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WATER HOLDING PROPERTIES AND SOIL WATER TYPES IN FINE TEXTURED VERTISOL SOILS OF THRACE REGION IN TURKEY

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Abstract. The study was carried out on 16 selected model soil profiles, located on lands covered with soils exhibiting vertic properties in Thrace Region of Turkey. Different horizons and/or sub-horizons of 16 characteristic soil profiles were evaluated in field or laboratory conditions in terms of water holding capacity and water types properties. Total of 105 soil samples were analyzed for routine physical characteristics. Soil water holding capacity was determined applying negative potentials (Ψ) of -0.33 bar, -15.5 bar and -31.5 bar (pF 2.54; 4.2 and 4.5), using a pressure-membrane extraction apparatus. In addition to gravitational, available, unavailable and hygroscopic soil water types, the soil samples were investigated also in terms of crystal-lattice water content. The highest amounts of the listed water types were determined in soils of Büyük Mandira, Türkgeldi and Seymen containing the highest rates of smectite clay mineral. The mass percentage (Pw) rates of the mentioned water types of the investigated profiles varied in the ranges of 29.1–66.3%, 10–2.15%, 22.0–32.4%, 6.0–9.0% and 5.6–8.6%, respectively. Though the mass percentages of enumerated water types in the soils of Osmanli and Yeni Mahalle, all owning high sand and lower clay content on the other hand, are between 28.9–40.6%, 6.1–15.5%, 7.4–16.8%, 2.4–4.8% and 1.7–4.4%, respectively.

Keywords: cracking soils, texture, clay, hydraulic properties

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INTRODUCTION

Approximately 400,000 hectares of fine textured soils of Vertisol order are located in Kirklareli, Edirne and Tekirdag provinces and Silivri and Gelibolu districts of Thrace region of Turkey. As a whole, the chemical and water holding properties of Vertisol soils are favourable, and the percentage of base saturation is almost 100%; cation exchange capacity reaches very high values of 25–66 meq/100 g (Smedema 1984, Çakir 1993, Çakir 1997). However, there are significant problems arising from the physical properties of these soils. In general, Vertisols are characterized as clayey soils, cracking during the dryer periods of the year and the agricultural management of these soils is extremely difficult. On the other hand, formation of the hard layer due to compaction in result of soil tillage, limits the infiltration of the water applied through irrigation. In addition, the specified soils form deep and wide cracks during the dry periods of the year and cause moisture loss from the lower horizons of the soil profile. As a result of the deep and wide cracks formed, large amounts of water losses occur during irrigation, and the plant root development in these soils is limited due to mechanically breaking the plant roots.

In several studies carried out in Turkey and abroad, the properties of Vertisol soils are evaluated in terms of irrigation, fertilization, soil tillage and engineering practices. Ozkan and Akalan (1976) examined some physical properties of the upper horizons of the Vertisol soils in Thrace region of the country and determined that the clay content of the evaluated soils reached up to 45%, which lead to high field capacity, wilting point and readily available water percentages, varying in the ranges of 29.13–39.08%; 23.19–31.47% and 4.74–13.86%, respectively. Smedema (1984) determined that the infiltration rate of Vertisol soils is very high at the start of irrigation application, followed by a sudden decrease due to the high swelling and shrinkage properties of the dominant smectite clay mineral in the soil. Some authors (Cangir 1985, Cangir 1987) reported that high amounts of irrigation water are lost due to deep and wide cracks appearing as a result of high content of clays owing high swelling and shrinkage properties. In earlier studies carried out in Thrace region of Turkey, Vertisols are compared with Entisols and Alfisols, and it was determined that the clay content of the studied soils reached up to 40–75%, providing high field and water storage capacity values. In a study conducted in Ethiopia (Astatke *et al.* 1995), the water storage capacity of these soils was found to be 200 mm/50 cm (4 mm/cm).

