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LEACHING OF THE BASIC NUTRIENTS FROM IRRIGATED SOILS OF THE DRY SUBTROPICAL ZONE OF AZERBAIJAN

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Abstract

The article presents the results of researches on the influence of water consumption and the length of the irrigation furrow on the leaching of nutrients and humus from irrigated soils of dry subtropics of Azerbaijan under tomato cultivation. The effect of different fertilization systems on tomato yields was also investigated. With a slope in a 100 - meter furrow at a water flow rate of 3.0 l/s, the content of leachable biogenic elements (N, P) and humus with soil was 0.03% for nitrogen, 0.02% for phosphorus and for humus 0.07%. Increasing water flow from 3.0 l/s up to 3.5 l/s negatively affects the leaching of humus and nutrients from the soil. With an increase in water consumption to 3.5 l/s, these indicators increased markedly by 0.01% for nitrogen and phosphorus, and by 0.02% for humus. It was found that with an increase in the length of the furrow to 200 meters, at the same norms, the flow of water, leaching of humus and nutrients was not observed. Using of an organic-mineral fertilizer system had a positive effect on the yield of tomato. So, in the free-fertilized variant, the tomato yield was 0.32 t/ha per at 100 m furrow.

Key words: *leaching of the basic nutrients, irrigated soils, fertilizers system.*

INTRODUCTION

The problem of protection, restoration and increase of soils fertility is relevant for arid and dry subtropical zones of many countries, including Azerbaijan. In particular, it is a great importance for irrigated lands. The area of irrigated land in Azerbaijan is 1.42 million hectares and more than 65% of these lands are located in areas with a significant slope. In the irrigated soils of dry subtropics, irrigation erosion processes develop, causing damage to agricultural production (Гурбанов, 2010; Гурбанов & Мамедов, 2009; Мамедов, 1989; Агрофизические..., 1966; Azizi et al., 2008).

Losses of nutrients from the soil and fertilizers are associated primarily with the amount of water entering in the soil and with the water regime of the soil. The research of the amount and composition of solid runoff carried out by waste water during irrigation is important for studying changes in the properties of irrigated soils (Доспехов, 1985; Мамедов, 1997; Лапа & Босак, 2006).

Using the fertilizers in irrigated eroded sloping soils has recently received little attention. In this regard, researches aimed at studying removing of nutrients with solid and liquid runoff during norms of irrigation, ratios and fertilizers, their dependence on the slope degree of the terrain are relevant (Заславский, 1983; Кудеяров & Семенов, 2004; Khomami et al., 2016).

MATERIALS AND METHODS

The object of the research was alluvial meadow-forest soils under irrigated conditions in the Guba-Khachmaz zone of Azerbaijan. The researches were carried out on the territory with a slope of 0.009 *tgα* under tomato cultivation. The experiments were laid in the Gusarchay experimental station of the Ministry of Agriculture of Azerbaijan located on the territory of the Khachmaz region. The laying of field experiments and carrying out phenological observations were carried out according to the method of field experiment Dospekhov B.A. (Доспехов, 1985; Кауричев & Лыков, 1979; Агрохимические методы..., 1975; Гусейнов, 1976). The degree of soil susceptibility to erosion and leaching of nutrients was determined according to Zaslavsky M.И. (Заславский, 1983; Лапа & Босак, 2006). Agrotechnical measures were carried out in accordance with agricultural rules adopted for the region.

Ammonium nitrate, simple superphosphate and potassium chloride were used as mineral fertilizers. The organic fertilizer was cattle manure at a moisture content of 60-65%, containing an average of 0.5% N, 0.25% P_2O_5 and 0.6% K_2O.

Annual norms of organic fertilizers were applied for ploughing in autumn (100%). Mineral fertilizers under tomato plants were applied at 3 terms during the growing season: when seedlings were transferred to the field; at the beginning of budding; at the start of fruiting.

