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Effect of different soil conditioners application on some soil characteristics and plant growth III- Effect on saturated and unsaturated water flow

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Abstract : Soil conditioners used for improvement poor physical properties of coarse tuxtured soils like low water retention and reduction of water use, especially in arid and semi-arid regions like Egypt. The aim of the study is to investigate the influence of bentonite clay as natural deposits (0, 2, 4, 6; 8 %) and farmyard manure, FYM at 2 %wb on water flow under saturated and unsaturated condition in treated sandy soil. Soil sample was collected from surface layer (0-30 cm depth) of the Agricultural Experiment and Research Station at Production and Research Station of National Research Centre, Nubaria, Behera Governorate, Egypt.

Results indicated that increasing the application bentonite significantly decreased the cumulative infiltration, which more pronounced at higher rates. Also, bentonite at 8 % was more effective to reduce the cumulative infiltration. However, aapplication of bentonite deposits to sandy soil led to decrease hydraulic conductivity from 9.75 to 1.75 cm h^{-1}, intrinsic permeability improved from 11.63 to 2.09 m^2 and mean weight diameter from 19.29 to 8.17 µ as compared with control and soil treaded by 8 % bentonite, respectively. Bentonite addition encouraged soil resistance to water movement 0.103 (day/meter) in untreated soil while the value in soil treated by 8 % bentonite recorded 0.571 (day/meter). The percent of change of the studied soil properties, there is no match between increasing bentonite by unite (2%) and percentage of change especially for hydraulic conductivity, intrinsic permeability and mean weight diameter. So it is clear that increased bentonite application rate associated with improvement in all studied soil characteristics.

Keywords: Sandy loam, bentonite, hydraulic conductivity, infiltration rate, Intrinsic permeability; MWD.

Introduction

Regarding to the population problem in Egypt and hence their needs from food and fiber, turned the attention of the government to reclaim new lands annually. However, sandy soil usually has a poor characteristics (surface area, water retention, organic matter content, fertility and weak ability to retain water[1]. Soil conditioners improves the hydro-physical properties of soil[2] and include both synthetic and natural products that include many kinds of organic materials, gypsum, lime, natural deposits[3,4]. The introduction of natural deposits might be a good mean that could be used as a source of soil amendment to alleviate some of the abovementioned poor properties of sandy soil thus increase the soil productivity. The addition of different natural conditioners (bentonite) could overcome those problems[5].

The addition of bentonite (clay deposits) to the sandy soil decreased downward water flow and hence restricted deep percolation[6]. [7]found that shale deposits added to sandy soil improved physico-chemical properties and in particular soil moisture content. Also, continues application improve not only physico-bio-chemical properties of sandy soils but also their productivity. In this concern, in Saudi Arabia, [5]found a marked decrease in evaporation, cumulative infiltration and depth of wetting front and consequently increase ꝍ of wetted area with increasing the rates of bentonite up to 4 %. It is clear to mention to the importance of organic matter, especially for sandy soils is following the water and must considered to overcome the poor physical properties especially hydro-physical properties and encourage aggregates formation[1]**.** [8]indicated that it can improve the physical properties such as soil porosity, infiltration rate and soil water content at different tention.

Saturated hydraulic conductivity (***Ksat***) is a vital soil hydro-physical characteristics, which its determination is needed for many applications. Also, *Ksat* is a key parameter for solutions in soil physics, hydrology, soil and groundwater protection against pollution, soil reclamation, irrigation and drainage for agricultural[9]. Water flow under saturated condition of bentonite-based buffer materials is often measured by hydrating the specimen under constant volume condition with a constant inlet water pressure and by monitoring the water inlet and/or outlet flow. Saturated hydraulic conductivity is calculated using Darcy's law. It has been observed that **K*sat*** decreased dramatically with increased dry density, by increased bentonite content[10,11].

The aim of the present study is to examined the influence of bentonite rates and FYM on water movement under saturated and unsaturated flow in sandy soil.

