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The system of soil protection and general balance of main nutrient elements in perennial plantations of semi-desert natural soil zone of Armenia

S.S. Harutyunyan*, L.G. Matevosyan, A.G. Ghukasyan and M.H. Galstyan

Scientific Centre of Agriculture, Isi-le-Mulino 1, AM1101 Ejmiatsin, Armavir region, Armenia
*Correspondence: ss_harutyunyan@mail.ru

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Abstract. The aim of the research is to study the biological removal of the main nutrient elements from the most common technical grape varieties, as well as from apricot and peach plantations in the farms, situated on semi-desert natural soils of Armenia, to identify the extent of their input and losses due to natural factors and to calculate the balance associated with the soil conservation system in the absence of comprehensive fertilization. In the inter-row spaces of all fruit plantations and even vineyards of the republic, grass cover of productive significance has been established (4.5–6.5 t ha^{-1} yield of air-dry grass), through which the removal of nutrient elements is 2–3 times higher than the biological removal through trees and vines. The research was conducted in 2015–2020, in the grape, apricot and peach plantations of the semi-desert natural zone of Armenia (Armavir region), where the irrigation norm is 5,000 m^3 ha^{-1}, and the atmospheric precipitation is 256 mm, through which 40 kg ha^{-1} N, 2 kg ha^{-1} P_2O_5, and 44 kg ha^{-1} K_2O enter the soil. The losses due to erosion and washing away are N - 12 kg ha^{-1}, P_2O_5 - 7 kg ha^{-1}, K_2O - 75 kg ha^{-1}. The balance of nutrient elements in all plantations is negative, nitrogen in plantations with industrial grass cover is 154, P_2O_5 - 52, K_2O - 311, and in the system of black fallow - 15, 16 and 85 kg ha^{-1}, respectively. The negative balance of nitrogen in apricot and peach plantations is 121, P_2O_5 - 44, K_2O - 296 kg ha^{-1}.

Key words: grass stand, black fallow, grape vine, apricot tree, peach tree, balance.

INTRODUCTION

The nutrient balance in soils reflects their general agrochemical characteristics, being the primary condition for the rational use of organic fertilizers and for increasing soil fertility, and is one of the important principles for ensuring the ecological safety of plant products and the environment. In agrochemical research, the balance approach has intensified, especially with the intensification of agriculture and with the addition of fertilizers per unit area, which resulted in a positive nitrogen-phosphorus balance in Russia, Ukraine, Belarus, Moldova, and Eastern Europe in the 1980s (Dasberg et al., 1984; Donos, 1988; Shafran & Korchaghina, 1990; Ladonin & Velichko, 1994; Mineyev, 2000). Studies conducted in Armenia have shown that in 1976–1983 nitrogen-phosphorus balance in arable land and perennial plantations was +61.8 and +38.2 and K_2O was negative (-22.5 kg ha^{-1}) (Avagyan, 1980; Babayan, 1980, 1985).

After the break-up of the Soviet Union, unprecedented changes took place in the agro-complex of Armenia: privatization of lands and agricultural objects, as a result of which 340 thousand farms were formed, natural plots (about 150 thousand) were divided into 1200 thousand small plots, where crop rotation, irrigation and application of mechanisms became very difficult. The use of organic fertilizers has been sharply reduced, as a result of which the deficit of nitrogen, phosphorus and potassium in all agricultural soils is increasing year by year, the yield of crops has been significantly reduced. Prior to land privatization (1991), the agricultural system in Armenia was intensive. The annual use of mineral fertilizers was 350 thousand tons and 1.8 million tons of local organic fertilizers, which contained 57,000 tons of N, 33,300 tons of P_2O_5 and 24,300 tons of K_2O (per 100% of active substance), providing arable lands and perennial plantations with $N_{100}P_{58}K_{43}$ kg ha^{-1} doses (Harutyunyan & Sabeti, 2012). After the privatization of the land the use of organic fertilizers became spontaneous. Every year an average of 30–40 thousand tons of ammonium nitrate (in physical weight) is used, but not by all farmers, and phosphorus-potassium fertilizers are imported in very limited quantities by large landowners for their needs.

The deficit of nutrient elements is also deepening in Russia, where the largest amount of fertilizers was used in the 1980s - about 13 million tons of NPK, which was only 60% of the real demand. Since 1990, the use of mineral fertilizers in the Russian Federation has been reduced thrice, and of organic fertilizers 2.5 times, as a result of which the balance of nutrient elements in the soil has become negative, leading to a sharp decline in arable land efficiency (Milashchenko, 1999; Mineyev, 2000).

