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Impact of Natural Conditioners on Water Retention, Infiltration and Evaporation Characteristics of Sandy Soil

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Abstract: Soil conditioners i.e., natural deposits and organic fertilizer are used for alleviate some of poor physical properties of sandy soils such as low water retention and inefficient water use, especially in arid and semi-arid regions such as in Saudi Arabia conditions. The present study aims to investigate the impact of clay deposits and organic fertilizer on water characteristics, cumulative infiltration and intermittent evaporation of loamy sand soil. Soil sample was collected from surface layer (0-30 cm depth) of the Agricultural Experiment and Research Station at Dierab, 40 km south west of Riyadh, Saudi Arabia. Two samples of clay deposits (CD#22 and CD#23) collected from Khyleis area, Jeddah-Madina road in addition of commercial Organic Fertilizer (OF) were used in the present study. The experiments were done during August to December 2005 in soil physics laboratory, the soil was mixed with clay deposits and organic fertilizer at rates of 0, 1, 2.5, 5.0 and 10.0% (w/w). The transparent PVC columns were packed with soil to depth of 30 cm every 5.0 cm intervals to insure a homogeneity of soil in columns. The clay deposits (CD#22 and CD#23) and Organic Fertilizer (OF) mixed with the soil were packed in the upper 0-5.0 cm of each soil column. The infiltration experiment was done using a flooding apparatus (Marriot device) with constant head of 3.0 cm over the soil surface. The cumulative infiltration and wetting front depth as a function of time were recorded. The evaporation experiment was conducted in 40 cm long transparent sectioned Lucite cylinders (5.0 cm ID). Fifty millimeters of tap water were applied weekly for three wetting/drying cycles. Cumulative evaporation against time was measured daily by weighing each soil column. The soil moisture distribution at the end of the experiment was determined gravimetrically for each 5.0 cm interval. The results indicated that the three conditioners significantly increased the water constants of mixed soil (i.e., SWC, FC, PWP and AW), but the CD#22 has a superior effect. The results clearly indicated that increasing the application rate of conditioners significantly decreased the cumulative infiltration (D). The decrease in D more pronounced at higher rates. The CD#22 was more effective in reducing the cumulative infiltration. The relationship between (D) as a function of Time (T) was done by fitting the data to the Kostiakov and Philip equations. Increasing the application rate of natural conditioners restricted the wetting front movement and need more time to reach 30 cm depth. The natural conditioners significantly reduced the cumulative evaporation throughout the 3 evaporation cycles. The reduction significantly increased with increasing the application rate, except for the higher rate (10%), which increases the cumulative evaporation under the present conditions. The improvement of soil hydro-physical properties and reduction in water infiltration and cumulative evaporation are good practices for plant growth in region limited in water such as most regions in Saudi Arabia.

Key words: Soil infiltration, clay deposit, organic fertilizer, intermittent evaporation, natural conditioners, cumulative infiltration

INTRODUCTION

The maintenance of water and nutrients at optimal levels within the root zone depth of plants is a primary factor to achieve high growth, yield and yield quality of crops, especially in sandy soils (El-Kholy *et al*., 2000). Sandy soil usually have a poor properties i.e., low specific surface area, low water retention, low organic matter content, low fertility and high infiltration rate. These poor physical properties cause inefficient water use, especially

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in arid and semiarid regions. These adverse factors can solve by several means; one of them is the addition of different natural conditioners, such as natural deposits (Al-Omran *et al.*, 2004; Sallam *et al.*, 1995; Abu-Gabal *et al.*, 1990) and organic materials (Abdel-Nasser, 2004 and 2005; Abdel-Nasser and Hussein, 2001) beside that can use it as fertilizers (Matloub, 1998).

Soil conditioners defined as a substance that improves the physical properties of soil (Wallace and Terry, 1998; Al-Omran and Al-Harbi, 1998). Soil conditioners include both synthetic and natural products. Soil conditioners as defined include many kinds of organic materials, gypsum, lime, natural deposits, various water-soluble polymers and cross-linked polymers that hold water in soil, living plants, microbes, many industrial waste products and others. Actually, there are a number of organic products that can be used as soil conditioners, but perhaps the most popular are the products described as composts. But also included are bio-solids (sewage sludge), straws, sawdust, manures, litter, pet mosses, lignites or humate, paper, all crop residues, animal products and more (Wallace, 1998).

