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Influence of peatmoss and polymer on moisture characteristic curve of soils with different gypsum and clay contents

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ABSTRACT

To determine the hydraulic properties of several soils with varying clay and gypsum contents and treatments with peat moss and polymer, a laboratory experiment was done. Gypsum ratios varied from 410 g kg-1 to 46 g kg-1, while clay ratios ranged from 0 to 435 g kg-1. Two soils were employed, one having 410 g kg-1 of gypsum and the other containing 435 g kg-1 of clay. Peat moss and a polymer were used to treat the five soils. Three soaking and drying cycles were performed on soil that had been treated with conditioners by packing it into plastic columns that were 5 cm in diameter and 25 cm high with a bulk density of 1.3 mcg m^3. The experiment's goal was to improve the ability of gypsiferous soils to retain water. The moisture characteristic curves were computed using the connection between the volumetric moisture content () and the matric tension, which ranged between 0.1 and 1500 kPa. The results revealed that the values of for the study's soil and treatment methods decreased as matric tension increased, and the discrepancies were more pronounced at low tensions. With rising gypsum and falling clay, the values of decreased. As gypsum was raised from 46 to 410 g kg-1, the values of the available water reduced from 0.276 cm3 cm-3 to 0.191 cm3 cm-3. The addition of peat moss (1%), polymer 1 (2%), and a combination of the two clearly increased the amount of water that was accessible while also changing the amounts of clay and gypsum in all treatments.

تأثير البتموس والبوليمير على منحنيات الوصف الرطوبي لترب مختلفة في محتواها الجبسي والطيني

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الخلاصة

أجريت تجربة مختبريه لتحديد الخواص الهيدروليكيه لترب ذات نسب متفاوتة من الجبس والطين والمعاملة بالبتموس والبوليمير. تراوحت فيها نسب الجبس من 410 غم كغم$^{-1}$ الى 46 غم كغم$^{-1}$ بينما تراوحت نسب الطين من 0 الى 435 غم كغم$^{-1}$.استعملت تربتان أحدهما فيها نسبة جبس 410 غم كغم$^{-1}$ والأخرى فيها نسبة طين435غم كغم$^{-1}$ وخلطتا بخمس نسب ت عوملت الترب الخمس بالبتموس والبوليمير ومعاملة من دون إضافة. و عرضت لثلاث دورات ترطيب وتجفيف. عبئت الترب المعاملة بالمحسنات في اعمده بلاستيكية قطرها 5 سم وارتفاعها 25سم عند كثافة ظاهرية 1.3ميكاغرام م$^{-3}$. و كان الهدف من التجربة هو تحسين قدرة التربة على الاحتفاظ بالماء . تم حساب منحنيات الوصف الرطوبي من العلاقة بين المحتوى الرطوبي الحجمي (θ) والشد الهيكلي لشدود تراوحت بين 0.1 و1500 كيلو باسكال، وكان الهدف من التجربة زيادة قابلية الترب الجبسية على مسك الماء. أظهرت النتائج انخفاض قيم θ لترب ومعاملات الدراسة مع زيادة الشد وكانت الاختلافات أكثر وضوحا في الشدود الواطئة، وقد انخفضت قيم θ بزيادة نسب الجبس وانخفاض نسب الطين. اذ انخفضت قيم الماء الجاهز من 0.276 سم^{3}سم$^{-3}$ الى 0.191 سم^{3}سم$^{-3}$ عند زيادة الجبس من 46 الى 410 غم كغم$^{-1}$. وقد كان لأضافة البتموس1% والبوليمير1 و2% وخليط من الاثنين تأثير واضح في زيادة الماء الجاهز مع زيادة نسبة الطين وانخفاض نسبة الجبس ولجميع المعاملات وبنسب متفاوتة.

الكلمات المفتاحية: الوصف الرطوبي، الجبس ، الطين ، البوليمير ، البتموس.