The negative balance of nutrients in Russia's arable land continues to grow. If in 2011 the negative nitrogen balance was 34–50 per year, P_2O_5 was 9–16, K_2O was 38–64 kg ha^{-1} (Kudeyarov & Semenov, 2014), then in 2016 the deficit was 63.5 kg, 23 and 62.2 kg ha^{-1}, respectively, for 18 kg of nitrogen, 6 kg of phosphorus and 5 kg of potassium per hectare of active substance (Kudeyarov, 2018). Almost the same result is recorded in the lands of the non-chernozem zone of Russia in 2011–2013, where the balance of basic nutrients was negative. nitrogen - 22, phosphorus - 6, potassium - 31 kg ha^{-1}, and the compensation was 40, 45 and 21%, respectively (Shafran, 2016). According to the author, in the arable lands of Russia in 2018 16 kg ha^{-1} of nitrogen was used, and the removal through harvest was 42 kg ha^{-1}, deepening the negative balance to - 26 kg ha^{-1} (Shafran, 2020).

At present, Armenia pays no attention to soil protection systems, to the ecological situation of the environment and the consumption of soil humus and nutrient elements. During the last 30 years, detailed studies have been conducted in different regions of Armenia on different varieties concerning the removal of the main nutrient elements from grape and fruit plantations, as well as from the fields of clean-cultivated crops. As a result, large variations in the removal of nutrient elements were detected, depending on the doses of fertilizers, irrigation factor, and the size of the vegetative mass (Harutyunyan & Harutyunyan, 1985; Harutyunyan, 1995; Harutyunyan, 1996; Harutyunyan & Harutyunyan, 2002; Harutyunyan & Grigoryan, 2005, Harutyunyan & Sabeti, 2012; & Miqaelyan, 2021).

Purpose of the research and problems

The aim of the research is to study the reasons of decrease in soil fertility and crop yield in perennial plantations of Armenia, depending on soil protection system. For this reason it is necessary to specify the extent of biological removal of main nutrients from the most common technical varieties of grapes, as well as apricot and peach plantations. It is necessary to calculate the entrance and losses of nitrogen, phosphorus and potassium, as well as their balance due to natural factors, in the absence of fertilization.

The scientific novelty of the work is directly connected with the protection of the balance of main nutrients and soil fertility in perennial plantations. The results of the research will enable us to rely on the balance of main nutrients in different phytocenoses and to work out an optimal system of fertilization, which will prevent the decline of soil fertility and dehumification. This is the utilitarian goal of the study.

Materials and methods

Field experiments were conducted in 2015–2020 in the semi-desert zone (236.2 thousand hectares), one of the most favorable natural areas for grape, apricot and peach plantations cultivated in Armenia, which occupies the lowlands of the foothills of Ararat valley, Ararat, Armavir, Aragatsotn, Kotayk districts (800–1,250 m above sea level), where the climate is very dry, with cold winters and hot summers. The average annual air temperature is 10–12 °C, the sum of temperatures above 10 °C is 3,800–4,200 °C, the average annual precipitation is 230–300 mm, the humidity coefficient is 0.3. Four soil types have been formed in this zone: semi-desert gray (152.2 thousand ha), irrigated meadow gray (53 thousand ha), saline-alkaline (29 thousand ha), paleohydromorphic (2 thousand ha). Perennial plantations are based exclusively on semi-desert gray soils, located in the communities of Armavir region, where the irrigation norm is 5,000 m^3 ha^{-1}. Irrigation is provided by Nerkin Hrazdan and Talin canals.

The vineyards are 10–25 years old with a feeding area of 1.5: 2.5 m. The white grape variety 'Rkatsiteli' is cultivated in Aragats community, the red variety 'Anahit' and the black variety 'Haghtanak' are cultivated in Aghavnatun community, the white variety 'Kangun' and the black variety 'Haghtanak' are cultivated in Talvorik community. The vines are trained in multi-trunk fan system, raised on the supporting wires. The vines are buried in winter, and the spring pruning is done according to the strength. The mixed plantation of apricots (Yerevan and Sateni varieties) is about 25–30 years old, the feeding area of the trees is 8 : 6 m, the mixed peach plantation (varieties Mijahas Narinj and Limoni) is 12 years old, the feeding area of the trees is 5 : 4 m. The apricot and peach plantations are situated in the community (village) Mrgashat (All the communities are in the Armavir region). The founding of mixed plantations is associated with tree pollination. The yield from the vines and trees, pruned and leaf masses were calculated on 45 vines and 30 trees, and the grass was calculated on about 500 m^2 (the hay was removed with the help of a hand scythe, as hay-cutting machines are not available in these farms).