The introduction of natural deposits might be a good mean to alleviate some of the above-mentioned properties of sandy soil thus increase the soil productivity. Affifi (1986) reported that the addition of clay deposits (Bentonite) to the sandy soil increased the retention and the availability of soil moisture as well as the increase of the cohesive force among their particles. He also concluded that the addition of bentonite reduced the velocity of downward water movement and restricted the deep percolation and leaching out the nutrients. Das and Dakshinamurti (1975) showed that the infiltration rate and hydraulic conductivity of sandy loam soils treated with bentonite were reduced compared to untreated soils. They concluded that the horizontal infiltration as well as the diffusivity very much reduced in the treated soils. Sallam *et al.* (1995) concluded that the mixing shale deposits with sand at different rates (15, 17.5, 20 and 22.5%) of the total weight improved the physico-chemical properties and in particular the soil moisture characteristics and cation exchange capacity. Abou-Gabal *et al.* (1990) found that the addition of local Tafla (43% silt, 24%clay and 32% fine sand dominated by bentonite) to the sandy soil in Egypt improved the soil texture and consequently soil-water plant relationships. El-Sherif and El-Hady (1986) revealed that mixing sandy soil with local bentonite improved soil mechanical, hydrophysical and chemical properties and consequently increasing water use efficiency. In Saudi Arabia, Al-Omran *et al.* (2004) reported a marked decrease in cumulative infiltration, evaporation and depth of wetting front with increasing the rates of bentonite up to 4% in sandy soil.

The importance of organic matter to agriculture, especially for sandy soils is following the water and must considered to overcome the poor physical properties (Abdel-Nasser, 2005). The organic materials can improve the physical properties of sandy soils (Asker *et al.*, 1994; Abdel-Sabour *et al.*, 1997; El-Sersawy, 1998) such as soil porosity, infiltration rate and soil water retention (Asker *et al.*, 1994; Abdel-Sabour *et al.*, 1997; El-Sersawy, 1998; Abdel-Nasser, 2004, 2005). In addition, it can increase the productivity through providing the essential plant nutrients (Fresquez *et al.*, 1990). Application of some organic materials as soil conditioners or amendments act as water absorbent materials that can increase the water retention of soil and improve the soil structure (Pagliai *et al.*, 1981). The aim of the present study is to investigate the impact of different rates of natural deposits and organic fertilizer on soil water characteristics, cumulative infiltration and intermittent evaporation in sandy soil.

MATERIALS AND METHODS

Soil: A sample of loamy sandy soil, was collected from the surface layer (0-30 cm) of the Agricultural Experiment and Research Station at Dierab (24°25' N and 46°34' E), 40 km south west of Riyadh, College of Food and Agriculture Sciences, Saudi Arabia. The soil sample air-dried and passed through a 2 mm sieve. The physical and chemical properties of soil sample were determined according to procedures outlined by Page *et al.* (1982) Some of its physical and chemical characteristics are illustrated in Table 1.

Natural conditioners: Two samples of clay deposits; namely CD#22 (gray color, lat. 22°13′ 53.1″ N and Long. 39°13′ 53.1″ E) and CD#23 (red color, Lat. 22°09′ 09.2″ N and Long. 39°20′ 31.6″ E) collected from khyleis area, Jeddah-Madina road, Saudi Arabia were used in the current study. In addition, commercial Organic Fertilizer (OF) was used. Some physical and chemical characteristics of these conditioners outlined in Table 1 and 2.

Soil moisture characteristics: Loamy sand soil was mixed with natural conditioners at rates of 0, 1, 2.5, 5 and 10% (on dry weight basis). The conditioners were thoroughly hand mixed with air-dried soil sample. Soil water parameters; such as Saturation Water Content (SWC), Field Capacity (FC), Permanent Wilting Point (PWP) and Plant Available Water (PAW) were determined

Table 1: Physical and chemical properties of clay deposits and soil used in the present study

Parameters	CD#22	CD#23	Soil
Particle-size distribution (%)			
Sand	10.52	13.52	82.39
Silt	17.00	24.00	9.50
Clay	72.48	62.48	8.11
Texture class	Clay	Clay	Loamy sand
$CaCO_3$ (g Kg^{-1})	21.00	18.00	20.59
Organic matter (g Kg^{-1})	6.80	5.10	1.50
pH (saturated past)	7.02	7.14	7.62
ECe (dS m^{-1})	39.00	22.00	3.24
Saturation water content (%)	86.50	56.00	26.81
Field capacity (%)	64.40	36.48	10.39
Permanent wilting point (%)	40.44	20.25	2.05
Available water capacity (%)	23.96	16.23	8.34
Soluble Cations (m L^{-1})			
Ca^{2+}	65.4	47.30	12.60
Mg^{2+}	45.6	32.00	7.50
Na^{+}	272.3	136.90	9.40
K^{+}	1.5	2.70	0.40
Soluble Anions (m L^{-1})			
CO_3^{-2}	Tr	Tr	Tr
HCO_3^{-}	1.6	1.70	3.50
CL^{-}	351.6	202.60	12.80
SO_4^{-2}	35.7	13.60	15.60

Table 2: Physical and chemical properties of Organic Fertilizer (OF) used in the present study

