

## Adding Vertisol and emulsified lubricating oil as soil conditioners and its effect on moisture retention in sandy soil and the dry weight yield of natural plants

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### Abstract:

A field experiment was conducted at the Al-Burjasiya Research Station, Al-Zubair District, during the 2023-2024 winter season, on a sandy loam soil, to demonstrate the effect of Vertisol and emulsified lubricating oil as soil conditioners, on soil moisture retention and desert plant growth. The experiment included the use of soil conditioners, two soil conditioners. The first; Vertisol, at levels of 10% (C1), 20% (C2), and 30% (C3), as a suspension at a ratio of 1 part soil to 6 parts water, added directly to the surface of the experimental units, calculated per 1 cm<sup>3</sup> of sandy soil. The second conditioner is used lubricating oil mixed with water. It was emulsified by adding a synthetic emulsifying agent (an anionic surfactant). It was added at levels of 0.1% (O1), 0.3% (O2), and 0.5% (O3). The conditioners were added based on the weight (W/W) of the soil, to a depth of 15 cm, in addition to the control treatment (C0%). The moisture and rainfall treatment factor included four treatments: Re-irrigation after 50% of the available water has been lost to the soil's field capacity (R1), irrigation treatment equivalent to the highest rainfall (R2), attenuation treatment equivalent to the average rainfall (R3). R2 and R3 were derived from rainfall data, for a 41-year time series of previous years. These were added as standard irrigation treatments equivalent to rainfall, distilled water (R.O.) was used as a substitute for rainwater, and a direct rainfall treatment of the study year (R4), irrigation and re-irrigation were carried out in treatments (R2 and R3), based on the highest frequency of rainfall in any given month. The results showed that the conditioners were superior in increasing soil moisture content, significant differences were observed among the application levels. Vertisols C3 soil treatment and the emulsified lubricating oil O3 treatment recorded the highest PW values (17.483 and 15.236%), this was significantly higher than the control treatment (10.376%). Regarding moisture content, treatment (R1) recorded the highest PW value, significantly higher than the other treatments, reaching 14.455%, the lowest value was recorded in treatment (R3), which reached 13.711%. The results also showed a significant advantage of soil conditioners in the dry weight of desert plants compared to the control treatment. The emulsified lubricating oil conditioner outperformed the Vertisol soil conditioner in recording the highest dry weight values. O3 lubricating oil treatment recorded the highest values (16.845 tons ha<sup>-1</sup>). There was a significant difference between the levels of added conditioners, the lowest dry weight was recorded in the control treatment (2.580 tons ha<sup>-1</sup>). The results also showed that the moisture treatment R1 resulted in the highest plant dry weight (13.122 tons ha<sup>-1</sup>), the lowest values were recorded using the moisture treatment R3 (6.524 tons ha<sup>-1</sup>).

**Keywords:** Soil conditioners, Emulsifying lubricant, Vertisols, Moisture content, Natural plant growth.

### Introduction:

Sandy soils are widespread throughout most of the world, these soils are characterized by degraded physical, chemical, and hydrological properties. They are characterized by low clay and organic matter content, they also have low water retention capacity. Furthermore, they have a high content of loose calcium carbonate, they have low specific surface area and cation exchange capacity (Alghamdi *et al.*, 2018).

These soils are widespread in most areas of central and southern Iraq, especially in Basrah Governorate. This is due to the prevailing climatic conditions in Basra Governorate, where the climate is hot and dry, and rainfall is very low most of the time, less than 100 mm annually. High wind speeds and sparse vegetation cover, all these characteristics make them in need of reclamation, and conversion into soil with good agricultural productivity. This is usually done by adding natural and artificial conditioners (Simansky *et al.*, 2019).