In studies conducted recently (Zurovec and Cadro 2016), there have been evaluated soil water characteristics of different soils, through using negative potentials (Ψ) of -0.33 bar (pF 2.54), -1 bar (pF 6.25), -6.25 bar (pF 3.8) and -15.5 bar (pF 4.2). Additionally, totally (TAW) and readily (RAW) available water capacities were calculated. Toth *et al.* (2014) studied the soil properties of the main soil types in Hungary, including soil holding properties and soil water retention at -0.1, -33, -1,500 and -150,000 kPa.

The main objective of the study was to evaluate the hydraulic properties, including water types content, of the fine textured Vertisol soils, and to obtain some hints promoting irrigation management of the lands with mentioned type of soil in the region of the study.

MATERIALS AND METHODS

The areas covered with Vertisol soils, exhibiting peculiar features such as wide cracks and self-mulching (Fig. 1), and clod structure (Fig. 2), located within the boundaries of Edirne, Tekirdag and Kirklareli provinces of Thrace region of Turkey, were investigated in the study. The surveyed soils were examined for morphologic soil characteristics such as soil colour, structure, consistency, pores, presence of roots and other special views of the profile studied *in situ* by following procedures described in Soil Survey Staff (1992). Brief information related to location and elevation of the studied soil profiles, as well as the depth and boundaries of the soil horizons and sub-horizons is presented in Table 1. Approximately 2 kg of soil samples were collected from each genetic horizon and/or sub-horizon of the studied profiles in the field, and delivered to the laboratory for laboratory analyses and further evaluations.

Fig. 1. Cracks and self-mulching view typical for Vertisols

Fig. 2. Clod structures characteristic for Vertisols

Routine physical analysis of the total of 105 soil samples was carried out by following the procedures given by Tuzuner (1990). Soil water holding capacity was determined at negative potentials (Ψ) of -0.33 bar, -15.5 bar and -31.5 bar (pF 2.54; pF 4.2 and pF 4.5) by using a pressure-membrane extraction apparatus described by Richards (1954). Soil water types of the soils of the horizons and sub-horizons were evaluated for pF 1.84, 2.54, 4.2, and 4.5 by procedures reported by Munsuz (1982). While crystal-lattice water content of oven dried soils at 105ºC was determined by fragmentation of the crystal structure of the clays at 950ºC (Black 1965).

Table 1. Evaluated Vertisol soil profiles

Profile	Location (settlement) and Elevation	Geographical Position	Classification
D1	Eski kadın – Edirne 106 m	41°42'56N; 26°27'24E	Chromic Calcixerert (Soil Taxonomy); Calcic Vertisol (FAO/UNESCO)
D2	Osmanlı – Havsa 115 m	41°35'07N; 26°51'33E	Udic Haploxeret (Soil Taxonomy); Eutric Vertisol (FAO/UNESCO)
D3	Osmanlı – Havsa 90 m	41°34'30N; 26°51'00E	Udic Haploxerert (Soil Taxonomy); Eutric Vertisol (FAO/UNESCO)
D4	Akardere – Süloğlu 140 m	41°40'13N; 26°57'02E	Udic Haploxerert (Soil Taxonomy); Eutric Vertisol (FAO/UNESCO)
D5	Ulukonak – Kırklareli 143 m	41°39'37N; 27°00'50E	Typic Calcixerert (Soil Taxonomy); Calcic Vertisol (FAO/UNESCO)
D6	Yeni Mahalle – Babaeski 156 m	41°34'19N; 27°08'00E	Chromic Haploxerert (Soil Taxonomy); Eutric Vertisol (FAO/UNESCO)
D7	Karahalil – Babaeski 148 m	41°35'59N; 27°03'50E	Udic Haploxerert (Soil Taxonomy); Eutric Vertisol (FAO/UNESCO)
D8	Kadıköy – Babaeski 89 m	41°28'50N; 27°03'55E	Udic Haploxerert (Soil Taxonomy); Eutric Vertisol (FAO/UNESCO)
D9	Babaeski – Kırklareli 89 m	41°25'08N; 27°07'20E	Typic Calcixerert (Soil Taxonomy); Calcic Vertisol (FAO/UNESCO)
D10	Büyük Mandıra – Babaeski 30 m	41°35'58N; 27°04'53E	Sodic Haploxerert (Soil Taxonomy); Eutric Vertisol (FAO/UNESCO)
D11	Lüleburgaz Türkgeldi – Kırklareli 79 m	41°22'55N; 27°19'13E	Udic Haploxerert (Soil Taxonomy); Eutric Vertisol (FAO/UNESCO)
D12	Lüleburgaz Türkgeldi – Kırklareli 74 m	41°22'50N; 27°19'07E	Sodic Haploxerert (Soil Taxonomy); Eutric Vertisol (FAO/UNESCO)
D13	Beyazköy – Saray 101 m	41°21'25N; 27°40'24E	Lithic Calcixerert (Soil Taxonomy); Calcic Vertisol (FAO/UNESCO)
D14	Vakıflar – Çorlu 118 m	41°15'56N; 27°39'27E	Udic Haploxerert (Soil Taxonomy); Eutric Vertisol (FAO/UNESCO)
D15	Seymen – Çorlu 114 m	41°05'58N; 27°56'41E	Sodic Haploxerert (Soil Taxonomy); Gypsic Vertisol (FAO/UNESCO)
D16	Karacakılavuz – Tekirdağ 184 m	41°09'40N; 27°20'04E	Udic Haploxerert (Soil Taxonomy); Eutric Vertisol (FAO/UNESCO)

