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Production removal of the main nutrient elements from winter wheat and barley crops in the conditions of the Ararat Valley of Armenia

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Abstract. The aim of the research is to identify the extent of production removal of the main nutrient elements in the irrigated grain-growing lands of Armenia, to optimize the norms of organo-mineral fertilizers, to stabilize the yield of plants and prevent dehumification. The field experiments were carried out in the conditions of the Ararat Valley on winter wheat and barley in 2020–2022. The production removal of nitrogen by 5–7 t ha^{-1} grain of winter wheat and 9.6–13.3 t ha^{-1} straw varies between 155–247, P_2O_5: 60–88, K_2O: 134–197 kg ha^{-1} , and the amounts removed by barley grain 4.5–6.5 t ha^{-1} and straw 6.9–9.7t ha^{-1} were 122–194, 49–77 and 106–159 kg ha^{-1}, respectively. The amounts of nitrogen and potassium production removal from plant crops are about 2 times higher than the doses of applied fertilizers, and the amount of phosphorus is almost balanced by these doses.

Key words: Winter wheat and barley, organo-mineral fertilizers, main nutrient elements, production removal.

INTRODUCTION

One of the main ways of increasing the yield of agricultural crops and stabilizing the soil fertility is the application of organo-mineral fertilizers, as the nutrient elements removed with commodity and non-commodity crops must somehow be returned to the soil. The amounts of nitrogen, phosphorus and potassium removal depend on the species and varietal characteristics of the plants, the level of the yield, soil and climatic conditions, the applied agricultural machinery, norms of fertilization and other factors. Global climate changes in various countries of the world, including Armenia, are becoming a crucial factor for ecological security, as well as for crop growth and yield. The studies conducted in 2009–2015 on different varieties of winter wheat in Latvia have shown that the effect of nitrogen fertilizers on grain yield and protein content is 3–35%, climatic conditions - 33–46%, and cultivation conditions - 34% (Skudra & Ruza, 2016; Linina & Ruza, 2018).

In Armenia, the sowing of grain crops regularly occupy120–200 thousand hectares of land. From this point of view, the Ararat valley is considered the most active agricultural region of Armenia and occupies 8.4% of the total area (29.8 thousand km^2). About 45 thousand hectares of grain (mainly winter wheat and barley) are cultivated in the area. The irrigation factor is problematic here. Regardless of the level of agricultural machinery, variety, fertilization, it is impossible to cultivate any plant without water in this semi-desert zone. The sum of active temperatures (over 10 °C) here reaches 4,000–4,300 °C annually, and the average temperature is 10.6 °C. The absolute minimum air temperature in winter reaches -30. -33 °C, the amount of precipitation is 200–260 mm, the evaporation capacity (annual deficit) is 600 mm, the humidity coefficient according to Shashko is 0.20–0.25.

The Scientific Center of Agriculture, with its production and experimental base, where the field experiments were carried out, is located in the central part of the Ararat valley, at an altitude of 853 m above sea level. During the years of research, the climatic and irrigation conditions of this zone were quite stable, although the influence of the greenhouse effect is also noticeable here. Moreover, because of the deepening deficit of nutrients, especially nitrogen, the yield of crops has been gradually reducing in the agricultural lands of the republic.

Almost everywhere in the world, insufficient amount of nitrogen is considered to be a limiting factor for good yield of the crops. The researches in this field have shown that the $N_{150}P_{50}$ combination noticeably increases the yield of winter wheat and barley and protein content in the grains (Hlisnikovsky et al., 2019).