Some studies have shown that clay and oil conditioners, have the ability to improve some properties of sandy soils (Al-Omran *et al.*, 2002; Al-Dabbagh *et al.*, 2010). Adding montmorillonite-rich clays, to improve the properties of sandy soils and plant growth, such as Vertisol, bentonite, and clayey sediments, a common technique in many arid and semi-arid regions of the world, it has been used to improve the physical and chemical properties of soils. Studies have shown that it has very important economic and environmental benefits, which positively impacts crop production (Alghamdi *et al.*, 2018; Dheyab *et al.*, 2024). The addition of bentonite and zeolite conditioners led to an increase in plant biomass. Plant growth increased with increasing levels of conditioner addition compared to the control treatment (Katal *et al.* 2010). This may be due to improved properties of the sandy soil, increased moisture content, and increased nutrient content. Adding bentonite clays to sandy soil resulted in a significant increase in biomass, grain yield, and improved water use efficiency (Mi *et al.*, 2017). The moisture content of sandy soils increased when using soil conditioners, this was achieved by adding Vertisol clay soil and zeolite conditioner at levels of 1, 2, and 3%. The soils were irrigated at three irrigation levels: 60, 80, and 100 ppm, this was calculated using the American evaporation pond, in laboratory tests to estimate the moisture content curve under pressures of 0, 0.3, 0.5, 1, 3, 5, 10, and 15 bar, a comparison with a control treatment showed the superiority of the Vertisol soil conditioner over the zeolite conditioner. The highest variance was observed at 0.3 bar, with an increase of 32.35%. The increase then decreased between the two conditioners, reaching its lowest value at 15 bar, this had a positive impact on barley plant growth (Al-Madhi, 2018). Treating soil with clay sludge mixed with wheat straw, increased moisture retention capacity, this was attributed to improved soil structure, and a reduction in evaporation potential with the increased proportion of added natural clay sludge, as well as an increase in biomass, vegetative and dry weight, and plant height of the Sudan grass (Alghamdi *et al.*, 2024). The effect of emulsified lubricating oil on moisture content, when sandy loam soil was treated with fuel oil, the following was observed, the available water content, confined between 0.5 and 15 bar, increased from 22.24% in the control treatment to 23.34% (Al-Dabbagh *et al.*, 2010). In a laboratory experiment conducted in Nigeria, organic fertilizers were used as a biological treatment at levels of 0.5 and 10 tons ha<sup>-1</sup>, on soil contaminated with used lubricating oil at concentrations of 0.5% and 10% (w/w). The growth and yield of herbaceous plants increased in the oil-contaminated soil treated with the organic matter (Osaigovon *et al.*, 2013). Adding used lubricating oil to sandy loam soil, at levels of 0, 1, 2, 2.5, 3, and 3.5%, resulted in a significant increase in soil moisture content, with increasing levels of addition compared to the control treatment without oil (Ebulue and Ebulue, 2022).

This study aims to improve the properties of sandy soils, and increase their moisture retention capacity, and increase the dry weight of desert plants, using the soil conditioner Vertisol, and an emulsified lubricating oil, under different humidity and rainfall conditions.

### Materials and Methods:

The study included two experiments. The first experiment was a laboratory experiment, it was conducted at the Agricultural Research Station, University of Basrah, Karma Ali, at pots measuring 20×20 cm, 8.5 kg of sandy soil was used. This soil was obtained from the Al-Burjasiya Research Station at Al-Zubair. The second experiment (field experiment) it was conducted at the Al-Burjasiya Research Station, General Authority for Agricultural Research, Ministry of Agriculture, located in the Al-Zubair, Kraytat Al-Gharbiya area, during the 2023-2024 growing season. The physiography of the area is located within desert regions, it has an arid climate, at latitude and longitude 30.3902787N and 47.6811552N, it has a sandy loam texture, its soil is classified as a type of quartz sand. The field experiment area was divided into three blocks, each block was divided into 28 experimental units, each measuring 1×1 m. A randomized complete block design (RCBD) with three replicates was used. The study factors included: **First factor:** Improvement treatments, specifically Vertisol soil. Vertisol is a black, cracked clay soil taken from sugarcane fields in Maysan Governorate, it is characterized by its high content of expanded clay (Table 1).