Field experiments under irrigation conditions on alluvial meadow-forest soils under tomato culture were carried out in triplicate. To establish the leaching of nutrients with the washed off soil, the experiments were carried out according to the scheme indicated below (Table 1, Figure 1). Each plot is 200 m^2 (tomato planting pattern 70 x 30 cm), in each variant - 95 plants. In the experiments, the furrow length - 200; 150; 100 m and water flow - 3.0 and 3.5 l/s.

Table 1. Conditions and scheme of the experience

Soil	Slope, *Tgα*	Water consumption, l/s	Furrow and strip length, m
Furrow irrigation, tomato culture			
Alluvial meadow-forest	0.009	3.0; 3.5	100, 150, 200

On the experimental site, the slope of the relief was 0.009 *tgα*. The furrow length is set in three options, i.e., 100, 150 and 200 m. In each variant, different water flow rates were taken along the furrows, 3.0 m/s and 3.5 m/s.

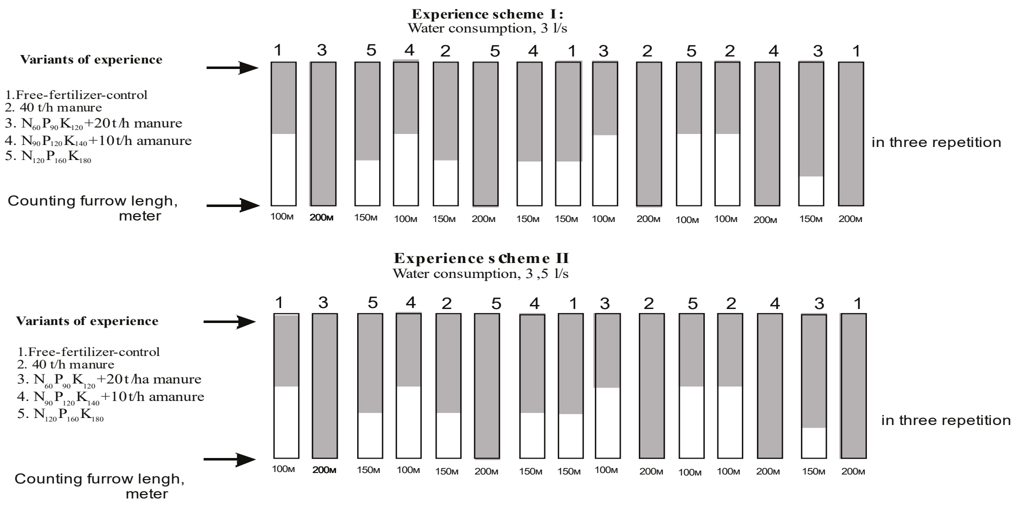

Figure 1. Experience scheme I and II

RESULTS AND DISCUSSIONS

As a result of many years of field experiments, it has been established that the application of mineral fertilizers for vegetable crops on sloping lands, during irrigation, should be differentiated, taking into account the elements of the slope and irrigation soil erosion (Мамедов, 1997, 2010, 2017; Arncon et al., 2005; Гусейнов, 1976); Мовсумов, 1978).

The soils of the Guba-Khachmaz zone of the north-western part of the Greater Caucasus within Azerbaijan are intensively used in agricultural production. Some of these soils are subject to the process of irrigation erosion, that is, leaching of the main nutrients and humus with the soil.

To study the agrochemical characteristics of the soils of the experimental plots, soil sections were laid and soil samples were taken along the genetic horizons, in which soil properties and their significance for fertility (Гурбанов, 2010; Мамедов, 1997; Edwards et al., 1996; Arncon et al., 2005) were studied according to generally accepted methods.

In experimental plots with vegetable crops under irrigated conditions (Table 2), the agrochemical properties of alluvial meadow-forest soils were carried out and studied.