The research conducted on grain crops shows that in different soil and climatic conditions, the amounts of production removal of the main nutrient elements by 1 t of grain and the corresponding mass of straw differ significantly. Thus, nitrogen removed by winter wheat varies between 26–37, P_2O_5: 8–13 and K_2O:16–27 kg, by winter rye 22–28, 8–10 and 24–26 kg, respectively, by barley N: 24–28, P_2O_5: 8–10, K_2O: 23–30 kg, by spring wheat N: 31–47, P_2O_5: 11–12, K_2O: 18–19 kg etc. (Peterburgsky, 1979; Babayan, 1980; Voitovich & Laboda, 2005; Shafran et al., 2008; Khachidze & Mamedov, 2009). Much lower data are reported by experiments in the USA in 1950-s. 11.7 kg of N, 2.1 kg of P_2O_5, 5.6 kg of K_2O are removed from wheat, 12.2; 1.9; 9.0 kg from barley. The release of K_2O in the commodity harvest of all crops was 3–4 times less than that of nitrogen, and by straw it exceeded the release of nitrogen by 1.5–3 times (Collings, 1960). The position of the slopes in the agrolandscape also has a certain effect on the root mass of winter wheat and the macro- and micro- elements accumulated in them. Root mass on northern slopes exceeded that of the plants growing on southern slopes, and the nutrient content was higher on southern slopes (Dubovik & Dubovik, 2015).

The studies conducted in Armenia show that 2.0–2.8 kg of N, 1.0–1.2 kg of P_2O_5, and 3.3–4.0 kg of K_2O are removed by 1 t of the tomato variety 'Lia' and corresponding vegetative mass, and in the case of the variety 'Sunrise' it was 3.3–3.8; 1.4–1.6 and 4.3–5.2 kg, respectively. 2.4 kg of N, 1.5–1.7 kg of P_2O_5 and 3.0–3.4 kg of K_2O are removed by the pepper variety 'Almond 55' (Harutyunyan, 2009; Harutyunyan & Miqaelyan, 2021). Monoculture farming in the cereal farms of Armenia has caused unprecedented soil fatigue. The inclusion of pea, lentil, soybean, korghan, alfalfa in the crop rotation of grain crops prevents not only soil fatigue, but also enriches the soil with biological nitrogen. It has been found out that chickpeas fixed 109–288 kg ha^{-1} of nitrogen, soybean 264–312 kg ha^{-1} and alfalfa 486 kg ha^{-1} over a year (Tanchyk et al., 2021).

Purpose of the research and problems

The purpose of the research is to study the reasons for the decline of soil fertility and plant yield in the cereal lands of Armenia, related to the disruption of crop rotation and the insufficiency of organo-mineral fertilizers in farms. The main issues arising from the goal are: 1. to identify the extent of production removal of the main nutrient elements in winter wheat and barley crops, 2. to adjust the doses of organic and mineral fertilizers, which will allow to stabilize the soil fertility, prevent dehumification and create a dynamic balance of nutrient elements in the crops.

The scientific novelty of the work is directly related to the main problem of agrochemistry, which is to ensure the balance of nutrients and humus in agrocenoses. From this point of view, calculations of the entrance and losses of main nutrient elements in irrigated and waterless grain phytocenoses of the republic have not been carried out during the last 45 years, while their regular implementation is considered a mandatory monitoring task in the control of soil fertility reproduction.

Materials and methods

The field experiments were carried out in 2020–2022 at the Ejmiatsin production experimental farm of Armenian Scientific Centre of Agriculture, on irrigated meadow gray soils (40°16' and 44°29'). The experiments were based on the varieties of Armenian red grain soft wheat 'Nairi 68' and barley 'Ara' with 4 repetitions (each repetition: 50 m^2). The schemes are given in tables, where the principles of the only difference and comparability are preserved. In field experiments, the norm of sowing wheat was 250 kg ha^{-1} (about 4.2–4.5 million grains), and that of barley - 200 kg ha^{-1} (about 4.0–4.5 million grains). Phosphorous-potassium fertilizers and 40% of nitrogen were introduced into the soil in the autumn under the plow, during the 3rd decade of October, and 60% of nitrogen was introduced in the spring as nutrition during the 1st and 3rd decades of April. The sowing was done in the 3rd decade of October. In field experiments, as well as in production sowing, 4 irrigation periods are performed (in the autumn, immediately after sowing, in the 2nd decade of April, in the 2nd decade of May and in the 1st decade June), with an irrigation norm of 900 m^3 ha^{-1}. Harvesting was performed in the 1st decade of July. Ammonia nitrate, granulated super-phosphate (P_2O_5: 19.5%) and potassium chloride (K_2O: 60%) were used as mineral fertilizers, semi-rotted cattle manure (N: 0.48; P_2O_5: 0.23; K_2O: 0.55%), as organic fertilizer, biohumus (N: 1.8–2.0; P_2O_5: 0.85–2.0; K_2O: 0.51–0.73% according to the certificate). In April, chemical control was carried out against two-stemmed weeds with the herbicide Grodil maxi at 0.11 l/ha, and against one-stemmed weeds with the doses 1 L ha^{-1} of Lastiktop.

