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The Impact of Soil Tillage Methods, Fertilizers of Various Origins and Bentonite on the Yield and Quality of Winter Wheat

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ABSTRACT

The article presents the results of a three-year study on the effects of different soil cultivation methods, equivalent doses of mineral fertilizers and biohumus, and the timing of bentonite application on the yield and quality indicators of winter wheat. Based on field experiments and production trials, it was substantiated that in the conditions of non-irrigated agriculture in Hrazdan region of Kotayk Province, cultivating winter wheat by loosening the soil to a depth of 10-12 cm (instead of conventional plowing to 22-25 cm or zero-tillage) contributes to the regulation of soil aeration, water properties, and nutrient regime. As a result, crop yield increases, and quality indicators improve. At the same time, laboratory studies revealed that the autumn application of bentonite at a rate of 3 tons/ha, on the background of equivalent doses of mineral fertilizers and biohumus, had a more favorable effect on the yield and grain quality of winter wheat grown in non-irrigated conditions compared to spring application of bentonite under the same background conditions.

Introduction

The correct management of the mineral nutrition process for agricultural crops, including cereals, should be aimed at obtaining high and stable yields, improving product quality, as well as ensuring the reproduction of soil fertility and enhancing the ecological state of the environment (Maksyutova, 2017; Chiriţă, et al., 2023).

Numerous studies by both local and foreign scientists have established that mineral and organic fertilizers have a beneficial effect on the yield and quality indicators of cereal crops, particularly intensive varieties of winter wheat. These fertilizers contribute to improved soil fertility by providing essential nutrients, which in turn supports better plant growth, higher productivity, and superior grain quality (Bertic, et al., 2007; Piskaeva, et al., 2017; Litke, et al., 2018; Lachutta & Jankowski, 2024).

Some authors noted that mineral fertilizers can have a more effective impact on winter crops when they create the right balance of nutrients in the soil, which determines the yield (Lazursky & Lebedinskaya, 1969; Alnaass, et al., 2021). D.N. Pryanishnikov's studies revealed that the effect of phosphorus fertilizers is largely dependent on the availability of other nutrients, especially easily hydrolyzed nitrogen, for cereals (Pryanishnikov, 1945).

V.G. Mineev, summarizing the results of scientists from various countries, pointed out that the level of nutrient absorption by winter wheat plants is highly dependent on the degree of availability of other nutrients. For example, in the absence or shortage of nitrogen, phosphorus, although accumulating in the plants, hardly contributes to the formation of organic matter. Potassium and phosphorus significantly promote nitrogen uptake by plants (Mineev, 2004; Mineev, et al., 2006).

According to I.A. Melnik, M.H. Galstyan, the average doses of mineral fertilizers tested on the Bezostaya 1 variety of winter wheat under different soil and climatic conditions resulted in yield increases of 5.5-16.0 c/ha or 20.0-42.0 %, and when combined with foliar feeding with micronutrients, the yield increase was 10.2-32.5 c/ha or 30.0-79.8 %. At the same time, these authors noted a positive correlation between fertilizer efficiency and nutrient availability in the soil: the fewer nutrients in the soil, the higher the fertilizer efficiency (Melnik, 1990; Galstyan, 2007; Galstyan, et al., 2024).

Spiryn and Tagirov highlight the importance of moisture-saving soil treatments and their impact on soil water-physical properties and wheat productivity (Spiryn, 2005; Tagirov, et al., 2015). Their findings emphasize the need for effective soil management practices to enhance water conservation and agricultural yields.

Bentonite plays a vital role in agriculture due to its distinctive properties. As a soil conditioner, it enhances soil structure by increasing its moisture retention capacity, which is particularly beneficial in dry regions and for crops requiring significant water, such as winter wheat (Hassan, 2018; Mi, et al., 2020). The chemical composition of bentonite is as follows: SiO_2 - 58.25 %, Al_2O_3 - 14.37 %, Fe_2O_3 - 4.37 %, FeO - 0.50 %, TiO_2 - 0.36 %, CaO - 2.07 %, MgO - 3.62 %, P_2O_5 - 0.18 %, S - 0.14 %, K_2O - 1.2 0 %, Na_2O - 2.25 %. The clay particles in bentonite aid in binding soil particles, leading to improved aeration. Additionally, bentonite's high cation exchange capacity allows it to retain essential nutrients, making them more readily available to plants. These combined advantages contribute to healthier soil conditions, promoting vigorous crop growth and boosting agricultural productivity (Zhou, et al., 2019; Kozlov, et al., 2023; Yomgirovna, 2023).

