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The Effect of Drip Irrigation on Several Physical and Chemical Features of Soil

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Abstract

Anthropic influences resulted in the alteration of soil fertility, as the main limiting factors, such as compaction, acidification, structure destruction, etc., had a negative influence on the physical and chemical features of soil. The most important changes in several physical and chemical features of soils resulted from the action of irrigation, drainage, fertilization and improvement of agricultural soils. Research carried out between 2011 and 2012 aimed to determine the effect of drip irrigation on several physical features of soil, such as bulk density (BD), total porosity (TP) and compaction degree (CD), as well as several chemical features such as the soil soluble salts content mg/100g soil, the content in mobile ($N\text{-}NH_4$ + $N\text{-}NO_3$) (ppm), P and K. The experience was one bifactorial: factor A=variety (apricot: a1–'Dacia', a2–'Comandor', a3–Tudor'; apple: a1-'Romus 3', a2-'Generos', a3-'Ionathan'), factor B = hydric regime (b1-unirrigated Control-Ct, b2-drip irrigation 4l/h), placed after the linear method with 5 trees/variant. In both fruit-tree species, compaction degree increased with depth experimental variants. The soil soluble salts content (mg/100g soil) varied between 32 and 36 mg/100g soil, was uniformly distributed in all the experimental variants under study, and correspond to the non-saline soil. The N amount available to the plants ($N\text{-}NH_4$ + $N\text{-}NO_3$) was very low in all variants. The comparison between the variants of the water regime showed that the N amount was slightly higher in b2 (irrigated), which was specific to each soil type.

Keywords: *drip irrigation, soil, physical and chemical properties, apple, apricot*

1. Introduction

In Romania, the data recorded by the National System of Soil Quality Monitoring showed that about 7.5 mil ha of the arable lands were affected by one or several limiting factors. Moisture deficit was recorded on 7.1 mil ha, i.e. 48.2% of the degraded area, followed by water erosion – 4.3 mil ha, i.e. 29.5% of the total degraded area. Other types of degradation account for less: 8.4% chemical damage, 4.2% complex deterioration, 2.6% by wind erosion. In recent years a considerable area, more than 1 million hectares (6.9% of the total), has been removed from crop production circuit (MUNTEANU & al. [18]; MIHALACHE & al. [15]; CÎMPEANU & al. [11]). More important changes of some physical and chemical soils properties are noted under the influence of irrigation, drainage, fertilization and amendment (CANARACHE [3], [4], [5]). Thus, for example, under the influence of irrigation water, soil structure undergoes predominantly negative changes. At the sudden contact with irrigation water, the air from the dry soil aggregates is 'trapped' within the latter. Air pressure increases inside the aggregate, based on the capillary tension caused by water intrusion. At some point, the air pressure inside the aggregate, defeat is higher than its cohesion and causes its 'explosion'(PLEȘA & al. [19]; PLEȘA & al. [20]; DUMITRU & al. [11]). Fertilization and good quality water irrigation led to an increase in organic matter, particularly at 20-40 cm depth in the chernozem of the Mărculeşti area, and in the alluvial soils. Irrigation resulted in the removal of $CaCO_3$ from the surface to a depth of 25-30 cm. This increase of the humus content in the ploughed layer for 20 years and the proper application of technological components resulted in the very good conservation of these soils characterized by a high level of fertility (MIHALACHE & al.[14]; MIHALACHE [17]). The cambic chernozems of Fundulea recorded a reduction of the humus content, mobile potassium, mobile phosphorus, as well as an increased reaction under the influence of the irrigation rate, especially in the unfertilized variants, due to the irrigation that used less satisfactory water. Structural hydraulic conductivity showed a slight decrease under the influence of irrigation, as the fertilized variants were the most visible. In such cases, the content in water stable aggregates was reduced from 15 to 11% while the structural instability index increased from 0.42 to 0.54. The bulk density determined on chernozem decreased slightly from 1.25 g/cm^3 to 1.22 under the influence of irrigation; the same trend was also recorded in alluvial soil and cambic chernozem (MIHALACHE & al. [14]; MIHALACHE [17]).The other agro-physical features, such as penetration resistance, macro-porosity and water permeability of the soils under study, indicated no statistically significant differences between the experimental factors (MIHALACHE & al. [14]; MIHALACHE, 2014 [17]). The combined effect of hydrological, pedological improvement work performed on the gleyic mollic soils of the Radauti Depression 24 years ago, showed an increase in bulk density and porosity, together with the significant decrease in the number of macropores. The high values of bulk density in the ploughed layer showed that soil compaction was caused by the secondary soil tillage, not by the direct effect of the plough (FILIPOV & al. [12]; AILINCĂI & al.[1]).Generally, more intense leaching of soluble salts is noted on the irrigated soils, when compared with the non-irrigated soil in the area. Leaching intensity depends on soil permeability, irrigation method and system, irrigation water composition, the presence of a drainage system. These issues are of particular interest for saline soils. Irrigation based on high amounts of water (submersion irrigation and surface drainage) favours the leaching of soluble salts; otherwise the effect is the opposite, i.e. salinisation. Sprinkling irrigation uses small amounts of water and results in washing of the soluble salts from the upper horizons to the lower ones, even in the absence of drainage. The experiments conducted on saline and alkaline soils demonstrate the effect of irrigation on soil desalination. It should be noted, however, that irrigation washes off not only the harmful soluble salts but also the fertilizing elements (nitric nitrogen, phosphorus, etc.).The application of the foliar fertilizer can be more efficient than the one applied to the soil. However, the combination between soil treatments and foliar treatments is recommended for nutrient management in apple tree (AMIRI & al.[2]). It is known that irrigation water, regardless of its origin, has higher mineral content than meteoric water. Therefore, its effect on salts accumulation will differ essentially from that of rainwater. It is understandable that the intensity of salts accumulation in the soil will increase at the same time with the mineralization level of the irrigation water and the volume of water taken (total irrigation time) (CÎMPEANU & al. [6], [7], [8]). By irrigating with slightly mineralized waters (1 g/l), the high salinization of the soil occurs after about 20 years of irrigation, while the use of strongly mineralized irrigation water (>5 g/l) results in the actual salinization of soils after 1-2 years of irrigation (HANAN [13]). In addition to salts, irrigation water also brings large