INTRODUCTION

Gypsiferous soils are those that contain enough gypsum or calcium sulphate (CaSO4.2H2O) to negatively impact plant development and water retention (FAO, 1990). The estimated 88 thousand square kilometres of gypsiferous soils in Iraq make up around 20% of the country's total land area. Due to issues with their physical, chemical, and fertility qualities, gypsiferous soils have limited use for agricultural purposes. Particularly when its gypsum level surpasses 10%, which has a detrimental impact on the structure and water-retentiveness of the soil and affects the development of agricultural products. Consequently, it is crucial to increase the exploitation of these areas in order to provide enough food to feed an increasing population (Al-Hadithi *et al*., 2010).

The features of clay (soft-textured) soils can be improved for agricultural use by modifying the percentage of sand or gypsum in them when combined with coarse-textured soils or gypsum soils. By serving as a binding agent for soil particles, clay enhances soil aeration, structure, and water permeability while also helping to reorganise the geometrical arrangement of soil pores, which lowers the fraction of big pores (Al-Khatib and Al-Rawi, 2015).

Due to their large molecular weight, water solubility, and propensity to cause clay to flocculate, polymers have been employed as soil conditioners to improve soil stability. By making soil aggregates more stable, the use of polymers in soil management has a favourable impact on water conservation and erosion control. Its ability to absorb extremely large volumes of water compared to its weight, hold onto it, and release it when necessary means that it conserves water in the soil, prevents deep infiltration, and enhances the efficiency of using water and fertiliser (Beckett and Augarde) (Beckett and Augarde, 2013). The soil water retention curve, a crucial soil water connection, demonstrates the amount of the soil's capacity to hold or release moisture at various water tensions and aids in understanding the behaviour of soil under unsaturated water circumstances (Heshmati *et al*., 2012).

Through it, many significant aspects of the relationship between water, soil, and plants can be estimated, including describing the behaviour of soil under unsaturated water conditions, which represent the natural conditions for the g. It also aids in identifying the various moisture constants, such as field capacity, permanent wilting point, and available water, as these constants are useful in calculating the amount of added irrigation water (Lal and Shukla, 2004). (Dan and Topp, 2002). And based on what was previously indicated, this study was carried out to determine the behaviour of the moisture characteristic curves for soils treated with peat moss and polymers, which varied in their levels of gypsum and clay

MATERIALS AND METHODS

For the period of 14 February 2021 to 10 July 2022, a laboratory experiment was carried out at the College of Agriculture / University of Anbar-Irag to estimate various water functions of soils treated with several conditioners and differing with gypsum and clay content. Two soil samples were provided, the first of which contained 410 g.kg-1 of gypsum and was taken from the Ramadi/Anbar Governorate University, which is located 103 kilometres from Baghdad at latitude 33°23'55.14°N and longitude 43°14'56.83°E. The second soil, on the other hand, was transported from Al-Nasaf region, Fallujah district, Anbar governorate, 65 km west of Baghdad, located at longitude 43°40'48.28" east and latitude 33°21'27.73" north, with a clay concentration of 435 g kg-1. The study soils were sampled at depths ranging from 0 to 30 cm. The test soils were pulverised and run through a filter with a 2 mm diameter after being air dried. For the second soil, Clay Silty, the particle size distribution was assessed using the Hydrometer technique, while the texture was not identified for the first soil due to its high gypsum content. Based on the acetone technique given in Richard (1954), the percentage of gypsum was calculated to be 410 and 46g kg-1 for the first and second soils, respectively. For the first and second soils, respectively, the bulk densities of the soil using the core technique given in Black *et al*. (1965) were 1.02 and 1.29 mcg m-3. According to the mean weighted diameter, which was

0.698 and 0.599 mm for the first and second soils, respectively, the aggregate stability was calculated using the dry sieving method. According to Page *et al*., an electric conductivity metre and a PH metre were used to test the electrical conductivity and the level of soil pH in a soil extract-water (1-1) mixture (1982). For the first and second soils, respectively, the values for lime, electrical conductivity, and reaction degree were 138 and 174 g/kg-1, 2.42 and 3.17 ds m-1, and 7.83 and 7.78. The two study soils were combined in accordance with the ratios shown in Table (1) to create five new soils, denoted by the letters S1, S2, S3, S4, and S5, that varied in their gypsum and clay contents.