Since the privatization of land in Armenia (1991), the intensification of agriculture has been of particular importance in addressing strategic issues in the sector. This can be achieved through the application and adoption of scientific advances, new technologies, and best practices. The high level of agricultural chemicalization during the Soviet era led to the emergence of several negative environmental phenomena (Hayrapetyan & Shirinyan, 2003; Melkonyan, et al., 2004).

The increase in anthropogenic impact on the natural environment raised serious issues in the development and use of alternative agricultural methods. These included increasing the use of organic fertilizers and natural mineral resources, as well as developing and applying new soil cultivation technologies. This concerns the gradual ecological transition in agriculture, where biohumus and the natural mineral bentonite play key roles as valuable soil improvers.

Despite the extensive research conducted by local and foreign scientists to determine the effectiveness of mineral and organic fertilizers in winter wheat fields, comprehensive studies on the effectiveness of equivalent doses of mineral fertilizers and biohumus, combined with the timing of natural mineral meliorant bentonite application in the non-irrigated agricultural zone of Kotayk Province, especially under different soil cultivation methods, have not been conducted. This necessity prompted our studies, which are of great significance and relevance, aligned with the strategic requirements for food security and agricultural development in the Republic of Armenia.

Materials and methods

The studies were conducted from 2021 to 2024 in the conditions of non-irrigated agriculture in the Fantan administrative area of Hrazdan region, Kotayk Province (Gharakhanyan, 2022; Gharakhanyan, 2023; Gharakhanyan & Galstyan, 2023). The field experiments, as well as production trials in 2023-2024, were carried out on typical leached black soils, characteristic of this region. These soils are used primarily for the cultivation of winter cereal crops (mainly winter wheat), with humus content in the plow layer ranging from 4.9 to 5.5 %, a nearly neutral pH (6.9-7.1), and nutrient levels over the years showing 2.94-4.30 mg of easily hydrolyzable nitrogen, 3.41-6.9 mg of mobile phosphorus, and 37.0-37.72 mg of exchangeable potassium per 100 grams of soil.

The research aimed to study the effects of different soil cultivation methods in the non-irrigated conditions of the region, as well as the impact of equivalent doses of mineral fertilizers and biohumus, and the timing of bentonite application on winter wheat yield and grain quality indicators. The goal was to identify and justify through production trials the best soil cultivation method and fertilization technology for practical agricultural use.

The field experiments were conducted with three replications each year, with each fertilization treatment covering an area of 50 m². The production trials, without replications, tested the two best options, each over an area of 1000 m². The field experiments were organized according to the following variants:

1. Control (no fertilization),
2. $N_{60}P_{60}K_{60}$,
3. Biohumus 3.5 t/ha,
4. $N_{60}P_{60}K_{60}$ + Bentonite 3 t/ha (autumn),
5. Biohumus 3.5 t/ha + Bentonite 3 t/ha (autumn),
6. $N_{60}P_{60}K_{60}$ + Bentonite 3 t/ha (spring),
7. Biohumus 3.5 t/ha + Bentonite 3 t/ha (spring).

The specified variants of fertilizers and bentonite were applied under different soil cultivation methods: zero-tillage, soil loosening or disking (10-12 cm), and deep plowing (22-25 cm).

In all variants (except the control), the equivalent doses of mineral fertilizers and biohumus were applied to the soil in the fall, before sowing, by harrowing. The bentonite (3.0 t/ha) in the mineral fertilizer and biohumus variants (4th and 5th) was applied in autumn, while in the 6th and 7th variants, it was applied in spring and incorporated into the soil by harrowing.

The agrochemical indicators of the soils were determined using standard methods presented in the methodological guide on agrochemical analysis edited by B.A. Yagodin (Yagodin, et al., 1989). The quality indicators of winter wheat grain were determined as follows: 1000-grain weight by the gravimetric method, bulk density using a one-liter purka, ash content by dry combustion, crude protein using the Kjeldahl method, and fiber using the Henneberg-Stohmann method.