quantities of silt on the irrigated land (CÎMPEANU & al. [9]). The amount of deposited silt depends on the turbidity of the irrigation water and the irrigation standard. Low turbidity (0.5 g/l) and a moderate watering rate (3000 m^3/ha) leads to 1500 kg/ha silt accumulation. The materials held in suspension by the rivers have a significant influence on the quality of the irrigation water. The richest in nutrients are fine silts (ø 0.005 mm), but they lead to lower soil permeability. Silt intake may be an important factor for improving saline soils and those with sandy texture. Research carried out between 2011 and 2012 aimed to determine the effect of drip irrigation on several physical features of soil, such as bulk density (BD), total porosity (TP) and compaction degree (CD), as well as several chemical features such as the soil soluble salts content mg/100g soil, the content in mobile ($N\text{-}NH_4 + N\text{-}NO_3$) (ppm), P and K.

2. Materials and Methods

The experimental plots were located at the Belciugatele, Moara Domnească Teaching Farm, and included the study of two species: apricot grafted on Mirobolan and apple grafted on M9. The places belong to the Romanian Plain relief subdivision Vlăsiei, in the transition from steppe to forest area. Mostly, the relief is flat, with small depressions of different shapes and sizes. The groundwater is located at 6 to 10 m depths. The annually average rainfalls were 318.21 l/m^2 in 2011 and 401 l/m^2 in 2012. Both values are under the multiannual average of the 1960-2010 period (610.91 l/m^2). The soil under the experiments was typical reddish preluvosoil (according to SRTS-2012) or Chrome Luvisol (according to WRB-ST-1998). Table 1 presents soil chemical analysis (according to ICPA METHODOLOGY, 1987) [21], and show a weak acidic soil reaction with values ranging from 5.82 to 6.19 (pH units). Humus content was low (from 1.20 to 2.10%) in topsoil (0-72 cm, corresponding to the sequence of horizons Ap-AB), and very low (0.36 to 0.60%) at the bottom of the soil profile (72-150 cm).