Materials and Methods

Field experiment was carried out in Research and Production Station, National Research Centre, El-Nobaria, El-Behera Governorate, Egypt during the season of 2013 and 2014 on a sandy loam soil (23% silt; 8% clay) and mean of the two season was take place. The experimental design was completely randomized in three replicates and the plot area is 42 m^2 (1/100 of fed) and 1.5 m apart. Experimental plots were treated by bentonite and well mixed with the upper layer 25 cm (its fraction ≤ 1 mm) by 0, 2, 4, 6 and 8 % weight basis application rates, in addition to farm yard manure treatment (FYM) at 2 %wb.

Bentonite used in current work is characterized by clay in texture, 4.8 dSm^{-1} (soil paste extraction), 7.88, 4.6 % and 1.8 % for ECe, pH, $CaCO_3$ and organic matter content. Bentonite application rates were 0, 2, 4, 6 and 8 %, in addition to farm yard manure treatment (FYM) at 2 % on weight basis. Half of the plots were treated by bentonite examined rates in two equal doses (50%), the first one applied before maize and the second one during soil preparation for sowing barley.Some soil characteristics of the experimental soil before cultivation are determined after[12,13] i.e. $CaCO_3$ (2.5 %), organic matter content (0.36%), ECe (1.24 dSm^{-1} in soil paste extract), pH (8.12 in soil : water 1:2.5).

Barley (*Hardium vulgare L.*) Giza 124 was sown at mid of November on both seasons and irrigated by sprinkler irrigation. Three samples were collected from experimental plots after barley harvested from the surface layers 0-45 cm and15 cm each to determine soil hydraulic conductivity (HC) that was measured in the laboratory under a constant head technique [14] using the following formula:

$$HC = (QL)/(At\ \Delta H),$$

where: HC: water quantity flowing through saturated soil sample/area/ unit time, Q: volume of water flowing through saturated soil sample per unite time (L^3/t), A: cross sectional flow area (L^2) L: length of the soil sample and ΔH: differences in hydraulic head across the sample (L) and t: time (hr).

Infiltration ratewas estimated using the double ring infiltrometer technique (Fig. 1) in treated and untreated plots after barley harvested that described by [15] and Kostiakove equation was used to represent the water intake rate.

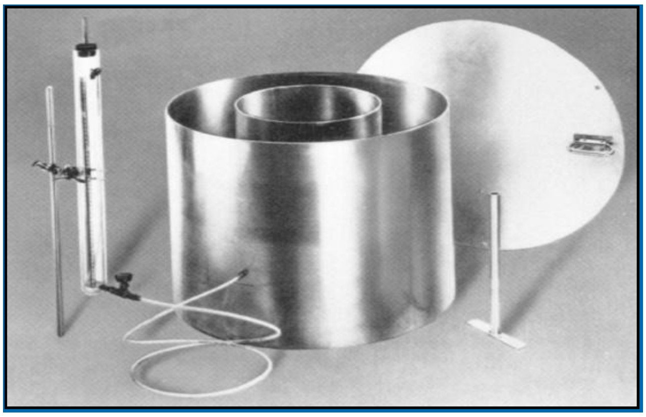

Fig. (1) Double ring infiltrometer technique

The weight sieve method was used to determine the mean weight diameter (MWD) as index of the soil aggregation. The wet sieving method after [16] was used with a set of sieves , 0.85, 0.50, 0.25 and 0.106 mm in diameter. Soil samples were passed through an 8 mm sieve and 100 g of the soil was put on the first sieve of the set and gently moistened to avoid a sudden rupture of aggregates. After the soil had been moistened, the soil was sieved in distilled water at 30 oscillations per minute. After 10 minutes of oscillation, the soil remaining on each sieve was dried and then sand and aggregates were separated [**17**]. Aggregate stability was expressed as MWD which calculated from the following equation:

$$MWD = \sum_{i=1}^{n} XiWi$$

where Xi is the mean diameter of each size fraction (mm) and Wi the proportion of the total sample mass in the corresponding size fraction after deducting the mass of stones (upon dispersion and passing through the same sieve) as indicated above .

The data were subjected to the analysis of variance (ANOVA) appropriate to the randomized complete block design applied after testing the homogeneity of error variances according to the procedure out- lined by **[18]**. The significant differences (LSD) between treatments were compared with the critical difference at 5% probability level.