Parameters	Values
Particle-size distribution (%)	
2.0-1.0 (mm)	4.20
1.0-0.5	16.90
0.5-0.25	28.90
0.25-0.125	29.50
0.125-0.63	15.80
<0.063	4.60
pH (saturated past)	7.06
ECe (dS m^{-1}, saturated past)	20.00
Organic carbon (g Kg^{-1})	161.80
Saturation water content (%)	65.00
Field capacity (%)	31.86
Permanent wilting point (%)	15.66
Available water capacity (%)	16.20
Soluble cations (m L^{-1})	
Ca^{2+}	51.50
Mg^{2+}	66.40
Na^{+}	79.20
K^{+}	2.00
Soluble anions (m L^{-1})	
CO_3^{-2}	Tr.
HCO_3^{-}	9.70
CL^{-}	130.30
SO_4^{-2}	59.00

according to the methods described by Klute (1986). Soil water retention curve was performed according to Carter (1993) using pressure plate extractor for tensions of 0.1 to 15 bars (100 to 15300 cm H_2O). Water retention data fitted to van Genuchten model (van Genuchten, 1980) using RETC software (van Genuchten *et al.*, 1991). The soil water retention function, $\theta(h)$ was calculated according to the following formula (van Genuchten, 1980).

$$\theta(h) = \theta_r + \frac{(\theta_s - \theta_r)}{\left[1 + (\alpha h)^n\right]^m} \quad (1)$$

or

$$S_e = \frac{1}{\left[1 + (\alpha h)^n\right]^m} \quad \text{for } h < 0 \qquad S_e = 1 \quad \text{for } h >= 0 \quad (2)$$

Where:

$$S_e = \frac{\theta - \theta_r}{\theta_s - \theta_r} \text{(Effective water content)} \quad (3)$$

h is the pressure head (cm),
θ_r is the residual soil water content(cm^3/cm^3),
θ_s is the saturated soil water content(cm^3/cm^3) and
α (cm^{-1}), n and m are empirical parameters (m = 1-1/n)

Infiltration experiment: For the infiltration experiment, air-dried (<2.0 mm) sieved soil sample (untreated soil) was packed at 1.6 g cm^{-3} bulk density in transparent sectioned Lucite cylinders (5.0 cm internal diameter and 5.0 cm length). The soil column consists of 8 pieces with length of 40 cm using adhesive strip to construct the column. The column closed at bottom end with piece of cloth held firmly by adhesive strip.

The transparent PVC columns were packed with soil to depth of 30 cm every 5.0 cm intervals to insure a homogeneity of soil in columns. The clay natural deposits (CD#22 and CD#23) and Organic Fertilizer (OF) were mixed with the soil at rates of 0, 1, 2.5, 5 and 10% (w/w) and then packed in the upper 5.0 cm of the soil column. A flooding apparatus (Marriot device) designed to maintain a constant head of 3.0 cm over the soil surface by means of a bubbler tube to allow accurate measurement of infiltration data as a function of time. The observations made during the infiltration experiment included change in the bubbler reading (cumulative infiltration) and the change of visible wetting front advance with time. When the wetting front reached the end of soil column (35 cm depth below the soil surface), infiltration experiment terminated. The soil column sectioned in 5.0 cm increments and soil water content was determined gravimetrically. Each treatment replicated three times.

Intermittent evaporation experiment: Evaporation experiment was conducted in 40 cm long transparent sectioned Lucite cylinders (5.0 cm internal diameter and 5.0 cm long) The column was packed up to 30 cm with untreated soil and then with 5.0 cm of treated soil with different rates of natural clay deposits and organic fertilizer as mentioned before (each treatment was replicated three times). The soil packed by tapping every 5.0 cm increment to give the desired bulk density (1.6 g cm^{-3}). The soil columns were placed on the bench inside the laboratory (25±2°C). Fifty millimeter of tap water (EC = 0.4 dS m^{-1}) was applied weekly for three wetting/drying cycles. Cumulative evaporation against time was measured daily by weighing each soil column. The soil moisture distribution at the end of the experiment was determined gravimetrically by sectioned the soil column in 5.0 cm increment. The water conserved in each treatment was determined as follows:

$$\text{Water conserved}(\%) = \frac{(\text{Cumulative applied water} - \text{Cumulative evaporation})}{\text{Cumulative applied water}} \times 100 \quad (4)$$

RESULTS AND DISCUSSION

Water retention characteristics: Soil water retention reflects the ability of soil to retain water. Mixing soil with natural conditioners, significantly increased the soil water retention i.e., Saturation Water Content (SWC), Field Capacity (FC), Permanent Wilting Point (PWP) and Available Water Capacity (AWC), calculated as the difference between FC and PWP (Table 3). With the statistical viewpoint, the three conditioners significantly increased the water constants of mixed soil, but the CD#22 has a superior effect. At the 10% application rate, the Increments in SWC were 22.75, 15.72 and 11.17% over the control treatment (soil without mixing with natural conditioners) for CD#22, CD#23 and OF, respectively.

