AGRISCIENCE AND TECHNOLOGY
Armenian National Agrarian University
ԱԳՐՈԳԻՏՈՒԹՅՈՒՆ ԵՎ ՏԵԽՆՈԼՈԳԻԱ АГРОНАУКА И ТЕХНОЛОГИЯ
International Scientific Journal
ISSN 2579-2822

Journal homepage: anau.am/scientific-journal
doi: 10.52276/25792822-2023.4-340

UDC 633.11:631.82

The Effect of Various Tillage Methods and Meliorants Application against their Background on the Dynamics of Macronutrients Accumulation in the Winter Wheat Plants and their Output via Crop Yield

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ARTICLE INFO

Keywords:
soil tillage,
meliorants,
biohumus,
bentonite,
nutrient dynamics

ABSTRACT

The article presents the results of two-year investigations related to the effect of different soil cultivation methods, application times of equal doses of mineral and organic fertilizers and bio-humus with bentonite application against their background on the dynamics of macronutrients accumulation and their removal/output through the crop yield. Considering the changes in the winter wheat growth, development, and yield capacity under the effect of different soil tillage methods, as well as the applied fertilizers and bentonite in rainfed conditions, and also the nutrition characteristics, to get high and sustainable yield the cultivation of winter wheat should be implemented only through loosening method, while fertilization should be implemented by introducing natural rock bentonite into the soil either on the background of mineral fertilizers ($N_{60}P_{60}K_{60}$) or bio humus (3.5 t/ha) in autumn, as a result of which the soil air, nutrition and humidity regimes improve, favorable conditions are created for the regular growth and development of the plant and 48.8-52 c/ha grain and 89-96 c/ha straw yield is ensured.

Introduction

It is well known that each crop demonstrates a certain selectivity and intensity of nutrients assimilation during its growth and development, which undergoes a specific change during the development process of the given plant. These phenomena are related to the biological characteristics of the plants and environmental conditions.

Nevertheless, the quantitative ratio of the nutrients in the plants' organs is the result of their biological characteristics rather than that of the external factor.

Due to different soil tillage ways and soil improvers application the yield amount and qualitative indicators also change significantly. On the whole, the supply of nutrients to the plants takes place unequally.

The studies related to the dynamics of nitrogen, phosphorus and potassium in the agricultural crops and those of their removal with crop yield are pivotal to increase the application efficiency of mineral and organic fertilizers, as well as different soil tillage methods. Hereby it becomes possible to adjust the doses and application times of fertilizers, as well as to identify the soil cultivation method which ensures the most efficient conditions for the regulation of plant growth, development and nutritional regime.

It has been found out that 35-60 % of dry matters in the plants of winter wheat are accumulated in the first half of the plants growth and development period (before ear formation) in case of traditional soil tillage method (deep plowing), whereas 40-65% - in the second half. The nutrients accumulation dynamics in the winter wheat plants is somehow related to the content of available nutrients in the soil and to the climatic conditions (Avagyan, et al., 1968; Galstyan, 2007).

According to the studies of numerous researchers, the mineral and organic fertilizers and also natural mineral rocks exert a certain effect on the growth and development, as well as on the nutrients dynamics in the winter wheat plants (Melkonyan, et al., 2004; Mineev, et al., 2006; Maksyutova, 2017; Galstyan, 2018; Gharakhanyan, 2022). In order to produce high and stable yields of wheat, is it necessary to apply yield-stimulating macronutrients (Rietra, et al., 2017; Stepien & Wojtkowiak, 2019).

Outstanding Russian scientist-agronomist I.E. Ovinsky (Ovsinsky, 1899), showed the redundancy of the plow in soil cultivation. He believed that most soil types contain a huge amount of nutrients and under the conditions of traditional soil cultivation, it is not possible to extract the huge reserves of plant food that are contained in the soil and in the atmosphere. This is accounted for the circumstance that the old soil tillage system not only fails to contribute to the activation of the factors generating plants available nutrients, but also significantly hinders this process.

