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Balance and coefficients of usage of nitrogen, phosphorus and potassium from the soil and fertilizers by tomatoes and peppers in the conditions of Ararat Plain of Armenia

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Abstract. The aim of the research is to reveal the biological removal, balance and coefficient rates of nitrogen, phosphorus and potassium use from soil, organo-mineral fertilizers and microbiological concentrates by tomato and sweet pepper in the conditions of Ararat Plain of Armenia. Field experiments were carried out in 2017–2019, on typical irrigated meadow brown soils in triplicate. It has been established that at tomato yields of 50–75 t ha^{-1}, the biological removal of nitrogen ranges from 110 (without fertilizers) to 178 kg ha^{-1} ($N_{150}P_{80}$), P_2O_5: 61–89, K_2O_5: 166–289 kg ha^{-1}, and at pepper yields of 23–32 t ha^{-1}, respectively - 55–76, 38–49 and 77–106 kg ha^{-1}. Tomato utilization rates from the soil (unfertilized version) are: N: 118, P_2O_5: 37, K_2O: 8%, and the negative balances are respectively: 107, 67 and 109 kg ha^{-1}, similar data for pepper were recorded at: N: 59, P_2O_5: 23, K_2O: 4% and 52, 44, 20 kg ha^{-1}. From fertilizers, tomato absorbs 27–45% nitrogen, 11–48% P_2O_5 and 48–72% K_2O with negative balances (N: 15–55, P_2O_5: 14–76, K_2O: 34–79 kg ha^{-1}), in poultry litter the balance P_2O_5 = + 94.2 kg ha^{-1}. For pepper, however, these data were respectively amounted to: N: 6–14, P_2O_5: 10–15, K_2O: 9–20%, and the balances were positive. Microbiological concentrates (Azoto + phosphate Barvar) showed poor effectiveness as compared to organo-mineral fertilizers. It was also found that the lower the amount of a mobile element in the soil, or in the fertilizer dose, the higher its utilization rate and vice versa.

Key words: tomato, pepper, soil, organo - mineral fertilizers, balance, coefficients of usage, nitrogen, phosphorus, potassium.

INTRODUCTION

Vegetable crops (tomato, pepper, cucumber, zucchini, cabbage, potatoes, herbs, etc.) occupy an important place in the human diet, providing the body with carbohydrates, vitamins and minerals. These plants are particularly sensitive to soil conditions and mineral nutrition, at the same time they intensively absorb and accumulate harmful substances in fruits (nitrates, nitrosamines, residual amounts of pesticides and heavy metals (HM), etc. Therefore, alternative farming and biotechnology should be primarily applied in these phytocenoses. Currently, many countries prohibit the application of ammonium nitrate to vegetable crops to avoid the nitrate accumulation in their commercial products. From this point of view, tomato and pepper in the conditions of Ararat Plain (the main region of Armenia for the cultivation of these crops) provide high yields, absorbing a significant amount of nutrients from soil and fertilizers.

The coefficients of use of nutrients by plants from the soil (CUS) and fertilizers (CUF) vary widely and depend on the plant type and variety, soil and climatic conditions, the capacity and agrochemical properties of the root layer of the soil, moisture availability and the level of agricultural technology, fertilizer systems, and many other factors affecting the growth and development of plants. In thirty- year experiments at the Dolgoprudny agrochemical station, winter wheat, rye, potatoes, oats in crop rotation used 26% nitrogen, 27% P_2O_5 and 57% K_2O from manure, and 51, 32 and 67%, from mineral fertilizers, respectively (Bugaev & Osipova, 1966). Approximately the same CUF data were obtained on light loamy soils of Belarus, and the utilization coefficients from the soil were: nitrogen: 13.4; P_2O_5: 7.6–9.3; K_2O: 15.3–20.8% (Bragin, 1970). Eight-year studies showed that the CUS and CUF of nitrogen, phosphorus and potassium in peas were respectively: 7 and 15, 15 and 30, 10 and 20, in winter rye: 15 and 50, 10 and 20, 10 and 30, in spring wheat: 10 and 55, 7 and 18, 7 and 60, oats: 10 and 60, 10 and 25, 10 and 60, corn: 20 and 50, 15 and 15, 15 and 40% (Sharyapov, 1976). When $N_{90}P_{60}K_{90}$ was applied locally together with 2 t ha^{-1} straw, the N utilization rate of barley was higher by 6–18% compared to the scattered application method (Shmyreva et al., 2004).

The results of 11.5 thousand field experiments showed that the coefficients of the nutrient elements use from mineral and organic fertilizers are very low, with row crops and technical crops more than by grains (Makarov & Nikitina, 1976). It was also found that the application of organic fertilizers increased plant yield by 34.1%, and mineral fertilizers by 14.1%, and the losses of NO_2-, NO_3-, and NH_4^+ from various organic fertilizers were significantly reduced than from nitrogen fertilizers. Application of manure at 40, 60 and 80 t ha^{-1} + $N_{56}P_{48}K_{60}$, increased soil humus content by 0.18; 0.24; and 0.21%, P_2O_5-41, 61 and 61, K_2O-36, 46 and 54 mg kg^{-1}, respectively (Kristaponyte, 2005; Cesoniene & Rutkoviene, 2009). Application of organic fertilizers such as litter and non-litter manure, bird droppings, composts, siderate, straw increased the yield of agricultural crops from 21 to 69%, while complete mineral fertilizers from 29 to 97% (Merzlaya, 2017). Vermicomost at doses of 3, 5 and 7 t ha^{-1} increased the potato yield of Aramis variety and the soil humus content (Butenko et al., 2020). Nitrogen utilization by plants per year of application is 42% with large fluctuations from 12 to 70%. Afterwards, nitrogen fertilizers show very low effectiveness (Korenkov, 1976).

Research with ^{15}N has shown that the coefficients of use of nitrogen fertilizers by plants in the year of application are 35–54%, and in the second and third years they drop sharply (Burtseva, 1969; Zamyatina & Varyushkina, 1973). The isotope method also revealed that fertilizers significantly increase the absorption of nutrients from the soil itself. Depending on soil conditions and plant species, this shift varies for nitrogen from 6 to 119%, for phosphorus: 39–87 and for potassium: 50–100%. This is explained by the fact that, under the influence of fertilizer, a more powerful root system is formed, penetrating a large volume of soil, thereby increasing the absorption of nutrients from the soil (Dontsov & Kravchenko, 1985). Compared to field experiments, in lysimetric and vegetation experiments, the results for CUS and CUF are somewhat overestimated, which is due to the coverage of the entire volume of soil by the plant root system, because of which plants absorb nutrients from soil and fertilizers almost equally (Lavreva, 1971).