Table 2. Agrochemical properties of irrigated soils in dry subtropics Guba-Khachmaz zone of Azerbaijan

Alluvial meadow-forest soils													
Genetic horizons	Depth, cm	Common humus, %	Common nitrogen, %	N-NH4			P_2O_5				K_2O		pH water
				water soluble	absorbed	NO_3, %	Common, %	water soluble	mobile	Common, %	water soluble	exchangeable	
				mq/kq				mq/kq			mq/kq		
A_p	0-18	3.95	0.24	4.95	17.4	8.13	0.16	4.2	23.2	3.66	25.4	231	7.5
A_1	18-37	2.87	0.17	3.52	11.2	5.25	0.12	3.1	21.7	3.18	24.7	208	7.8
B_1	37-65	1.75	0.11	3.05	9.75	3.10	0.09	2.2	13.1	2.56	21.5	198	8.1
B_2	65-90	1.06	0.04	2.16	6.84	1.08	0.06	1.5	10.2	1.73	17.8	160	8.0
C	90-115	0.41	0.01	1.12	4.92	0.12	0.03	1.2	7.2	1.43	14.7	139	8.1

In the arable soil layers, the humus amounted 3.95%; total nitrogen - 0.24%, and absorbed ammonium - 17.4 mg/kg of soil. Mobile phosphorus (P_2O_5) in the arable layer was 23.2 mg/kg, and total phosphorus - 0.16%; in the arable soil layer, exchangeable potassium - 231 mg/kg of soil, while total potassium was 3.66%. Subsurface soil layers were also studied, genetically soil horizons up to 115 cm. These indicators gradually decreased, respectively, in terms of gross value, humus to 0.41%; nitrogen (N) - up to 0.01%; phosphorus (P_2O_5) up to 0.03% and potassium up to 1.43%. With increasing depth, the content of humus and basic nutrients gradually decreased in the genetic horizons. Thus, alluvial meadow-forest soils are poorly provided in terms of the content of basic nutrients and humus content.

We also studied the structural composition (water-stable aggregates) of the soils of the experimental plot (Table 3). The structure of soils is closely related to their genesis; depending on the soil and climatic conditions, a certain shape and water resistance of soil aggregates are formed. Maintaining favorable physical conditions in the soil necessary for a particular crop is facilitated by the presence of an agronomically valuable water-resistant of fine-grained structure in its (Мамедов, 2017; Khomami et al., 2016; Mammadov & Leah, 2020, 2021; Boincean & Dent, 2019).

Numerous studies indicate that soil structure changes the direction of physico-chemical and biological processes, and also affects the nature of plant growth and development and crop quality (Leah, 2010; Leah & Ceban, 2019).

Structural soils are characterized by favorable physical properties and a good nutritional regime, water and air easily penetrate into them.

Table 3. Structural composition (water-stable aggregates) of soils in dry subtropics of the Guba-Khachmaz zone of Azerbaijan

Alluvial meadow-forest soils (under vegetables), %					
Genetic horizons	Depth, cm	Aggregate size, mm			
		<0.25	0.25-1.0	1.0-10.0	Total >0.25
A_p	0-18	79.6	16.2	4.2	20.4
A_1	18-37	76.3	14.4	9.3	23.7
B_1	37-65	28.2	19.3	52.5	71.8
B_2	65-90	30.8	30.4	38.8	69.2
C	90-115	34.1	29.0	36.9	65.9

As can be seen from the data in the Table 3, water-stable aggregates in the arable layer in the amount of 0.25-1.0 mm were also 16.2% which indicates a poor soil structure.

The content of humus, gross nitrogen and phosphorus was determined in the solid runoff (Table 4).