Table (1) The proportions of mixing the two soils and the values of gypsum and clay content in the mixing soils

Seq	mixing ratio	gypsum content of the first soil, g/kg^{-1}	Clay content of the second soil g/kg^{-1}	Mixing soil symbol
1	100% first soil + 0% second soil	410	0	S_1
2	75% first soil + 25% second soil	319	108.75	S_2
3	50% first soil + 50% second soil	228	217.5	S_3
4	25%first soil + 75% second soil	137	326.25	S_4
5	0%first soil + 100% second soil	46	435.0	S_5

The five resulting soils from the mixing process were treated with peat moss at levels 0 and 1% as well as with super absorbent organic polymer (polyacrylamide, polypropylene amide, or polycarbamy lethylene), and abbreviated (-CH2CHCONH2-) SAP, at three levels (0%, 1%, and 2%). The small amount of clay in the first soil was neglected in the calculations of the clay content, and only the second soil was relied. The five soils treated with conditioners were packed into plastic column 5 cm in diameter and a height of 25 cm, which were blocked from the bottom with glass wool, soil mass was calculated for each column based on the column size and 20 cm depth with a bulk density of 1.3 mcg m^{-3}, the study soil columns were subjected to three cycles of wetting and drying for approximately 14 weeks, after they were fixed vertically on table, and wetting was carried out from the bottom.

The connection between matric tension and volumetric moisture content, which represents the moisture characteristic curves for soil samples sieved through a 2 mm sieve utilising metal rings with an inner diameter of 3.6 cm and a height of 2 cm. After the soil has been soaked with water for 24 hours, pressures between 0.1 and 1500 kPa were applied, using a pressure plate apparatus for tensions between 33 and 1500 kPa and a Haines-type equipment for tensions between 0.1 and 0.2 kPa. Two groups of replicates were employed for the measurement. The weighted moisture content at the applied stress was calculated for the first group. In the second group, volumetric soil moisture was computed using measurements of the bulk soil density at each tension. According to the Van Genuchten equation (1980), the link between the volumetric moisture content and the soil's matric tensions was categorised as follows:

$$\Theta = [\, 1 + (\alpha\, \psi\,)^{n}]^{-m} \quad ....1$$

Since Θ relative moisture content is calculated from the volumetric moisture data obtained from measuring the moisture characteristic curve according to the following equation:

$\Theta = \theta - \theta_r / \theta_s - \theta_r$ 2

When we substitute Equation 1 into Equation 2, the following results:

$\Theta = (\theta_s - \theta_r)[1+(\alpha\,\Psi)^n]^{-m} + \theta_r$ 3

Since:

α, n and m are constants

θ_r Initial moisture content at tension 1500 kPa

θ_s moisture content at saturation.

Θ instantaneous moisture content between θr and θs

In order to get the best fit for the moisture characteristic curve data, the Retention Curve programme (RETC, version 6.0), an arithmetic operating programme, was used to solve Equation 3 and find the criteria, n, and m by the Iterative Method, assuming that m=1-1/n by drawing the relationship between the volumetric moisture values of the soil in units of cm3-cm3 with the values of the applied tensions to the soil in units of kilopascal. It was feasible to acquire the values of the aforementioned equation parameters and a match between the measured and estimated values from the programme because the measured moisture content values (0-0.1-0.2-33-100-500-1500) kPa were utilised in the RETC software.

