeds (1.0 l/t) was with simultaneous etching with a fungicide Bunker (0.4 l/t), as well as, winter wheat crops' treatment in the tillering phase with stimulator Vimpel (0.5 l/ha) and micro-fertilization Oracle multicomplex (2.0 l/ha) with simultaneous introduction of the herbicide Ballerina (0.5 l/ha). The second treatment with the mentioned growth stimulant and micro-fertilization during the flag leaf appearance in winter wheat in the corresponding average, the number of preserved plants before harvesting (286.1 pcs/m^2) gained the plant height (88.9 cm), with productive bushiness (1.15 pcs), grains per spike (22.2 pcs), 1000-grain weight (34.8 g), and the grain yield (2.2 t/ha).

Reasonably superior parameters of production developed during the processing of seeds with biofertilizer Biobars–M (1.0 l/t), crops in the tillering phase with Biobars–M (0.5 l/ha), and the earring phase (0.7 l/ha). In this variant of the experiment, the number of preserved plants before harvesting was 279.1 pcs/m^2, with the plant height (92.7 cm), productive bushiness (1.11 pcs), grains per spike (21.9 pcs), 1000-grain weight (33.0 g), and the grain yield (2.0 t/ha).

The best productive variables of grain yield were visible after applying the recommended averages of mineral fertilizers ($P_{45}N_{70}$ kg/ha) and on the variant with calculated norms of mineral fertilizers. After introducing the previously recommended norms of $P_{45}N_{70}$ kg/ha, the number of preserved plants per unit area was 288.6 pcs/m^2, with plant height (97.4 cm), productive bushiness (1.15 pcs), grains per spike (28.0 pcs), 1000- grain weight (35.0 g), and grain yield (2.8 t/ha). By applying the calculated fertilizer rates for obtaining 3.0 t/ha of grain, the above indicators of winter wheat productivity amounted to 290.4 pcs/m^2, 98.2 cm, 1.17 pcs, 28.1 pcs., 35.1 g, and 2.8 t/ha, respectively (Figure 1, Table 2).

Results revealed that the studied growth stimulator, micro-fertilizers, and biofertilizers significantly enhanced the production indicators and the winter wheat's grain yield. The growth stimulator, with micro-fertilization in the principal growth phases during 2022, contributed to a two-fold increase in winter wheat grain harvest (2.2 t/ha). Using Biobars-M biofertilizer, the grain yield was slightly lower than 2.0 t/ha and 1.9 times higher than the control variant (non-maneuverable), depending on the prevailing environmental conditions (Figure 3).

For the average 2022, the winter wheat yield of 1.7 t/ha received pre-sowing seed treatment of bio-fertilization Biobars-M (1.0 l/t) in a tank mixture with a protectant Bunker (0.4 l/t) and spraying of winter wheat crops in early spring periods in the tillering phase at a rate of 0.5 l/ha was with the herbicide Ballerina (0.5 l/ha). In the stage of the beginning of earring, winter wheat crops' treatment with biofertilizer Biobars-M (0.7 l/ha) continued. With appropriate care and Biobars-M biofertilizer use, the winter wheat's grain yield increased by 0.6 t/ha compared with the control treatment.

By applying the previously recommended norms of mineral fertilizers ($P_{45}N_{70}$ kg/ha) with zero tillage technology of winter wheat cultivation, applying phosphorus fertilizers P_{45} kg/ha simultaneously with sowing with a Brazilian FANKHAUSER 2115 seeder to a depth of 10 cm, and nitrogen fertilizers N_{70} kg/ha in early spring periods in the tillering phase with a fertilizer spreader NRU-0.3, followed by harrowing of winter grain crops. With appropriate care, the winter wheat grain yield was 2.8 t/ha, exceeding the disapproved version of the experiment by 1.7 t/ha (Figure 3).