Different researchers in the RA and abroad have justified that the nutrients output/removal from the winter wheat yield (grain, straw) is mostly related to the yield amount, varietal characteristics, the supply rate of mobile nutrients in the soil and to the climatic conditions (Davtyan & Babayan, 1966; Avagyan, et al., 1968, Mineev, 2004; Galstyan, 2007; Pepó, 2007; Litke, et al., 2018; Yan, et al., 2020).

Materials and methods

The studies were carried out within 2021-2023 in Fantan administrative area of the Hrazdan consolidated community at the Kotayk region, in rainfed conditions. The field experiments were set up in decalcified common black soils, which are characteristic to that region and the winter cereal crops (mostly 99.2 % winter wheat) are cultivated on those soil types, where the humus content makes 4.9-5.5 %, the medium reaction is close to neutral (*pH* 6.9-7.2), the content of easy hydrolysable nitrogen per 100 g soil makes 2.94 mg, that of mobile phosphorus – 3.41 mg, and the exchangeable potassium – 37.72 mg.

The research activities aimed to study, for the first time in the region, the effect of different soil tillage methods, application times (autumn, spring) of equal doses of mineral fertilizers and biohumus together with bentonite against the latter's background on the dynamics of nutrients accumulation in the plants of winter wheat and their output/removal via crop yield (grain, straw).

During the two-year investigations the field experiments were set up in three replications; each experimental bed of fertilization in every soil tillage method made 50 m^2, the experimental options were as follows:

1. Control (without fertilization),
2. $N_{60}P_{60}K_{60}$,
3. Bio-humus 3.5 t/ha,
4. $N_{60}P_{60}K_{60}$ + bentonite 3 t/ha (in Autumn),
5. Bio-humus 3.5 t/ha + bentonite 3 t/ha (in Autumn),
6. $N_{60}P_{60}K_{60}$ + bentonite 3 t/ha (in Spring),
7. Bio-humus 3.5 t/ha + bentonite 3 t/ha (in Spring).

The mentioned variants of fertilizers and bentonite have been applied throughout various soil tillage methods, namely in case of no-tillage or zero-tillage method, in case of only loosening or disc harrowing method (10-12 cm) and in case of deep ploughing (22-25 cm).

In all variants, except for the control one, the equal doses of mineral fertilizers and bio-humus were introduced into the soil in Autumn, before sowing (by raking), the doses of bentonite in the options of mineral fertilizers and biohumus (4th and 5th)were applied in autumn, while in the 6th and 7th options it was introduced in spring, again by mixing it with the soil via raking. Sowing, further cultivation and harvesting activities of winter wheat Bezostaya-1 have been implemented in compliance with the agricultural rules common in the region.

In the plant samples taken throughout the bushing, ear formation and maturation phases during vegetation period, the content of N, $P_2 0_5$ and $K_2 0$ have been determined through the generally accepted methods introduced in the methodical guideline on agrochemical analysis published under the editorship of B.A. Yagodin (Yagodin, et al, 1989). The amount of grain and straw yield of winter wheat has been determined during the harvesting period by means of widely used yield calculation method (Rudenko, 1950).

Results and discussions

The research results have indicated that both in all soil cultivation methods and in the fertilized options set up on those methods, the dynamics of nutrients accumulation in the winter wheat plants took place ununiformly during the vegetation period and more amount of nutrients was accumulated at the bush formation stage. So, if in case of zero-tillage of soil the NPK content in the plants made 2.1, 0.92 and 2.61 %, respectively at the bushing stage, in case of only loosening method - 2.2, 0.96 and 2.54, then during the further stages of wheat growth and development, in case of all soil tillage methods, the migration of nutrients into the plants gradually declined (Table 1). As compared to bush formation stage, in case of no-tillage method, the amounts of nitrogen, phosphorus and potassium decreased in 2.56; 1.77 and 2.46 times, respectively at the ear formation stage, in case of only loosening method - 2.53; 1.67; 2.25 times and in case of traditional ploughing the decrease of those nutrients made 2.41; 1.81 and 2.31, respectively. Similar patterns have been observed in various research works (Avagyan, et al., 1968; Mkrtchyan & Hayrapetyan, 2008; Stepanyan, et al., 2011; Galstyan, 2018).