The yield data were subjected to mathematical analysis, determining the experimental error (Sx, %) and the least significant difference ($LSD_{0.95}$, c/ha) according to Dospekhov (Dospekhov, 1973).

Results and discussions

The results of the three-year field and laboratory studies revealed that both the soil cultivation methods and the equivalent doses of mineral fertilizers and biohumus, along with the timing of bentonite application at the same rate, had a significant impact on the yield and quality indicators of winter wheat.

The yield of winter wheat grain, averaged over three years, was 19.1 c/ha under the zero-tillage method, 19.5 c/ha under conventional plowing, and 23.1 c/ha when the soil was cultivated only by loosening. This represents an increase in yield of 20.9 % compared to zero-tillage and 18.5 % compared to conventional plowing.

This can be explained by the significant changes in the agrochemical and agrophysical properties of the soil, depending on the cultivation method. Organic matter and nutrients available to plants were distributed differently across the plow layer depths. Under conventional plowing, they were mostly concentrated at a depth of 20-30 cm, whereas under loosening and zero-tillage, they were concentrated at 0-10 cm. Regarding the nearly equal yields obtained under conventional plowing and zero-tillage methods, this is attributed not to differences in soil compaction or other agrophysical properties but rather to the level of frost damage to the plants grown under zero-tillage. In the zero-tillage method, the percentage of frost-damaged plants was 4.7 % higher than in conventional plowing. The number of plants per square meter lost due to frost damage was 131 in zero-tillage, 100 in conventional plowing, and 98 in loosening (Gharakhanyan, 2022).

In addition to this explanation, data from our studies on soil water permeability showed that, compared to conventional plowing, zero-tillage and especially loosening improved water permeability in both the plow layer and subsoil in winter wheat fields. The permeability in the plow layer exceeded conventional plowing by 0.42 mm/min or 10.8 %, and in the subsoil by 1.63 mm or 63.4 % (Gharakhanyan, 2024).

These factors undoubtedly contributed to the differences in yield of winter wheat grown using the loosening method compared to conventional plowing and zero-tillage. It is noteworthy that similar patterns were observed in all fertilization technology variants. In the case of zero-tillage, the grain yield of winter wheat either remained equal or increased slightly, with the difference averaging 1.3-5 c/ha over three years. However, with loosening and the appropriate technologies, the yield increase was as much as 10 c/ha (Table 1).

Table 1. The Impact of Different Soil Cultivation Methods, Equivalent Doses of Mineral Fertilizers and Biohumus, and the Timing of Bentonite Application on Winter Wheat Yield*

N	Variants	No-tillage (0 cm)							Only loosening (10-12 cm)							Conventional plowing (22-25 cm)						
		grain yield by year (c/ha)			average grain yield (c/ha)	average straw yield (c/ha)	grain yield increase		grain yield by year (c/ha)			average grain yield (c/ha)	average straw yield (c/ha)	grain yield increase		grain yield by year (c/ha)			average grain yield (c/ha)	average straw yield (c/ha)	grain yield increase	
		2022	2023	2024			c/ha	%	2022	2023	2024			c/ha	%	2022	2023	2024			c/ha	%
1	Control (without fertilization)	20.6	17.8	19.0	19.1	37.0	-	-	23.6	21.2	24.6	23.1	41.1	-	-	20.2	18.6	19.6	19.5	38.0	-	-
2	$N_{60}P_{60}K_{60}$	28.8	25.2	24.8	26.3	54.6	7.2	37.7	33.0	29.0	28.9	30.3	60.1	7.2	31.2	28.2	27.8	27.2	27.7	56.2	8.2	42.1
3	Bio-humus 3.5 t/ha	30.2	26.6	25.7	27.5	56.2	8.4	44.0	32.5	29.1	30.0	30.5	60.8	7.4	32.0	28.6	27.8	28.0	28.1	55.8	8.6	44.1
4	$N_{60}P_{60}K_{60}$ + bentonite 3 t/ha (in Autumn)	40.8	35.6	37.2	37.9	74.9	18.8	98.4	51.3	46.3	47.3	48.3	92.0	25.2	109.1	43.4	43.8	44.0	43.7	81.1	24.2	124.1
5	Bio-humus 3.5 t/ha + bentonite 3t/ha (in Autumn)	44.8	38.8	39.0	40.9	79.5	21.8	114.1	54.9	49.1	50.3	51.4	98.0	28.3	122.5	45.2	44.8	45.5	45.2	84.0	25.7	131.8
6	$N_{60}P_{60}K_{60}$ + bentonite 3t/ha (in Spring)	29.8	26.2	27.0	27.7	56.2	8.6	45.0	38.6	34.2	36.6	36.5	70.4	13.4	58.0	32.2	32.0	33.3	32.5	60.0	13.0	66.7
7	Bio-humus 3.5 t/ha + bentonite 3t/ha (in Spring)	31.9	26.1	25.9	28.0	57.4	8.9	46.6	38.0	35.6	37.4	37.0	69.9	13.9	60.2	31.4	32.4	31.3	31.7	61.2	12.2	62.6