Results and Discussion

It is worthy to mention that during infiltration (I) process, the water enters the soil in response to one or more of the following :i) potential gradients of water potential and ii) gravitational potential. The water potential term is governed by the dryness of the soil and the pore structure of the soil and they combine to form a sorptivity factors that made up effects of capillary and adhesive forces to surfaces of soil. Increasing the application rate of bentonite significantly decreased the cumulative infiltration (**D**), which has a pronounced effect at higher rates. Bentonite at 8 % rate was effective more to reduce **D**. Also, the relationship between D as a function of Time (T) was done by fitting the obtained data to the Kostiakov and Philip equations. In addition, [19] observed that water **I** at constant volume that modified soil microstructure, giving rise to ***Ksat*** decrease. Our obtained data supported by [**20**]**,** who reported that modification in soil textural class from sandy to loamy sand, was happened after increase clay content. In same sequences bulk density, macro-pores and ***Ksat*** values were improved markedly, whereas, values of total porosity, water content at maximum water holding capacity, field capacity and available moisture were progressively increased.

Infiltration is the vertical flow of water in a soil profile and the ease or difficulty with which water can pass into and through a soil profile is important. To avoid shot effects such as compaction, surface smearing and other properties that generally leads to structure decline. During infiltration events, the water enters the soil in response to potential gradients of water potential and gravitational potential. The water potential term is governed by the dryness of the soil, structure and pore size distribution. These two factors together form a sorptivity factor which is made up of the combined impact strongly of capillary action and adhesive forces to soil solid surfaces.

It is worthy to mentioned that it could be expressed of velocity of the accumulated water intake rate (**I cum**) by the following equation:

$I\ cum = a\ t^{n}$ …………………………………………………..1

Where: t: is the time, a: is a constant depends mainly on te soil under investigation, and n: is a constant depends on the soil moisture (1> n > 0).

When the integration process was carried out for the previous equation relatively to time we got an instantaneous water take (I ins) as follow:

$I_{ins} = dI\ cum/dt$ ……………..........................……2

From equations 1 and 2 we obtained

$I_{ins} = d\ I\ cum/t$ …………………...........................…..3

We could notice when we divided equation 1 on time we got the average velocity of the water intake rate (I av) as follow:

$I\ av = I\ cum/t = a\ t^{n-1}$ ……………..........................……4

Regarding to the obtained equations (Fig. 1). If we expressed on **a** by intersect of the **Y** axis at time 1 min. and **n** it is the slop. These constants (**a and n**) are useful indicators that water intake in soil where a expresses on the volume of water that intake in soil vertically through unite area from soil surface after one minute from starting the infiltration determination whereas, n expresses the changes in water intake with time and the following table (**1**) recorded these constants as affected by bentonite application rate.

Regarding the (**a)** parameter, the resulted data indicated that (**a)** values increased with the first rate of bentonite (2%) then reduced with increasing the application rate. Whereas, in case of organic manure application, value of (**a)** decreased with increasing 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, [8,21]supported our obtained results and attributed them by the decreasing effect may be attributed to more aggregation of mixed soil then restrict the downward water movement in soil profile or mainly due to the increase the fine pores that responsible for moisture retention in soil**.**

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[8].

The following table (1) could concluded the following; i) water intake rate at the first minute from the determination (a) increased by increasing bentonite application rate, ii) after while soil water intake rate decreased with increasing bentonite application rate that due to mainly to the effect of bentonite on the soil aggregation, iii) regarding top the slopes of the obtained straight relation between water intake with time that decreased by increasing bentoniote application rate. This result indicated that bentonite application extending the time needed to reach a constant intake, and iv) application of FM located in the middle between 2 and 4 % bentonite application rate.