The data of Table 1 indicate that in case of all soil tillage methods, both in the fertilized and unfertilized options at the ear formation stage the plants demand for potassium was more than that of for nitrogen and phosphorus. Besides, at the mentioned stage the ratio of N, P_2O_5, K_2O in the unfertilized option makes 1, 0.6, 1.29 in case of zero-tillage, while in case of only loosening method it makes 1, 0.69, 1.37, and in traditional tillage it is 1, 0.63, 1.33, respectively.

At the stage of full maturation, in all soil tillage methods, both in fertilized and unfertilized options some redistribution of nutrients occurred in winter wheat plants. Nitrogen (1.94-2.16%) and phosphorus (0.64-0.90%) were accumulated in more amounts in the grains in case of no-tillage method than potassium (0.4-0.49%), whereas in straw potassium was in relatively more amounts than nitrogen and phosphorus.

The same regularities in terms of nutrients redistribution were also observed in the plant grains and straw of fertilized and unfertilized options in case of only loosening and traditional ploughing methods at the phase of full maturation.

The accumulation of nitrogen, phosphorus and potassium in the grain and straw of winter wheat took place at a certain ratio. If in case of unfertilized no-tillage method, this ratio was 1:0.28:0.2 in grain, 1:0.53:2 in straw, then in the fertilized options of the same method in case of mineral fertilizers the ratio of those nutrients in the grain made 1:0.37:0.47, in straw 1:0.65:2.2, meanwhile in case of bio-humus option the ratio in the grain was 1:0.42:0.2, in straw 1:0.74:2.2.

Investigating the issue related to the effect of application times of equal doses of mineral fertilizers and bio-humus with bentonite against their background, as well as that of different soil tillage methods on the nutrients removal/output from the soil together with winter wheat yield (grain and straw), it has been found out that the winter plants have removed various amounts of macronutrients from per hectare soil. The amount of nutrients output was related to the soil cultivation method, crop yield amount, the type of applied fertilizers and to the introduction method of bentonite into the soil (Table 2).

Thus, if in case of no-tillage method 48.2 kg nitrogen, 16.2 kg phosphorus and 30.1 kg potassium was removed from the soil via 19.2 c/ha grain and 36.2 c/ha straw yield per the two-year data, in case of soil tillage through only loosening method 22.4 c/ha grain and 40.0 c/ha straw yield was received and the amount of nitrogen, phosphorus and potassium removed therethrough made 57.2, 19.4 and 34.9 kg, respectively, then in case of traditional ploughing of the soil 47.2 kg nitrogen, 16.4 kg phosphorus and 30.1 kg potassium was removed through the received 19.4 c/ha grain and 36.8 c/ha straw yield. It comes to the point that per the calculation of the removed nutrients from the soil by winter plants related to the soil tillage method, in case of zero soil tillage, 2.51 kg nitrogen, 0.84 kg phosphorus and 1.57 kg potassium was removed from the soil together with 1 centner grain and equal straw yield. Whereas with 1 center grain and equal straw yield of winter plants cultivated through traditional ploughing 2.43 kg nitrogen, 0.85 kg phosphorus and 1.55 kg potassium was removed from the soil and the plants cultivated in conditions of only loosening method removed 2.55 kg nitrogen, 0.87 kg phosphorus and 1.56 kg potassium via the same amount of grain and straw yield.

Table 1. The impact of various soil tillage methods, timing of equal mineral fertilizer and biohumus with bentonite applications on the dynamics of macronutrients accumulation in winter wheat plants*