The degree of absorption of nutrients by wheat and barley plants in rainfed conditions strongly depends on soil moisture. In wet years, plants used 51–52% nitrogen, 24–29% P_2O_5 and 5.7% K_2O from the soil, and in dry years 24.3; 12.2 and 2.2% respectively. Similar data from fertilizers are 2–3 times less (Khachatryan & Abazyan, 1986). In studies on CUS and CUF by fruit crops very low levels of nutrient elements assimilation was registered. CUS constitute: N: 2–9, P_2O_5: 4.6–5.2; K_2O: 1.0–3.6%, and from fertilizers: 0.8–8.0% (Grigel et al., 1986).

Research data on establishing the balance and degree of use of nutrients from the soil and fertilizers by tomato and pepper are almost absent in the literature. However, some studies have investigated the changes in lycopene and ß-carotene content during fruit ripening of some tomato varieties (Radzevičius et al., 2009), as well as their quality and yield when the roots of these plants are colonized with arbuscular mycorrhizal (AM) fungi of the Funelliformis mosseae strain at the same time, the yield increased by 50%, and the content of sugars, amino acids, and ß-amylase also increased compared to the option without fungal colonization (Palumbo et al., 2020). In field and vegatation experiments, the effectiveness of organo-mineral fertilizers on the yield and quality of tomato, as well as the biological removal of macronutrients by these plants was established (Harutyunyan, 2009; Harutyunyan et al., 2020).

Purpose of the research and problems

Tomatoes and peppers cultivated in field and greenhouse conditions are used almost all year round by people of different countries, and modern technologies are aimed not only at increasing yields, but also at improving the quality of the fruits of these crops. The aim of our research is to find ways to stabilize mineral nutrition of these crops and preserve soil fertility. In accordance with the stated goal, the research objectives include: 1. to reveal qualitative indices of tomato and pepper fruits at moderate doses of organo-mineral fertilizers, 2. to calculate the coefficients of use of nitrogen, phosphorus and potassium from the soil and fertilizers by these crops in field experiments, 3. to determine the NPK balance on the background of equivalent doses of different fertilizers and microbiological concentrates. The presented research is conducted in Armenia for the first time, and its scientific novelty is directly related to the disclosure of the degree of absorption of nutrients from soil and fertilizers, which are important arguments for preventing soil dehumification in farms.

Materials and methods

Field experiments were carried out on typically irrigated meadow brown soils in 2017–2019 on tomato 'Lia' and sweet pepper 'Almond 55' varieties of Armenian selection in Voskehat educational and experimental farm of National Agrarian University of Armenia (NAUA), located almost in the center of Ararat Plain (Etchmiadzin region, 40°08′and 44°19′ at an altitude of 850 m above sea level). The experiments were carried out in triple repetition (70 tomato and 80 pepper plants in each repetition), the distance between their rows was 80 cm. The schemes of experiments are given in Tables 2–8, where the principles of the only difference and comparison between the options are preserved.

Ammonium nitrate (N: 33%), simple superphosphate (P_2O_5: 18%), potassium salt (K_2O: 40%), and organic fertilizers - semi-rotted cattle manure (N: 0.48; P_2O_5: 0.23; K_2O: 0.55%), granulated poultry manure (N: 3.45; P_2O_5: 3.64; K_2O: 2.87% - according to certificate), organomix (a mixture of biohumus, peat and compost from organic waste:

N: 2.0; P_2O_5: 0.52; K_2O: 1.20% - according to the certificate), manufactured by ´ORWACO CJSC: an Armenian-Norwegian joint company were used as mineral fertilizers. Microbiological concentrates (Azoto and Phosphate Barvar) are produced in Iran in the form of a husk-like powder in packages of 100–120 g and are used in the form of aqueous solutions (water volume per one package is 1,000 liters). According to the certificate, Azoto Barvar contains nitrogen-fixing bacteria, Phosphate Barvar bacteria decomposing phosphorus-containing organic-mineral compounds of the soil that are hard for plants to access, converting P_2O_5 into mobile and water-soluble forms. All fertilizers were applied to the soil in spring (around April 20–25) as the main fertilizer before planting - as a strip at a depth of 20–25 cm with embedding. Agrotechnical measures (watering, hilling, weeding, control of weeds, pests and diseases) were carried out according to all options and repetitions simultaneously.

Soil samples of field participants were taken from the upper layer (0–40 cm depth) where tomato and pepper root systems (rhizosphere layer) are distributed. Laboratory soil analyzes were carried out according to generally accepted methods: mechanical composition - by the classical pipette method and assessed according to the gradation of N.A. Kachinsky (Alexandrova & Naidionova, 1976; Soil science edited by I.S. Kaurichev, 1982) with a P^H potentiometer, humus by Tyurin, hygroscopic moisture by gravimetric method, CO^2 by calcimeter, dry residue of aqueous extract by calcination method, total nitrogen by Kjeldahl, easily hydrolyzed nitrogen by Tyurin & Kononova, mobile phosphorus and potassium by Machigin with the further use of FEC and a flame photometer (Yagodin, 1987). The yield and vegetative mass of plants were measured by the gravimetric method (fresh and air-dried form). In air-dried plant samples, the content of total nitrogen was determined by the Kjeldahl method, phosphorus and potassium by wet ashing according to Ginzburg, with further determination of phosphorus by FEC, and potassium by a flame photometer. The sugar content in tomato and pepper fruits was determined by the Bertrand method, vitamin C by I. Murri (Yagodin, 1987), nitrates by nitrate tester ´SOEKS´ (NUC-0.19-2), and dry substances by drying and weight method. Statistical processing of yield data was carried out by analysis of variance (Dospekhov, 1985).

The coefficients of NPK use by tomato and pepper were calculated on the basis of the biological removal of these elements from the soil in control variants and by the difference method from fertilizers (Yagodin, 1987) using the following formulas:

$$Cs = \frac{100 \cdot Bc}{Cs} \quad (1)$$

where Cs – coefficients of nutrient utilization by plants from the soil, %; Bc – biological nutrient removal in the control variant, kg ha^{-1}; Cs – content of mobile nutrients in the soil rhizosphere, kg ha^{-1},

$$Dc = \frac{Bf - Bc \cdot 100}{D} \quad (2)$$

where Dc – difference coefficient, %; Bf – biological removal of the element in the fertilized version, kg ha^{-1}; Bc – biological removal of the element in the control variant, kg ha^{-1}; D is the dose of fertilizer in the fertilized version, kg ha^{-1} of active substance.

Balance coefficients for the use of nutrients from fertilizers are determined by the formula:

$$Bc = \frac{Bf \cdot 100}{D} \quad (3)$$

where Bc – balance coefficient, %; Bf – biological removal of the element in the fertilized version, kg ha^{-1}; D is the dose of fertilizer in the fertilized version, kg ha^{-1} of active substance.

RESULTS AND DISCUSSION

The Ararat Plain (805–950 m altitude) is the most active agricultural region of Armenia. The sum of active temperatures (above 10 °C) per year reaches 4,000–4,300 °C (average temperature +10.6 °C), in winter the absolute minimum temperature reaches (-30) - (-35 °C), the amount of precipitation -200–260 mm, humidity coefficient according to Shashko is 0.20–0.25 (Agroclimatic resources of Armenian edited by R.S. Mkrtchyan et al., 2011). Two sites were selected for laying field experiments not far from each other in order to avoid soil fatigue (Table 1). After the 2017 experience, field No. 1 was left as black fallow in 2018. The volumetric weight of the soil in field No. 1 was 1.2 kg dm^3, and in field No. 2: 1.4 kg dm^3.