The climatic conditions of the Ararat valley are represented by average data (Agroclimatic resources of Armenia edited by R.S. Mkrtchyan et al., 2011). Laboratory analyses of soils and plants were performed using the well-known methods in the agrochemistry laboratory of the Scientific Centre of Agriculture (Alexandrova & Naidonova, 1976; Yagodin, 1987). The mechanical composition of soils was determined by the classical pipette method and evaluated according to the classification scale of N.A. Kachynski (Soil science edited by J.S. Kaurichev, 1982). The pH of the water extract was determined by the potentiometric method, and the dry residue was not determined, as salinization is excluded in the studied and adjacent lands, since the groundwaters are at a depth of 7–10 m and do not pose any threat to crops. Humus was determined by I.V. Turin method, and total nitrogen by the Kjeldahl method. Easily hydrolyzable nitrogen in the soil was determined by the method of I.V. Tyurin and M.M. Kononova (Yagodin, 1987), and the mobile forms of phosphorus and potassium were determined by the Machigin method, which is based on the principle of their removal by a 1% $(NH_4)_2CO_3$ solution. Total nitrogen, P_2O_5 and K_2O in plant samples were determined by K. Ginzburg's wet ashing method, after which nitrogen was determined by Kjeldahl's micro-method. P_2O_5 was determined by photoelectrocalorimeter, and K_2O by flame photometer. The mathematical processing of the yield was done by the method of dispersion analysis (Dospekhov, 1985).

RESULTS AND DISCUSSION

The entire production and experimental plot of the Scientific Centre of Agriculture in Ejmiatsin is a homogeneous plane, where an area of about 5 hectares was selected for field experiments. At the beginning of October, 2019, in the central part of the plot one soil cut was made, from which, soil samples were taken according to genetic horizons, for laboratory analysis. Within that plot, field research was conducted in 2020–2022, where lentils and chickpeas were sown alternately in different parts of the experimental plot, followed by wheat and barley. Lentils and chickpeas were of background importance but nitrogen fixed by them was not calculated due to methodological difficulties. The irrigated meadow gray soils are characteristic of the semi-desert natural zone of the Ararat Valley and occupy 53 thousand hectares. The agrochemical characteristic of the soil is given in the first table.

From the data in the first table, it can be seen that the soil of the test plot is quite strong (A + B = 81 cm). Its mechanical composition is mainly medium and heavy loam, the physical clay (< 0.01 mm particles sum) in the horizon A is 35.09; in the horizon B_1 it is 59.92; in the horizon B_2 it is 33.4%, and in the horizon C it is considered to be light loam (22.6%). The roots of wheat and barley in these soils mainly spread in the 0–30 cm layer, and individual roots penetrate to a depth of 60–80 cm. The carbonate content in the topsoil is small, 1.1–1.5%, and the pH of the water extract is alkaline and varies between 7.6–8.3. The content of humus and total nitrogen is quite low, because the processes of mineralization of organic matter in these soils are quite intensive at high temperatures. The content of the available forms of the main nutrient elements is average. With optimum fertilization in these soils, all crops grow well and produce high yields.

The indices of grain and straw in the studied crops have been quite stable during the research years (Table 1), which is mainly explained by the stability of climatic conditions and agrotechnical measures. However, it should also be noted that under irrigation conditions a very strong competition arises between crops and weeds. Weed plants germinate and bloom intensively from early spring to late autumn, aggressively using up soil and fertilizer nutrients. In case of weak ecological and chemical control, an unprecedented drop in the yield of grain crops (up to 80%), as well as a decrease in the quality of the grain takes place. The degree of competition between crops and weeds in a flax crop rotation system can be represented in the following descending order: flax-potato-barley-winter wheat-winter rye (Conova & Samoilov, 2015).