Table 3: Soil water content of mixed soil with natural conditioners at different rates

Natural conditioner	Rate (%, w/w)	SWC (%)	FC (%)	PWP (%)	AWC (%)
CD#22	0	26.81	10.39	2.05	8.34
	1	27.52	10.95	2.15	8.80
	2.5	28.58	11.78	2.65	9.13
	5	29.47	13.17	2.86	10.31
	10	32.91	15.95	3.14	12.81
LSD (0.05)	1.01**	0.61**	0.16**	0.48**	
CD#23	0	26.71	10.19	2.01	8.18
	1	27.22	10.65	2.10	8.55
	2.5	28.24	11.04	2.45	8.59
	5	29.12	11.69	2.68	9.01
	10	30.91	12.67	3.05	9.62
LSD (0.05)	0.86**	0.94**	0.22**	0.92**	
OF	0	26.76	10.25	1.97	8.28
	1	27.42	10.63	2.20	8.43
	2.5	27.81	11.00	2.43	8.57
	5	28.28	11.65	2.85	8.80
	10	29.75	12.84	3.15	9.69
LSD (0.05)		1.22**	0.82**	0.33**	0.93**

** $p<0.01$

Table 4: Moisture constants and van Genuchten parameters for soil mixed with natural conditioners

Rate (%,w/w)	SWC (%)	FC (%)	PWP (%)	α (cm^{-1})	n	R^2
CD#22						
0	26.81	10.39	2.05	0.01671	1.59564	0.9948
1	27.52	10.95	2.15	0.01623	1.59863	0.9952
2.5	28.58	11.78	2.65	0.01571	1.63327	0.9948
5	29.47	13.17	2.86	0.01582	1.62672	0.9921
10	31.91	15.95	3.14	0.01675	1.62786	0.9776
CD#23						
0	26.81	10.39	2.05	0.01671	1.59564	0.9948
1	27.22	10.65	2.10	0.01653	1.59494	0.9936
2.5	28.24	11.04	2.45	0.01760	1.60269	0.9944
5	29.12	11.69	2.68	0.01838	1.60271	0.9942
10	30.91	13.00	3.05	0.02013	1.60245	0.9920
OF						
0	26.81	10.39	2.05	0.01671	1.59564	0.9948
1	27.42	10.63	2.20	0.01692	1.59907	0.9948
2.5	27.81	11.00	2.43	0.01655	1.61034	0.9947
5	28.28	11.65	2.85	0.01627	1.63170	0.9938
10	29.75	12.84	3.15	0.01762	1.62739	0.9918

The corresponding increments for FC were 53.51, 24.34 and 25.27%, for PWP were 53.17, 51.74 and 59.89% and for AWC were 53.59, 17.60 and 17.03%, respectively. The increments more pronounced with PWP. The superiority of CD#22 attributed to more content of clay, especially smectite.

Soil hydraulic parameters were calculated by fitting water retention data to van Genuchten model (van Genuchten, 1980) using RETC code (van Genuchten *et al.*, 1991) are shown in Table 4. The values of α(cm^{-1}) decreased significantly, except for the higher rate (10%). The values of n parameter increased significantly with increasing the application rate.

Cumulative infiltration: Cumulative infiltration expressed as Depth of equivalent water (D) related to infiltration Time (T) shown in Table 5 and Fig. 1 for loamy sandy soil amended with clay deposits and organic manure. The results clearly indicate that increasing the application rate of amendments significantly decreased the cumulative infiltration. The decrease in D more pronounced at higher rates. The clay CD#22 was more effective in reducing the cumulative infiltration. The relationship between cumulative infiltrations (D) as a function of Time (T) was done by fitting the data to the Kostiakov's equation (Kostiakov, 1932), Table 6 and Philip's equation (Philip, 1957), Table 7. The equations written as follows:

$$\begin{aligned} D &= K * T^{n} && \text{Kostiakov's equation} \\ D &= S_p * T^{0.5} + A * T && \text{Philip's equation} \end{aligned} \quad (5)$$

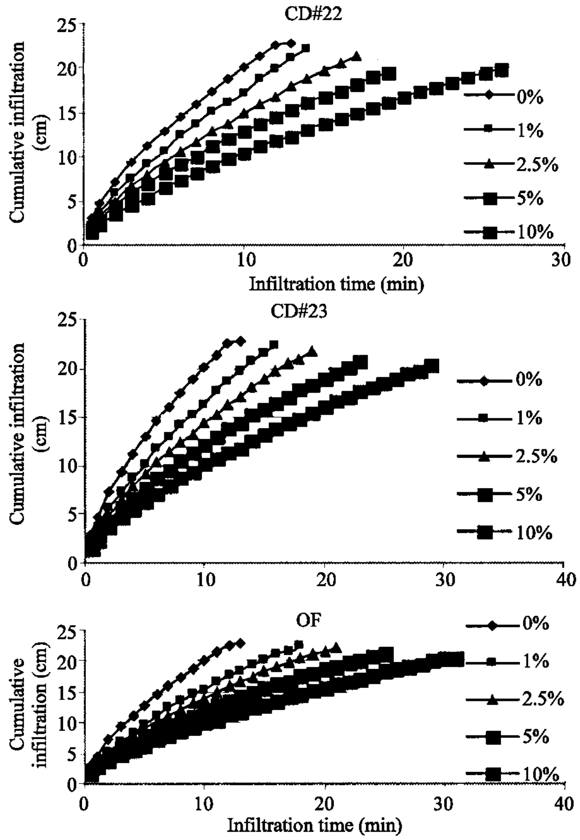

Fig. 1: Cumulative infiltration in loamy soil treated with different conditioners