Options/ Variants	Bushing									Earing/Ear formation								
	No-tillage/zero-tillage			Only loosening			Traditional ploughing			No-tillage			Only loosening			Traditional ploughing		
	N	P_2O_5	K_2O	*N*	P_2O_5	K_2O	*N*	P_2O_5	K_2O	*N*	P_2O_5	K_2O	*N*	P_2O_5	K_2O	*N*	P_2O_5	K_2O
Control (without fertilization)	2.10	0.92	2.61	2.20	1.00	2.70	2.00	0.96	2.54	0.82	0.50	1.06	0.87	0.60	1.20	0.83	0.53	1.10
$N_{60}P_{60}K_{60}$	2.49	1.29	2.90	2.64	1.40	2.94	2.50	1.30	2.86	1.18	0.95	1.85	1.33	1.13	1.93	1.18	0.98	1.90
Bio-humus 3.5 t/ha	2.44	1.30	2.97	2.59	1.38	2.99	2.42	1.28	2.98	1.12	0.80	1.82	1.17	0.92	1.90	1.14	0.83	1.82
$N_{60}P_{60}K_{60}$ + bentonite 3 t/ha (in Autumn)	2.52	1.35	3.19	2.75	1.46	3.31	2.55	1.34	3.09	1.29	0.90	2.00	1.38	1.10	2.18	1.30	0.87	1.98
Bio-humus 3.5 t/ha + bentonite 3t/ha (in Autumn)	2.50	1.32	3.30	2.70	1.40	3.33	2.51	1.29	3.28	1.32	0.87	2.03	1.44	1.04	2.10	1.30	0.91	2.00
$N_{60}P_{60}K_{60}$ + bentonite 3 t/ha (in Spring)	2.46	1.22	2.95	2.63	1.30	3.00	2.40	1.20	2.99	1.20	0.92	1.84	1.35	1.08	1.93	1.19	0.94	1.83
Bio-humus 3.5 t/ha + bentonite 3 t/ha (in Spring)	2.45	1.30	2.94	2.61	1.38	3.12	2.48	1.29	2.96	1.15	0.92	1.85	1.30	1.02	1.98	1.16	0.90	1.88

Options	Full maturation																	
	Grain									Straw								
	No-tillage			Only loosening			Traditional ploughing			No/Zero-tillage			Only loosening			Traditional ploughing		
	N	P_2O_5	K_2O	*N*	P_2O_5	K_2O	*N*	P_2O_5	K_2O	*N*	P_2O_5	K_2O	*N*	P_2O_5	K_2O	*N*	P_2O_5	K_2O
Control (without fertilization)	1.94	0.54	0.40	1.98	0.58	0.38	1.90	0.56	0.39	0.30	0.16	0.62	0.32	0.16	0.66	0.28	0.15	0.61
$N_{60}P_{60}K_{60}$	2.15	0.80	0.46	2.22	0.86	0.49	2.09	0.82	0.47	0.34	0.22	0.76	0.36	0.27	0.82	0.32	0.23	0.77
Bio-humus 3.5 t/ha	2.10	0.89	0.45	2.16	0.91	0.49	2.10	0.89	0.44	0.35	0.26	0.77	0.38	0.26	0.82	0.36	0.25	0.76
$N_{60}P_{60}K_{60}$ + bentonite 3 t/ha (in Autumn)	2.16	0.90	0.49	2.20	0.94	0.51	2.16	0.91	0.50	0.33	0.28	0.85	0.38	0.29	0.90	0.34	0.28	0.84
Bio-humus 3.5 t/ha + bentonite 3t/ha (in Autumn)	2.15	0.87	0.48	2.19	0.94	0.50	2.16	0.89	0.48	0.34	0.26	0.88	0.36	0.26	0.93	0.33	0.28	0.90
$N_{60}P_{60}K_{60}$ + bentonite 3 t/ha (in Spring)	2.12	0.81	0.45	2.19	0.88	0.48	2.07	0.83	0.46	0.31	0.25	0.75	0.37	0.27	0.80	0.31	0.24	0.76
Bio-humus 3.5 t/ha + bentonite 3 t/ha (in Spring)	2.08	0.80	0.46	2.14	0.90	0.49	2.06	0.80	0.45	0.33	0.23	0.76	0.36	0.23	0.81	0.32	0.24	0.75

*Composed by the authors.