Soil sampling in all plantations was done according to genetic horizons (up to the depth of active root propagation), irrigation water samples were taken from the canals entering the plantations. The total data of the last 6 years of atmospheric precipitation were taken from the agrometeorological station of Armavir city. The yield of vines and trees, mass of spring prunings, mass of green cuttings, leaf mass and the mass of harvested hay was calculated by the weight method. The samples were made air-dry in the laboratory. Soil, water and plant analyses were performed in the agrochemistry laboratory of the Agricultural Science Center. The balance of main nutrient elements was calculated by the method accepted in agronomy (Yurkin, 1974; Guidelines for compiling the balance..., 1975).

Physico-mechanical and agrochemical analyses of soils were performed by well-known methods (Alexandrova & Naidionova, 1976; Workshop on agricultural chemistry by Yagodin, 1987). The data on the pH of the water content of the dry matter, as well as total nitrogen, were not included in Table 1, so as not to overload it, but their values are presented in the text. Soil analyses were performed on samples sifted with a 1 mm sieve. The mechanical composition was determined by the classical pipette method and evaluated according to the N.A. Kachinsky classification scale. The pH of the water extract which characterizes the actual acidity of the soil, was determined by the potentiometric method, and the dry residue by the weight method. Carbonates were determined by calcimeter using 10% HCl. Humus was determined by the I.V. Turin method, total nitrogen by the Kjeldal method. The easily hydrolyzable nitrogen in the soil was determined by I.V. Turin and M.M. Kononova methods, which is considered to be an indicator of mobile nitrogen compounds, and the mobile forms of phosphorus and potassium by the Machigin method, which is based on the principle of removing them by a 1% $(NH_4)_2SO_4$ solution.

Total nitrogen, P_2O_5 and K_2O in plant samples were determined by K. Ginsburg wet ash method, after which nitrogen was determined by the Kjeldal micromethod, P_2O_5 by photoelectric calorimeter, and K_2O by flame photometer (Workshop on agricultural chemistry by Yagodin, 1987). The content of nitrogen, phosphorus and potassium in atmospheric precipitation and irrigation water was determined according to the instruction developed by O.B. Gasparyan (1970).

RESULTS AND DISCUSSION

The soils of the test site belong to the semi-desert gray soil type. The data in Table 1 show that the mechanical composition in these soils (the sum of < 0.01 mm particles or physical clay) in different genetic horizons according to N.A. Kachinsky classification (Soil science edited by Kaurichev, 1982) is rated as light-clay-sandy (20–30%), medium-clay-sandy (30–45%), heavy-clay-sandy (45–60%), and only in the horizon C_1 of the peach plantation (107–140 cm) it is considered light-clayey (63.5%). In all the mentioned soils, the pH of the water extract is alkaline and is in the range of 8.1–8.6, and the dry residue of the water extract in the upper humus horizons A and B is 0.09–0.21%, i.e. the content of harmful salts (Na_2CO_3, $NaHCO_3$, NaCl, Na_2SO_4) does not represent any danger to the plants. The total nitrogen content in the soil profile is also low, ranging from 0.02 to 0.097%, which is primarily due to the low humus content. As for carbonates, their content in the horizons A and B of the studied lands (except for the Talvorik test field: 14.5–15.4%) is low, ranging from 1.1 to 5.4%. The humus content in the soil horizons A and B is rather low due to the active mineralization of organic matter at high temperatures.

The soils of the test field according to Turin and Kononova scale have very low (< 3) and low (4 mg per 100 g soil) nitrogen content (mobile or available to plants). The upper horizons of soils, studied according to the Machigin grouping, are also assessed at the same levels by their content of P_2O_5: very low (< 1), low (1–1.5) and medium (1.5–3 mg per 100 g in soil). The content of mobile forms of nitrogen and phosphorus in the soil depends on both the degree of mineralization of organic matter and the hydrolysis and oxidation of mineral compounds, where the microbiological activity of the soil plays an important role. As for K_2O, test soils have high (40–60) and very high (> 60 mg per 100 g soil) levels according to the Machigin scale (Workshop on agricultural chemistry..., 1987).

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

Community, plantation and variety	Genetic horizon and depth, cm		< 0.01 mm - sum of particles (phys. clay), %	$CaCO_3$ according to CO_2, %	Humus, %	Mobile forms mg per 100 g in the soil		
						N	P_2O_5	K_2O
Aragats, grape (Rkatsiteli, white variety)	A	0–36	46.1	1.5	1.57	4.20	1.95	85
	B_1	37–67	35.7	2.3	0.98	2.52	2.10	70
	B_2	68–85	24.3	5.4	0.83	2.24	1.57	68
	C	86–120	21.3	8.2	0.77	1.40	0.82	60
Aghavnatun, grape (Anahit - red), (Haghtanak - black)	A	0–35	44.4	2.7	1.58	3.92	1.68	75
	B	36–62	37.0	4.9	0.54	3.36	1.64	71
	C	63–130	27.9	8.7	0.50	2.24	1.33	57
Talvorik, grape (Kangun - white), (Haghtanak - black)	A	0–46	35.4	14.5	1.68	3.84	2.81	53
	B	47–65	37.2	15.4	1.52	3.61	1.73	46
	C	66–107	38.6	10.9	1.08	2.29	1.02	48
Mrgashat, apricot tree (Yerevani, Sateni) mixed plantation	A	0–24	47.5	1.1	1.26	3.61	2.10	80
	B_1	25–46	43.8	-	0.79	3.18	1.04	88
	B_2	47–71	35.4	-	0.34	3.00	0.62	73
	C_1	72–102	34.4	1.5	0.33	2.82	0.56	73
Mrgashat, peach tree (Narinj mijahas, Limoni) mixed plantation	A	0–33	41.9	1.5	1.54	3.84	1.90	67
	B	34–70	45.3	2.1	0.89	3.40	1.56	64
	C_1	71–107	59.3	-	0.78	3.15	0.56	65
	C_2	108–140	63.5	1.1	0.70	2.62	0.50	67