Table 1. The main chemical properties of the soil - Moara Domnească

Level	Depth cm	pH$_{H2O}$ units pH	Humus (Corg x 1.72) %	SB me/100 g soil	Ah %	*T=**SB+***Ah	****V%
Ap	0-16	6.12	2.10	13.61	6.57	20.18	67
Apt	16-29	5.82	1.92	13.39	6.33	19.72	68
Am	29-40	6.19	1.80	15.98	4.30	20.28	79
AB	40-72	6.00	1.20	20.09	2.60	22.69	89
Bt$_1$	72-93	6.02	0.60	21.09	2.53	23.62	89
Bt$_2$	93-130	6.04	0.36	22.03	1.70	23.73	93
Bt$_3$	130-150	6.18	0.36	22.03	1.70	23.73	93

*T = Cation exchange capacity; **SB=Sum of exchangeable cations ***Ah = Hydrolitic acidity; V%= Percentage of base saturation

The orchards were founded in 2004 and the tree planting distances were: 5 x 4 m for apricot and 4 x 3.5 m for apple. The experiment was bifactorial: factor A = variety (apricot: a1 – ′Dacia′, a2 – ′Comandor′, a3 – ′Tudor′; apple: a1-′Romus 3′, a2-′Generos′, a3-′Ionathan′), factor B = hydric regime (b1-non-irrigated Control - Ct, b2- drip irrigation 4l/h, placed after the linear method with 5 trees/variant). The soil physical properties considered were: bulk density (BD – g/cm^3), total porosity (TP - %v/v), compaction degree (CD - %v/v) and were analyzed according to the ICPA METHODOLOGY, 1987 [21]. Soil samples were collected in metal cylinders (Figure 1) from two depths (0-20 and 20-40 cm), from the water regime variants: b1 (non-irrigated) and b2 (irrigated) (Figure 2), and from the three varieties: Romus 3 - a1, Generos - a2 and Ionathan - a3 in case of apple orchard, and Dacia – a1, Comandor – a2 and Tudor – a3 in case of apricot orchard (Figure 3). The data was interpreted according to the ICPA METHODOLOGY, 1987 [21]). There were determined also several chemical characteristics of the soil, as follows: the soluble salts content (mg/100g soil) determined in watery extract 1:5; the nitric nitrogen ($N\text{-}NO_3$) (ppm) and the ammonium nitrogen ($N\text{-}NH_4$) (ppm) determined by the ammonium acetate-lactate method; the mineral nitrogen determined by summing of $N\text{-}NO_3$ (ppm) and $N\text{-}NH_4$ (ppm); the contents of mobile phosphorus and mobile potassium that can be extracted from acetate lactate. All the chemical characteristics were analyzed according to the ICPA METHODOLOGY, 1987 [21].

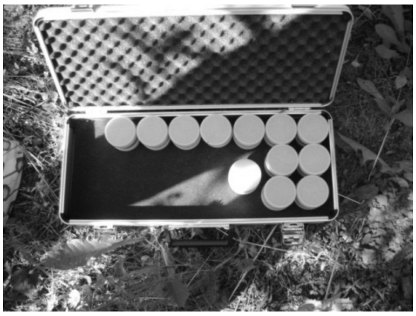

Figure 1. Metal cylinders used in soil sampling

Figure 2. Soil sampling from the water regime variants: b1-non-irrigated (left) and b2 - irrigated (right) in apple orchard

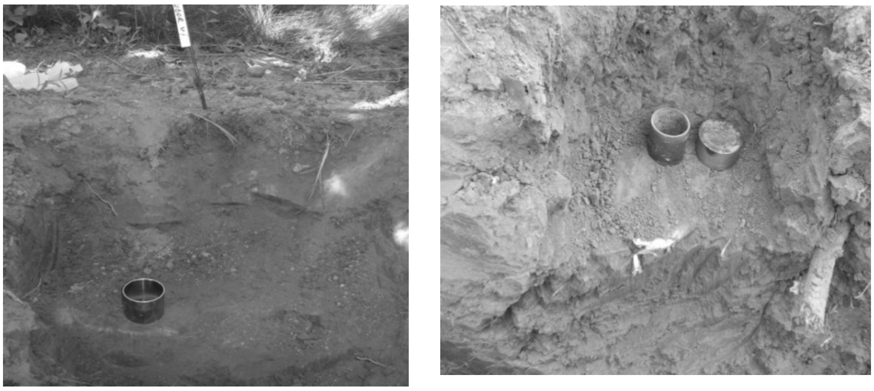

Figure 3. Soil sampling from the water regime variants: b1-non-irrigated (left) and b2 - irrigated (right) in apricot orchard