**Table (1) Some physical and chemical properties soil for a depth (0-5)(5-10) cm and Vertisol soil conditioner.**

Soil properties	Unit	Depth		Vertisol soil conditioner	
		0-5	5-10		
pH 1:1		7.80	8.10	7.80	
E.C	d.sm <sup>-1</sup>	4.20	4.40	6.12	
Moisture content saturated	%	31.55	31.88	65.80	
Field capacity		20.12	20.22	45.40	
Sand	gm.kg <sup>-1</sup>	887.000	885.000	58.000	
Silt		64.808	65.830	348.000	
Clay		48.192	49.170	592.000	
Texture		Loamy sand		Clay	
Particle density	mg. m <sup>-3</sup>	2.26	2.30	2.65	
Bulk density		1.65	1.66	1.30	
Porosity		36.96	38.55	50.94	
MWD	mm	1.545	1.540	0.47	
Saturated hydraulic conductivity	cm.hour <sup>-1</sup>	14.87	14.22	0.70	
CEC	centimole(+) kg-1	6.22	5.88	40.90	
Organic matter	gm. Kg <sup>-1</sup>	0.16	0.13	6.80	
Soluble ions	CaCO <sub>3</sub>	gm.kg <sup>-1</sup>	138	135	266.12
	Ca <sup>+2</sup>	mmole L <sup>-1</sup>	16.40	14.00	17.00
	Mg <sup>+1</sup>		18.00	17.80	16.40
	Na <sup>+2</sup>		6.22	6.30	22.50
	k		3.18	3.20	6.44
	HCO <sub>3</sub> <sup>-3</sup>		6.90	6.55	3.40
	CO <sub>3</sub> <sup>-2</sup>		0.00	0.00	0.00
	Cl <sup>-1</sup>		50.00	48.00	70.00
So <sup>-2</sup>	9.30		8.90	8.44	

These treatments were added at levels of 10% (C1), 20% (C2) and 30% (C3) of the weight of the sandy soil to a depth of 1 cm of the experimental unit area in the form of a suspension (1 soil: 6 water) sprayed on the soil surface. The treatment for the artificial conditioner is water-emulsified lubricating oil, using an anionic artificial emulsifier (surfactant), according to Dheyab (2017), at levels of 0.1% (O1), 0.3% (O2), and 0.5% (O3) w/w of the weight of the sandy soil to a depth of 15 cm, using the volume of the emulsion (oil/water), equal to bring the sandy soil to its field capacity limit to a depth of 15 cm. The second factor: the moisture and rainfall treatment, by four treatments: Irrigation treatment to field capacity limit (R1), in this treatment, irrigation is repeated to the field capacity limit after 50% of the available water has been drained to a depth of 15 cm of the sandy soil, Highest annual rainfall treatment (R2), Meaning rate treatment Rainfall (R3), Treatments (R2 and R3) are recorded from a 41-year time series, and a direct treatment of the rainfall in the current study year (R4). As shown in Table 2, these treatments were implemented in both field and laboratory experiments.