RESULTS AND DISCUSSION

The results obtained for the soil water types and the soil water holding capacity of the investigated soils are presented in Tables 2, 3, 4 and 5. From data included in the mentioned tables it could be concluded that just like in the case of the other soils having high clay content, the soil evaluated in the study also had high field capacity and water holding capacity values. However, due to the unfavourable size and distribution of the pores under high percentage of clay in the texture of the examined soil, the greater part (up to 18–20%) of the soil water content is not available for the plants.

The evaluation of data related to gravitational water located in pores larger than 10 μ showed that significant differences exist between the examined profiles. In this context, the soils of relatively lighter texture as D2 and D3, both on the territory of the Osmanli settlement, Eski Kadin (D1) and Karacakilavuz (D16) contain relatively low percentage of gravitational water, varying in the ranges of 28–35%, 31–38%, 32–38%, and 29–37%, respectively. On the other hand, the gravity-affected moisture in the soils of profiles containing higher clay amounts as D11 and D12, both located in the lands of the Türkgeldi Agricultural Farm Directorate, D10 (Büyük Mandira) and Seymen (D15) reach up to 35.8–52.7%, 42.2–53.8%; 29.0–66.0%, and 34.7–75.0%, respectively. Similar variations in water holding and retention properties of the soil in dependence of the texture and depth of the evaluated horizons and/or sub-horizons have been also reported by Cooper *et al*. (2012).

Table 2. Some physical and water holding properties of the soil of D1, D2, D3 and D4 profiles**

Profile	Horizons	Texture		Gravitation water	Capillary water (pF 2.5–4.5)		Hygros-copic water	Crystal-lattice water
		Clay (%)	Texture class*	(pF ≤ 2.5)	RAW (pF 2.5–4.2)	Unavailable for plant (pF 4.2–4.5)		
D1	Ap	38.78	CL	35.86	10.93	14.08	5.13	5.35
	A	38.81	CL	38.28	11.76	14.39	5.57	5.21
	2A	43.05	C	35.30	11.81	15.77	5.12	5.58
	3AC	38.34	CL	37.08	13.78	12.38	4.76	6.44
	3Ck1	35.96	CL	35.81	14.50	10.49	4.20	8.64
	4Ck2	35.51	CL	33.40	14.55	10.32	4.73	6.08
	4Ck3	40.02	C	31.77	18.16	7.92	5.15	4.93
D2	Ap	34.83	CL	33.34	7.97	14.09	3.60	3.22
	A	34.63	CL	33.19	7.64	11.25	2.92	2.73
	2Ass1	43.96	C	33.11	9.72	16.0	4.27	3.04
	2Ass2	44.12	C	31.42	10.08	16.75	4.75	3.31
	2AC	41.56	C	33.44	9.53	14.24	3.79	3.03
	2C	34.74	CL	35.08	9.32	11.48	3.12	2.63
	2Ck	26.15	SCL	28.77	8.10	8.91	2.22	2.28