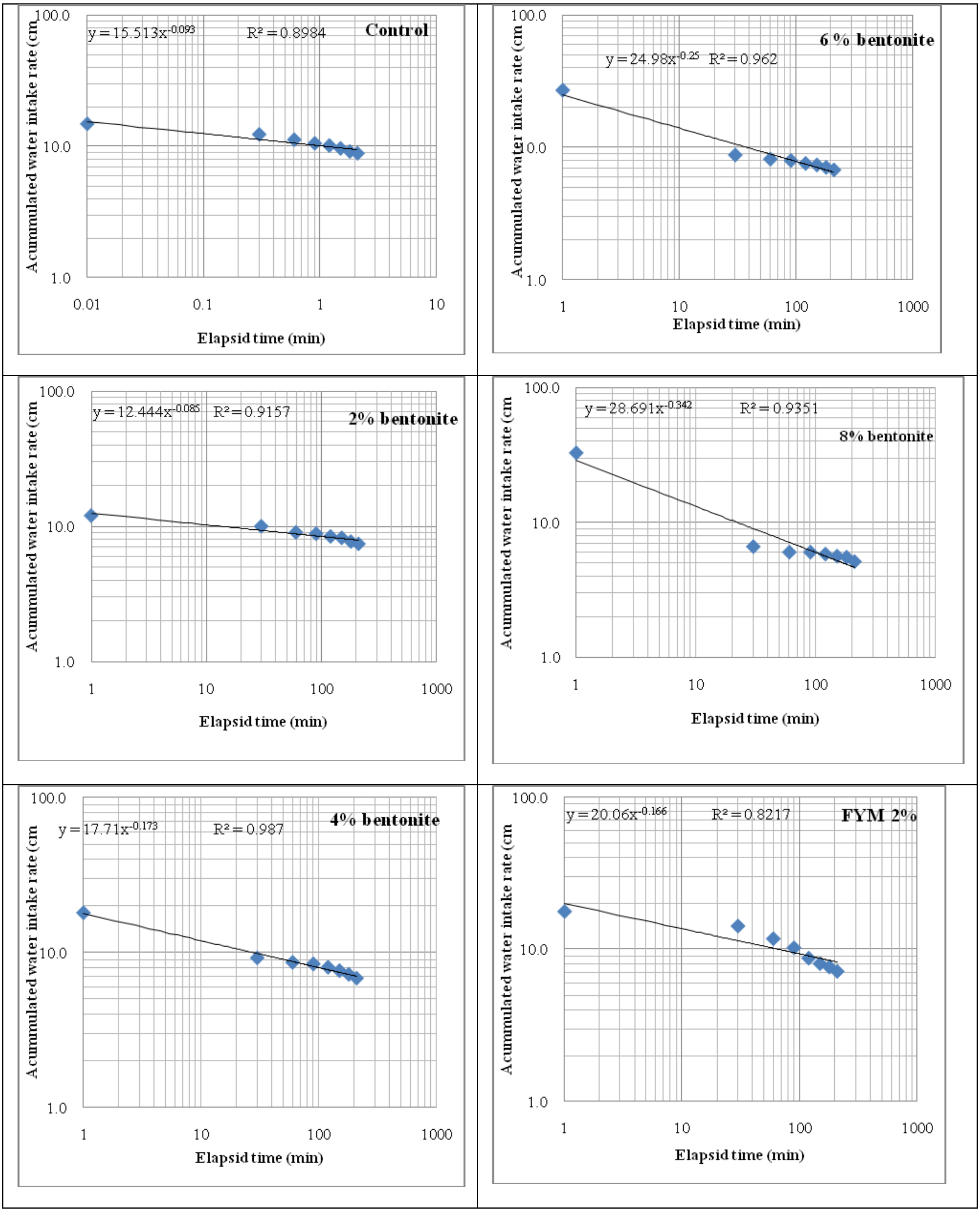

Fig. (1) Relation between accumulated water intake rate and time

Table (1) Effect of bentonite application rate on the a and n of the obtained equations of water intake rate

Bentonite application rates %	Line slope	n cm/minute	a cm/minute
0.0	15.51	- 0.098	0.898**
2.0	12.44	-0.045	0.915**
4.0	17.71	- 0.173	0.987**
6.0	24.98	- 0.250	0.962**
8.0	28.69	- 0.342	0.938**
2.0 FM	20.06	- 0.166	0.821**

Hydraulic conductivity

Hydraulic conductivity (HC) is a measure of soil ability to conduct solution under saturation conditions and it depends mainly on soil characteristics such as porosity and its distribution and solution together. Moreover, mechanisms controlling changes in infiltration depend on the way water is applied to the soil; in these experiments, total infiltration is directly related to hydraulic conductivity of the soil matrix. The saturated hydraulic conductivity (***ksat)*** is calculated using Darcy's law. It has been observed that ***Ksat*** decreased with increased dry bulk density [9], increased bentonite addition[10]**.**Whereas, [18]observed that water infiltration at constant volume modified the soil microstructure, giving rise to ***Ksat*** decrease. Various methods have been applied to describe the water transfer obtained from infiltration tests[1,21]**.**

Intrinsic permeability is a soil ability to conduct soil solution under saturated flow condition and it is usually used in geometric purposes and it depends mainly on soil characteristics only. Soil resistance to solution movement **is** a measure to soil ability to resist soil solution movement in other word is equal 1/HC. [22] reported that cultivated periods and type of the soil management could play an important ant role in improve hydro-physical properties.