**Table. (2) Timing and quantities of moisture equivalent to rain and current year(mm).**

Moisture and Rainfall treatment	Nov		December		Jan		Feb		Mar		Apr		MAY	
	date	Quant	date	Quant	date	Quant	date	Quant	date	Quant	Date	Quant	Date	Quant
R <sub>1</sub>	24	21	4	21	4	21	1	21	1	21	5	21	-	-
	29	21	10	21	11	21	8	21	7	21	10	21	-	-
	-	-	18	21	18	21	15	21	13	21	15	21	-	-
	-	-	22	21	25	21	22	21	19	21	20	21	-	-
	-	-	28	21	-	21	-	-	25	21	25	21	-	-
R <sub>2</sub>	2	11.18	1	2.91	2	5.18	10	3.76	18	8.27	2	12.52	-	-
	11	21.01	2	5.27	14	2.74	19	3.76	20	18.18	4	18.41	-	-
	24	16.13	5	7.65	15	3.41	24	5.26	24	27.1	6	4.88	-	-
	29	18.05	18	3.98	27	2.96	27	9.76	28	11	14	26.35	-	-
	-	-	30	7.3	31	4.33	-	-	-	-	-	-	-	-
R <sub>3</sub>	2	3.32	1	1.97	2	6.69	10	2.6	18	2.45	2	1.85	-	-
	11	6.23	2	3.57	14	3.53	19	2.59	20	5.4	4	2.73	-	-
	24	4.78	5	2.12	15	4.4	24	3.62	24	8.03	6	2.15	-	-
	29	5.35	18	2.69	27	3.83	27	6.73	28	3.26	14	3.9	-	-
	-	-	30	4.94	31	5.6	-	-	-	-	-	-	-	-
R <sub>4</sub>	26	1.4	-	-	1	1.0	1	0.3	11	1.4	8	3.3	1	19.8
	27	0.4	-	-	26	6.7	11	11.2	19	21.3	10	1.1	2	0.4
	-	-	-	-	-	-	12	0.1	22	5.4	15	0.1	3	0.2
	-	-	-	-	-	-	14	0.5	23	0.1	30	2.4	10	0.1
	-	-	-	-	-	-	15	2.0	24	0.2	-	-	-	-
	-	-	-	-	-	-	16	0.3	25	9.5	-	-	-	-
	-	-	-	-	-	-	24	10.7	-	-	-	-	-	-
	-	-	-	-	-	-	25	1.0	-	-	-	-	-	-
Total Water Depth Added from Irrigation Treatment and Rainfall (mm)														
R <sub>4</sub> = 100.9				R <sub>3</sub> = 93.88				R <sub>2</sub> = 249.82				R <sub>1</sub> = 609		

- R<sub>1</sub>: Irrigation after the water reaches 50% of the available water.
- R<sub>2</sub>: Equivalent humidity treatment represents the highest rainfall for a 41-year time series.
- R<sub>3</sub>: Equivalent humidity treatment represents the rainfall rate for a 41-year time series.
- R<sub>4</sub>: Represents rainfall data for the study year 2023.-2024 according to Agricultural meteorology/ station Research Bourgeois/Al-Zubair, affiliated with the Ministry of Agriculture.
- ---nothing Adding a moisture treatment or rainfall .

The irrigation dates and equivalent amounts for the two rainfall treatments (R2 and R3) were determined as follows:

- Identify the year with the highest rainfall over the past 41 years.
- Calculate the average rainfall over the past 41 years.
- Determine the dates of rainfall events distributed across the days of each month.
- Then calculate the cumulative frequency (the number of rainfall events per day of each month).
- Estimate the arithmetic mean of the number of rainfall events in each month.

$$\bar{y} = \frac{\sum y_i}{n}$$

Where:  $\bar{y}$  Arithmetic mean

$\sum y_i$ : Total number of showers per month over a period of 41 years.

n: Number of days in each month (28, 29, 30, 31).

1. Days in each month with a shower frequency higher than the monthly mean (mode peaks above the mean) were selected, while those with a lower mean were ignored.
2. The total rainfall over the past 41 years for both treatments (R2, highest rainfall) and (R3, average rainfall) was divided proportionally by the most frequent modes. The ratio of each mode value to the total number of frequencies calculated from the most frequent modes was then determined.

The study treatments were implemented before the start of the rainy season in early November. The process of adding RO water equivalent to the rainwater treatments continued until May 3rd (the end of the rainy season). All experimental units in the treatment were covered with plastic sheeting during rainfall, except for treatment R4, which was left uncovered to receive rainwater during the study year. Measurements of the studied characteristics were taken after the completion of the rainfall treatments at the end of the rainy season (May 3rd). In the experiment studying the laboratory treatments for moisture retention, the pots were moistened to their field capacity, and the moisture content was measured periodically every 48 hours for 14 days until the change in soil weight in the pots stabilized. The average of the moisture content values from 7 measurements across all experimental units was used for statistical analysis (analysis of variance). In the experiment investigating the effect of field treatment treatments on the growth and yield of natural plants, the vegetative parts of the growing plants were harvested on May 3rd in each experimental unit. They were placed in bags and oven-dried at 60°C, and their weight was recorded.