Table 2. The effect of different soil tillage methods, application times of equal doses of mineral fertilizers and biohumus with bentonite against their background on the nutrients output/removal via winter wheat crop yield (grain, straw)*

Soil tillage methods	Options/variants	Yield, c/ha		Nutrients output, kg/ha						Total output, kg/ha		
				Grain			Straw					
		Grain	Straw	*N*	P_2O_5	K_2O	*N*	P_2O_5	K_2O	*N*	P_2O_5	K_2O
No-tillage (0-tillage)	Control (without fertilization)	19.2	36.2	37.3	10.4	7.7	10.9	5.8	22.4	48.2	16.2	30.1
	$N_{60}P_{60}K_{60}$	27.0	54.0	58.1	21.6	12.4	18.4	11.9	41.0	76.5	33.5	53.4
	Bio-humus 3.5 t/ha	28.4	56.0	59.6	25.3	12.8	19.6	14.6	43.0	79.2	39.9	56.4
	$N_{60}P_{60}K_{60}$ + bentonite 3 t/ha (in Autumn)	38.2	74.8	82.5	34.4	18.7	24.7	20.9	63.6	107.2	55.3	82.3
	Bio-humus 3.5 t/ha + bentonite 3 t/ha (in Autumn)	41.8	80.0	89.9	36.4	20.1	27.2	20.8	70.4	117.1	57.2	90.5
	$N_{60}P_{60}K_{60}$ + bentonite 3 t/ha (in Spring)	28.0	55.2	59.4	22.7	12.6	17.1	13.8	41.4	76.5	36.5	54.0
	Bio-humus 3.5 t/ha + bentonite 3 t/ha (in Spring)	29.0	57.0	60.3	23.2	13.3	18.8	13.1	43.3	79.1	36.3	56.6
Only loosening	Control (without fertilization)	22.4	40.0	44.4	13.0	8.5	12.8	6.4	26.4	57.2	19.4	34.9
	$N_{60}P_{60}K_{60}$	31.0	59.0	68.8	26.7	15.2	21.2	14.2	48.4	90.0	40.9	63.6
	Bio-humus 3.5 t/ha	30.8	59.0	66.5	28.0	15.1	22.4	15.3	48.4	88.9	43.3	63.5
	$N_{60}P_{60}K_{60}$ + bentonite 3 t/ha (in Autumn)	48.8	89.0	107.4	45.9	24.9	33.8	25.8	80.1	141.2	71.7	106.0
	Bio-humus 3.5 t/ha + bentonite 3 t/ha (in Autumn)	52.0	96.0	113.9	48.9	26.0	34.6	25.0	89.3	148.9	73.9	115.3
	$N_{60}P_{60}K_{60}$ + bentonite 3 t/ha (in Spring)	36.4	70.8	79.7	32.0	17.5	26.2	19.1	56.6	105.9	51.1	74.1
	Bio-humus 3.5 t/ha + bentonite 3 t/ha (in Spring)	36.8	71.0	78.8	33.1	18.0	25.6	16.3	57.5	104.4	49.4	75.5
Traditional ploughing	Control (without fertilization)	19.4	36.8	36.9	10.9	7.6	10.3	5.5	22.5	47.2	15.4	30.1
	$N_{60}P_{60}K_{60}$	28.0	55.8	58.5	23.0	13.2	17.9	12.8	43.0	76.4	35.8	56.2
	Bio-humus 3.5 t/ha	28.2	56.0	59.2	25.1	12.4	20.2	14.0	42.6	79.4	39.1	55.0
	$N_{60}P_{60}K_{60}$ + bentonite 3 t/ha (in Autumn)	43.6	81.0	94.2	39.7	21.8	27.5	22.7	68.0	121.7	62.4	89.8
	Bio-humus 3.5 t/ha + bentonite 3 t/ha (in Autumn)	45.0	84.0	97.2	40.1	21.6	27.7	23.5	75.6	124.9	63.6	97.2
	$N_{60}P_{60}K_{60}$ + bentonite 3 t/ha (in Spring)	32.1	60.0	66.5	26.1	14.8	18.6	14.4	45.6	85.1	40.5	60.4
	Bio-humus 3.5 t/ha + bentonite 3 t/ha (in Spring)	31.9	61.0	65.7	25.5	14.4	19.5	14.6	45.8	85.2	40.1	60.2

*Composed by the authors.