Table 1. Physico-mechanical and agrochemical characteristics of experimental soils Plots

Experimental plots, Experimental years and rhizosphere layer	Mechanical composition (sum of particles < 0.01 mm) of phys. Clay %	Hygroscopic moisture, %	$CaCo_3$ by CO_2, %	Dry residue of aqueous extract, %	pH(H_2O)	Humus, %	Total nitrogen, %	Mobile forms, mg per 100 g of soil		
								N	P_2O_5	K_2O
Field No. 1, 2017–2019, 0–40 cm	25.4	3.62	1.51	0.025	7.54	1.30	0.068	1.40	3.40	34
Field No. 2, 2018, 0–40 cm	32.4	4.34	4.60	0.064	7.46	1.84	0.120	2.15	3.08	46

Table 1 shows that by mechanical composition, the soil of experimental plot No. 1 is light loamy (25.4%), and No. 2 is medium loamy (32.4%). The soils of both plots are slightly alkaline (pH-7.54 and 7.46), slightly carbonate (1.51 and 4.60%), humus is 1.30 and 1.84%, respectively, the soils are not saline with easily soluble salts (dry residue of water extract does not exceed 0.064%), the availability of mobile forms of nitrogen according to the Tyurin and Kononova gradations in both plots is very low, P_2O_5 and K_2O according to the Machinin gradation are optimal.

The research has shown that the yield of tomato and pepper in experimental plot No. 2 was higher (due to relatively high fertility and active crop rotation there) than in the first one (where in recent years, including 2018 it was fallow). The average tomato yield for three years (Table 2) in the variant without fertilizers was 51.8 t ha^{-1} (2.71 t ha^{-1} in terms of air-dry weight), and in the fertilized variants it ranged from 62.6 (3.08) - Azoto Phosphate Barvar up to 75.3 / 3.98 t ha^{-1} (NP_{150P80}). It should be noted that the tomato yield in 2017 variants of organomix (58.9/2.02 t ha^{-1}) and Azoto-Phosphate Barvar (59.9/2.00 t ha^{-1}, and also in 2018 69.8/5.07 t ha^{-1}) compared to control were unreliable (LSD_{05}: in 2017 9.94 t, 2018 - 7.28 t). Similar phenomenon in the observed variants was observed in 2017 in pepper experiment (Table 3, LSD_{05}: 6.07 t).

Table 2. The influence of organo-mineral fertilizers and microbiological concentrates on the yield, the content of nutrients in tomato fruits and their removal by fruits

Experiment options	Harvest t ha^{-1}, fresh air. dry				Average for 3 years on air-dry weight, content, % removal, kg ha^{-1}		
	2017	2018	2019	average	N	P_2O_5	K_2O
1. No fertilizer (control)	51.1	64.7	39.5	51.8	2.70	1.48	3.66
	2.01	4.48	1.64	2.71	73.2	40.1	99.2
2. Mineral fertilizers	66.5	90.7	66.3	74.5	2.63	1.43	3.78
($N_{150}P_{80}K_{150}$ kg ha^{-1})	3.18	6.28	2.36	3.94	103.6	56.3	148.9
3. Manure 30 t ha^{-1}	63.0	92.2	66.4	73.9	3.04	1.49	4.63
	2.09	6.38	2.96	3.81	115.8	56.8	176.4
4. Poultry manure 5 t ha^{-1}	61.2	88.7	65.8	71.9	2.89	1.44	3.90
	2.15	6.14	2.52	3.60	104.0	51.8	140.4
5. Organomix	58.9	90.0	61.0	70.0	3.04	1.49	4.15
(ORWACO) 9 t ha^{-1}	2.02	6.17	3.04	3.74	113.7	55.7	155.2
6. Azoto+PhosphateBarvar	59.9	69.8	58.2	62.6	3.57	1.49	4.45
(100 + 100 g ha^{-1} in 1,000 L water)	2.00	5.07	2.17	3.08	110.0	45.9	137.1
7. Mineral fertilizers	71.6	89.7	64.5	75.3	3.08	1.54	4.74
$N_{150}P_{80}$ kg ha^{-1}	2.94	6.20	2.79	3.98	122.6	61.3	188.7
Sx^{-}, %	5.2	2.8	3.9	4.0	-	-	-
*LSD_{05}, t for fresh weight	9.94	7.28	7.24	8.39	-	-	-

**LSD* – Lowest Significant Difference.

Pepper yield was almost 2 or more times lower than that of tomato, and the content of nutrients in the components of the fruit and their removal by these plants was comparatively less (Table 3). The table shows that the average yield pepper for three years in the control variant was 23.1 t ha^{-1} (1.61 t ha^{-1} in terms of air-dry weight), and in fertilized variants this figure varied from 28.7/1.82 t ha^{-1} (Azoto +Phosphate Barvar) up to 32.0/2.17 t ha^{-1} (poultry manure). Pepper fruits were divided into two components: fruit pulp and seedpod with petioles in order to establish the nutrient content of these components separetrly, as well as to account for the excretion by these organs.

Table 3 shows that the fresh fruit pulp of pepper variety 'Almond 55' made up 75–80% of the weight of the fruit, and in terms of air-dry weight: 64–72%, i.e. testes with petiole in fresh fruits account for 20–25%. Table 3 also shows that in the fruit pulp of pepper the nutritional elements within the studied options were: N: 1.55–1.96; P_2O_5: 1.27–1.35 and K_2O: 2.11–3.29%, and in the seedpod with a petiole, respectively: 1.84–2.30; 1.29–1.37; 2.96–3.88%.

Table 3. The influence of organo-mineral fertilized and microbiological concentrates on the yield, the content of nutrients in pepper fruits and their removal by fruits