**Results and Discussion:**

**Solution Conservation:**

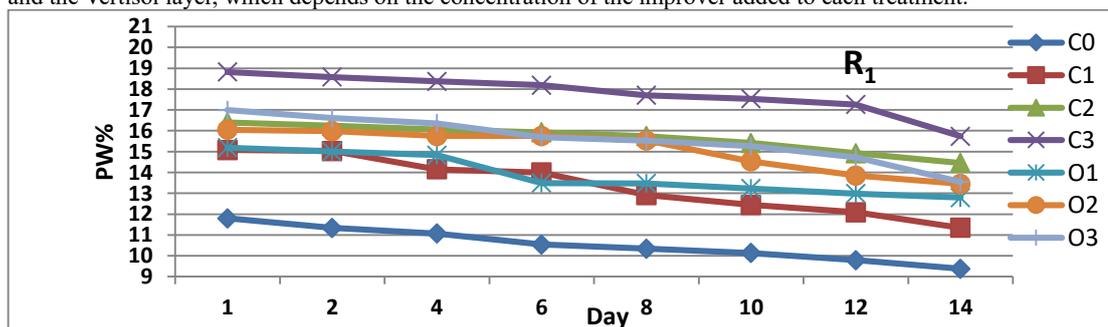
The curves in Figure (1) show the interaction effect of soil conditioners at their respective levels and the soil moisture and rainfall levels on soil moisture conservation (PW%). This measurement was taken with varying measurement time after irrigating the experimental units up to the field capacity limits. The moisture content was then estimated over a period of 1-14 days, with 8 measurements taken at equal intervals of 2 days, except for the first measurement, which was taken 1 day after irrigation, the results showed a variation in moisture content at the first measurement after 1 day of irrigation. The figure shows a clear variation in moisture content between the treatments of the added conditioners, with different types and levels of moisture conservation. This variation was observed over different time periods, and the highest moisture conservation was achieved with treatment C3, followed by O3, with the lowest achieved with the control treatment C0. The treatments were selected based on their content. Humidity for all transactions and time periods:-