LSD_{05} = 2.42 c

*Composed by the authors.

As the data show, the equivalent doses of biohumus and mineral fertilizers had a similar effect on the increase in grain and straw yield of winter wheat under all three soil cultivation methods. However, when bentonite was applied at a rate of 3.0 t/ha in these conditions, the yield of winter wheat increased compared to the same background without bentonite.

Thus, when bentonite at a rate of 3.0 t/ha was applied in autumn on the background of mineral fertilizers ($N_{60}P_{60}K_{60}$), the yield increase in grain compared to the same background was 11.6 c/ha (44.1 %) under zero-tillage, 16.0 c/ha (58.7 %) under conventional plowing, and 18.0 c/ha (59.4 %) under the loosening method. On the background of biohumus (3.5 t/ha), the autumn application of bentonite at the same rate resulted in additional grain yields of 13.4 c/ha (zero-tillage), 17.1 c/ha (conventional plowing), and 20.9 c/ha (loosening) compared to the respective background.

At the same time, as shown in Table 1, although the spring application of bentonite at the same rate (3.0 t/ha) on the mentioned backgrounds also increased the yield, these increases were almost half of those obtained from autumn applications across all soil cultivation methods. The significant differences in yield increases due to the timing of bentonite application in all soil cultivation methods are undoubtedly related to the duration of bentonite's presence in the soil and its beneficial impact on the soil's agrochemical and agrophysical properties.

In addition to increasing grain yield and improving the structural components of the crop, the impact of the fertilization technology on the quality indicators of food products is of great importance. According to scientific literature, the quality indicators of winter wheat grain vary depending on soil type, irrigation norms, and the level of nutrient availability. Various studies have shown that under the influence of mineral and organic fertilizers, the protein content in grain can range between 10-15 %, starch up to 60 %, ash content up to 2 %, and fiber up to 3.5 %. Fertilizers can also significantly affect both bulk density and the weight of 1000 grains (Agapie & Bostan, 2020; Lachutta & Jankowski, 2024).

Our laboratory studies showed that the different soil cultivation methods (zero-tillage, conventional plowing, and loosening) had no significant impact on the 1000-grain weight, ash content, fiber content, or crude protein content of winter wheat (Tables 2.1, 2.2, 2.3). However, the equivalent doses of mineral fertilizers and biohumus tested under different soil cultivation methods, along with the timing of bentonite application at the same rate, significantly improved the quality indicators of winter wheat grain.

For instance, in the variants without fertilization, the bulk density and 1000-grain weight of winter wheat grown under zero-tillage, loosening, and conventional plowing conditions (averaged over two years) were 783-790 g/L and 33.6-34.6 grams, respectively, while the ash, fiber, and crude protein contents were 1.73-1.80 %, 3.30-3.40 %, and 8.9-9.8 %, respectively. In the variants with mineral fertilizers, biohumus, and bentonite application, the bulk density of winter wheat grain increased by 10-49 g/L, the 1000-grain weight increased by 4.6-15 grams, ash and fiber contents decreased by 0.03-0.18% and 0.3-0.6 %, respectively, and crude protein increased by 0.7-2.1 %.