The average yield of 3 years from grape plantations of different varieties varies considerably in different communities, which in our observations depends not only on the characteristics of the variety, but also on the individual approaches of the owner farmer, the effectiveness of disease and pest control, as well as the irrigation factor (Table 2). From this point of view, Aghavnatun community is well supplied with irrigation water, as it is located at the bottom of Nerkin Hrazdan canal. From the data in Table 2 it can be seen that despite the rather large differences in the yields of the studied grape varieties, in case of recalculation of 10.0 t ha^{-1}, the weight of grape juice fluctuates in the approximate range 8.8. t ha^{-1} (Hakhtanak) - 9.57 t ha^{-1} (Kangun). In case of recalculation of 10.0 t ha^{-1} yield, there are bigger differences between grape stems (65.8 Kangun - 149.9 Hakhtanak kg ha^{-1} air-dry) and seeds (239.9 Hakhtanak - 293.1 Rkatsiteli kg ha^{-1} air-dry), which is definitely conditioned with varietal features. However, it should also be noted that the masses of the yield of the variety Hakhtanak, as well as the masses of their stems and seeds cultivated in two different places (Aghavnatun and Talvorik) are quite different, which in our opinion is conditioned by the level of agro-technical measures and violations in the irrigation water regime. The mass of the spring prunings (1,292–1452 kg ha^{-1}, air-dry) leaving the above-mentioned grape plantations, as well as the mass of green cuttings (275–398 kg ha^{-1}, air-dry) are quite close in different varieties, which is due to their almost identical growth intensity. It can also be seen from the table that at the end of the vegetation the leaf mass of the black variety Hakhtanak exceeds the leaf mass of the white varieties.

Table 2. Annual biomass removed from grape plantations (average of 2018–2020)

Community, variety and soil conservation system	Commodity yield and its structural elements				Air-dry, kg ha^{-1}			
	Yield, t ha^{-1}	Juice with peels, t ha^{-1}	Dry stem (air-dry), kg ha^{-1}	Seed (air-dry), kg ha^{-1}	Mass of spring prunings	Mass of green cuttings	Leaf mass	Mown hay
Aragats (Rkatsiteli), natural grass	5.48	5.20	43.5	160.6	1,452	275	741	6,580
Aghavnatun (Anahit), natural grass	14.89	13.77	162.7	375.4	1,448	367	798	6,667
Aghavnatun (Haghtanak), natural grass	21.18	19.36	249.8	508.2	1,292	295	854	6,533
Talvorik (Kangun), black fallow	6.69	6.40	44.0	163.5	1,352	345	814	-
Talvorik (Haghtanak), black fallow	10.04	8.84	150.5	290.2	1,350	398	1,029	-

The data in Table 3 show that the three-year average yield from the apricot plantations was 13.0 t ha^{-1} and from the peach plantation it was 10.2 t ha^{-1}. It should also be noted that with proper implementation of agro-technical measures, the yield from apricot and peach plantations in Armenia can reach 20–25 t ha^{-1}, which was often recorded in the 1980s. Nitrogen is the first limiting nutrient element for almost all crops in the soils of Armenia. It is not surprising that the N + manure combination provides the highest quality and high yield of peaches in other countries, too (Chatzitheodorou, et al., 2004). In case of recalculation on 10 t ha^{-1} of apricot, the pulp is 9.45 t ha^{-1}, the average mass of the kernel is 118.0 kg ha^{-1}, the shell of the kernel is 233.0 kg ha^{-1} (air-dry), while in the case of peaches these indices are respectively 9.08 t ha^{-1}, 30.6 and 389.0 kg ha^{-1} (air-dry). The pruned mass removed from the apricot plantation was about 200 kg more than the mass leaving the peach plantation in the spring, and the leaf mass in the peach plantation was about 110 kg more, which is due to both the size of the trees and the differences in their feeding surface. In addition, the wood of apricot trees is heavier than that of peach trees.