Table 1. Physico-mechanical and agrochemical characteristics of test site soils

Genetic horizon and depth, cm	Hygroscopic humidity, %	< 0.01 mm sum of particles (phys. clay), %	The pH of the water draft	Humus, %	Total N, %	Mobile forms mg per 100 g in the soil		
						N	P_2O_5	K_2O
A 0–30	4.5	35.09	7.9	1.85	0.20	4.5	2.6	36
B_1 30–57	3.5	59.92	7.6	1.12	0.08	4.2	2.8	25
B_2 57–81	4.4	33.40	8.3	0.78	0.05	3.5	1.9	21
C 81–106	2.3	22.60	8.4	0.45	0.03	1.7	1.6	16

The data in Table 2 show that the 3-year average grain yield of wheat and barley is almost the same in all the options, while there are significant differences between the masses of the straw. The mass of wheat straw exceeds the mass of barley straw by about 30–40%, which can be explained by species and varietal characteristics. As for the effects of fertilizers, the yield of wheat grain in those options increased by 27.3–37.2 compared to the control; and the mass of straw - by 27.7–38.9%. In barley these indices were 36.1–42.5 and 33.8–41.0%, respectively, with the highest values recorded for $N_{120}P_{80}K_{90}$, as well as for biohumus in options. Relatively high results were also obtained in the $N_{120}K_{90}$ version, which is due to the strength of the plant stems, disease resistance, and full ripening of the grains. The surplus in wheat and barley yields in the fertilization options are reliable compared to the control in all years (LSD_{05} values).

Table 2. Effect of mineral and organic fertilizers on grain and straw yield of wheat and barley

Crop	Options	Grain harvest, t ha^{-1}				Straw, t ha^{-1}			
		2020	2021	2022	3 year average	2020	2021	2022	3 year average
Wheat	1. No Fertilization (Checker)	5.11	4.72	5.02	4.95	10.14	8.75	9.85	9.58
	2. $N_{120}P_{80}K_{90}$ kg ha^{-1}	7.29	6.37	6.72	6.79	13.96	12.35	13.63	13.31
	3. $N_{120}P_{80}$	6.58	6.16	6.26	6.33	13.19	11.92	11.26	12.46
	4. $N_{120}K_{90}$	6.76	6.47	6.53	6.59	13.53	11.68	12.82	12.68
	5. Biohumus-6 t ha^{-1}	6.57	6.21	6.48	6.42	13.34	11.47	12.41	12.41
	6. Manure-25 t ha^{-1}	6.43	6.13	6.35	6.30	13.04	11.36	12.29	12.23
	Sx, %	1.28	2.06	2.15	1.24				
	LSD_{05}, t	0.23	0.41	0.38	0.24				
Barley	1. No Fertilization (Checker)	4.54	4.52	4.65	4.57	6.82	6.86	6.89	6.86
	2. $N_{120}P_{80}K_{90}$ kg ha^{-1}	6.48	6.36	6.69	6.51	9.69	9.67	9.64	9.67
	3. $N_{120}P_{80}$	6.10	6.27	6.30	6.22	9.12	9.21	9.21	9.18
	4. $N_{120}K_{90}$	6.31	6.12	6.46	6.30	9.45	9.35	9.47	9.42
	5. Biohumus-6 t ha^{-1}	6.38	6.58	6.52	6.49	9.64	9.30	9.51	9.48
	6. Manure-25 t ha^{-1}	6.24	6.26	6.43	6.31	9.30	9.08	9.31	9.23
	Sx, %	2.36	3.29	0.83	0.87				
	LSD_{05}, t	0.43	0.56	0.18	0.17				

LSD – Lowest Significant Difference.

Removal of nitrogen, phosphorus and potassium from soil and fertilizers through crop yield and vegetative mass is considered to be the main factor in nutrient balance losses, while the content of nitrogen and ash elements in grains increases with favourable agrotechnical measures, such as optimal chemical treatment, targeted soil cultivation, active crop rotation and etc. In the case of the basic minimum soil cultivation and fertilization, with a yield of 3–4 t ha^{-1}, the nitrogen content in the grains of spring wheat reaches 2.61–2.82%, the removal of nitrogen makes 78–113 kg tha^{-1}. Nitrogen removal increases when chemicalization is intensified (Sineshchekov & Tkachenko, 2018).