Table 2.1 The Impact of Zero-Tillage Soil Cultivation, Equivalent Doses of Mineral Fertilizers and Biohumus, and the Timing of Bentonite Application on Several Quality Indicators of Winter Wheat Grain*

№	Options / Variants	2022					2023					two-year average				
		1000-grain weight (g)	bulk density (g/l)	%			1000-grain weight (g)	bulk density (g/l)	%			1000-grain weight (g)	bulk density (g/l)	%		
				ash	fiber	crude protein			ash	fiber	crude protein			ash	fiber	crude protein
1	Control (without fertilization)	34.0	798	1.78	3.15	8.8	33.2	768	1.82	3.35	9.0	33.6	783	1.80	3.25	8.90
2	$N_{60}P_{60}K_{60}$	37.5	806	1.80	2.90	9.0	38.9	794	1.74	2.90	10.2	38.2	800	1.77	2.90	9.60
3	Bio-humus 3.5 t/ha	41.2	812	1.70	2.88	9.2	38.8	792	1.65	2.80	10.6	40.0	802	1.68	2.84	9.90
4	$N_{60}P_{60}K_{60}$ + bentonite 3t/ha (in Autumn)	47.1	825	1.80	2.75	9.4	45.3	802	1.60	2.70	10.8	46.2	814	1.70	2.73	10.10
5	Bio-humus 3.5 t/ha + bentonite 3t/ha (in Autumn)	46.8	829	1.65	2.80	10.0	47.2	815	1.58	2.67	12.0	47.0	822	1.62	2.74	11.00
6	$N_{60}P_{60}K_{60}$ + bentonite 3t/ha (in Spring)	40.8	801	1.78	2.70	9.0	41.2	784	1.70	2.82	11.2	41.0	793	1.74	2.76	10.10
7	Bio-humus 3.5 t/ha + bentonite 3t/ha (in Spring)	43.4	809	1.88	3.00	9.2	40.6	799	1.68	2.80	11.4	42.0	804	1.78	2.90	10.30

*Composed by the authors.

Table 2.2 The Impact of Only Loosening Cultivation Method, Equivalent Doses of Mineral Fertilizers and Biohumus, and the Timing of Bentonite Application on Several Quality Indicators of Winter Wheat Grain*

№	Options / Variants	2022					2023					two-year average				
		1000-grain weight (g)	bulk density (g/l)	%			1000-grain weight (g)	bulk density (g/l)	%			1000-grain weight (g)	bulk density (g/l)	%		
				ash	fiber	crude protein			ash	fiber	crude protein			ash	fiber	crude protein
1	Control (without fertilization)	35.2	795	1.70	3.20	9.60	34.0	785	1.76	3.40	10.0	34.6	790	1.73	3.30	9.80
2	$N_{60}P_{60}K_{60}$	42.0	829	1.65	3.00	10.00	38.4	811	1.68	3.00	10.8	40.2	820	1.67	3.00	10.40
3	Bio-humus 3.5 t/ha	41.9	830	1.60	2.92	10.60	41.3	818	1.64	2.90	11.2	41.6	824	1.62	2.91	10.90
4	$N_{60}P_{60}K_{60}$ + bentonite 3t/ha (in Autumn)	47.3	841	1.60	2.88	11.00	48.3	813	1.62	2.96	11.2	47.8	827	1.61	2.92	11.10
5	Bio-humus 3.5 t/ha + bentonite 3t/ha (in Autumn)	48.7	845	1.56	2.78	11.20	48.5	819	1.62	2.80	11.6	48.6	832	1.59	2.79	11.40
6	$N_{60}P_{60}K_{60}$ + bentonite 3t/ha (in Spring)	40.5	832	1.70	2.90	10.48	42.3	798	1.72	2.88	11.0	41.4	815	1.71	2.89	10.74
7	Bio-humus 3.5 t/ha + bentonite 3t/ha (in Spring)	41.3	833	1.60	2.90	10.76	42.7	796	1.62	2.94	11.2	42.0	815	1.61	2.92	10.98