RESULTS AND DISCUSSION

The study soils and treatments' moisture characteristic curves are shown in Figure 1. Figure 1 shows that the relationship between volumetric moisture content and matric tension was inverse, with all study soils showing a decrease in moisture content with increasing tension. However, the difference in moisture content is most noticeable at low tension, while the differences become smaller with increasing tension or at high tension. Additionally, the moisture content values decreased as the gypsum content rose (Fig. 1 -A), with the values of reaching (0.535, 0.524, 0.494, 0.459, 0.402) cm3 cm-3 at zero tension (saturation) and (0.505, 0.454, 0.437, 0.403, 0.317)cm3 cm-3 at one kPa, (0.468, 0.423, 0.401, 0.3788,0.292and and (0.331, 0.308, 0.266, 0.222, 0.190) cm3 cm-3 at a tension of 100 kPa, (0.223, 0.204, 0.191, 0.157, 0.112) cm3 cm-3 at a tension of 500 kPa, and (0.131, 0.118, 0.097, 0.088, 0.065) cm3 cm-3 at a tension of 1500 kPa for gypsum content 46, 137 (Fig. 1-a, b, c, d, t, f).

The amount of water that is accessible for the study's soil and treatments is shown in Table (2) and Figure (2). It was discovered that for all of the treatments applied to the study soil, the values of the accessible water fell as the gypsum concentration rose. At the gypsum concentration of 46, 137, 238, 319, and 410 g kg-1, the values of the available water were 0.276, 0.239, 0.216, 0.214, and 0.191 cm3 cm-3, respectively. regarding untreated dirt. With a rise in the percentage of accessible water when treating soil with conditioners in various amounts, soil treated with conditioners took the same context in the connection of available water with the soil's gypsum content. This is due to either a decrease in total porosity caused by an increase in gypsum or the poor water holding capacity of soils with an increase in gypsum content (Bassam and Abd Al Gabar,2013).

In addition to the results of combining the two study soils, which included an increase in gypsum concentration and a decrease in clay content. The role of clay in binding the particles and aggregates is what causes the volumetric moisture content to rise with the decrease in gypsum content, and this is consistent with (Salim, 2001 and, Homaee and Firouzi, 2008) and other studies. This raises the question of whether the soil can hold more water as a result (Al-Khatib and Al-Rawi, 2015).