By applying the calculated norms of mineral fertilizers for the planned grain harvest of 3.0 t/ha, the actual grain yield of winter wheat amounted to 2.8 t/ha. In this variant, the calculated norms of phosphorus fertilizers' application when sowing winter wheat used a Brazilian FANKHAUSER 2115 seeder to a depth of 10 cm, and early spring fertilizing with nitrogen fertilizers in the tillering phase of winter wheat with a mounted fertilizer spreader. Markedly, in winter wheat tubulation and formation of the reproductive organs of the grain, the rainfall was significantly less than usual, and drought was evident during the grain formation and maturation periods. The precipitation of 67.4 mm surfaced since the beginning of May (the average monthly air temperature was 21.7 °C, with a norm of 19.6 °C) with a decrease in relative humidity to 19% and 16%, respectively. In this regard, the grains' formation was more or less even, and as a result of grains per spike and 1000-grain weight, the grain yield was entirely satisfactory. With the improvement of the nutritional conditions of the plants using the growth stimulator Vimpel, micronutrient Oracle, and biofertilizer Biobars-M, the winter wheat grain yield showed a significant increase compared with the control variant (Figure 3).

Table 2. The effectiveness of using growth stimulants, micronutrients, biofertilizers, and mineral fertilizers with zero technology cultivation of winter wheat on the rainfed lands of Southern Kazakhstan (2021–2022).

Options	Winter wheat grain yield (t ha^{-1})		Costs ha^{-1} (USD)		Realizable value of winter wheat grain (USD/t)		Cost of received products (USD)		Net income ha^{-1} (USD)		Cost of winter wheat grain (USD/t)	
	2021г.	2022г.	2021г.	2022г.	2021г.	2022г.	2021г.	2022г.	2021г.	2022г.	2021г.	2022г.
1	0.68	1.08	70.00	84.89	300	266.6	204.0	288.0	134.0	203.1	102.9	78.6
2	0.87	1.41	75.56	86.44	300	266.6	261.1	376.0	185.5	289.5	86.8	61.3
3	0.94	1.58	84.44	93.56	300	266.6	282.0	463.3	197.5	369.7	89.8	59.2
4	1.28	1.88	131.11	118	300	266.6	384.0	501.3	252.8	383.3	102.4	62.7
5	1.46	2.21	141.11	145.78	300	266.6	438.0	389.3	296.8	443.5	96.65	65.9
6	0.84	1.46	87.78	88.89	300	266.6	252.0	389.3	164.2	300.4	104.5	60.8
7	0.97	1.69	106.89	95.56	300	266.6	290.8	450.0	184.0	355.1	110.19	56.54
8	1.08	2.02	120.22	104.44	300	266.6	324.0	538.6	203.7	434.2	111.31	51.7
9	1.5	2.83	171.11	333.11	300	266.6	449.5	754.6	278.4	421.5	114.07	117.7
10	1.56	2.86	163.56	307.78	300	266.6	468.0	762.6	304.4	454.8	104.8	107.6

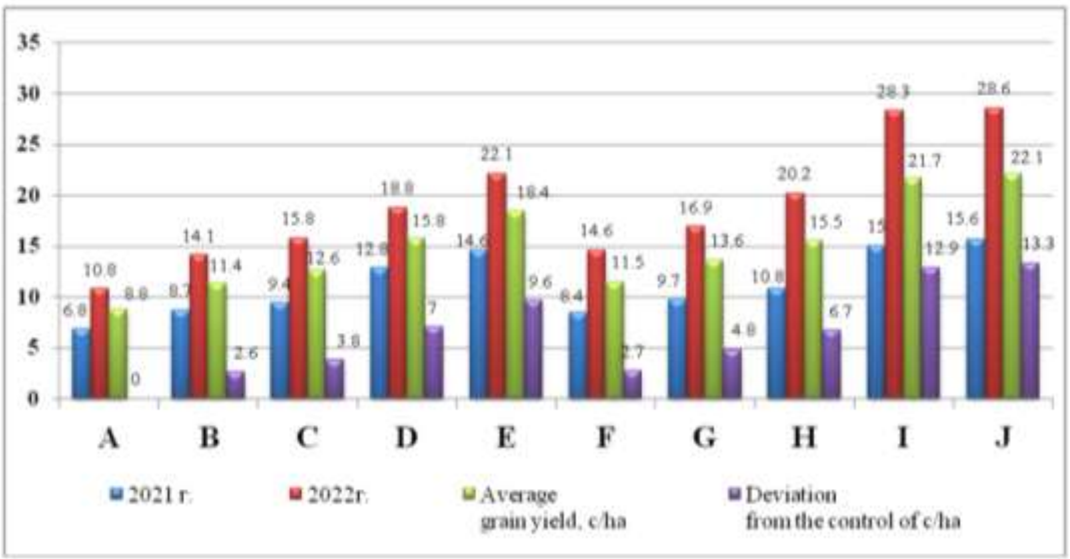

Figure 3. Winter wheat grain yield with "zero" cultivation technologies depending on the use of fertilizers (2021–2022).