Table 2.3 The Impact of Conventional plowing Soil Cultivation Method, Equivalent Doses of Mineral Fertilizers and Biohumus, and the Timing of Bentonite Application on Several Quality Indicators of Winter Wheat Grain*

№	Options / Variants	2022					2023					two-year average				
		1000-grain weight (g)	bulk density (g/l)	%			1000-grain weight (g)	bulk density (g/l)	%			1000-grain weight (g)	bulk density (g/l)	%		
				ash	fiber	crude protein			ash	fiber	crude protein			ash	fiber	crude protein
1	Control (without fertilization)	34.2	792	1.70	3.30	10.0	33.8	780	1.80	3.50	9.6	34.0	786	1.75	3.4	9.8
2	$N_{60}P_{60}K_{60}$	39.8	822	1.60	3.00	10.9	38.6	802	1.72	3.20	10.1	39.2	812	1.66	3.1	10.5
3	Bio-humus 3.5 t/ha	40.7	821	1.50	2.96	11.2	40.1	803	1.66	3.00	10.4	40.4	812	1.58	2.98	10.8
4	$N_{60}P_{60}K_{60}$ + bentonite 3t/ha (in Autumn)	46.2	832	1.48	2.90	11.6	45.6	810	1.54	2.86	10.6	45.9	821	1.51	2.88	11.1
5	Bio-humus 3.5 t/ha + bentonite 3t/ha (in Autumn)	46.7	828	1.46	2.84	11.8	46.9	812	1.48	2.86	11.0	46.8	820	1.47	2.85	11.4
6	$N_{60}P_{60}K_{60}$ + bentonite 3t/ha (in Spring)	41.1	805	1.60	2.98	11.0	41.3	791	1.64	2.98	10.4	41.2	798	1.62	2.98	10.7
7	Bio-humus 3.5 t/ha + bentonite 3t/ha (in Spring)	41.0	806	1.58	2.92	11.3	41.8	796	1.60	2.96	10.8	41.4	801	1.59	2.94	11.05

*Composed by the authors.

The patterns of the impact of fertilizers and bentonite have been generally preserved in both the loosening and conventional plowing soil cultivation methods (Tables 2.1 and 2.2).

It is known that the lower the ash and fiber content and the higher the crude protein in wheat grain, the better the quality indicators of the wheat (Khan, et al., 2010). The experimental results indicate that under arid conditions, the optimal doses of mineral fertilizers and equivalent amounts of biohumus, along with the autumn application of bentonite at a rate of 3.0 t/ha, positively influenced the growth, development, yield, and quality of winter wheat.

The best variants from our field experiments were $N_{60}P_{60}K_{60}$ + bentonite 3 t/ha and biohumus 3.5 t/ha + bentonite 3 t/ha, where all fertilizers and bentonite were applied in autumn during the loosening soil cultivation method. These were also tested in production trials over 1000 m² for each variant.

According to the results of the production trials, the variant with mineral fertilizers and bentonite produced 482 kg of wheat and 770 kg of straw per 1000 m², equivalent to 48.2 c/ha of grain and 7.7 tons of straw per hectare. The variant with biohumus and bentonite yielded 497 kg of wheat and 790 kg of straw, which corresponds to 49.7 c/ha of grain and 7.9 tons of straw per hectare.

Conclusion

Summarizing the results of the three-year field experiments and one-year production trials, as well as the laboratory research conducted, the following conclusions and recommendations can be made:

Among the three tested soil cultivation methods for winter wheat in the non-irrigated conditions of the Fantan administrative area of Hrazdan region in Kotayk Province, the most effective method is soil loosening (to a depth of 10-12 cm). Compared to conventional plowing and zero-tillage, this method increased yield, with the yield increase amounting to 18.5 % and 20.9 %, respectively.

Under all soil cultivation methods, the equivalent doses of mineral fertilizers and biohumus had a similar impact on the yield and quality indicators of winter wheat. However, the highest results were recorded with soil loosening, which provided a grain yield increase of 3.1-4.1 c/ha compared to deep plowing and zero-tillage, as observed in the variants without fertilization.

The autumn application of bentonite, alongside equivalent doses of mineral fertilizers and biohumus, proved more beneficial for the yield and quality of winter wheat than the same rate applied in spring.