In our field experiments, some increase in main nutrient elements was observed in wheat and barley grain and straw due to the use of organo-mineral fertilizers (Table 3). Thus, the total nitrogen content in the wheat grain of the test version was 2.00; in straw it was 0.58%, in the grain of the fertilization options it ranged from 2.16 ($N_{120}P_{80}$) to 2.42% ($N_{120}P_{80}K_{90}$), and in the straw it was 0.62–0.64%. The content of phosphorus in the grain and straw of the test version was 0.78 and 0.22%, respectively, and that of potassium - 0.68 and 1.05%. In the fertilization options these ash elements did not is almost indistinguishable from similar values in wheat. It shows that in flat-homogeneous soils the biological requirements of wheat and barley, as well as their selective and nutrient absorption properties are similar. It can be seen from Table 3 that the content of nitrogen in grains is about 3–4 times higher than that of straw, and the content of K_2O in straw is 1.5 times higher than in grain. As for phosphorus, its content in commodity plant crops is about 3.5–4 times more than in straw and about 3 times less than the amount of nitrogen contained in grain.

Table 3. The content of the main nutrient elements in the biomass of wheat and barley in relation to the application of organo-mineral fertilizers, % (average data for 2020–2021)

Crop	Options	Grain			Straw		
		Total N	P_2O_5	K_2O	Total N	P_2O_5	K_2O
Wheat	1. No Fertilization (Checker)	2.00	0.78	0.68	0.58	0.22	1.05
	2. $N_{120}P_{80}K_{90}$ kg ha^{-1}	2.42	0.84	0.71	0.62	0.24	1.12
	3. $N_{120}P_{80}$	2.16	0.83	0.70	0.64	0.24	1.08
	4. $N_{120}K_{90}$	2.29	0.86	0.74	0.63	0.22	1.14
	5. Biohumus-6 t ha^{-1}	2.32	0.81	0.69	0.63	0.23	1.10
	6. Manure-25 t ha^{-1}	2.22	0.82	0.69	0.64	0.22	1.11
Barley	1. No Fertilization (Checker)	1.82	0.76	0.72	0.57	0.21	1.07
	2. $N_{120}P_{80}K_{90}$ kg ha^{-1}	2.00	0.83	0.74	0.66	0.23	1.15
	3. $N_{120}P_{80}$	1.89	0.83	0.72	0.65	0.24	1.12
	4.$N_{120}K_{90}$	1.97	0.81	0.75	0.67	0.21	1.13
	5. Biohumus -6 t ha^{-1}	2.03	0.80	0.73	0.66	0.25	1.14
	6. Manure -25 t ha^{-1}	1.98	0.82	0.73	0.67	0.23	1.14

Based on the data in Tables 2 and 3, the production removal of the main nutrient elements related to the application of organomineral fertilizers in winter wheat and barley crops has been calculated (Table 4).

It can be seen from Table 4 that the removal of nitrogen by the grain of the studied plants is significantly higher than the amount of potassium, and the removal of potassium by straw exceeds the amount of nitrogen. The removal of phosphorus by grain is about 2 times higher than the amount removed by straw. As for the amounts of production removal of basic nutrients with the biomass of field-harvested wheat and barley, the amounts of nitrogen and potassium are about 2 times higher than the norms of applied fertilizers, and the amount of phosphorus removed is almost balanced with the norms of fertilizers. In the control versions of wheat and barley, nitrogen production removal was 154.6 and 122.3; P_2O_5-59.7 and 49.1; K_2O-134.3 and 106.3 kg ha^{-1}, respectively.