Experiment options	Harvest componens	Harvest, t ha^{-1}, fresh air. dry				3 – year average by air-dry weight, content, % removal, kg ha^{-1}		
		2017	2018	2019	Average	N	P_2O_5	K_2O
1. No fertilizer	Fruits	14.7	41.2	13.5	23.1		-	-
(control)		1.01	2.82	0.99	1.61			
	Fruit pulp	10.8	30.5	10.6	17.3	1.66	1.32	2.17
		0.63	1.47	0.68	1.03	17.1	13.6	22.4
	Seed with	3.9	10.7	2.9	5.8	2.06	1.37	3.82
	a petiole	0.38	1.05	0.31	0.58	11.9	7.9	22.2
2. Mineral fertilizers	Fruits	21.6	54.5	19.1	31.7	-	-	-
($N_{150}P_{80}K_{150}$ kg ha^{-1})		1.45	3.01	1.31	1.92			
	Fruit pulp	15.8	40.3	14.8	23.6	1.55	1.31	3.29
		0.88	2.39	0.87	1.38	21.4	18.1	45.4
	Seed with	5.8	14.2	4.3	8.1	1.84	1.35	3.88
	a petiole	0.57	0.62	0.44	0.54	9.9	7.3	21.0
3. Manure 30 t ha^{-1}	Fruits	22.1	54.5	18.4	31.7	-	-	-
		1.41	3.64	1.28	2.11			
	Fruit pulp	16.7	42.0	13.0	23.9	1.74	1.35	2.37
		0.90	2.44	0.85	1.40	24.4	18.9	33.2
	Seed with	5.4	12.5	5.4	7.8	1.94	1.30	3.42
	a petiole	0.51	1.20	0.43	0.71	13.8	9.2	24.3
4. Poultry manure	Fruits	23.4	54.8	17.7	32.0	-	-	-
5 t ha^{-1}		1.56	3.64	1.30	2.17			
	Fruit pulp	17.5	41.6	12.5	23.9	1.66	1.27	2.11
		0.98	2.37	0.84	1.40	23.2	17.8	29.5
	Seed with	5.9	13.2	5.2	8.1	2.13	1.34	2.96
	a petiole	0.58	1.27	0.46	0.77	16.4	10.3	22.8
5. Organo-mix	Fruits	19.0	53.3	17.6	30.0	-	-	-
(ORWACO) 9 t ha^{-1}		1.02	3.72	1.26	2.00			
	Fruit pulp	14.8	42.0	13.6	23.5	1.96	1.35	2.24
		0.73	2.51	0.84	1.36	26.7	18.4	30.5
	Seed with	4.2	11.3	4.0	6.5	1.97	1.29	3.16
	a petiole	0.29	1.21	0.42	0.64	12.6	8.3	20.2
6. Azoto+phosphate	Fruits	20.8	49.2	16.1	28.7	-	-	-
Barvar		1.14	3.27	1.04	1.82			
(100 + 100 g ha^{-1} in	Fruit pulp	17.2	40.8	12.5	23.5	1.67	1.30	2.89
1,000 L water)		0.71	2.27	0.69	1.23	20.5	16.0	35.6
	Seed with	3.6	8.4	3.6	5.2	2.00	1.30	3.22
	a petiole	0.43	1.00	0.35	0.59	11.8	7.7	19.0
7. Mineral fertilizers	Fruits	22.7	54.8	18.1	31.9	-	-	-
$N_{150}P_{80}$ kg ha^{-1}		1.40	3.79	1.05	2.08			
	Fruit pulp	18.2	44.2	11.4	24.6	1.83	1.29	2.57
		1.11	2.45	0.71	1.42	26.0	18.3	36.5
	Seed with	4.5	10.6	6.7	7.3	2.30	1.35	3.88
	a petiole	0.29	1.34	0.34	0.66	15.2	8.9	25.6
Sx^{-},%	-	9.5	1.7	3.2	3.7	-	-	-
LSD_{05}, t for fresh weight	-	6.07	2.68	1.70	3.36	-	-	-

Thus, the removal of nitrogen from the fruit pulp of pepper in the unfertilized version was: 17.1; P_2O_5: 13.6 and K_2O: 22.4 kg ha^{-1}, and seedpod with petioles: 11.9; 7.9 and 22.2 kg ha^{-1}, respectively. In fertilized variants, these indicators were in the range: nitrogen: 20.5–26.7 and 9.9–16.4; P_2O_5: 16.0–18.9 and 7.3–10.3; K_2O: 29.5–45.4 and 19.0–25.6 kg ha^{-1}, respectively. From the above data, it is evident that organo-mineral fertilizers significantly increased the pulp of the fruit, reducing the removal of nutrients through the seedpod with petioles.

The dry matter content in tomato fruits varied from 4.75 to 5.11%, total sugars: 4.0–5.2%, and vitamin C: 22.7–29.8 mg %, and in some fertilized varieties these indicators were lower than the control option, which can be explained by the increase in yield in these options (Table 4). As for the content of nitrates in fruits, it should be noted that in all variants these compounds were 28 (control) to 35 mg kg^{-1} ($N_{150}P_{80}K_{150}$ and organomix) higher than the maximum permissible concentration MPC for open ground (150 mg kg^{-1}), which may be due to varietal characteristics and a particularly active effect on the plant of soil No. 2, which has always been in intensive exploitation with the use of organo-mineral fertilizers.

Table 4. Effect of organo-mineral fertilizers and microbiological concentrates on the content of nitrates and quality indicators of tomato and pepper fruits

Crop	Experiment options	Nitrates, mg kg^{-1}				3 – year average		
		2017	2018	2019	average	dry matter, %	total sugars, %	vitamin C, mg %
Tomato	1. Without fertilizer (control)	185	191	159	178	5.00	4.0	25.3
	2. Mineral fertilizers $N_{150}P_{80}K_{150}$ kg ha^{-1}	173	203	180	185	5.09	4.4	25.7
	3. Manure 30 t ha^{-1}	178	197	171	182	4.90	4.8	29.8
	4. Poultry manure 5 t ha^{-1}	174	195	178	182	4.75	5.2	26.6
	5. Organomix (ORWACO) 9 t ha^{-1}	179	196	179	185	5.09	4.1	22.9
	6. Azoto+phosphate Barvar (100 + 100 g ha^{-1} in 1,000 L water)	173	202	174	183	4.78	4.3	26.4
	7. Mineral fertilizers ($N_{150}P_{80}$ kg ha^{-1})	173	190	177	180	5.11	3.6	22.7
Pepper	1. Without fertilizer (control)	52	56	48	52	6.98	5.9	163
	2. Mineral fertilizers with $N_{150}P_{80}K_{150}$ kg ha^{-1}	59	76	68	68	7.87	5.4	138
	3. Manure 30 t ha^{-1}	54	81	64	66	6.64	5.4	150
	4. Poultry manure 5 t ha^{-1}	59	73	62	65	6.80	5.8	146
	5. Organomix (ORWACO) 9 t ha^{-1}	57	60	66	61	6.74	5.3	150
	6. Azoto+phosphate Barvar (100 + 100 g ha^{-1} in 1,000 L water)	58	72	58	62	6.18	6.8	146
	7. Mineral fertilizers ($N_{150}P_{80}$ kg ha^{-1})	58	67	51	59	6.43	5.6	158

The data in Table 4 also show that in comparison with tomatoes, pepper fruits contained more dry matter, sugars, and especially vitamin C, which is 5–6 times higher than the content in tomato. At the same time, it is observed that in the unfertilized version these substances were much higher than in the target variants (except for dry substances in option $N_{150}P_{80}K_{150}$ and total sugars in the option of microbiological concentrates). As for nitrates, in pepper fruits these compounds were 3–3.5 times lower than the MPC for open ground (200 mg kg^{-1}).