The differences in the masses of hay removed from grape and fruit plantations (Tables 2 and 3) are mainly due to the amount of harvested hay. In the inter-row spaces of grape plantations, hay is harvested 3 times: in late May, mid-July and mid-September (before harvest), and about 6.5 t ha^{-1} of dry grass is obtained. In apricot and peach plantations, hay is harvested twice (in mid-June, before the apricot harvest, and in late August, before the peach harvest), because the trees have more shading, and the resulting grass is about 4.5 t ha^{-1}.

Table 3. Annual biomass removed from apricot and peach plantations (average of 2015–2017)

Community and fruit type	Commodity yield and its structural elements				Air-dry, kg ha^{-1}		
	Yield, t ha^{-1}	Pulp, t ha^{-1}	Stone kernel (air-dry), kg ha^{-1}	Stone shell (air-dry), kg ha^{-1}	Mass of spring prunings	Leaf mass at the end of vegetation	Mown hay
Mrgashat, apricot tree (mixed plantation)	13.0	12.29	154.3	302.9	1,690	2,426	4,666
Mrgashat, peach tree (mixed plantation)	10.2	9.26	31.2	396.8	1,480	2,540	4,673

Removal of nitrogen and ash elements from the soil by means of crop and vegetative mass is considered to be the main article in the loss of nutrient balance.

Numerous studies show that the amounts of nitrogen, phosphorus and potassium removed from the soil depend on the crop variety characteristics, selective properties, yield level, soil-climatic conditions, soil moisture and agrotechnics, fertilizer doses, their ratio and other factors. The amount of nitrogen, phosphorus and potassium removed through 1 t of commodity and corresponding non-commodity products of different agricultural crops varies in a wide range, thus: autumn wheat: N - 24–27, P_2O_5 - 10–13, K_2O - 18–23 kg ha^{-1}, barley - 22–24, 9–10, 17–23, corn - 2–3, 1–2, 2–3, clover (grass) - 18–22, 5–6, 14–18, sugar beet - 4–6, 1–1.5, 7, potatoes - 4–6, 1.5–1.6, 4–7, raw cotton - 45, 15, 45, tomatoes - 2.1, 1.19, 3.21, pepper - 2.39, 1.65, 3.33, respectively (Harutyunyan & Miqaelyan, 2021; Krivenya, 1977; Marinchik & Zakharova, 1987; Peterburgsky, 1979).

54–110 kg ha^{-1} of nitrogen, 17–40 kg ha^{-1} phosphorus, 70–130 kg ha^{-1} potassium are removed from the soil annually through the vegetative mass of 10.0 t ha^{-1} of different varieties of grapes (Bondarenko, 1986; Malakhova, 1980; Merzhanyan, 1951; Serpukhovitina, 1982; Walessky & Kononikhina, 1983). In a number of European countries, grape and fruit plantations are founded on poor, rocky, sloping lands with mandatory grass cover in the intercropping space, which is a significant land conservation measure. However, the amount of nutrient elements removed from plantations with industrial grass cover is 2–5 times higher than the amount of nutrient elements removed from black fallow. And if the harvested grass remains in its place, the fertilizers are applied superficially, which preserves the quality of the grapes (Batukayev, 1999; Novosadyuk, 1988).

The content of main nutrient elements in different organs of grapes varies to a large extent, while the concentration of nitrogen in the same organ is 2–5, and that of K_2O is 2–10 times higher than the concentration of P_2O_5, due to which nitrogen and potassium are removed in larger quantities (Table 4). The data from Table 4 show that the lowest content of nutrient elements is present in the grape juice, where nitrogen content fluctuates between 0.076–0.102%, that of P_2O_5 - 0.029–0.045% and K_2O - 0.23–0.39%, which causes the largest removal of potassium by the clusters. The nitrogen content in the mass of spring prunings in different varieties varies in the range of 0.55–0.72%, P_2O_5 - 0.17–0.21%, K_2O - 0.58–1.22%, and the removal is definitely conditioned by the size of that mass. The content of nutrient elements in the green cuttings and leaf mass is significantly higher than their content in the trimmed mass, which leads to greater removal of these elements. As for natural grass, it has the highest content of nutrient elements, so their removal by this mass is 2–3 times greater than the amount removed by the vine. The data in Table 4 show that the nitrogen removed by the vines (taking into account the yield level) ranges from 29.1 to 55.4 kg ha^{-1}, P_2O_5 - 8.6–19.2 and K_2O - 34.4–110.0 kg ha^{-1}, while with the grass, respectively, 138.2–143.3, 31.4–36.0 and 209.7–216.5 kg ha^{-1} of nutrient elements are removed. In case of recalculation of 10.0 t ha^{-1} grape harvest and the corresponding vegetative mass, nitrogen removal (average of five field experiments) is 43.2, P_2O_5 - 12.9 and K_2O - 67.8 kg ha^{-1}, which can be compensated by organic mineral fertilizers in the conditions of black fallow.