3. Results and discussions

The effect of drip irrigation on the soil physical properties

The research carried out between 2011 and 2012 aimed to observe the effect of drip irrigation on several physical properties of soil, such as: bulk density (BD), total porosity (TP) and compaction degree (CD) (Table 2). The values of bulk density (BD) indicating the soil loosening or compaction in the non-irrigated variant (b1) at 0-20 cm depth, ranged between the limits, i.e. 1.24 (moderately loose) – 1.45 g/cm^3 (slightly compact). As for the 20-40 cm depth, the bd values varied within a narrow interval, i.e. between 1.57 (moderately compact) and 1.62 g/cm^3 (moderately compact), in the irrigated variant (b2), bulk density (BD) values ranged between 1.36 (slightly aerated, not compact) and 1.45 g/cm^3 (slightly compact) at 0-20 cm depth, and between 1.60 (moderately compact) and 1.64 g/cm^3 (moderately compact) at 20-40 cm depth. This shows that the compaction level increases with depth in both experimental variants (table 2). The bulk density increase at 20-40 cm depth is closely determined by the increase of clay content within the soil profile (Table 2). The arrangement of the solid soil particles, together with bulk density, can be expressed by the total soil porosity (TP). This feature provides information about the loosening and water movement potential within the soil (e.g. Higher values of TP means that the soil has high water retention capacity, high permeability and good loosening). As for soil characterization in terms of total porosity (TP), the values of this parameter were inversely proportional to bulk density. It is noteworthy that in variant b1 (non-irrigated) at 0-20 cm depth, the porosity was high, i.e. between 49.5 and 52.5 % v/v, when compared to variant b2 (irrigated), which had medium values, between 44.5 and 47.5% v/v. In both experimental variants (b1 and b2), at 20-40 cm depth and at the same water rate, the TP values ranged between 38-39% v/v in case of b1 variant, and from 37.5 to 39% v/v in case of b2 variant (Table 2). These values correspond to a low total porosity and thus to a system lacking loosening and water movement. In conclusion, we can say that irrigation can influence the state of soil settlement. As concerns the soil compaction degree (CD), the table from below indicates that the apple-tree orchard is located on a non-compacted soil. In b1 variant (non-irrigated), at 0-20 cm depth, the CD limits varied between -1.16 (non-compaction) and 4.83%v/v (slightly compaction), whereas in b2 variant (irrigated) the values ranged between -9.14 and -3.15%v/v, which correspond to a non-compacted soil (Table 2). The CD values corresponding to the compacted layer were recorded at 20-40 cm depth and were found in both experimental water regime variants, b1 (-24.81..-21.84%v/v) and b2 (-25.795..-22.83%v/v) (Table 2).

Table 2. The main soil physical properties of the apple orchard

	Experimental variant	**Depth (cm)**	**BD (g/cm^3)**	**TP (% v/v)**	**CD (% v/v)**
Romus 3 (a1)	b1 Ct	0-20	1.325	49.5	-1.1545
		20-40	1.595	39	-22.83
	b2	0-20	1.435	45.5	-9.145
		20-40	1.64	37.5	-25.795
Generos (a2)	b1 Ct	0-20	1.31	49.5	-1.16
		20-40	1.575	39.5	-21.84
	b2	0-20	1.455	44.5	-3.155
		20-40	1.615	38	-24.81
Ionathan (a3)	b1 Ct	0-20	1.24	52.5	4.83
		20-40	1.62	38	-24.81
	b2	0-20	1.365	47.5	-5.15
		20-40	1.6	39	-22.83