Table 5. Effect of organo-mineral fertilizers and microbiological concentrates on the above-ground and root mass of tomato and pepper, t ha^{-1} (fresh/air-dry weight)

Crop	Experiment options	Above ground mass				Root mass			
		2017	2018	2019	average	2017	2018	2019	average
Tomato	1. Wihout fertilizer (control)	15.77	29.31	12.36	19.15	1.75	2.96	1.89	2.20
		2.52	5.16	2.20	3.29	0.39	0.65	0.54	0.53
	2. Mineral fertilizers	18.21	38.31	23.88	26.80	2.34	4.54	3.18	3.35
	($N_{150}P_{80}K_{150}$ kg ha^{-1})	3.06	6.92	4.24	4.74	0.71	1.10	0.90	0.90
	3. Manure 30 t ha^{-1}	18.13	35.94	25.44	26.50	2.42	3.84	3.39	3.22
		3.26	6.80	4.53	4.86	0.76	0.93	0.96	0.88
	4. Poultry manure 5 t ha^{-1}	17.64	35.92	23.07	25.54	2.10	3.10	3.10	2.77
		2.99	6.84	4.10	4.64	0.62	0.74	0.88	0.75
	5. Organomix (ORWACO)	17.78	32.54	22.37	24.23	1.98	3.32	2.90	2.73
	9 t ha^{-1}	3.03	6.04	3.98	4.35	0.60	0.72	0.83	0.72
	6. Azoto+phosphate Barvar	17.07	29.67	13.36	20.03	1.90	2.92	2.27	2.36
	(100 + 100 g ha^{-1} in 1,000 L in water)	3.03	5.61	2.38	3.67	0.54	0.65	0.65	0.61
	7. Mineral fertilizers	17.74	36.68	24.11	26.18	2.22	4.51	3.20	3.31
	($N_{150}P_{80}$ kg ha^{-1})	3.09	7.16	4.29	4.85	0.68	1.07	0.91	0.89
Pepper	1. Wihout fertilizer	7.94	6.59	6.70	7.08	0.77	1.25	0.73	0.92
	(control)	2.30	1.43	1.59	1.77	0.35	0.34	0.24	0.31
	2. Mineral fertilizers	8.31	8.98	8.24	8.51	0.85	2.22	1.04	1.37
	($N_{150}P_{80}K_{150}$ kg ha^{-1})	2.41	2.04	1.95	2.13	0.41	0.56	0.35	0.44
	3. Manure 30 t ha^{-1}	7.49	9.35	8.11	8.32	0.77	1.76	1.09	1.21
		2.19	2.18	1.78	2.05	0.35	0.48	0.36	0.40
	4. Poultry manure 5 t ha^{-1}	8.95	8.52	7.49	8.32	0.85	1.75	0.95	1.18
		2.63	1.86	1.78	2.09	0.38	0.46	0.32	0.39
	5. Organomix (ORWACO)	6.71	9.21	7.50	7.81	0.66	1.98	1.00	1.21
	9 t ha^{-1}	1.90	2.06	1.78	1.91	0.31	0.51	0.33	0.38
	6. Azoto+phosphate Barvar	10.11	7.84	6.87	8.27	1.01	1.58	0.79	1.13
	(100 + 100 g ha^{-1} in 1,000 L in water)	2.97	1.65	1.63	2.08	0.46	0.41	0.26	0.38
	7. Mineral fertilizers	10.48	9.05	7.89	9.14	0.73	2.11	1.07	1.30
	($N_{150}P_{80}$ kg ha^{-1})	3.04	2.03	1.87	2.31	0.34	0.55	0.36	0.42

Biological removal of nitrogen and ash elements from the soil and fertilizers by the commercial yield and vegetative mass of cultivated crops is considered to be the main basis for establishing the degree of nutrient assimilation. Table 5 shows data on the above-ground and root mass of the studied crops for the studied year. The vegetative mass of tomato varied over the years according to the yield pattern, i.e. the highest aboveground and root mass was formed in the 2nd field plot (2018), when, as in pepper, there was no big difference between years. On average for 3 years the wet above-ground mass of tomato in the control variant was 19.15 t ha^{-1} (3.29 t ha^{-1} air-dry weight), while the root mass was 2.20 and 0.53 t ha^{-1}. In fertilized versions the above-ground mass varied from 20.03/3.67 t ha^{-1} (Azoto+phosphate Barvar) to 26.80/4.74 t ha^{-1} ($N_{150}P_{80}K_{150}$), and the root mass in the same variants: 2.36/0.61 and 3.35/0.90 t ha^{-1}. As for pepper, its above-ground wet weight for 3 years in the control variant was 7.08 t ha^{-1} (1.77 t ha^{-1} air-dry weight), root weight: 0.92 and 0.31 t ha^{-1}. In fertilized variants, these data ranged from 7.81/1.91–9.14/2.31 t ha^{-1} and 1.13/0.38–1.37/0.44 t ha^{-1}, respectively. According to Table 5, the wet root mass of a tomato averages 10–11% of the total vegetative mass, while for pepper it is 11.5–14%, and in terms of air-dry weight, these data increase relatively.

In average samples (mixed sample from all variants) of the above-ground mass of tomato, the total nitrogen was: 0.99; P_2O_5: 0.56 and K_2O: 1.74%, in roots: 0.86; 0.54 and 1.76% by air-dry weight. In similar organs of pepper, these data were respectively: 1.28; 0.78; 1.53 and 1.14; 0.86; 1.68% by air-dry weight. Based on the above data and average air-dry data for three years of vegetative mass (Table 5), the removal of nutrients by the above-ground and root mass of tomato and pepper was determined (Table 6). This table shows that the removal of nitrogen by the above-ground mass of tomato varied from 32.6 (control) to 48.1 kg ha^{-1} (manure 30 t ha^{-1}), P_2O_5: 18.4–27.2 and K_2O: 57.2–84.6 kg ha^{-1} in the same variants, and the root mass, respectively, was 4.6–7.7; 2.9–4.9 and 9.3–15.8 kg ha^{-1} in control and $N_{150}P_{80}K_{150}$ options. Nitrogen removal by the above-ground pepper mass varied from 22.7 (control) to 29.6 kg ha^{-1} ($N_{150}P_{80}$), P_2O_5: 13.8–18.0; K_2O: 27.1–35.3 kg ha^{-1} in the same variants, and root mass, respectively: 3.5–5.0; 2.7–3.8 and 5.2–7.4 kg ha^{-1} in the control and $N_{150}P_{80}K_{150}$ options.