Table 4. Biological removal of main nutrient elements from grape plantations (according to the initial data of Table 2)

Commu-nity, variety and soil conserva-tion system	Nutrient elements	Biomass (numerator %, denominator kg ha^{-1})							Removed, sum, kg ha^{-1}
		Juice with pulp	Dry stem (air-dry)	Seed (air-dry)	Mass of spring pru-nings (air-dry)	Mass of green cut-tings (air-dry)	Leaf mass (air-dry)	Mass of mown hay (air-dry)	
Aragats (Rkatsi-teli), natural grass	N	0.078/4.06	1.05/0.46	1.59/2.55	0.60/8.71	1.38/3.80	1.28/9.48	2.10/138.2	167.3
	P_2O_5	0.045/2.34	0.28/0.12	0.82/1.31	0.21/3.04	0.28/0.77	0.32/2.37	0.50/32.9	42.8
	K_2O	0.32/16.64	2.25/0.98	0.56/0.90	0.58/8.42	1.32/3.63	1.35/10.0	3.29/216.5	257.1
Aghav-natun (Anahit), natural grass	N	0.076/10.47	0.92/1.50	1.31/4.92	0.61/8.83	1.27/4.66	2.05/16.36	2.15/143.3	190.0
	P_2O_5	0.030/4.13	0.29/0.47	0.65/2.44	0.17/2.46	0.25/0.92	0.37/2.95	0.54/36.0	49.4
	K_2O	0.36/49.57	2.48/4.03	0.61/2.29	1.22/17.67	1.33/4.88	1.10/8.78	3.19/212.7	299.9
Aghav-natun (Haghta-nak), natural grass	N	0.095/18.39	1.07/2.67	1.77/9.00	0.55/7.11	1.39/4.10	1.65/14.09	2.14/139.8	195.2
	P_2O_5	0.040/7.74	0.36/0.90	0.71/3.61	0.17/2.20	0.35/1.03	0.44/3.76	0.48/31.4	50.6
	K_2O	0.37/71.63	4.22/10.54	0.57/2.90	0.67/8.66	1.62/4.78	1.37/11.70	3.21/209.7	319.9
Talvorik (Kangun), black fallow	N	0.082/5.25	0.76/0.33	1.52/2.49	0.72/9.73	1.53/5.28	1.51/12.29	–	35.4
	P_2O_5	0.029/1.86	0.24/0.11	0.55/0.90	0.21/2.84	0.31/1.07	0.22/1.79	–	8.6
	K_2O	0.23/14.70	2.49/1.10	0.56/0.92	0.59/7.98	1.29/4.45	0.64/5.21	–	34.4
Talvorik (Haghta-nak), black fallow	N	0.102/9.02	0.88/1.32	1.64/4.76	0.69/9.32	1.80/7.16	1.72/17.70	–	49.3
	P_2O_5	0.038/3.36	0.28/0.42	0.65/1,89	0.21/2.84	0.49/1.95	0.31/3.19	–	13.6
	K_2O	0.39/34.48	2.56/3.85	0.60/1.74	0.74/9.99	1.46/5.81	1.05/10.80	–	66.7

In Armenia, in apricot, peach, plum and other fruit plantations, including intensive apple plantations, alfalfa or natural mixed grass is also grown, which increases the removal of nutrient elements by about 50–70%. Table 5 presents the data on the biological removal of nutrient elements from apricot and peach plantations, which are widespread in Armavir region, according to which most of the nutrient elements are removed by the harvested hay, which makes 63% of nitrogen and 58% of phosphorus and potassium. In grassy vineyards and fruit plantations the stubble is regularly tilled into the ground. Studies in Russia during 2005–2010 show that in one year 24 kg ha^{-1} of nitrogen enters the soil through the stubble of a papilionaceous plants, 8.9 kg ha^{-1} from annual grasses and 21 kg ha^{-1} from perennial grasses (Zavalin & Blagoveshchenskaya, 2012).