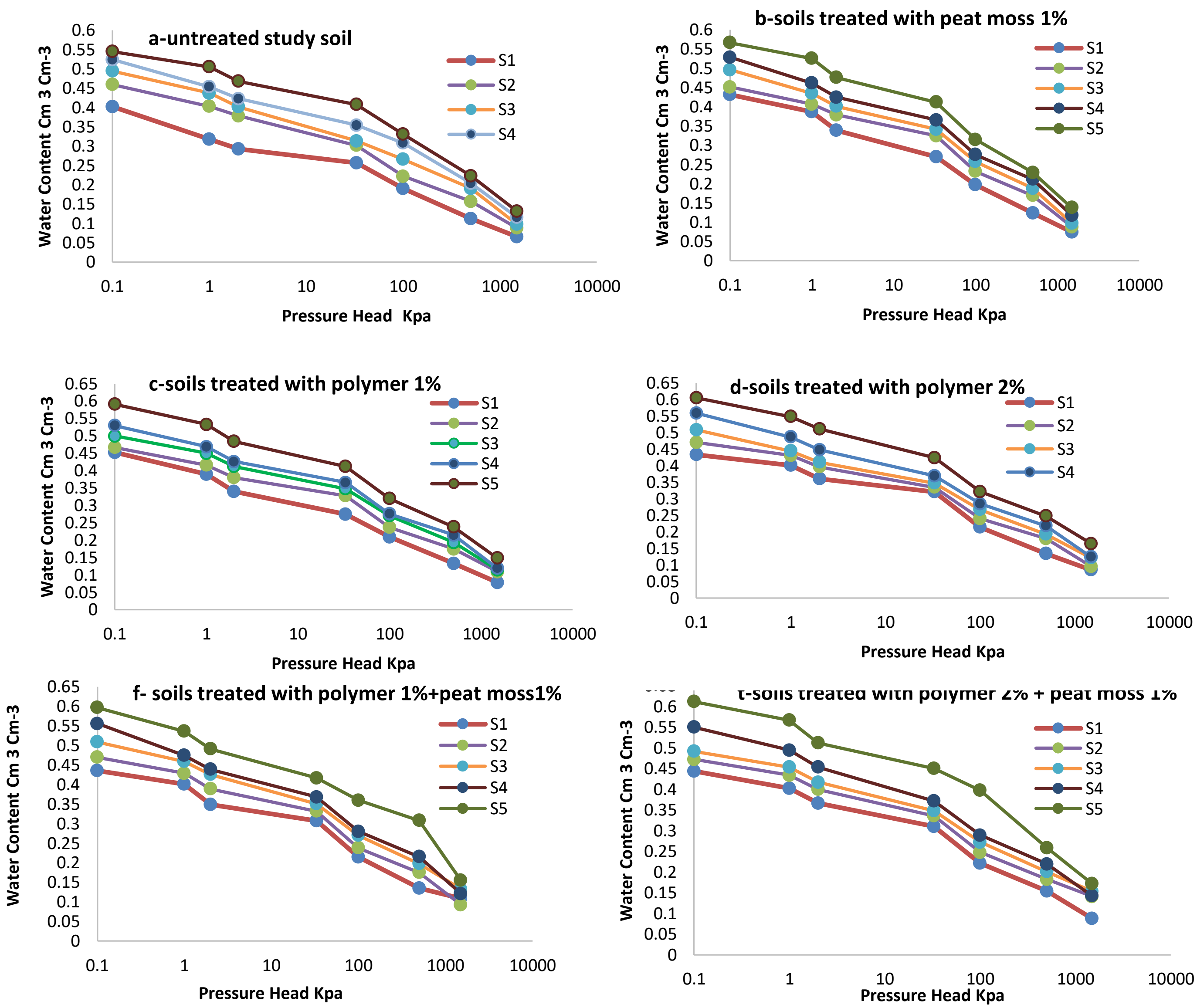

Figure (1): moisture characteristic curves for soils and treatment of study

Table (2) available water for soils and treatments of study

study soils	**Gypsum content g kg^{-1}**	**Available water cm^3 cm^{-3}**					
		study treatments					
		untreated soils	**Treated with peat moss 1%**	**Treated with polymer 1%**	**Treated with polymer 1%**	**Treated with peat moss 1% + polymer 1%**	**Treated with peat moss 1% + polymer 1%**

S_1	410	0.191	0.196	0.196	0.236	0.198	0.223
S_2	319	0.214	0.236	0.218	0.240	0.240	0.194
S_3	238	0.216	0.244	0.233	0.226	0.248	0.195
S_4	137	0.239	0.247	0.246	0.245	0.247	0.229
S_5	46	0.269	0.274	0.263	0.260	0.262	0.278

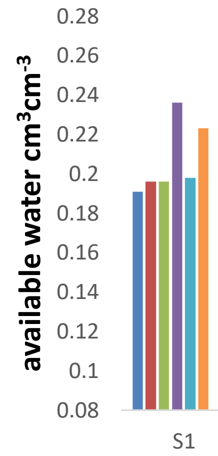

Figure (2) available water for soils and treatments of study

Figure (1-b) and Table (2) show that the addition of peat moss has an impact on increasing the volumetric moisture content and the available water, particularly with the increase in clay content and the decrease in gypsum content, as evidenced by the values of available water reaching 0.196, 0.236, 0.244, 0.247, 0.274 cm 3 cm-3 when the Gypsum content was 410, 319,238, 137, 4.9 g kg-1 sequentially.