The values of bulk density (BD), reflecting the soil loosening or compaction in the non-irrigated variant (b1) at 0-20 cm depth, varied between the limits of 1.2 (moderately loose) - 1.45 g/cm^3 (slightly compact), and between a relatively narrow interval of 1.56 (moderately loose) - 1.65 g/cm^3 (moderately compact) at 20-40 cm depth. In case of the irrigated variant (b2), bulk density (BD) values ranged between 1.28 (slightly loose non-compacted) and 1.37 g/cm^3 (slightly loose non-compacted) at 0-20 cm depth, and between 1.61 (moderately loose) and 1.63 g/cm^3 (moderately loose) at 20-40 cm depth. It results that the compaction level increases with depth in both experimental variants on the hydrological regime (Table 3). In variant b1 (irrigated) at 0-20 cm depth, the porosity values ranged between 44.5% v/v (medium) and 54.5% v/v (high). These values were close to those obtained in variant b2 (irrigated), which recorded values between 46 (medium) and 51% v/v (high) (Table 3). In both experimental variants (b1 and b2) at the 20-40 cm depth, the values varied between 21-40% v/v (b1) and from 37.5 to 38.5% v/v (b2) (Table 3). These values correspond to a very low total porosity, indicating that the systems lack of proper aeration and water movement. In conclusion, it can be noticed a decrease of the total soil porosity within the soil profile due to soil compaction by applying irrigation. Analysis of the results on soil compaction degree (CD) from the table below showed that the soil from the apricot orchard was non-compacted. In variant b1 (non-irrigated), at 0-20 cm depth, the values ranged between -11.11% v/v (loose) and 8.82% v/v (slightly compacted), whereas in b2 variant (irrigated) the values correspond to a non-compacted and slightly compacted soil, ranging from -8.15% v/v and 1.83% v/v (Table 3). At the 20-40 cm depth, there was noticed that the compacted soil shifted to non-compacted soil in both the experimental variants of the water regime, i.e. from -27.77% v/v to -2.85% v/v in b1 (non-irrigated) and from -25.8% v/v to 0.25% v/v in b2 (irrigated) (Table 3).

Table 3. The main soil physical properties of the apricot orchard

Variety (a)	**Experimental variant**	**Depth (cm)**	**BD (g/cm^3)**	**TP (% v/v)**	**CD (% v/v)**
Dacia (a1)	b1 Ct	0-20	1.45	44.50	-11.11
		20-40	1.56	40	-2.85
	b2	0-20	1.37	46.00	-8.15
		20-40	1.63	37.50	-25.80
Comandor (a2)	b1 Ct	0-20	1.2	54.5	8.82
		20-40	1.59	21.5	-21.83
	b2	0-20	1.37	47.5	-5.15
		20-40	1.61	38.5	-23.82
Tudor (a3)	b1 Ct	0-20	1.25	50.5	0.84
		20-40	1.65	36.5	-27.77
	b2	0-20	1.28	51	1.835
		20-40	1.62	37.5	-0.25

The effect of drip irrigation on the soil chemical properties

The research carried out between 2011-2012 aimed to measure the following soil chemical properties: the content in soluble salts as mg/100g soil, the N content ($N\text{-}NH_4$ + $N\text{-}NO_3$) (as ppm), mobile P and K contents (Tables 4, 5). Analysis of the soil soluble salts content (mg/100g soil) showed that the values ranged between 32 and 36 mg/100g soil, were uniformly distributed in all the experimental variants studied, and correspond to non-saline soils (Table 4). The nitrogen sources for plant nutrition are both ammonia and nitric forms, and depend on the species and plant age, soil reaction, the soil buffer capacity and the presence or absence of certain cations and anions. Based on a formula used by the ICPA METHODOLOGY, 1987 [21], we calculated the amount of nitrogen available in plants ($N\text{-}NH_4$ + $N\text{-}NO_3$). The obtained result was a very low N content in all variants studied, significantly below the standard limit of 40 ppm (Table 4). Thus, in the case of Romus 3 and Ionathan varieties, in the irrigated variant (b2), the nitrogen amount at 0-20 cm depth was higher, reaching values of 27.55 ppm (Romus 3) and 28.5 ppm (Ionathan). As for the Generos variety at the same depth, the N content was only 8.55 ppm, and higher (18.05 ppm) in the irrigated variant (b2) at 20-40 cm depth (Table 4). The values of accessible (mobile) phosphorus indicated a medium content in the first 20 cm depth in b2 variant (irrigated), i.e. 25.26 ppm for Romus 3 variety and 30.79 ppm for Generos variety, and a high content (37.37 ppm) for Ionathan variety. At the other depth (20-40cm), the b2 variant (irrigated) recorded a low content in phosphorus; in b1 variant (non-irrigated) only in Ionathan variety the content was medium (28.37 ppm) at 0-20 cm depth and low at 20-40 cm depth (13.15-15.22 ppm) (Table 4). The evaluation of accessible (mobile) K^+ was based on the values calculated for 0-40 cm depth, and ranged between the limits of 25-40 ppm, which can be classified as low contents (Table 4).