Table 6. Removal of main nutrients by the vegetative mass of tomato and pepper, kg ha^{-1} per air-dry weight (according to average data for 2017–2019)

Crop	Experiment options	Above ground mass			Root mass		
		N	P_2O_5	K_2O	N	P_2O_5	K_2O
Tomato	1. Without fertilizer (control)	32.6	18.4	57.2	4.6	2.9	9.3
	2. Mineral fertilizers ($N_{150}P_{80}K_{150}$ kg ha^{-1})	46.9	26.5	82.5	7.7	4.9	15.8
	3. Manure 30 t ha^{-1}	48.1	27.2	84.6	7.6	4.8	15.5
	4. Poultry manure 5 t ha^{-1}	45.9	26.0	80.7	6.5	4.1	13.2
	5. Organomix (ORWACO) 9 t ha^{-1}	43.1	24.4	75.7	6.2	3.9	12.7
	6. Azoto+phosphate Barvar (100 + 100 g ha^{-1} in 1,000 L water)	36.3	20.6	63.9	5.2	3.3	10.7
	7. Mineral fertilizers ($N_{150}P_{80}$ kg ha^{-1})	48.0	27.2	84.4	7.7	4.8	15.7
Pepper	1. Without fertilizer (control)	22.7	13.8	27.1	3.5	2.7	5.2
	2. Mineral fertilizers ($N_{150}P_{80}K_{150}$ kg ha^{-1})	27.3	16.6	32.6	5.0	3.8	7.4
	3. Manure 30 t ha^{-1}	26.2	16.0	31.4	4.6	3.4	6.7
	4. Poultry manure 5 t ha^{-1}	26.8	16.3	32.0	4.4	3.4	6.6
	5. Organomix (ORWACO) 9 t ha^{-1}	24.4	14.9	29.2	4.3	3.3	6.4
	6. Azoto+phosphate Barvar (100 + 100 g ha^{-1} in 1,000 L water)	26.6	16.2	31.8	4.3	3.3	6.4
	7. Mineral fertilizers ($N_{150}P_{80}$ kg ha^{-1})	29.6	18.0	35.3	4.8	3.6	7.1

On the basis of nutrient elements removal by tomato and pepper fruits (Tables 2 and 3) and the vegetative mass of these plants (Table 6), the annual biological removal of nitrogen, phosphorus and potassium was determined, the data of which are the basis for accounting the coefficients of their use from soil and fertilizers (Table 7). This table shows that the main part of the annual biological removal of nutrients from tomatoes was produced by the fruits, which on average was: nitrogen: 68, P_2O_5: 65 and K_2O: 63%. 28–30% of NPK was: removed by the above-ground mass of tomato, and only 3–4% by the root system. At 50–75 tha^{-1} of tomato yield, the applied doses of fertilizers remain in deficit, if we also take into account that about 30–50% of the elements of the fertilizers applied to the soil are absorbed by the plants. In pepper, the biological removal of NPK at a yield of 23–32 t ha^{-1} does not exceed the dose of applied fertilizers. As for microbiological concentrates, they showed poor effectiveness on both crops, due to the low efficiency of bacterial strains.

In addition to biological removal, to calculate the coefficients of use of nutrients from the soil (in non-fertilized variants), it is necessary to have general data of the mobile forms of NPK in the rhizosphere layer of the studied plants. The active rhizosphere of tomato and pepper in the irrigated conditions of Ararat Plain lies in a layer of 0–40 cm, and individual roots deepen to 60–80 cm depth. Based on the data of the 40 cm soil layer and the volumetric weights of the experimental plots (field No. 1–1.2 and field No. 2–1.4 kg dm^{-3}), the total soil mass was determined, which for the fields was 4,800 and 5,600 t ha^{-1}, respectively. The mass of medium loamy soil with an arable horizon of 20 cm per hectare is on average 3 million kg and each mg of nutrient element per 100 g of soil is equivalent to 30 kg ha^{-1} (Yagodin, 1987). Thus, according to Table 1, the content of mobile nitrogen in the rhizosphere of field No. 1 is: 67.2; P_2O_5: 163.2 and K_2O: 1632.0 kg ha^{-1}, and in field No. 2, respectively: 120.4; 172.5 and 2576.0 kg ha^{-1}. Total nitrogen on average for the two fields is: 93.8; P_2O_5: 167.9 and K_2O: 2104 kg ha^{-1}, on the basis of which the degree of use of NPK by tomato and pepper from the soil in unfertilized variants, in the Azoto+phosphate Barvar variant, as well as K_2O in the $N_{150}P_{80}$ variant were calculated.

Table 7 shows that the coefficients of use of nutrients from the soil by tomato on average per year are: nitrogen: 117.7; P_2O_5: 36.6 and K_2O: 7.9%, and for pepper, respectively: 58.8; 22.6 and 3.7%.

High degree of nitrogen absorption by tomato (117.7%) and pepper (58.8%) is due to its low content in soils (1.40 and 2.15 mg per 100 g of soil). Regarding CUF, nitrogen uptake in tomato ranges from 26.7 (poultry manure) to 45.3% ($N_{150}P_{80}$). P_2O_5: 11.3– 9.9 in the same variants and K_2O: 47.8 (poultry manure) - 72% (organomix). The same dynamics on the use of nutrients from fertilizers is repeated in pepper, at a significantly low level of biological removal. The coefficients of use of nutrients from soil and organic-mineral fertilizers show that the less a nutrient element is in the substrate, the higher the coefficient of its use by the plant and vice versa. For example, a high content of P_2O_5 in poultry manure (182.0 kg at a dose of 5 t ha^{-1}) reduces the degree of absorption of this element (11.3% in tomato and 5.4% in pepper).

Balance coefficients give an idea not only about the degree of absorption of nutrients from fertilizers and soil by plants, but also about the possible change in soil availability when applying this fertilizer. Naturally, balance coefficients are always higher than difference coefficients, and on poor soils they are always lower than on rich soils. If the balance coefficient is 100%, then the balance is zero and the supply of soil with elements does not change; if the coefficient is less than 100%, the balance is positive and the soil will be enriched with this element. If the coefficient is more than 100%, the balance is negative, and the soil will be depleted of this element (Yagodin, 1987). From these considerations it follows that in tomato, in addition to nitrogen and phosphorus in the dose of poultry manure (90.7 and 45%) and nitrogen in the organomix (90.6%) in fertilized variants, the balance coefficients of nutrients are mainly negative, while in pepper, they are positive.

Table 7. Biological removal and utilization rates of nitrogen, phosphorus and potassium from soil and fertilizers by tomato and pepper