Table 5: cumulative infiltration (cm) in sandy soil mixed with different amendments

Rate (%, w/w)	CD#22	CD#23	OF
0	22.8	22.8	23.8
1	22.1	22.4	22.6
2.5	21.4	21.7	22.2
5	19.5	20.7	21.3
10	19.9	20.3	20.6
LSD(0.05)	0.59**	0.67**	0.56**

** p<0.01

Where:
D is the cumulative infiltration depth (cm),
T is infiltration time (minute),
K and n are fitting parameters,
Sp is soil parameter related to soil sorptivity (cm min^-0.5) and
A is soil parameter related to soil hydraulic conductivity (cm min^{-1})

Fitting the infiltration data to the above equations gave correlation coefficient (r) ranging between 0.9983 and 0.9999 Table 5.

The empirical parameter K affected by both type and rate of natural conditioners applications. The K values decreased with increasing the application rate Table 5. The K value represent the initial infiltration at T = 1 min., thus represent the ability of soil to intake water. The K values can be regressed to the application rate in the following form (polynomial equation):

$$K = a + b * R + c * R^2 + d * R^3 \qquad (6)$$

Where:
R is the application rate (%),
a, b, c and d are fitting parameters.

The fitting equation presented in Table 8.

In addition, the empirical parameters Sp and A are affected by both type and application rate of amended materials. The values of Sp and A were decreased as

Table 6: Fitting parameters of infiltration equation (Kostiakov's equation) for natural conditioners

Rate (%, w/w)	K	n	R^2
CD #22			
0	4.7653	0.6221	0.9992
1	3.5710	0.6903	0.9997
2.5	3.1747	0.6739	0.9998
5	2.8733	0.6532	0.9999
10	2.1844	0.6798	0.9999
CD #23			
0	4.7653	0.6221	0.9992
1	3.5185	0.6697	0.9997
2.5	3.1965	0.6536	0.9998
5	2.8199	0.6367	0.9999
10	2.2138	0.6593	0.9998
OF			
0	4.7653	0.6221	0.9992
1	3.4593	0.6512	0.9997
2.5	3.2575	0.6340	0.9996
5	2.8882	0.6220	0.9998
10	2.2763	0.6443	0.9996

Table 7: Fitting parameters of infiltration equation (Philip's equation) for natural conditioners

Rate (%, w/w)	Sp	A	R^2
CD #22			
0	4.4327	0.5908	0.9983
1	3.1178	0.7727	0.9994
2.5	2.3540	0.5792	0.9996
5	2.7406	0.4149	0.9993
10	2.2481	0.3752	0.9993
CD #23			
0	4.4327	0.5908	0.9983
1	3.2028	0.6200	0.9994
2.5	3.0385	0.4659	0.9994
5	2.7884	0.3286	0.9994
10	2.2432	0.2928	0.9994
OF			
0	4.4327	0.5908	0.9992
1	3.2711	0.5021	0.9991
2.5	3.1888	0.3818	0.9990
5	2.9015	0.2820	0.9995
10	2.3387	0.2570	0.9994

Table 8: Fitting equations for the relation between K parameter and application rate

Natural conditioners	Fitting equations	R^2
CD#22	$K = 4.6847-1.1385R+0.2249R^2-0.0136R^3$	0.9827
CD#23	$K = 4.6655-1.1198R+0.2168R^2-0.0129R^3$	0.9731
OF	$K = 4.6436-1.1105R+0.2113R^2-0.0134R^3$	0.9573

increasing the application rate Table 7. The Sp represent the soil sorptivity parameter of soil, it is reflect the ability of soil to conduct water through the pore space. The A parameter is related to the saturated hydraulic conductivity of soil. The results indicate that Sp parameter decreased with increasing the application rate of amended materials. The decreasing in cumulative infiltration attributed to the role of clay deposit or organic fertilizer in increasing the soil aggregation and then decreased the pore space (Abdel-Nasser, 2004; Al-Omran *et al.*, 2004).

Regarding the A parameter, the results indicated that A values increased with the first rate of clay deposits and then decreased with increasing the application rate. But, for organic manure application, the value of A parameter decreased with increasing the application rate. The clay deposit with low application rate may be increased the ability of mixed soil to conduct because of the aggregation effect, but at higher rates the aggregation effect led to decrease the pore space or clogging the pore with fine material of clay deposit and then increased the ability of soil to conduct water. For organic manure, the decreasing effect may be attributed to more aggregation of mixed soil then restrict the water flow in soil or due to the increase the fine pores that responsible for moisture retention in soil (Abdel-Nasser, 2004).

Application of natural conditioners greatly decreased the ability of soil to conduct water, such effect attributed to the modification of pore size distribution, decreasing the large pores (drainable pores), increasing the fine pores (water retention pores) and consequently decreasing the water movement rate (Abdel-Nasser, 2004).