Table 4. Production removal of nitrogen, phosphorus and potassium from wheat and barley seeds, according to the average data of 2020–2022

Crop	Options	Through grain, kg ha^{-1}			Through straw, kg ha^{-1}			The amount of production removal, kg ha^{-1}			1 t by grain and corresponding straw mass*, kg		
		Total N	P_2O_5	K_2O	Total N	P_2O_5	K_2O	Total N	P_2O_5	K_2O	Total N	P_2O_5	K_2O
Wheat	1. No Fertilization (Checker)	99.0	38.6	33.7	55.6	21.1	100.6	154.6	59.7	134.3	31.3	12.1	27.2
	2. $N_{120}P_{80}K_{90}$ kg ha^{-1}	164.3	57.0	48.9	82.5	31.1	149.1	246.8	88.1	197.3	36.3	13.0	29.1
	3. $N_{120}P_{80}$	136.7	52.5	44.3	79.7	29.9	134.6	216.4	82.4	178.9	34.2	12.9	28.3
	4. $N_{120}K_{90}$	150.9	56.7	48.8	79.9	27.9	144.6	230.8	84.6	193.4	35.0	12.8	29.3
	5. Biohumus -6 tha^{-1}	148.9	52.0	44.3	78.2	28.5	136.5	227.1	80.5	180.8	35.4	12.5	28.1
	6.Manure -25 tha^{-1}	139.9	51.7	43.5	78.3	26.9	135.8	218.2	78.6	179.3	34.6	12.5	28.4
Barley	1. No Fertilization (Checker)	83.2	34.7	32.9	39.1	14.4	73.4	122.3	49.1	106.3	26.7	10.7	23.2
	2. $N_{120}P_{80}K_{90}$ kg ha^{-1}	130.2	54.0	48.2	63.8	22.2	111.2	194.0	76.2	159.4	29.8	11.8	24.5
	3. $N_{120}P_{80}$	117.5	51.6	44.8	59.7	22.0	102.8	177.3	73.6	147.6	28.5	11.8	23.8
	4. $N_{120}K_{90}$	124.1	51.0	47.3	63.1	19.8	106.4	187.2	70.8	153.7	29.7	11.3	24.4
	5. Biohumus -6 tha^{-1}	131.7	51.9	47.4	62.6	24.9	108.1	194.3	76.8	155.5	29.9	11.8	23.9
	6. Manure -25 tha^{-1}	124.9	51.7	46.1	61.8	21.2	105.2	186.7	72.9	151.3	29.6	11.6	23.9

*For example: In the control version of wheat, the average grain yield of 3 years was 4.95 t ha^{-1}, and the mass of straw was 9.58 t ha^{-1}. The mass of straw equivalent to 1 t of grain will be 9.58:4.95 = 1.94 t ha^{-1}.

In fertilization options, those indices in wheat crop ranged from N - 216.4–246.8; P_2O_5-80.5–88.1 to K_2O-178.9–197.3 kg ha^{-1}, and in barley, respectively; in the range of 177.3–194.3; 70.8–76.8 and 147.6–159.4 kg ha^{-1}.

The amount of nutrients removed by 1 t of grain and corresponding straw mass in wheat crop varied between N: 31.3–36.3; P_2O_5: 12.1–13.0; K_2O: 27.2–29.3, and in the barley scheme in the range of 26.7–29.9; 10.7–11.8 and 23.2–24.5 kg ha^{-1}, respectively. Taking into account the loss of nutrients from fertilizers and their assimilation coefficients in the year of application (N: 50–60%; P_2O_5: 20–30%, K_2O: 60%), we can assume that the danger of a deepening deficit of basic nutrients is quite obvious. The reconsideration and optimization of doses of organo-mineral fertilizers in the Ararat valley and in the cultivated lands of the republic has become urgent.

CONCLUSION

1. The soils of the experimental fields belong to the type of irrigated meadow gray soils, which are quite strong (A + B = 81 cm), have an average content of available nutrient elements, are alkaline (pH: 7.6–8.4) and are favorable not only for cereals, but also for cultivation of all plant species.
2. The crop of winter wheat and barley grain in the Ararat valley provided a high-quality yield of 5–7 t ha^{-1} grain within the tested fertilization scheme. In the case of optimization of organo-mineral fertilizers, the yield of plants can reach 8–9 t ha^{-1}.
3. The amounts of nitrogen and potassium production removal from winter wheat and barley crops are about 2 times higher than the doses of applied fertilizers, and the amount of phosphorus is almost balanced with the doses of fertilizers, that is, the plants use more of the nitrogen and potassium in the soil.
4. The amount of nutrient elements removed by 1 t of grain and corresponding straw mass in the wheat sowing varied between N: 31–36; P_2O_5: 12–13, K_2O: 27–29, and in barley seeds in the range of - 27–30, 11–12 and 23–24 kg ha^{-1}, respectively.