Crop	Experiment options	Biological output, kg ha^{-1}			CUS and CUF, %			Balance coefficients, %		
		N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
Tomato	1. Without fertilizer (control)	110.4	61.4	165.7	117.7	36.6	7.9	-	-	-
	2. Mineral fertilizers ($N_{150}P_{80}K_{150}$ kg ha^{-1})	158.2	87.7	247.2	31.9	32.9	54.3	105.5	109.6	164.8
	3. Manure 30 t ha^{-1}	171.5	88.8	276.5	42.4	39.7	67.2	119.1	128.7	167.6
	4. Poultry manure 5 t ha^{-1}	156.4	81.9	234.3	26.7	11.3	47.8	90.7	45.0	163.3
	5. Organomix (ORWACO) 9 t ha^{-1}	163.0	84.0	243.5	29.2	48.3	72.0	90.6	179.5	225.5
	6. Azoto+phosphate Barvar (100 + 100 g ha^{-1} in 1,000 L water)	151.5	69.8	211.7	161.5	41.6	10.1	-	-	-
	7. Mineral fertilizers ($N_{150}P_{80}$ kg ha^{-1})	178.3	93.3	288.8	45.3	39.9	13.7	118.9	116.6	-
Pepper	1. Without fertilizer (control)	55.2	38.0	76.9	58.8	22.6	3.7	-	-	-
	2. Mineral fertilizers ($N_{150}P_{80}K_{150}$ kg ha^{-1})	63.6	45.8	106.4	5.6	9.8	19.7	42.4	57.2	70.9
	3. Manure 30 t ha^{-1}	69.0	47.5	95.6	9.6	13.8	11.3	47.9	68.8	57.9
	4. Poultry manure 5 t ha^{-1}	70.8	47.8	90.9	9.0	5.4	9.8	41.0	26.3	63.3
	5. Organomix (ORWACO) 9 t ha^{-1}	68.0	44.9	86.3	7.1	14.7	8.7	37.8	95.9	79.9
	6. Azoto+phosphate Barvar (100 + 100 g ha^{-1} in 1,000 L water)	63.2	43.2	92.7	67.4	25.7	4.4	-	-	-
	7. Mineral fertilizers ($N_{150}P_{80}$ kg ha^{-1})	75.6	48.8	104.5	13.6	13.5	5.0	50.4	61.0	-

The balances of basic nutrients and humus in world agriculture are highly variable and clearly depend on human activity. In the middle of the 20th century, the assessment of the economic balance in agriculture became most widespread, and included in its structure the removal of NPK by main and by-products, all losses and gains of nutrients, including symbiotic and non-symbiotic nitrogen fixation (Yurkin, 1974, 1975). The balance deficit in agriculture of the USSR in 1940 was for nitrogen: 73.8, phosphorus: 68.3 and potassium: 76.1%, meanwhile, on soils with an average level of actual fertility, the balance of nutrients should be positive, for nitrogen by 10–20, phosphorus - 80–100 and potassium 10% (Pryanishnikov, 1945). The negative balance of basic nutrients (N: 37, P_2O_5: 5 and K_2O: 31 kg ha^{-1}) in grain crops of the USSR continued until 1976 (Peterburgsky, 1979).

The maximum amount of mineral fertilizers in Russia and Ukraine was used in the second half of the 1980s - about 13 million tons of NPK, which was only 60% of the need, and since 1990 their use decreased by 3 times, organic fertilizers and lime by 2.5 times, because of which the NPK balance for 1991–1995 amounted to (-58), for 1998–1999 (-65) kg ha^{-1}, and the yield of grain crops in 1999–2000 was 1.56 t ha^{-1}, while in France it was 7.26; in England- 7.17; Germany- 6.37; USA- 5.85 t ha^{-1} (Lebed et, al., 1997; Miloshchenko, 1999; Mineev, 2000; Mineev & Bichkova, 2003; Shafran, 2004).

In arable soils of Belarus for 1993–2001 the K_2O balance was +33 kg ha^{-1}, and in Western Siberia of Russia for 1988–2017 at NPK 75, 100, 125% was also positive (Bogdevich et al., 2004; Yakimenko, 2019), but in Russia in general the NPK balance from 1992 to 2018 was negative. The nitrogen deficit in agriculture in 2018 was 26 kg ha^{-1} (Kudeyarov, 2018, 2021; Shafran, 2020). Potassium plays a huge role in the mineral nutrition of plants. The gross content of potassium in the arable soil layer is 5–50 times more than nitrogen and 8–40 times more than phosphorus. However, the removal of potassium by agricultural crops on average exceeds the amount of nitrogen and phosphorus. In plants, potassium is in ionic form and is not included in the organic compounds of cells. Potassium increases winter hardiness and plant resistance to fungal and bacterial diseases (Agrochemistry edited by Yagodin, 1982). In a stationary field experiment on the light chestnut soil of the Saratov Trans-Volga region, the decisive role of the essential forms of potassium in the potassium nutrition of plants and in replenishing the negative balance of this element was established (Kononchuk & Nikitina, 2002). The balance of the main nutrients in the conditions of Armenia was formed according to the same dynamics as in Russia. According to long-term studies, after 1975, the gross and economic balances of nitrogen and phosphorus changed in a positive direction, and after the collapse of the USSR, all three elements in all lands became negative (Babayan, 1978, 1980, 1985; Harutyunyan et al., 2023).

It should also be noted that numerous political, economic, social, military, environmental, cultural and educational problems have been revealed in the post-Soviet countries, which have a strong negative impact on agriculture and the environment (Raukas, 2010; Harutyunyan & Sargsyan, 2018).

In our research, the balance of nutrients was deduced in order to establish all items of inputs and expenditures in tomato and pepper phytocenoses (Table 8). The expenditure items include: biological removal of elements, losses of nutrients by erosion (mainly irrigation), which for row crops in Ararat Plain is: N: 5.56; P_2O_5: 8.42 and K_2O: 12.86 kg ha^{-1} and by leaching: N: 6.80; P_2O_5: 1.25 and K_2O: 14.06 kg ha^{-1} (Babayan, 1980), gaseous nitrogen losses from applied doses of organic-mineral fertilizers are assumed to be on average 20% (Korenkov, 1976). In the inputs used: NPK intake with fertilizers, with irrigation water, with precipitation (N: 3.60; P_2O_5: no, K_2O: 7.0 kg ha^{-1}) and nitrogen from non-symbiotic nitrogen fixation. In the zone of brown chestnut and brown soils, as well as carbonate humus of Armenia, the supply of nitrogen by free-living nitrogen fixers is assumed to be 5.2 kg ha^{-1} per year (Babayan, 1980).

For irrigation of tomato and pepper phytocenoses, artesian water from Ararat Plain from a depth of 100–120 m is used. During the growing season, these plantations are watered 17 times with an irrigation rate of 600 m^3 ha^{-1} (irrigation rate during the vegetation 10,200 m^3 ha^{-1}). Laboratory analyzes of some artesian water sources showed that the total nitrogen content is: 0.65; P_2O_5: 0.37 and K_2O: 7.50 mg L^{-1}. Based on these data and irrigation rates, the amount of NPK per hectare of tomato and pepper was established, which was: N:6.63; P_2O_5: 3.77 and K_2O:76.5 kg ha^{-1}. However, under irrigation conditions it is extremely difficult to neutralize the influence of weeds on cultivated annual crops. Throughout the growing season, there is a fierce competition plants and weeds, and only active ecological, agrotechnical and biological methods of struggle against them ensure the expected yield. In a flax crop rotation which included potatoes, barley, winter wheat, winter rye, annual and perennial weeds consumed a significant amount of NPK, which negatively affected crop productivity (Conova & Samoilov, 2015).