Advance of wetting front: The advance of wetting front (Z) in cm as related to Time (T) in minutes for types and rates of natural conditioners application is illustrated in Fig. 2. Increasing the application rate of natural conditioners restricted the wetting front movement. The values of wetting front depth were affected by both type of conditioners and rate of application. The relationship fitted to power equation giving highly significant correlation coefficient Table 9.

Time required for wetting front to reach 30 cm depth as affected by application rate presented in Table 10. It is clear that the conditioners resulted in restrict wetting front movement then delayed the wetting of soil and need more time to reach 30 cm depth. The time is regressed against the application rate and the data fitted to the linear equation in the form of:

$$T_{30} = a+b*R \quad (7)$$

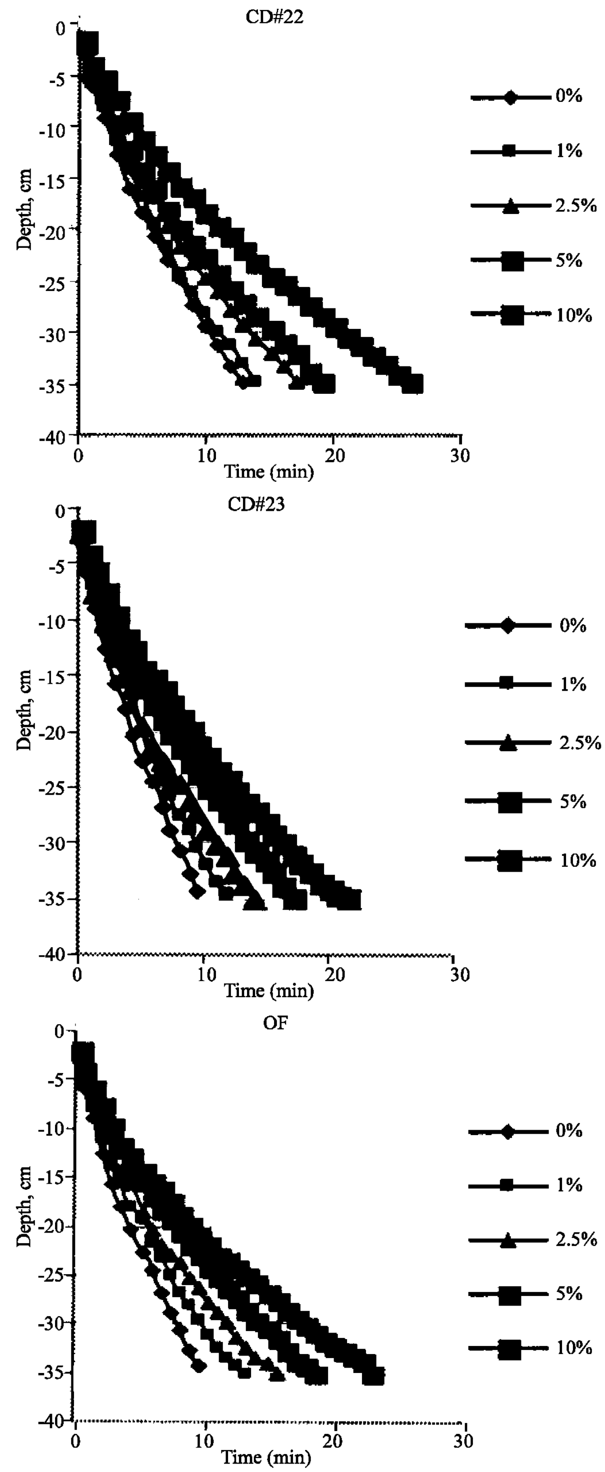

Fig. 2: Wetting front depth in loamy sand soil treated with different conditioners

Where:

T_{30} is the time required for wetting front to reach 30 cm depth (min)

Table 9: Fitting parameters of wetting front depth as affected by type and rates of natural conditioners application

Rate (%, w/w)	A constant	B constant	R^2
CD#22			
0	6.0282	0.6882	0.9995
1	5.5110	0.6930	0.9982
2.5	5.2529	0.6679	0.9976
5	4.7176	0.6735	0.9987
10	3.7267	0.6894	0.9994
CD#23			
0	5.9077	0.6882	0.9995
1	5.3160	0.6815	0.9991
2.5	5.3601	0.6397	0.9978
5	4.2799	0.6679	0.9995
10	3.8857	0.6594	0.9991
OF			
0	5.9077	0.6882	0.9995
1	5.6427	0.6421	0.9984
2.5	5.2669	0.6285	0.9979
5	4.2040	0.6625	0.9995
10	4.2242	0.6184	0.9991

Table 10: Time (minutes) required for 30 cm wetting depth

Rate (%, w/w)	CD#22	CD#23	OF
0	10.3	10.6	10.6
1	11.5	12.7	13.5
2.5	13.6	14.8	15.9
5	15.6	18.5	19.4
10	20.6	22.2	23.8
LSD(0.05)	1.74**	1.44**	1.54**
Fitting constants for regression equation			
a	10.5750	11.5470	11.9770
b	1.0122	1.1386	1.2603
R^2	0.9948	0.9629	0.9581