The results of the field studies, as well as the effective soil cultivation method (tilling only by loosening to a depth of 10-12 cm) and the application of equivalent doses of mineral fertilizers and biohumus, showed that the use of bentonite at a rate of 3.0 t/ha in the autumn, based on production trial results, achieved winter wheat grain yields of 48.2 and 49.7 c/ha, respectively. These findings have been recommended for widespread implementation and adoption in Kotayk Province and similar soil-climatic conditions (in non-irrigated agricultural settings) as resource-saving and environmentally friendly technologies.

References

1. Agapie, A., Bostan, C. (2020) The influence of mineral fertilization on the quality of winter wheat. Life Science And Sustainable Development. Vol. 1, No. 2, - pp. 45–50.
2. Alnaass, N., Agil, H., Ibrahim, H. (2021) Use of fertilizers or importance of fertilizers in agriculture // International Journal of Advanced Academic Studies. 2021. Vol. 3, no. 2, - pp. 52–57. https://doi.org/10.33545/27068919.2021.v3.i2a.770.
3. Bertic, B., Loncaric, Z., Vukadinovic, V., Vukobratovic, Z. & Vukadinovic, V. (2007). Winter wheat yield responses to mineral fertilization. Cereal Research Communications, 35(2), 245–248. https://doi.org/10.1556/CRC.35.2007.2.20.
4. Chiriţă, S., Rusu, T., Urdă, C., Cheţan, F., & Racz, I. (2023). Winter wheat yield and quality depending on chemical fertilization, different treatments, and tillage systems. AgroLife Scientific Journal, 12(1), 34–39. https://doi.org/10.17930/AGL202315.
5. Dospekhov, B.A. Methodology of Field Experiments; Kolos: Moscow, 1973 (in Russian).
6. Galstyan, M. (2007). Efficiency of fertilizing winter wheat and potatoes in the conditions of the Sevan Basin. Limush, 156 (in Armenian).
7. Galstyan, M., Matevosyan, L., Zadayan, M., Ghukasyan, A., Harutyunyan, S., Sargsyan, K., & Osipova, R. (2024). Assessment of the impact of micro fertilizers on winter wheat and winter barley crops under the Sevan Basin conditions. Bioactive Compounds in Health and Disease, 7(4), 199–210. https://doi.org/10.31989/bchd.v7i4.1292.