Table 4. The content of gross humus, gross forms of nitrogen and phosphorus in solid waste, % (in the control version)

Slope, *tgα*	Water consumption, l/s	Furrow start			Furrow end (waste water)		
		Humus	N	P	Humus	N	P
	At 100 m furrow						
0.009	3.0	3.86	0.22	0.17	3.81	0.19	0.15
	3.5	3.86	0.22	0.17	3.79	0.17	0.13
	At 150 m furrow						
	3.0	3.86	0.22	0.17	3.84	0.21	0.16
	3.5	3.86	0.22	0.17	3.81	0.19	0.15
	At 200 m furrow						
	3.0	3.86	0.22	0.17	3.90	0.24	0.18
	3.5	3.86	0.22	0.17	3.92	0.25	0.19

Note: 1^0 slopes=0.017 tga

The content of humus, nitrogen (N) and phosphorus (P) at the beginning of the furrow (100, 150 and 200 m) was 3.86%, respectively; 0.22 and 0.17%, when irrigating in furrows with a water flow rate of 3.0 l/s and 3.5 l/s.

At a water flow rate of 3.0 l/s and 3.5 l/s, the content of total forms of humus, nitrogen and phosphorus at the end of the furrow was 3.81%, respectively; 0.19 and 0.15% in the soil. At the end of the 150 m furrow, the content of total forms of humus, nitrogen and phosphorus gradually increased. At the end of the 200 m furrow, the content of total forms of these elements was at a water flow rate of 3.0 l/s, respectively - 3.90; 0.24; and 0.18%, and at a water flow rate of 3.5 l/s, respectively - 3.92; 0.25 and 0.19%.

On the field experimental plot, removing of biogenic elements and humus with washed out solid runoff from alluvial meadow-forest soils was also studied at water flow rates of 3.0 and 3.5 l/s (Table 5).

Table 5. Removing (Leaching) of biogenic elements and humus with washed soil during irrigation of agricultural crops in the control variant on experimental plots, %

Slope, $tg\alpha$	Variant		Humus	N	P
	Furrow length, m	Water consumption, l/s			
0.009	100	3.0	0.07	0.03	0.02
		3.5	0.09	0.04	0.03
	150	3.0	0.02	0.01	-
		3.5	0.04	0.02	0.01
	200	3.0	-	-	-
		3.5	-	-	-

The results of soil analyses for the content of humus, total nitrogen and phosphorus, as well as mobile forms of these elements, testified to a significant change in soil fertility, depending on the elements of the slope and leaching of humus, nutrients with the soil as a result of irrigation.

Irrigation waters of the irrigation systems of the Republic of Azerbaijan carry out an average of 0.66-0.98 kg of $N\text{-}NH_4$ and 0.69-0.88 kg of $N\text{-}NO_3$ per season; 2.7-7.0 kg P, 44-70 kg K and 84-162 kg of organic matter/ha.

The influence of different furrow lengths (m) and water consumption (l/s) in different irrigation rates has a different effect on the leaching of N, P and humus with washed away soil in the alluvial meadow-forest soil.

Thus, in 100 m furrow, at a water flow rate of 3.0 l/s, the content of leached biogenic elements (N, P) and humus with washed soil was 0.03% for nitrogen, 0.02% for phosphorus, and 0.07% for humus. With increased water consumption up to 3.5 l/s, these indicators increased by 0.01% for nitrogen and phosphorus, and by 0.002% for humus.

Leaching of humus and nutrients with the washed away soil was not observed with an increase in the length of the furrow to 200 meters, at the same water consumption rates.

When the furrow is extended up to 200 m, and the water flow rate is 3.0 l/sec the leaching of biogenic elements decreased and stopped in comparison with the 100 m furrow.

Leaching of the total forms of biogenic elements (N, P) and humus gradually stabilized with the lengthening of the furrow to 200 m at the same water discharge rates and was more effective than in a short (100 m) furrow.

It was found that at a water flow rate of 3.5 l/s, the leaching of biogenic elements and humus was higher than at a water flow rate of 3.0 l/s.

The amount of removal of nutrients and gross humus during furrow irrigation was directly dependent on the amount of water consumption.

We also studied the effect of the fertilizer application system when nutrients were washed out with washed soil on the yield of a tomato plant (Table 6).