Table (2) Effect of bentopnite application rate on some hydraulic properties and mean weight diameter of treated sandy soil.

Bentonite application rate %	Hydraulic conductivity cm/h	Intrinsic permeability (m^2)	MWD µ	1/HC (day/meter)
0	9.75	11.63	19.29	0.103
2	6.27	7.48	15.47	0.159
4	4.21	5.02	12.68	0.238
6	2.79	3.33	10.32	0.358
8	1.75	2.09	8.17	0.571
Farm yard manure	5.38	6.87	18.21	0.186
LSD 5%	1.13	0.98	1.35	0.047

According to the obtained results (Table 2 and Fig. 2), data notice that application of bentonite deposits to sandy soil led to decrease hydraulic conductivity (HC) from 9.75 to 1.75 cm h^{-1}, intrinsic permeability from 11.63 to 2.09 m^2 and MWD from 19.29 to 8.17 µ as compared with control (untreated) and soil treaded by 8 % bentonite, respectively. Application of bentonite deposits to sandy soil encourages soil resistance to water movement 0.103 (day/meter) in untreated soil while the value in soil treated by 8 % bentonite recorded 0.571 (day/meter). From the previous results, it is clear that increasing bentonite application rate associated with improvement in all studied soil characteristics. Also, data noticed that the percent of change for the studied soil properties, there is no match between increasing bentonnite by unite (2%) and percentage of change especially for HC, intrinsic permeability and MWD (Fig. 3).

Our results are in line with those obtained by [8]who stated that 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.

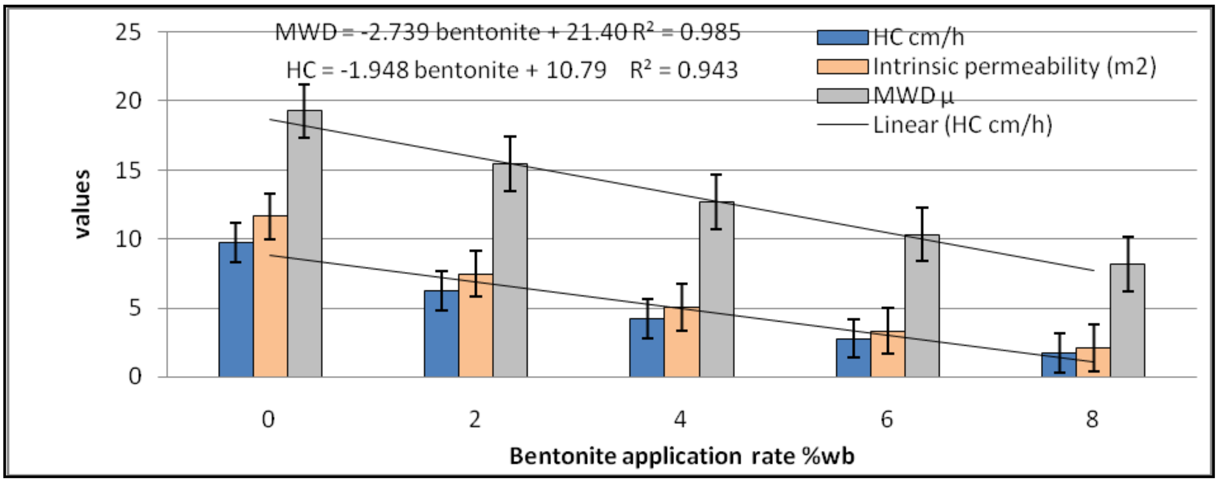

Fig. (2) Effect of bentonite application rate on the some soil hydraulic properties.