Profile	Horizons	Texture: Clay (%)	Texture: Texture class*	Gravitation water (pF ≤ 2.5)	Capillary water (pF 2.5–4.5): RAW (pF 2.5–4.2)	Capillary water (pF 2.5–4.5): Unavailable for plant (pF 4.2–4.5)	Hygroscopic water	Crystal-lattice water
D3	A1	31.78	SCL	37.34	6.13	12.87	2.66	2.74
	A2	29.73	SCL	38.11	7.36	10.72	2.81	2.43
	A3	33.13	CL	34.42	9.19	10.58	2.81	2.77
	A4	30.44	SCL	30.60	10.86	10.51	3.03	2.54
	Ass	39.19	CL	33.97	12.13	12.96	3.93	2.41
	2C	23.94	SCL	30.35	5.89	7.37	2.39	1.65
D4	Ap	47.00	C	44.42	9.5	17.19	5.89	4.44
	A	46.93	C	37.38	13.14	17.90	5.58	4.38
	Ad	49.18	C	40.21	12.26	18.76	5.57	4.17
	Ass1	49.37	C	36.24	11.58	18.28	5.90	4.72
	Ass2	51.30	C	36.88	13.91	17.8	5.41	4.26
	2A	51.40	C	32.69	13.64	18.04	5.59	4.31
	2CA	53.48	C	41.42	16.51	17.78	5.59	4.49
	3C	63.75	C	34.55	12.64	17.54	5.27	6.73

* C – clay; CL – clay loam; SCL – sandy clay loam, ** water types in all tables are presented as % mass

Table 3. Some physical and water holding properties of the soil of D5, D6, D7 and D8 profiles

Profile	Horizons	Texture: Clay (%)	Texture: Texture class*	Gravitation water (pF ≤ -2.5)	Capillary water (pF 2.5–4.5): RAW (pF 2.5–4.2)	Capillary water (pF 2.5–4.5): Unavailable for plant (pF 4.2–4.5)	Hygroscopic water	Crystal-lattice water
D5	Ap	45.76	C	38.04	11.85	17.26	4.85	3.98
	A	45.85	C	36.91	13.30	16.33	5.46	3.68
	Ass1	48.41	C	32.2	12.19	18.47	5.14	3.25
	Ass2	49.09	C	35.86	13.04	18.11	4.99	4.01
	Ass3	51.26	C	33.68	13.01	17.29	6.02	4.63
	Ck	55.23	C	36.71	13.68	16.78	4.83	5.72
	C	58.50	C	35.89	13.78	17.43	4.90	7.53
D6	Ap	32.57	SCL	40.57	7.39	11.34	3.70	3.43
	Ad	34.70	SCL	38.90	8.37	11.81	3.92	3.59
	Ass1	39.08	SC	38.70	8.48	14.23	4.59	3.28
	Ass2	34.95	SCL	32.09	8.58	12.75	3.58	3.07
	A1	36.79	SC	32.27	9.81	13.34	3.58	3.06
	A2	38.32	SC	28.94	9.77	14.47	3.82	3.37
	Cn	45.09	C	36.23	12.52	15.07	4.18	4.42
D7	Ap	43.34	C	41.15	8.28	17.45	5.12	4.39
	A	45.59	C	37.74	11.07	17.8	5.39	4.17
	Ass1	41.42	C	38.71	7.99	17.88	5.42	3.92
	Ass2	45.85	C	35.85	9.97	18.73	5.45	3.96
	Ass3	52.43	C	34.26	12.38	19.72	5.64	4.05
	C	52.08	C	31.30	16.09	19.81	4.80	4.11
D8	Ap	50.77	C	43.82	8.82	19.35	5.01	5.05
	A	50.88	C	39.75	12.02	19.77	5.46	4.78
	Ass1	55.77	C	39.73	11.35	19.29	6.63	4.63
	Ass2	53.47	C	43.80	11.33	19.88	5.99	4.31
	CA	55.11	C	38.64	11.74	16.46	5.16	5.62
	2C	30.13	CL	33.02	14.91	7.73	3.34	4.13