The smallest significant difference $_{095}$ - 1.21c/ha in 2021

The smallest significant difference $_{095}$ – 2.42 c/ha in 2022

Options of experiment	
A – Control	F - Seed treatment with bio-fertilizers "Biobars-M" - 1.0 l/t
B- Seed treatment with a growth stimulator "Vimpel" 0.5 l/t	G - Processing of crops in the phase of sowing "Biobars-M" 0.5 l/ha
C - Seed treatment with growth stimulators "Vimpel" - 0.5 l/t and micro-fertilizer "Oracle" seeds - 1.0 l/t	H - Processing of crops during the flowering period "Biobars-M" 0.5 l/ha and in the earring phase 0.7 l/ha
D- Processing of crops in the phase of winter wheat sowing with preparations "Vimpel" - 0.5 l/ha and "Oracle" multicomplex - 2.0 l/ha	I – Application of mineral fertilizers $P_{45}N_{70}$
E - Processing of crops in the tillering and flag-leaf phase of winter wheat with preparations "Vimpel" - 0.5 l/ha and "Oracle" multicomplex - 1.0 l/ha	J - The estimated rate of mineral fertilizers for the planned grain harvest $P_{20}N_{60}$

Economic estimations of 2022 showed that using growth stimulators Vimpel and micro-fertilizers Oracle, depending on the norms and multiplicity of processing of winter wheat crops during the growing season, the direct cost increased from USD 86.4 to USD 145.7/ha. By processing seeds with biofertilizer Biobars-M and depending on the norms and multiplicity of processing of winter wheat crops in the core phases of growth and development with these combinations, the direct cost of sowing amounted to USD 88.89–104/ha. However, the second option was slightly higher compared with the treatment of crops with growth stimulants and micro-fertilizers. It was also noticeable that the maximum amount of direct cost of USD 333.11 /ha was on the variant of the experiment by applying the recommended norms of mineral fertilizers $P_{45}N_{70}$ kg/ha based on the high market value and the additional costs of transporting mineral fertilizers and their application during the growing season of plants.

With the application of growth stimulants Vimpel and micronutrients Oracle multi-complex, the net income from one hectare of winter wheat sowing increased, ranging from USD 289.55 to USD 443.55 /ha. Increasing the number of treatments during the growing season in the chief growth phases, the development of winter wheat plants contributed to an increase in grain yield and the net income with a reduction in the cost of grain (USD 61.3–66.0 /kg) compared with the control version of the experiment (USD 78.6 /kg). One must note that the cost of winter wheat seeds was significantly lower compared to 2021 due to a higher grain yield in 2022.

By using bio-fertilizers Biobars M, the net income was at the level of USD 300.44–434.22 /ha, which was significantly higher compared with the control variant by 1.4–2.1 times; however, slightly lower compared with the best variant (with the growth stimulator and micro-fertilizers used). Somewhat high values of net income of USD 421.56 /ha by applying the recommended norms of mineral fertilizers ($P_{45}N_{70}$ kg/ha); although, in this variant, the cost of winter wheat grain increased to USD 117.7 /kg, exceeding the control variant, based on a market rate of mineral fertilizers with their transportation and application expenditures. Consequently, using stimulants, micro-fertilizers, and biofertilizers compared with mineral fertilizers proved to be an economically beneficial agrotechnical method, highly recommended for application in crop production.

CONCLUSIONS

Herbicides Ballerina and Lastik Top showed better weed control and higher efficiencies. Using growth stimulator Vimpel and micro-fertilization Oracle, with a fungicide Bunker during early spring, and using the same compounds during the flag leaf appearance of winter wheat contributed to the formation of winter wheat grain yield of 2.2 t/ha. Utilizing Biobars-M biofertilizer, the grain yield value was 2.0 t/ha. Applying the previously recommended norms of mineral fertilizers ($P_{45}N_{70}$ kg/ha) with zero tillage, the wheat grain yield was 2.8 t/ha. With growth stimulator Vimpel and micronutrients Oracle, an increased net income ranged from USD 289.56 to USD 443.56 /ha.

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