Table 5. Biological removal of main nutrient elements from apricot and peach plantations (according to initial data in Table 3)

Community and fruit type	Nutrient elements	Biomass (numerator %, denominator kg ha^{-1})						Removed sum, kg ha^{-1}
		Pulp	Stone kernel (air-dry)	Stone shell (air-dry)	Mass of spring prunings (air-dry)	Leaf mass at the end of vegeta-tion (air-dry)	Mown hay (air-dry)	
Mrgashat, apricot tree (mixed plantation)	N	0.093 / 11.43	2.87 / 4.40	0.23 / 0.70	0.47 / 7.94	1.40 / 33.96	2.08 / 97.05	155.5
	P_2O_5	0.037 / 4.55	0.54 / 0.83	0.024 / 0.07	0.17 / 2.87	0.31 / 7.52	0.50 / 23.33	39.2
	K_2O	0.38 / 46.70	0.78 / 1.19	0.23 / 0.70	0.31 / 5.24	3.43 / 83.21	3.29 / 153.51	290.6
Mrgashat, peach tree (mixed plantation)	N	0.049 / 4.54	2.97 / 0.93	0.25 / 0.99	0.50 / 7.40	1.44 / 36.58	1.91 / 89.25	139.7
	P_2O_5	0.037 / 3.43	0.54 / 0.17	0.025 / 0.10	0.17 / 2.51	0.40 / 10.16	0.49 / 22.89	39.3
	K_2O	0.26 / 24.07	1.11 / 0.35	0.21 / 0.83	0.30 / 4.44	2.06 / 52.32	3.17 / 148.13	230.1

The removal of about 24% of the nitrogen, 22% of P_2O_5 and 26% of K_2O occurs on the average through the leaf mass, the nutrient elements removed by the cuttings and the harvest are 5, 7, 2 and 7, 12, 14%, respectively. In case of recalculation of 10.0 t ha^{-1} of the yield and corresponding vegetative mass in the plantations, the nitrogen removed from the apricot plantation is 120, P_2O_5 - 30, K_2O - 224 kg ha^{-1}, and from the peach plantation 137, 38 and 226 kg ha^{-1}, respectively (accepting the same levels of vegetative mass of trees and the removed grass).

The calculation of nutrient elements removed from grape and fruit plantations grown in Armenia is directly or indirectly related to irrigation water, as this factor is mandatory and is always present in any plant cultivation system. Irrigation not only determines the final amount of nutrient balance, but is also the most active source of plant nutrition, so in the balance calculations the amount of nutrient elements entering the plantations through atmospheric precipitation should be taken into account. According to the studies, 44 kg ha^{-1} of N, 0.45 kg ha^{-1} of P_2O_5 and 14.7 kg ha^{-1} of K_2O enter annually into the perennial plantations of the semi-desert natural soil zone of Armenia, and through irrigation water 3.64 kg ha^{-1}, 7.5 kg ha^{-1} and 50.2 kg ha^{-1}, respectively. In addition, 5.2 kg ha^{-1} of nitrogen is detected on the average by the bacteria living freely in the soils of the mentioned zone (Babayan, 1980).

During the years of our research (2015–2020) the average amount of atmospheric precipitation in Armavir region was 256 mm or 2,560 m^3 ha^{-1} (mainly in the form of rain), in which the total nitrogen was 2.74 mg L^{-1} (7.02 kg ha^{-1}), P_2O_5 0.30 mg L^{-1} (0.77 kg ha^{-1}) and K_2O 2.30 mg L^{-1} (5.88 kg ha^{-1}). The plantations of the test fields are irrigated by the waters of Nerkin Hrazdan (Aragats, Aghavnatun) and Talin (Talvorik, Mrgashat) canals. Nitrogen content in the waters of Nerkin Hrazdan was 6.09 mg L^{-1} (30.45 kg ha^{-1}), P_2O_5 - 0.331 mg L^{-1} (1.66 kg ha^{-1}), K_2O - 10.04 mg L^{-1} (50.20 kg ha^{-1}), and in the waters of Talin canal these indices were 5.40 (27.0), 0.150 (0.75) and 6.70 (33.5), respectively. The recalculation was done in kg ha^{-1} according to the irrigation norm of 5,000 m^3 ha^{-1}.

The loss of main nutrient elements from perennial plantations by erosion and washing in semi-desert soils is N - 9.2; P_2O_5 - 6.8; K_2O - 68.4 kg ha^{-1} and N - 3.2; P_2O_5 - none, K_2O - 6.3 kg ha^{-1} annually (Babayan, 1980): According to studies, the highest nitrogen loss through water erosion occurs from clean-cultivated crops and makes 13.2 kg ha^{-1} per year, and about 0.3 kg ha^{-1} from perennial grasses (Tsybylka et al., 2013).

Nitrogen gas losses from the soil are based on the use of nitrogen fertilizers, which have not been taken into account, as there is no comprehensive fertilization in the plantations.

Table 6 shows the balance sheet calculations of the main nutrient elements in the studied plantations, according to which the average annual nitrogen loss from grape plantations with grass cover is 196.6, P_2O_5: 54.5, K_2O - 367.0 kg ha^{-1}, and in the soil conservation system of black fallow it is 54.7, 17.9 and 125.3 kg ha^{-1}. The balance of main nutrients in non-fertilized grape plantations in Ganja-Kazakh region of Azerbaijan is negative (Mammadov, 2015). The total nutrient losses in the apricot and peach plantations are less (nitrogen: 152.1–167.9, P_2O_5: 46.0–46.1 and K_2O: 304.8–365.3 kg ha^{-1}), which is mainly due to the amount of grass removed from these plantations. As for the nutrient inflow, the main difference here is related to the irrigation water.