* C – clay; CL – clay loam; SC – sandy clay; SCL – sandy clay loam

In terms of soil–water and soil–water–plant relationships, the amount of water, which is useful for plants (pF 2.5–4.2), and can easily be extracted from the soil through the roots of plants, is more important than the total water holding capacity of the soil. The highest values of this water type constituting a part of the capillary water, are determined in the soils of D10 (Büyük Mandira), D11 (Türkgeldi), D12 (Türkgeldi) and D15 (Seymen) locations. The amounts of the available water in various horizons of the listed soil profiles were determined to vary in the ranges of 12.48–21.15%, 13.0–18.9%, 10.0–17.5%, and 12.0–18.57%, respectively. The results related to water holding of the soils of different clay content and various texture obtained in our study, support those published earlier by Debnath *et al*. (2012) for soils of various texture and elevation in Sikkim region of India. Kaczmarek *et al.* (2017) also evaluated the water holding properties of soils of different texture and organic matter content of Central Poland, and determined that the total available water (TAW) and readily available water (RAW) values of studied soil varied in the ranges of 6.74–36.66 and 6.35–29.09 (%v/v), respectively, depending on soil texture and Mursh availability.

Great differences existed among the evaluated soil profiles and horizons in terms of the results related to water amounts, not available for plant and held in the soil under tension higher than 15 bar (pF 4.2–4.5). As a whole, the weight percentage of this type of water, held in micropores with a diameter of less than 0.2 μ in soils of all horizons and sub-horizons, except for C horizons, of relatively light textured D1, D2, D3, D4, D5, D6 (Table 2 and 3) and D13 (Table 5) profiles, was determined to vary in the ranges of 10.0% and 18.0%. The percentage of the water type unavailable for plants in the soils of Türkgeldi (D11 and D12), containing high clay amounts, was recorded to reach much higher levels, and varied in the ranges of 29–30% and 27–31%. It turned out that soils of Türkgeldi (D11 and D12) profiles, with very high (up to 65–75%) clay content, had two times higher percentages of moisture unavailable for plants, than those of the available for plants moisture. Similarly, 1.5–2 times higher percentages of unusable water content was determined in the case of Babaeski (D9) and Büyük Mandira (D10) soils, owing 60–65% clay content (Table 4). This contradiction probably appeared due to the fact that the part of water between the layers of the dominating smectite clay mineral, owing high swelling and shrinkage potential, is also removed from the environment during the drying process.

Since soils have hygroscopic properties, they absorb a certain amount of moisture from the atmosphere and show a trend to balance it with the moisture of the environment. The amount of the hygroscopic moisture in the examined soils was determined to vary from soil to soil and, above all, was related to the amount of clay contained of a given soil. While the lowest percentages of hygroscopic moisture, between 2.39% and 3.93% were found at different horizons of the Osmanli (D3) profile containing the lowest clay fraction, the highest ratios of the mentioned water type, in the ranges of 7.15–8.96% were determined in the soil samples collected from different horizons of the Türkgeldi (D11) profile, containing 63–77% clay. The values obtained for the hygroscopic soil water determined in our study are much higher than maximum hygroscopic water values in the ranges of 3.35–3.82 (% v/v) reported by Kaczmarek *et al*. (2013) reported for the soils of the experimental area of the Research and Didactics Centre of the Poznań University of Life Sciences. The higher values of the discussed water type determined in our evaluation probably appeared due to fine texture and high clay content of the studied Vertisol soils.

Similar results were determined in terms of the water type interpreted as crystal-lattice or chemically bound water, varying between 3 and 5% in the most studied soil. The lowest ranges of 1.65–2.74% and 2.28–3.22% were observed in the soils of D2 and D3 profiles, containing least clay amounts, while the highest ratios of 7.0–8.5% and 6.5–8.6% were recorded for the soils of different layers of D11 and D12 profiles, having high amounts of clay in their texture.