8. Gharakhanyan, K.A. (2022). The influence of various soil cultivation methods and soil conditioners on winter wheat winter hardiness and yield structure elements. Biological Journal of the Armenian Academy of Sciences, 74(4), 29–38 (in Armenian). https://doi.org/10.54503/0366-5119-2022.74.4-29.
9. Gharakhanyan, K.A. (2023). The influence of various soil cultivation methods and soil conditioners on winter wheat growth, development, phenological phases, and yield structure elements. Biological Journal of the Armenian Academy of Sciences, 75(2–3), 198–205 (in Armenian). https://doi.org/10.52276/25792822-2023.4-340.
10. Gharakhanyan, K.A. & Galstyan, M.H. (2023). The effect of various tillage methods and meliorants application against their background on the dynamics of macronutrients accumulation in winter wheat plants and their output via crop yield. Agricultural Science and Technology, 4(84), 340-346. https://doi.org/10.54503/0366-5119-2023.75.2-3-198.
11. Gharakhanyan, K., Galstyan, M. (2024). The effect of different soil tillage methods and application of soil improvers on the soil agrophysical and agrochemical properties. Norwegian Journal of Development of the International Science. No. 139, - pp. 4-9. https://doi.org/10.5281/zenodo.13505938.
12. Hassan, W. (2018). Preparation and properties of urea slow-release coated with potassium humate, bentonite, and polyacrylamide as compositely fertilizer which reflected on the productivity of wheat crop. Journal of Soil Science and Agricultural Engineering, 9(11), 627–635. https://doi.org/10.21608/jssae.2018.36477.
13. Hayrapetyan, E.M., & Shirinian, A.V. (2003). Agroecology. Textbook for Yerevan State Agricultural University students. Yerevan, 408 (in Armenian).
14. Khan, M., Anjum, F., Hussain, S., Nadeem, M. (2010). A Review of Wheat Quality Assessment. International Journal of BioSciences, Agriculture and Technology. Vol. 2, No. 2, - pp.12–20.
15. Kozlov, A.V., Kulikova, A.H., & Uromova, I.P. (2023). Influence of diatomite, zeolite, and bentonite clay on agrochemical indicators of sod-podzolic soil and yield of agricultural crops. Agrochemistry, (12), 22–30. (in Russian). https://doi.org/10.19047/0136-1694-2019-96-86-112.
16. Lachutta, K., & Jankowski, K.J. (2024). The quality of winter wheat grain by different sowing strategies and nitrogen fertilizer rates: A case study in northeastern Poland. Agriculture, 14(4), 552. https://doi.org/10.3390/agriculture14040552.
17. Lazursky, A.V., & Lebedinskaya, V.N. (1969). Timing and methods of applying mineral fertilizers for winter wheat in the forest-steppe zone of Ukraine. Agrochemistry, (10), - pp. 45–49.
18. Litke, L., Gaile, Z., & Ruža, A. (2018). Effect of nitrogen fertilization on winter wheat yield and yield quality. Agronomy Research, 16(2), 589–599. http://dx.doi.org/10.22616/rrd.23.2017.049.
19. Maksyutova, O. (2017). Functional minerals. Chemical Journal of the World Market, (8), 20–25.
20. Melkonyan, K.G., Ghazaryan, H.Gh., & Manukyan, R.R. (2004). The current ecological status of agricultural lands, the level of land use, improvement of management level, and ways to increase efficiency in the Republic of Armenia. Scientific Center of Soil Science, Agrochemistry, and Melioration, 56 (in Armenian).
21. Melnik, I.A. (1990). Earthworms in the service of agriculture. Agricultural Biology, Series Biology of Plants, (5), - pp. 162–164.
22. Mi, J., Gregorich, E.G., Xu, S., McLaughlin, N.B., & Liu, J. (2020). Effect of bentonite as a soil amendment on field water-holding capacity, and millet photosynthesis and grain quality. Scientific Reports, 10(1), 18282. https://doi.org/10.1038/s41598-020-75350-9.
23. Mineev, V.G. (2004). Agrochemistry. Kolos, 719 (in Russian).
24. Mineev, V.G., Gomonova, N.F., & Amelyanchik, O.A. (2006). Changes in the properties of soddy-podzolic soil with long-term comprehensive use of agrochemical means. Annals of Agrarian Science, (4), - pp. 17–21.
25. Piskaeva, A.I., Babich, O.O., Dolganyuk, V.F., & Garmashov, S.Y. (2017). Analysis of the influence of biohumus on the basis of a consortium of effective microorganisms on the productivity of winter wheat. Foods and Raw Materials, 5(1), - pp. 90–99.
26. Pryanishnikov, D.N. (1945). Nitrogen in the Life of Plants and Agriculture of the USSR. Moscow: Publishing House of the Academy of Sciences of the USSR, - pp. 134–171.
27. Spiryn, A.P. (2005). Moisture-saving soil treatment. Zemledelie (2), - pp. 18–20.

28. Tagirov, M.Sh., Shakirov, R.S., & Gilaev, I.G. (2015). Influence of basic treatment methods on the water-physical indicators of soil and productivity of spring wheat. Zemledelie, (8), - pp. 20–21 (in Russian).

29. Yagodin, B.A., Smirnov, P.M., Petersburgsky, A.V., Kudin, V.V., Sliptsik, A.V., Kuzukin, A.N., & Sablin, S.M. (1989). Agrochemistry (2nd ed., B.A. Yagodin, Ed.). Agropromizdat (in Russian).

30. Yomgirovna, R.G. (2023). Scientific aspects and efficacy of bentonite use in agriculture. European Journal of Modern Medical Practice, 3(11), - pp. 116–120.

31. Zhou, L., Monreal, C.M., Xu, S., McLaughlin, N.B., Zhang, H., Hao, G. (2019). Effect of bentonite-humic acid application on the improvement of soil structure and maize yield in a sandy soil of a semi-arid region. Geoderma, 338, 269–280. https://doi.org/10.1016/j.geoderma.2018.12.014.

Declarations of interest

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