Table 4. The main soil chemical properties of the apple orchard

Variety (a1)	Experimental variant	Depth (cm)	Soluble salts mg/100g soil	N ($N-NH_4$ + $N-NO_3$) (ppm)	P_{AL}(ppm)	K_{AL}(ppm)
Romus 3 (a1)	b1 Ct	0-20	35	17.1	28.37	40
		20-40	35	15.2	15.22	25
	b2	0-20	35	27.55	25.26	35
		20-40	35	21.85	14.53	25
Generos (a2)	b1 Ct	0-20	35	8.55	9.72	40
		20-40	35	9.5	13.15	25
	b2	0-20	35	8.55	30.79	40
		20-40	35	18.05	16.95	25
Ionathan (a3)	b1 Ct	0-20	32	10.45	26.98	25
		20-40	36	13.3	15.22	25
	b2	0-20	36	28.5	37.37	35
		20-40	35	19.0	15.57	25

The soil soluble salts content mg/100g soil) varied between 32 mg/100g soil and 42 mg/100g soil, were uniformly distributed in all the experimental variants under studied and correspond to non-saline soil (Table 5). Also in case of the apricot varieties, the N content was very low in all the variants, significantly below the standard limit of 40 ppm (Table 5). Comparing the variants of the water regime, were noted differences both between the depths and the varieties. Thus, the N content values were higher (i.e. 21.85 ppm) in b1 variant (non-irrigated) at 20-40 cm depth for the Tudor variety, followed by 17.1 ppm, at 0-20 cm depth in b2 (irrigated) for Dacia and also Tudor varieties in the same experimental variants. The very low values of nitrogen, between 4.75 ppm and 21.85 ppm, indicate the low N content in soil and as a result is recommendations for N-based fertilizer application (Table 5). The values of the accessible (mobile) phosphorus content were low and very low for the two depths in both experimental variants (b1 and b2). Only the Tudor variety recorded a medium level, i.e. 22.84 ppm (b1) and 20.07 ppm (b2) at 0-20 cm depth in both experimental variants (b1 and b2) (Table 5). The evaluation of accessible (mobile) K^+ content at 0-40cm depth, showed that the values ranged between the limits (25-35ppm), which indicate an extremely low K content (Table 5).

Tabel 5. The main soil chemical properties of the apricot orchard

Variety (a)	Experimental value	Depth (cm)	Soluble salts mg/100g sol	N-(NH_4+ $N-NO_3$) (ppm)	P_{AL} (ppm)	K_{AL} (ppm)
Dacia (a1)	b1 Ct	0-20	35	15.2	13.15	35
		20-40	32	9.5	12.46	25
	b2	0-20	32	17.1	13.15	25
		20-40	35	12.35	6.69	30
Comandor (a2)	b1 Ct	0-20	30	4.75	12.46	35
		20-40	30	6.65	6.95	30
	b2	0-20	42	5.7	13.15	30
		20-40	36	15.2	9.69	35
Tudor (a3)	b1 Ct	0-20	33	14.3	22.84	30
		20-40	35	21.85	14.88	35
	b2	0-20	36	17.1	20.07	30
		20-40	36	14.25	14.19	25

4. Conclusions

The soil compaction increases with depth in both experimental variants for both studied species. Bulk density at 20-40 cm depth is higher because of the higher clay content within the soil profile.

Application of irrigation has resulted in a decrease of total soil porosity at deeper layer due to compaction.

The soil compaction degree (CD) values have shown that the upper layer is not compacted.

The soil soluble salts content varied between 32 and 35 mg/100 g soil, in both apple and apricot, without significant differences between variants.

The nitrogen amount ($N\text{-}NH_4$ + $N\text{-}NO_3$) was low in all experimental variants, significantly under the standard of 40 ppm for both species. The b2 variant (irrigated) recorded a slight increase of N content for each variety, when the water regime variants were compared.

The very low values of nitrogen content obtained for both apple and apricot, resulted in recommendations for n-based fertilizer application.

The values of accessible phosphorus content, in b2 variant (irrigated) from apple orchard, varied between medium at 0-20 cm depth and low at 20-40 cm depth. In b1 variant (non-irrigated) the P content was low and medium at 0-20 cm depth, and low at 20-40 cm depth. In case of apricot orchard, the P content was low and medium in both hydric regime variants (b1, b2).

The evaluation of accessible (mobile) K^+ content for both studied species, at 0-40 cm depth, showed that the values ranged between the limits of 25-40 ppm, which indicate a low K content in soil.

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