** p<0.01

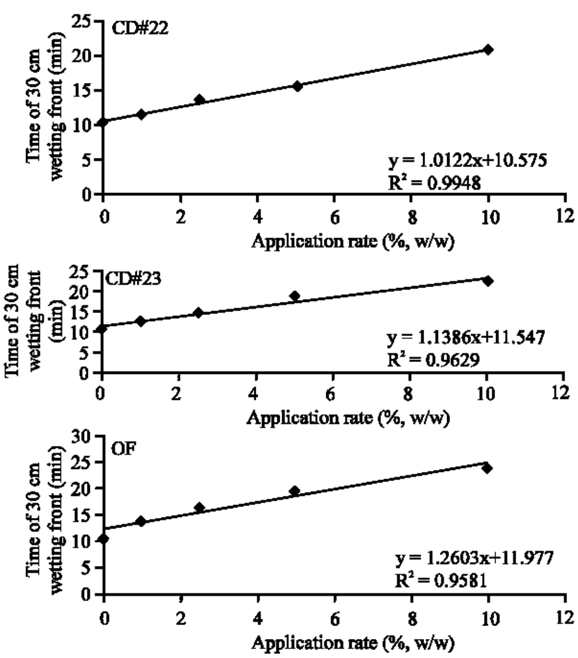

Fig. 3: Linear regression of time required for wetting front to reach 30 cm depth as a function of application rate of natural conditioners

Table 11: Cumulative evaporation (mm) of sandy soil mixed with natural conditioners at the end of the wetting-drying cycles

Application Rate (%)	Evaporation cycles 1	2	3	Total evaporation (mm)	Water retained (%)
CD#22					
0	17.6	52.9	18.1	52.9	30.76
1	16.3	49.3	17.1	49.3	35.47
2.5	16.0	47.3	15.1	47.3	38.09
5	15.7	44.6	13.5	44.6	41.62
10	16.8	46.4	13.9	46.4	39.01
LSD (0.05)	0.65**	1.05**	1.02**	1.05**	1.46**
CD#23					
0	14.0	53.4	21.6	53.4	30.10
1	13.8	51.3	20.9	51.3	32.85
2.5	14.3	49.6	19.1	49.6	35.08
5	13.4	47.2	18.4	47.2	38.22
10	14.0	49.0	18.3	49.0	35.86
LSD (0.05)	0.93**	1.14**	2.13**	1.14**	1.68**
OF					
0	16.8	53.6	19.4	53.6	29.84
1	15.7	52.7	21.5	52.7	31.02
2.5	14.6	51.2	20.1	51.2	32.98
5	14.6	48.3	18.2	48.3	36.78
10	15.1	49.8	19.2	49.8	34.82
LSD (0.05)	0.47**	1.40**	2.51**	1.40**	1.63**

** p<0.01

R is the application rate of natural conditioners (%) and a and b are fitting parameters

The results indicate that $T_{30\ cm}$ increased with increasing the application rate. Also, CD#22 need more time than CD#23 or Organic Fertilizer (OF) to reach the 30 cm depth Fig. 3.

Soil moisture profile: The distribution of soil moisture profile with depth for soil treated with natural conditioners illustrated in Fig. 4.

The soil moisture profile characterizes by three zones. The first zone extend from surface to 5 cm depth which influenced by material and rate of application. The soil water content increased with increasing the rate of application and reaches the saturation content, therefore called saturation zone. The second zone extends from 5 to 25 cm depth. The soil water content approximately uniform for each treatment and soil water content increased with increasing the application rate. This zone called transition zone. The third zone is almost dry and there are no differences between materials and rates. The soil water content is uniform and this zone called transmission zone, it is the limit between wetted soil and the initially dry soil.

Intermittent evaporation: The cumulative evaporation (mm) as function of time (days) for loamy sand treated with natural conditioners at different rates are presented in Table 11 and illustrated in Fig. 5.

In general, natural conditioners significantly reduced the cumulative evaporation throughout the 3 evaporation