It is worthy to mentioned that, although transmit soil category to another according to HC as a result to application of bentonite may be small but HC changed quickly in all treatments regarding to the used classification system. Whereas, this high decrease in HC of course led to decrease the loss in used fertilizers especially nitrogen ones. also, highly significant regression equations were obtained between HC and MWD from side and bentonite application rate (Fig. 3) that represent the possibility of expected data if increased bentonite application rates on the previous determined soil properties. This findings agreed with those obtained by[23,7].

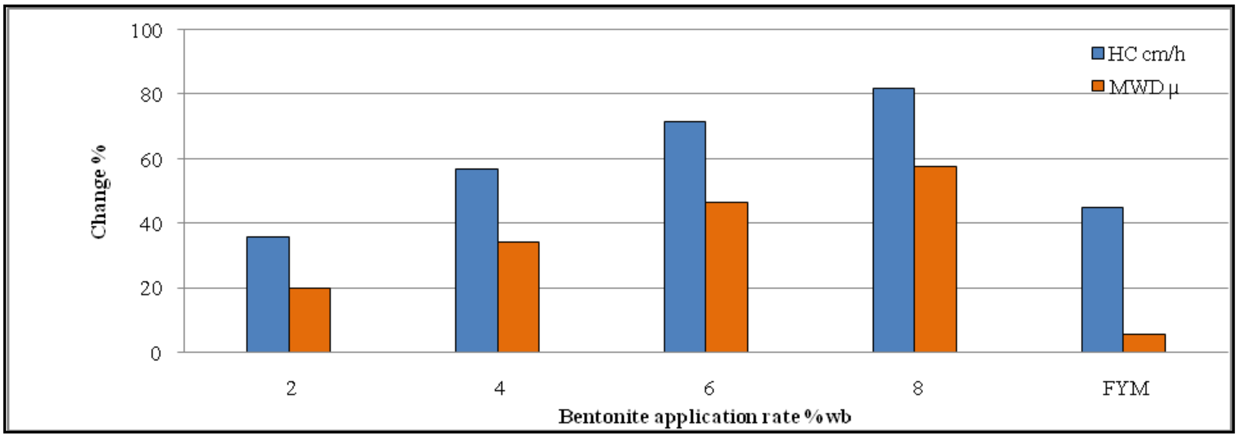

Fig. (3) Effect of bentonite application rate on the some soil hydraulic properties.

Also, volume of soil pores and hence mean weight diameter mainly depends on soil particles size distribution, due to entering fine particles of bentonite among sand particles, and clay would bending between them as a cement material , so increase aggregates formation is expected. 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[8,22].

It could be summarized the factors affecting the hydraulic conductivity of sand-bentonite mixture in the following: i) bentonite% decrease in HC becomes marginal, and will not be cost-effective in a design[23], ii) mixture and compaction the most effective compaction is reached when the mixture has a water content close to optimum or just above, about 2%, iii) water content optimal water content is determined, which defines the water content for which the highest dry density is obtained., iv) type of bentonite regarding to the minerals swell during uptake of water and the electrical bindings are mediated by the cations, which are loosely connected to the crystalline lattice, v) grain size distribution[1], and vi) time where the bentonite swells during uptake of water and, consequently, it will take a long time before the degree of saturation in the sample is homogeneous and the minimum HC is obtained due, to the low hydraulic conductivity of the bentonite[21].

Finally, addition of natural like bentonites at high rates seems an effective means of permanently improving the availability of nutrients and available water in low fertility sugarcane soils[25,26].

With the statistical viewpoint, the two conditioners (bentonite and FYM) significantly increased the water constants of mixed soil, but the bentonite at 8 % has a superior effect. Cumulative infiltration expressed as depth of equivalent water (D) related to infiltration time (T) shown in Table 1 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.

Conclusions

Results pointed out that application of bentonite up to 8% restricted the water infiltration in sandy soil. The beneficial effects may be due to the higher content of clay of soil treated with. The improvement of soil hydro-physical properties and reduction in water infiltration and soil hydraulic conductivity are good practices for plant growth under limited irrigation water. Also the decrease in downward movement gave a hint to the vertical flow to take place that help in maximizing water retention in root zone and covered the plant water needed.

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