The data in Table 6 show that in the absence of annual use of organic-mineral fertilizers in grape and fruit plantations, the balance of all nutrient elements is negative, especially if the plantations are placed under the grass of industrial significance. Balance losses include nutrient elements in the leaf mass which do not leave the plant and compensates for their deficiency to some extent. Corresponding nutrient losses and inflows in perennial plantations determine the intensity and volume of the balance, which is a unique key for understanding their overall displacement.

CONCLUSIONS

1. The soils under the vineyards and fruit plantations studied in the Ararat Valley are considered strong soils (A + B = 62–85 cm), but low levels of humus (0.34–1.68%), available nitrogen (2.24–4.20 mg per 100 g in soil) and phosphorus (0.62–2.81 mg per 100 g in soil) are a limiting factor for plant growth and yield, which can be overcome by annual fertilization. The soils have a high supply of K_2O.

2. The annual amount of nitrogen released through the grass of industrial importance (about 6.5 t ha-1 air-dry) grown in the inter-row spaces of grapevines is 76.2%, P2O5 - 70.2%, K2O - 72.9%, and through 4.5 t ha-1 of air-dry grass leaving apricot and peach plantations the annual amount of nitrogen is 63.1%, P2O5 - 58.8%, K2O - 58.6%. That is, the main factor in deepening the nutrient deficiency is the grass grown in the mid-rows of plantations.

Table 6. Total annual balance of main nutrient elements in perennial plantations of semi-desert natural soil zone of Armenia (according to generalized and averaged data of tables 4 and 5)

Irrigation source and norm, m^3 ha^{-1}	Community, plantation, soil conservation system and average yield ($t\ ha^{-1}$)	Nutrient elements	Losses, kg ha^{-1}			Entrance, kg ha^{-1}			Balance, kg ha^{-1} + -	Balance intensity, %	Balance volume, kg ha^{-1}
			Total removal	Erosion and washing	Total	Atmospheric precipitation	Irrigation water	Total*			
Nerkin Hrazdan canal, 5,000	Aragats, Aghavnatun, grape (natural grass), 13.85	N	184.2	12.4	196.6	7.0	30.5	42.7	-153.9	21.7	239.3
		P_2O_5	47.6	6.8	54.4	0.8	1.7	2.5	-51.9	4.6	56.9
		K_2O	292.3	74.7	367.0	5.9	50.2	56.1	-310.9	15.3	423.1
Talin canal, 5,000	Talvorik, grape (black fallow), 8.36	N	42.3	12.4	54.7	7.0	27.0	39.2	-15.5	71.7	93.9
		P_2O_5	11.1	6.8	17.9	0.8	0.8	1.6	-16.3	8.9	19.5
		K_2O	50.6	74.7	125.3	5.9	33.5	39.4	-85.5	31.4	164.7
	Mrgashat, apricot tree (natural grass), 13.0	N	155.5	12.4	167.9	7.0	27.0	39.2	-128.7	23.3	207.1
		P_2O_5	39.2	6.8	46.0	0.8	0.8	1.6	-44.4	3.5	47.6
		K_2O	290.6	74.7	365.3	5.9	33.5	39.4	-325.9	10.8	404.7
	Mrgashat, peach tree (natural grass), 10.2	N	139.7	12.4	152.1	7.0	27.0	39.2	-112.9	25.8	191.3
		P_2O_5	39.3	6.8	46.1	0.8	0.8	1.6	-44.5	3.5	47.7
		K_2O	230.1	74.7	304.8	5.9	33.5	39.4	-265.4	12.9	344.2

* 5.2 kg ha^{-1} of nitrogen accumulated in the soil by asymbiotic nitrogen fixation was added to the total input.

3. Regardless of the soil conservation system, the amount of nitrogen entering perennial plantations in the Ararat Valley through natural factors (atmospheric precipitation, irrigation water, asymbiotic fixation of nitrogen) exceeds the losses (erosion and washing away), while the losses of P2O5 and K2O are much greater.

4. In order to prevent further deepening of the deficiency of main nutrient elements in the vineyards and fruit orchards of Armenia, it is necessary to fertilize the grassy orchards of production significance with N150P80, K200 and in the black fallow system with doses of N80P60 K100 kg ha^{-1}, taking into account the high content of potassium in the soil, losses of nitrogen gas (about 20%) and the immobilization of phosphorus fertilizers in the form of hard to reach compounds.

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