This outcome is tied to the addition of peat moss in the same way that it is related to the rise in the proportion of clay that goes along with the rise in the proportion of gypsum. This is caused by the large specific surface area of the clay and the colloidal particles produced by the decomposition of peat moss, which causes them to stick to large amounts of water when they are hydrated. This is further enhanced by the fact that both of them (clay and colloidal particles) have negative charges on their surfaces, which enhance their ability to hold water. While Table (3) displays the values of the Genuchten Van equation's parameters (, n, and m) and the values of the coefficient of determination coefficient R2, Figure (2) compares the moisture content values that were really measured with those estimated through the use of the equation. It is evident that the values of R2 for untreated soils, treated with 1% peat moss, 1% polymer, 2% polymer, treated with 1% peat moss + 1% polymer, and treated with 1% peat moss + 2% polymer, respectively, were 0.791, 0.945, 0.892, 0.949, 0.921, and 0.947. The Genuchten Van equation can be used to predict the moisture characteristic curves even though its default constants give estimated results and are not entirely precise. The values of R2 showed good agreement between the actually measured values of and those calculated by the Genuchten Van equation for all levels of gypsum and the addition of conditioners in the range of water tension.

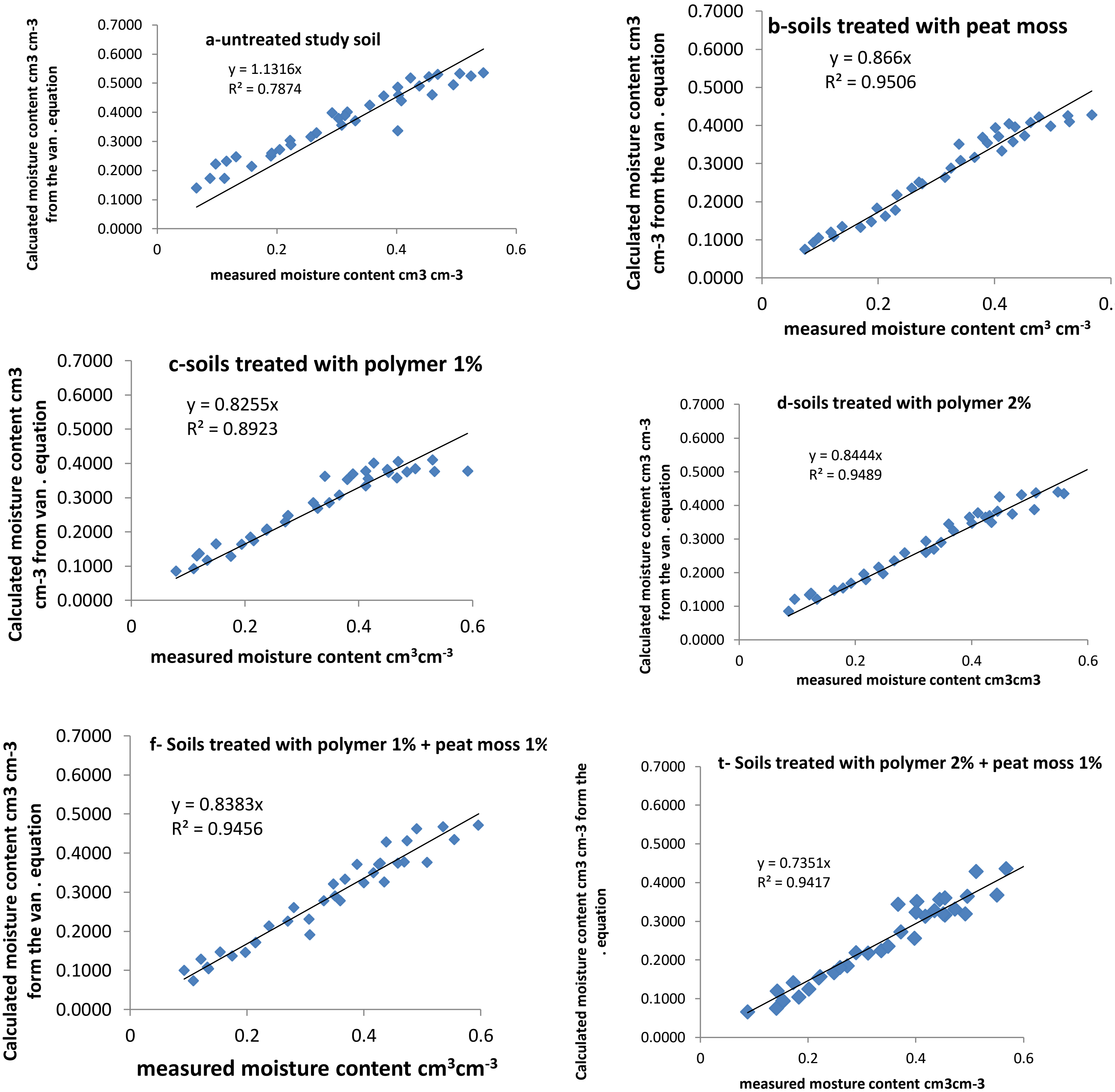

Figure (3) comparison of the actual measured moisture with calculated moisture content by Van Genucchten equation

Table (3) values of the parameters of the (Van Genuchten) equation for the soil and treatments of the study using RETC

study soil	**Study soils treatments**	**Van Genuchten Equation parameters**			**coefficient of determination**