Table 4. Some physical and water holding properties of the soil of D9, D10, D11 and D12 profiles

Profile	Horizon	Texture		Gravitation water	Capillary water (pF 2.5–4.5)		Hygroscopic water	Crystal-lattice water
		Clay (%)	Texture class*	(pF ≤ -2.5)	RAW (pF 2.5–4.2)	Unavailable for plant (pF 4.2–4.5)		
D9	Ap	63.94	C	37.60	14.45	23.7	7.25	6.86
	A	65.17	C	44.43	14.95	25.49	7.16	5.31
	Ass	67.22	C	47.4	14.79	25.39	6.42	6.83
	Ak	69.47	C	37.2	13.76	23.81	6.23	6.88
	ACk	67.23	C	41.06	12.47	19.48	3.99	9.11
	C	73.12	C	41.66	14.51	22.7	4.13	8.61
D10	Ap	62.11	C	29.13	12.48	22.39	6.00	5.98
	Ad	64.10	C	34.52	14.19	22.02	6.27	5.87
	Assn1	69.15	C	35.67	18.34	22.05	6.94	5.87
	Assn2	71.12	C	48.29	20.16	23.82	6.73	6.13
	Assn3	72.76	C	66.33	21.15	27.12	6.40	5.61
D11	Ap	63.01	C	48.27	12.97	30.61	7.15	8.07
	A	70.23	C	52.69	13.78	29.43	8.12	7.74
	Ass1	72.66	C	45.32	14.21	30.97	8.42	7.35
	Ass2	72.22	C	50.29	16.37	30.25	8.09	7.78
	Ass3	72.56	C	46.89	17.25	29.89	8.96	8.14
	AC	77.05	C	48.85	15.35	30.23	8.57	7.70
	C	74.54	C	35.83	18.91	30.43	8.83	8.45
D12	Ap	62.46	C	50.49	13.71	27.07	7.73	6.85
	A	66.23	C	45.45	9.62	32.43	7.51	8.60
	2Ass	66.70	C	46.70	14.9	28.08	6.62	8.54
	2AC	68.41	C	42.17	15.28	28.92	7.63	8.54
	3Ass	75.17	C	43.58	17.24	27.37	7.81	8.11
	3Cn	71.54	C	53.8	16.52	24.37	6.31	6.65

* C – clay

Table 5. Some physical and water holding properties of the soil of D13, D14, D15 and D16 profiles

Profile	Horizons	Texture		Gravitation water	Capillary water (pF 2.5–4.5)		Hygroscopic water	Crystal-lattice water
		Clay (%)	Texture class*	(pF ≤ -2.5)	RAW (pF 2.5–4.2)	Unavailable for plant (pF 4.2–4.5)		
D13	Ap	39.18	SC	43.71	6.4	14.2	3.69	3.12
	Ad	39.48	SC	36.06	8.93	16.3	4.71	3.25
	Ag	41.90	SC	49.76	9.13	16.71	5.53	3.94
	ACmg	39.61	SC	42.44	8.04	16.69	4.83	4.24
	CAmk	42.91	C	37.46	10.01	12.28	3.25	5.80
	Cmk	36.80	SC	36.25	8.21	11.0	3.54	5.63
D14	Ap	42.15	SC	41.84	8.04	17.38	4.74	4.34
	A1	42.60	SC	39.30	8.84	16.82	5.04	4.86
	A2	45.80	SC	37.89	9.86	16.89	5.36	3.87
	Ass	45.00	C	40.23	8.79	17.68	5.30	4.03
	CA	47.24	C	36.81	10.15	17.77	5.27	3.52
	Ckg	46.95	C	37.71	10.35	17.12	4.82	9.11
D15	Ap	51.52	C	36.75	11.61	18.3	5.34	3.97
	Ad	54.24	C	34.63	12.81	17.68	6.88	3.96
	Ass	65.76	C	52.94	18.57	25.22	6.27	6.25
	Assny1	76.17	C	61.49	18.57	23.65	6.39	6.18
	Assny2	52.20	C	47.23	17.57	22.57	6.63	6.42
	2CAny	48.33	SiC	64.24	17.09	22.48	6.17	6.03
	3Cnyg	59.63	C	78.53	17.72	22.63	6.08	6.67
D16	Ap	39.27	CL	32.87	10.22	12.65	5.26	4.63
	A	41.28	C	37.68	12.37	12.53	5.42	4.84
	Ad	41.46	C	29.09	11.95	13.08	4.88	4.86
	AC	41.56	C	33.76	11.45	12.97	4.82	4.80
	CA	45.89	C	33.69	11.14	13.06	5.11	3.58
	CAss	45.85	C	32.73	12.20	13.17	4.85	4.42
	CA'	45.82	C	37.03	12.06	14.21	4.70	4.23
	Ck	43.65	C	34.93	12.23	13.67	5.17	4.37