REFERENCES

Agroclimatic resources of Armenian edited by R.S. Mkrtchyan, D.H. Melkonyan & V.H. Badalyan, 2011, Yerevan, 41–49 (in Armenian).

Alexandrova, L.N. & Naidonova, O.A. 1976. *Laboratory-practical trainings on soil science*, 3rd edition, Kolos, Leningrad, 280 pp. (in Russian).

Babayan, G.B. 1980. B*alance of nitrogen, phosphorus and potassium in the agriculture of the Armenian SSR*. Yerevan, pp. 13–180 (in Russian).

Collings, G.H. 1960. *Comercial fertilizers, their sources and use*. Moscow, pp. 515–520 (in Russian).

Conova, A.M. & Samoilov, L.N. 2015. Removal of nutrients cultural and weeds in the crop rotation. *Agrochemistry* **5**, 46–53 (in Russian).

Dospekhov, B.A. 1985. *Methodology of Field Practice*. Agropromizdat, Moscow, pp. 207–248 (in Russian).

Dubovik, D.V. & Dubovik, E.Y. 2015. The accumulation of macro- and microelements by winter wheet roots on grey forest soil in the slope agrolandscape. *Agrochemistry* **10**, 50–56 (in Russian).

Harutyunyan, S.S. 2009. Biological removal of nitrogen, phosphorus and potassium by tomatoes in different background of fertilizing. *Biological journal of Armenia* **61**(4), 43–50 (in Russian).
Harutyunyan, S.S. & Miqaelyan, H.A. 2021. Biological removal of main nutrient elements by tomato and pepper of the background of organic-mineral fertilizers and microbiological concentrates. *Biological journal of Armenia* **73**(3), 18–26 (in Russian).
Hlisnikovsky, L., Cermak, P., Kunzova, E. & Barlog, P. 2019. The effect of application of potassium, magnesium and sulphur on wheat and barley grain yield and protein content. *Agronomy Research* **17**(5), 1905–1917.
Khachidze, A.S. & Mamedov, M.G. 2009. Effect of cultivar features and growing technology on the removal of nutrients by cereal crops and the return of fertilizers. *Agrochemistry* **5**, 42–48 (in Russian).
Linina, A. & Ruza, A. 2018. The influence of cultivar, weather conditions and nitrogen fertilizer on winter wheat grain yield. *Agronomy Research* **16**(1), 147–156.
Peterburgsky, A.V. 1979. Cycle and balance of nutrients in agriculture. *Science,* 30–47 (in Russian).
Shafran, S.A., Vasil'ev, A.I. & Andreev, S.S. 2008. Efficiency of nitrogen top-dressing of winter wheat cultivars on leached chernozem. *Agrochemistry* **2**, 18–25 (in Russian).
Sineshchekov, V.E. & Tkachenko, G.I. 2018. Nitrogen removal by spring wheat grain harvest with soil tillage minimisation. *Agrochemistry* **12**, 22–25 (in Russian).
Skudra, I. & Ruza, A. 2016. Winter wheat grain baking quality depending on environmental conditions and fertilizer. *Agronomy Research* **14**(Issue II), 1460–1466.
Soil science edited by J.S. Kaurichev. Kolos, 1982, Moscow, 25–35 (in Russian).
Tanchyk, S., Litvinov, D., Butenko, A., Litvinova, O., Pavlov, O., Babenko, A., Shpyrka, N., Onychko, V., Masyk, I. & Onychko, T. 2021. Fixed nitrogen in agriculture and its role in agrocenoses. *Agronomy Research* **19**(2), 601–611.
Voitovich, N.V. & Loboda, B.P. 2005. Nutrient uptake by crops in different agrocenoses of the central nonchernozemic zone. *Agrochemistry* **10**, 48–52 (in Russian).
Yagodin, B.A. 1987. *Workshop on agricultural chemistry*. Agropromizdat, Moscow, 512 pp. (in Russian).