		α	n	m	R^2
S_1	Untreated	0.053	1.345	0.256	0.921
	peat moss 1%	0.042	1.354	0.261	0.960
	Polymer 1%	0.097	1.231	0.187	0.963
	polymer 2%	0.066	1.272	0.214	0.971
	Peat moss 1% +polymer 1%	0.061	1.276	0.216	0.942
	Peat moss 1% +polymer 2%	0.070	1.333	0.250	0.975
S_2	Untreated	0.048	1.322	0.243	0.961
	Peat moss 1%	0.051	1.304	0.233	0.960
	polymer 1%	0.058	1.273	0.214	0.968
	polymer 2%	0.061	1.255	0.203	0.978
	Peat moss 1% +polymer 1%	0.111	1.290	0.225	0.959
	Peat moss 1% +polymer 2%	0.061	1.301	0.231	0.972
S_3	Untreated	0.111	1.351	0.157	0.949
	Peat moss 1%	0.089	1.177	0.191	0.953
	polymer 1%	0.030	1.222	0.177	0.896
	polymer 2%	0.060	1.311	0.237	0.987
	Peat moss 1% +polymer 1%	0.120	1.217	0.178	0.963
	Peat moss 1% +polymer 2%	0.099	1.211	0.174	0.961
S_4	Untreated	0.089	1.232	0.188	0.945
	Peat moss 1%	0.041	1.265	0.210	0.948
	polymer 1%	0.074	1.315	0.239	0.949
	polymer 2%	0.070	1.284	0.221	0.986
	Peat moss 1% +polymer 1%	0.057	1.280	0.219	0.948
	Peat moss 1% +polymer 2%	0.061	1.269	0.212	0.956
S_5	Untreated	0.087	1.238	0.192	0.970
	Peat moss 1%	0.012	1.325	0.245	0.953
	polymer 1%	0.097	1.297	0.228	0.913
	polymer 2%	0.084	1.250	0.200	0.963
	Peat moss 1% +polymer 1%	0.094	1.227	0.185	0.965
	Peat moss 1% +polymer 2%	0.111	1.221	0.181	0.974

CONCLUSION

In this study, our goal was to explore the impact of applying polymer, peat moss, and three cycles of soaking and drying on moisture characteristic curves and improve the ability of gypsum soils to retain water for soils differing in gypsum and clay contents. It can be concluded that adding peat moss (1%) and polymer (1 and 2%), separately or combination, increased the amount of available water with a decrease in clay ratio and an increase in gypsum ratio in all treatments.

CONFLICT OF INTEREST

The authors declare no conflicts of interest associated with this manuscript.

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