Analysing the behavour of winter wheat grown under different soil tillage methods regarding the nutrients absorption, as well as the yield amount of grain and straw, it becomes clear that the plants have put out from the soil almost equal amount of nitrogen, phosphorus and potassium through 1 centner wheat and the same amount of straw, nevertheless, related to soil cultivation methods different amounts of grain and straw yield have been developed. This circumstance is mainly related to the fact, that soil tillage by means of only loosening method, has created more favorable conditions in terms of air and humidity regimes for the plants growth and yield development ensuring 22.4 c/ha grain yield, whereas in case of no-tillage and traditional ploughing methods the grain yield has made 19.2 c/ha and 19.4 c/ha, respectively.

Meanwhile the data of Table 2 indicate, that the equal amounts of mineral fertilizers and biohumus with bentonite applied in different time periods against their background throughout different soil tillage methods, have considerably affected the development of winter wheat grain and straw yield, as well as the amount of nutrients removal/output via the crop yield.

Under the effect of equal doses of mineral fertilizers and bio-humus and application times of bentonite (autumn and spring) against their background the plants have removed almost twice and thrice more nutrients via the yield in case of all soil tillage methods, than the grain and straw produced in unfertilized options in case of appropriate soil tillage method. The phenomenon of chemotaxis was probably observed here, i.e. plants in nutrient-rich soil environment absorbed available nutrients faster and in more amounts than from a relatively poor environment (in unfertilized options).The calculations have shown that the same doses of fertilizers and bio-humus have equally affected both the nutrients accumulation dynamics and their removal/output through 1 c wheat yield (grain, straw).

Conclusion

Summing up the results of the study on the effect of different soil tillage methods, equal doses of mineral fertilizers and bio-humus with bentonite applied at different time periods against the latter's background on the dynamics of macrunutrients accumulation in winter wheat plants and on their output rate via crop yield the following conclusions have been drawn:

1. In the winter wheat plants of Bezostaya 1 variety, irrespective of soil tillage methods and the doses and application ways of soil improvers, the major part of nutrients are accumulated during the first stages of plants growth and development. The intensity of nutrients accumulation slows down in further stages. From the bushing stage up to the ear formation one the winter plants demand is more for nitrogen and potassium than for phosphorus, while from ear formation to the maturation phase the need for potassium grows up.

2. The equal doses of mineral fertilizers and bio-humus have uniformly affected the dynamics of nutrients accumulation and their removal/output via yield.

3. The nutrients outcast from the soil and their output with the crop yield is related to the soil tillage method, the amount of grain and straw yield, the doses of fertilizers and their application times.

4. Fo the development of 1 c grain and equivalent straw yield in conditions of zero soil tillage, only loosening and traditional ploughing methods, the winter wheat plants absorb NPK from the soil 2.51, 0.84 and 1.57 kg; 2.43, 0.85 and 1.55 kg, and 2.55, 0.87 and 1.56 kg, respectively. i.e., the soil tillage method has no significant effect on the nutrients removal/output rate.

5. The analysis of the data on the effect of different soil tillage methods for the development of grain and straw yield in unit amount under rainfed conditions, as well as that of applied fertilizers and bentonite has been conducted. In order to ensure high and sustainable yield of winter wheat plants cultivated under the mentioned conditions, it is necessary to cultivate the soil through only loosening method (loosening the soil with the depth of 10-12 cm), while when organizing fertilization activities the natural mineral rock bentonite (3 t/ha) on the background of either equal doses of mineral fertilizers ($N_{60}P_{60}K_{60}$) or bio-humus (3.5 t/ha) should be introduced into the soil in autumn, as a result of which the soil air, nutritional and humidity regimes improve, favorable conditions are created for the regular growth and development of the plants and per two-year average data 48.8-52 c/ha grain and 89.0-96.0 c/ha straw yield is ensured.

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Accepted on 16.10.2023
Reviewed on 04.12.2023