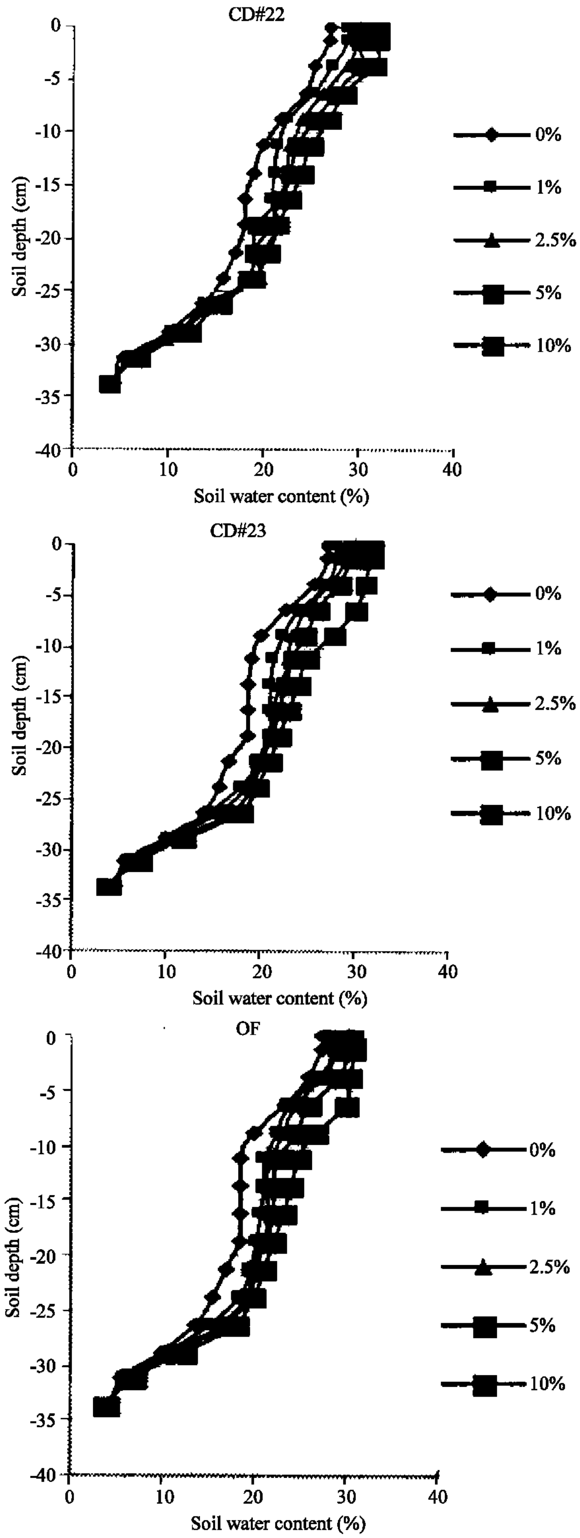

Fig. 4: Moisture profile of soil treated with natural conditioners

cycles. The reduction significantly increased with increasing the application rate, except for the higher rate

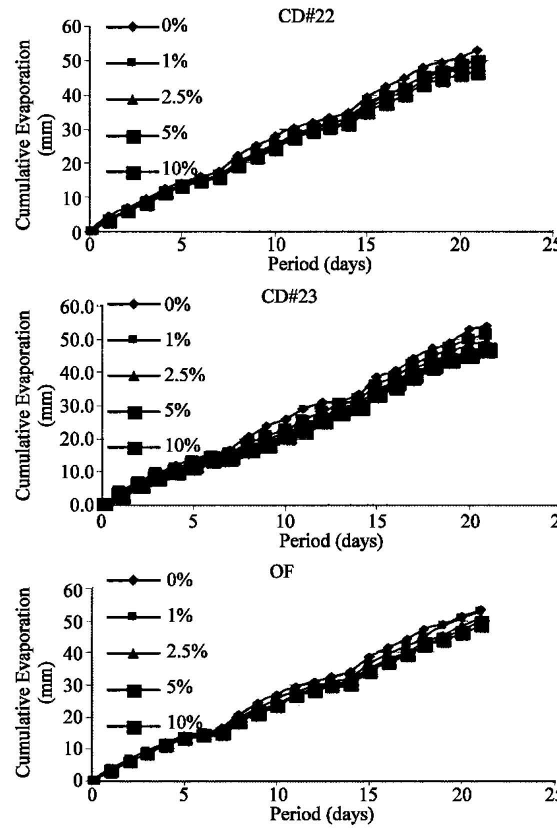

Fig. 5: Cumulative evaporation in loamy soil treated with different conditioners during the three evaporation cycles

(10%), which increases the cumulative evaporation under the present conditions. Application of natural conditioners restricts the water movement and increases the water retention by soil, then more water retained in soil surface available for evaporation.

CONCLUSIONS

In general, the positive effects of different natural conditioners on improving soil properties encourage farmers to use it in sandy soil cultivation, especially in regions limited in water resources. The high content in the natural deposits is desirable to improve the water holding capacity of coarse-textured soils. In addition, these soils are poor in organic matter, thus addition of organic fertilizers or organic materials lead to improve the organic matter content of these soils, frequently increased their ability to retain water. Also, the natural conditioners are commercially available in the market in Saudi Arabia in many forms. The present study suggest that the application of natural conditioners such as organic fertilizers and natural deposits (rich in c lay content) caused an increase in water holding capacity and a reduction in cumulative evaporation, then increased the water conserved at rates up to 10%. In addition, the application of natural conditioners up to 10% restricted the water infiltration in sandy soil. The beneficial effects more pronounced with CD#22. This trend may be due to the higher content of clay and organic matter of soil treated with natural conditioners. The improvement of soil hydro-physical properties and reduction in water infiltration and cumulative evaporation are good practices for plant growth in region limited in water such as most regions in Saudi Arabia.

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