Table 6. Tomato yield on alluvial meadow-forest soils under irrigation, depending on the removing of humus and biogenic elements N, P_2O_5 (water flow rate of 3 l/s)

Fertilizer system	Dose of fertilizer	Productivity, t/ha					
		Counting furrow length, m			average	Increase from option 1 (from control)	
		100	150	200		t/ha	%
Free-fertilizer-control	0	32.4	32.9	33.5	32.9	-	-
Organic	40 t/ha manure	49.5	49.7	50.1	49.7	16.8	51.1
Organic-mineral	$N_{60}P_{90}K_{120}$+20 t/ha manure	52.8	53.0	53.2	53.0	20.1	60.9
Organic-mineral	$N_{90}P_{120}K_{140}$+10 t/ha manure	47.9	48.7	49.0	48.5	15.6	47.3
Mineral	$N_{120}P_{160}K_{180}$	45.2	45.3	45.5	45.6	12.6	38.3

Fertilizer systems as well as various furrow lengths and irrigation rates had a different effect on the tomato yield. The average tomato yield (100, 150 and 200 m^3) was 32.9 t/ha in the experimental plot under vegetable crops in the control variant. In the experiment, positive indicators were noted in a 200-meter furrow at various water rates when using the organic-mineral fertilizer system at the rate of $N_{60}P_{90}K_{120}$ + 20 t/ha, and amounted to 54.2 t/ha. With a furrow length of 150 m and 100 m, the yield was, respectively, 53.4 and 52.8 t/ha, which indicates a positive factor for furrow lengthening up to 200 meters, with the same fertilizer application rates and at different water consumption rates (3.0 and 3.5 l/s).

With a water flow rate of 3.0 l/s, using of organic, organo-mineral at the rate of $N_{60}P_{90}R_{120}$ + 20 t/ha of manure and mineral fertilizer systems, the average tomato yield increased compared to the control, respectively, to 49.7, 53.0 and 45.6 t/ha.
When using the organo-mineral fertilizer system in the $N_{60}P_{90}K_{120}$ variant + 20 t/ha of manure, in a 200 m furrow, the yield was higher by 2.0 t/ha compared to 150 m furrow and by 1.4 t/ha compared to 100 meters.
Thus, using of different fertilizer systems and different furrow lengths had a different effect on the yield of tomato, under irrigation conditions on alluvial meadow-forest soils.
The organic-mineral fertilizer system had a positive effect on the yield of tomato. So, in an unfertilized version, on a 100 m furrow tomato yield was 32.4 t/ha. The yield gradually increased due to the use of fertilizers with the lengthening of the furrow to 150 and 200 meters, and a decrease in the leaching of nutrients. In these variants, the tomato yield reached 32.9-33.5 t/ha, respectively. The effect on increasing the yield of the same doses, with the lengthening of the furrow, is due to the leaching of nutrients from the upper runoff. Since when using the organic-mineral fertilizer system in the norm $N_{60}P_{90}K_{120}$ + 20 t/ha of manure, the tomato yield in 100, 150 and 200 m furrows, respectively, was 52.8; 53.0 and 53.2 t/ha. At the same time, it was found that, compared with a 100 m furrow in 150 and 200 m furrows, the tomato yield is gradually increasing.
In the fertilized variants, the regularity of the removing out of nutrients and humus with the washed away soil did not change, depending on the slope degree of the relief and the length of the furrow.
Thus, when using an organic-mineral fertilizer system in the norm of $N_{60}P_{90}K_{120}$ + 20 t/ha of manure (200-meter furrow in a water flow rate of 3.0 l/s), The average tomato yield was 53.0 t/ha, while the increase to the unfertilized variant was 20.1 t/ha or 60.9%. Table 7 shows the results of taking into account the yield, when irrigating with a water flow rate of 3.5 l/s.
With an increase in the irrigation rate and water consumption up to 3.5 l/s due to increased soil leaching of the main biogenic elements and humus, the yield gradually decreased depending on the applied fertilizers.
With a change in water consumption rates, that is, at a rate of 3.5 l/s, in the variant without fertilizers, the yield was 32.1 tons per hectare at a 100-meter furrow and when the furrow was extended to 200 meters, a pattern was also observed at the same water consumption rate. At high rates (3.5 l/s) of water flow, there was a constant decrease in tomato yield compared to lower rates (3.0 l/s).