* C – clay; CL – clay loam; SC – sandy clay; SiC – silty clay

Our results related to the high clay content in soil samples collected from the evaluated soil confirmed the findings which were published earlier for Vertisols of the region. TOPRAKSU (1974) characterised the soils of the Vertisol order as fine, heavy textured soils, containing more than 30% swelling-shrinking clays in their texture. The high rates of the clay minerals determined as 64–73% and 62–73% in Babaeski (D9) and Büyük Mandira (D10) soil profiles, were completely consistent with those of 59–71% clay values reported by Hindistan (1978) for Babaeski-Karapirenk lands in the region of the study.

Ekinci *et al*. (1993) stated that Vertisol soils of Karacakilavuz in Tekirdag Province owned poor physical and management properties, due to high amounts (53–56%) of smectite clay mineral in their texture. Statements related to unfavourable (heavy) texture of the studied soils are reported also in the foreign scientific literature (Hulme *et al.* 1991, McKenzie *et al.* 1994, Islam *et al.* 1994).

Zurovec and Cadro (2016) also determined that water amounts in the soil profile vary from soil to soil, and the highest amount of water in the soil over the entire water potential range (pF), is available in Luvisol, and the lowest in Fluvisol soil profiles. The authors also claimed that Pseudogley had the best water characteristics and the highest capacity of readily available water, due to favorable conditions in its sub-surface horizon.

CONCLUSIONS

From studies carried out across the Thrace region, it could be concluded that the evaluated Vertisols have high moisture values over the entire water potential range (pF 1.84, 2.54, 4.2, and 4.5), changing with the amount of the clay minerals in their texture.

In general, the moisture content of the evaluated soil profiles and horizons at -0.33 and -15.5 bar negative tension, are determined as 20–55% and 15–40%, respectively. Relatively low moisture values in the ranges of 20.9–31.8% (-0.33 bar) and 10–22% (-15 bar) are recorded for the soils of D2 and D3 (Osmanli), D6 (Yeni Mahalle) and D13 (Beyazköy), all containing less clay amounts. The highest moisture values, between 47.2–58.2% and 31.0–40.0% under negative tensions of -0.33 and -15.5 bars respectively, are observed in the soil samples collected from the horizons of D11 and D12 (Türkgeldi) profiles, characterising with the highest clay amounts in the texture.

The highest amounts of gravitational, available and unavailable for plants, hygroscopic, and crystal-lattice water types exist in the soils of D10 (Büyük Mandira), D11 and D12 (Türkgeldi) and D15 (Seymen) containing the highest amount of smectite clay mineral. The mass percentage (Pw) rates of water types in the mention profiles vary in the ranges of 29.1–66.3%, 10–2.15%, 22.0–32.4%, 6.0–9.0% and 5.6–8.6%, respectively. While on the other hand, the mass percentages of the enumerated water types in the soils of D2 and D3 (Osmanli) and D6 (Yeni Mahalle), all owning high sand and lower clay content, are between 28.9–40.6%, 6.1–15.5%, 7.4–16.8%, 2.4–4.8% and 1.7–4.4%, respectively.

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