Table 8. Balance of main nutrients in tomato and pepper plantations between cultivated

Crop	Experiment options	Total losses include: biological removal, erosion, leaching, gaseous losses of nitrogen from fertilizers, kg ha^{-1}			Total revenue include: fertilizers, irrigation water, precipitation, non-symbiotic nitrogen fixation, kg ha^{-1}			Balance, + - kg ha^{-1}, balance intensity, %		
		N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
Tomato	1. Without fertilizer (control)	122.8	71.1	192.6	15.4	3.8	83.5	-107.4	-67.3	-109.1
								12.5	5.3	43.4
	2. Mineral fertilizers ($N_{150}P_{80}K_{150}$ kg ha^{-1})	200.6	97.4	274.1	165.4	83.8	233.5	-35.2	-13.6	-40.6
								82.5	86.0	85.2
	3. Manure 30 t ha^{-1}	212.9	98.5	303.4	159.4	72.8	248.5	-53.5	-25.7	-54.9
								74.9	73.9	81.9
	4. Poultry manure 5 t ha^{-1}	202.8	91.6	261.2	187.9	185.8	227.0	-14.9	+94.2	-34.2
								92.7	202.8	86.9
	5. Organomix (ORWACO) 9tha^{-1}	211.4	93.7	270.4	195.4	50.6	191.5	-16.0	-43.1	-78.9
								92.4	54.0	70.8
	6. Azoto+phosphate Barvar (100 + 100 g ha^{-1} in 1,000 L water)	163.9	79.5	238.6	15.4	3.8	83.5	-148.5	-75.7	-155.1
								9.4	4.8	35.0
	7. Mineral fertilizers ($N_{150}P_{80}$ kg ha^{-1})	220.7	103.0	315.7	165.4	83.8	83.5	-55.3	-19.2	-232.2
								74.9	81.4	26.4
Pepper	1. Without fertilizer (control)	67.6	47.7	103.8	15.4	3.8	83.5	-52.2	-43.9	-20.3
								22.8	8.0	80.4
	2. Mineral fertilizers ($N_{150}P_{80}K_{150}$ kg ha^{-1})	106.0	55.5	133.3	165.4	83.8	233.5	+59.4	+28.3	+100.0
								156.0	151.0	175.2
	3. Manure 30 t ha^{-1}	110.4	57.2	122.5	159.4	72.8	248.5	+49.0	+15.6	+126.0
								144.4	127.3	202.9
	4. Poultry manure 5 t ha^{-1}	117.2	57.5	117.8	187.9	185.8	227.0	+70.7	+128.3	+109.2
								160.3	323.1	192.7
	5. Organomix (ORWACO) 9 t ha^{-1}	116.4	54.0	113.2	195.4	50.6	191.5	+79.0	-4.0	+78.3
								167.9	92.7	169.2
	6. Azoto+phosphate Barvar (100 + 100 g ha^{-1} in 1,000 L water)	75.6	52.9	119.6	15.4	3.8	83.5	-59.7	-48.7	-35.3
								20.5	7.2	70.3
	7. Mineral fertilizers ($N_{150}P_{80}$ kg ha^{-1})	118.0	58.5	131.4	165.4	83.8	83.5	+47.4	+25.3	-47.9
								140.2	143.2	63.5

Both balance coefficients and balances of nutrients, as well as their intensity, directly reflect the level of deficiency or surplus of nutrients in agrocenoses, revealing the dynamism of soil fertility. Table 8 shows that in the tomato phytocenosis, except for P_2O_5 introduced by poultry manure, the nutrients in all fertilized options are negative, and in the pepper plantation they are positive: nitrogen: 52.2–148.5; P_2O_5: 43.9–75.7 and K_2O: 20.3– 55.1 kg ha^{-1}. Nitrogen balance intensity in tomato ranges from 75–93, P_2O_5: 54–86.7 and K_2O: 71–87%. In the $N_{150}P_{80}$ variant, the negative K_2O balance and the intensity of the balance in tomato was: 232.2 kg ha^{-1} and 26.4%, and in pepper: 47.9 kg ha^{-1} and 63.5%.

The data in Table 8 show that in order to ensure a high tomato yield in Ararat Plain, it is necessary to increase the doses of nitrogen and potassium by 50, and P_2O_5 by 20%. It is necessary to maintain the applied doses of complete mineral and organic fertilizers to stabilize the yield at the level of 35 t ha^{-1} in pepper plantations.

CONCLUSION

1. In all phytocenoses of Ararat Plain of Armenia, the first limiting factor among macroelements is nitrogen, because the soils of this zone are poor in humus and nitrogen, and P_2O_5 and K_2O in certain field areas are moderately and optimally provided.
2. In tomato and pepper plantations, the effectiveness of equivalent doses of mineral fertilizers ($N_{150}P_{80}K_{150}$ kg ha^{-1}), semi-freshened manure (30 t ha^{-1}), granulated poultry manure (5 t ha^{-1}), and organomix (9 t ha^{-1}) are estimated at almost the same level, and bacterial concentrations (Azoto+phosphate Barvar) turned out to be weaker.
3. The biological removal of basic nutrients at tomato yield of 70–75 t ha^{-1} exceeds the doses of applied fertilizers, and in pepper 30–32 t ha^{-1} these doses remain in excess.
4. Under intensive irrigation conditions, tomato at 51 t ha^{-1} yield absorbs 118% nitrogen, 37% P_2O_5 and 8.0% K_2O from the soil, while pepper at 23 t ha^{-1} yield, respectively: 59, 23 and 4%. The low utilization coefficient of K_2O by plants is due to its relatively high content in the soil.
5. The coefficient of nitrogen use by tomato from mineral fertilizers varies from 32 to 45%, P_2O_5: 33–40 and K_2O: 54%, and from manure, poultry manure and organomix, respectively: 27–42, 11–48 and 48–72%. Similar data in pepper are significantly low. The balance coefficients of nutrients in tomato mostly exceed 100%, while in pepper it reaches a maximum of 70%.
6. Nitrogen losses by irrigation erosion and leaching from irrigated meadow brown soils of Ararat Plain are: 12.4 P_2O_5: 9.7; K_2O: 26.9 kg ha^{-1} per year. The input from atmospheric precipitation, irrigation waters and non-symbiotic nitrogen fixation are: N: 15.4; P_2O_5: 3.8; K_2O: 83.5 kg ha^{-1}.
7. In tomato phytocenosis, except for phosphorus introduced by poultry manure, the balance of nutrients in all fertilized options is negative, and in pepper plantation it is positive. The intensity of the nitrogen balance in tomato at full organic-mineral fertilization varies in the ranges from 75–93, P_2O_5: 54–88 and K_2O: 71–87%, and in pepper all three elements exceeded 100%.

PRACTICAL SUGGESTION: To provide high yield of tomatoes (70–75 h kg^{-1}) and to ensure positive balance of main nutrients in the Ararat Plain the farmers are recommended to fertilize the soil with mineral fertilizers in doses $N_{200}P_{120}K_{200}$ k ha^{-1}, 40 t ha^{-1} of semi-rotten manure or 6 t ha^{-1} of granulated poultry manure.

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