Table 7. Tomato yield on alluvial meadow-forest soils under irrigation, and depending on the removing of humus and biogenic elements (N, P_2O_5) with washed away soil (at a water flow rate of 3.5 l/s)

Fertilizer system	Dose of fertilizer	Counting furrow length, m			Productivity, t/ha		
					average	Increase from option 1 (from control)	
		100	150	200		t/ha	%
Free-fertilizer-control	0	32.1	32.3	32.6	32.3	-	-
Organic	40 t/ha manure	49.2	49.3	49.6	49.4	17.0	52.6
Organic-mineral	$N_{60}P_{90}K_{120}$+20 t/ha manure	52.4	52.8	53.0	53.0	16.4	63.9
Organic-mineral	$N_{90}P_{120}K_{140}$+10 t/ha manure	47.8	48.2	48.5	48.2	15.8	48.9
Mineral	$N_{120}P_{160}K_{180}$	45.1	45.3	45.7	45.5	13.2	40.8

CONCLUSIONS

The content of biogenic elements and humus in the arable layer of meadow-forest soils was generally low. The content of humus, nitrogen and phosphorus was 3.95, 0.24 and 0.16%, respectively, with an increase in the depth of genetic horizons, these indicators gradually decreased.
Water-resistant aggregates in the arable soil layer in the section 0.25-1.00 mm (meso-structure) were 16.2%, which indicates a poor structural condition of the soil.
In the non-fertilized variant, the content of total forms of humus, nitrogen and phosphorus in the solid runoff (%) was determined in the control variant. So, at the beginning of the furrow, the content of total humus, nitrogen and phosphorus was 3.86, 0.22 and 0.17%, respectively, and the removing of biogenic elements and humus with washed soil under the tomato crop was established. Washout in a 100-meter furrow at a water flow rate of 3.0 l/s is 0.07% for humus, 0.03% for nitrogen and 0.02% for phosphorus. With the lengthening of the washout furrow, it gradually stabilized and no washout was observed in the 200 m furrow.

Increasing water flow from 3.0 l/s up to 3.5 l/s negatively affects the leaching of humus and nutrients from the soil. With a water flow of 3.0 l/s in a 100-meter furrow, the removal with washed soil for humus was 0.06%, for nitrogen 0.03%, and for phosphorus 0.02%. With an increase in water flow to 3.5 l/s, in the same furrow, the removal of humus and biogenic elements from washed soil increased by humus to 0.08%, by nitrogen to 0.04%, and by phosphorus to 0.03%.

The maximum losses of nutrients and humus were observed in the upper part of the slope in a 100-meter furrow at a water flow rate of 3.5 l/s. They gradually decreased with the lengthening of the furrow.

Study of the effect of mineral, organic and organic-mineral fertilizer systems on tomato yield, depending on the leaching of humus, nitrogen and phosphorus, at different furrow lengths and different water flow rates.

Best average yield across all furrows at water flow rate 3.0 l/s obtained by using organic-mineral fertilizer system in the norms $N_{60}P_{90}K_{120}$ + 20 t/ha - 53.0 t/ha. At the same time, the increase from the control amounted to 20.1 t/ha or 60.1%.

In a 200-meter-long furrow with a slope of 0.009 *tgα* and a water flow rate of 3.0 l/s, due to the least leaching of nutrients from the soil, the tomato yield increased compared to other options. With an increase in water consumption to 3.5 l/s with the same length of the furrow and with the same rate of fertilizer application, due to the large leaching of soils with irrigation runoff, a decrease in tomato yield was found.

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