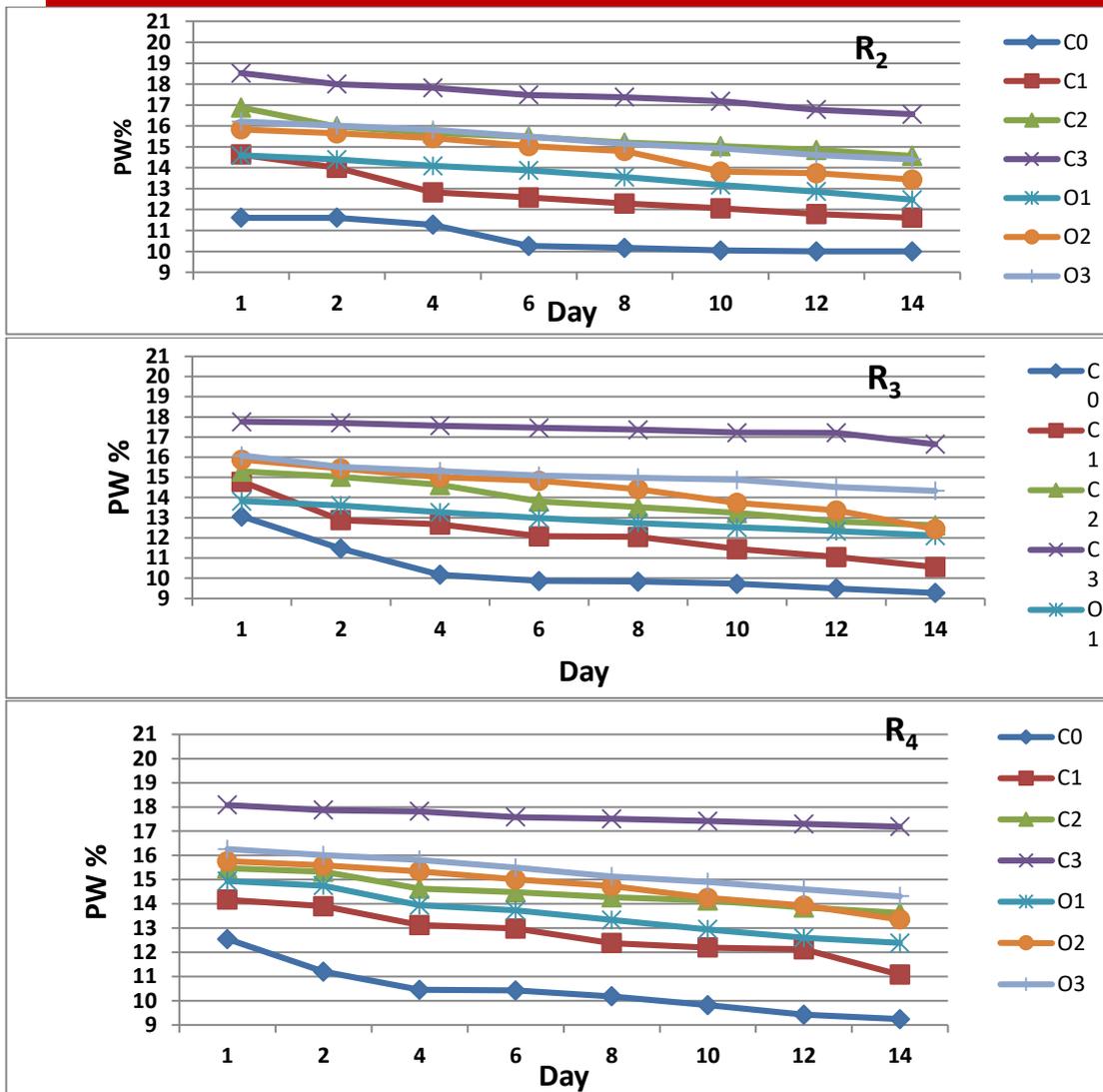
$$C3 > O3 > C2 > O2 > C1 > O1 > C0$$

Regarding the effect of humidity and rainfall treatments on moisture retention. Figure (1) shows that the variations in moisture content between the different treatment treatments at various measurement intervals. The highest differences were observed with the high humidity and rainfall treatments (R1), followed by R2 and then R4, and the lowest with treatment R3. Figure (1) shows that all added conditioner treatments resulted in a decrease in soil moisture content over time. Their moisture retention showed a clear difference in the magnitude of the decrease. Treatments C3 and O3 showed a moderately sloping decline in soil moisture content and moisture levels until the end of the measurement period (14 days). However, these two treatments (C3 and O3) showed a significant decrease in moisture content, represented by a steep decline at measurement periods 2, 4, and 6 days. The effect of active capillary action of soil water in the soil columns, was most pronounced in the control treatment C0 and across all moisture and rainfall treatments. C0 exhibited the highest and most consistent decrease in moisture content starting at measurement periods 2, 4, 6, and 8 days. The decrease then slows down as the soil moisture content approaches the equilibrium moisture level, with the surrounding environmental conditions. In terms of its binding energy, which is close to 10% PW. As for the remaining enhancer treatments C2, O2, C1, and O1. Figure (1) shows that the moisture curves have lower average values than the O3 treatment curve, higher than the C0 control treatment curve, and have the following order:

$$C2 > O2 > C1 > O1$$

For all moisture and rainfall treatments, most of the moisture curves showed balanced paths with slight and symmetrical slopes between them during the time period 1, 2 and 4 days. After that, there was a clear decrease and slope in treatments C1 and O1, while treatments C2 and O2 continued with their slight slopes and gradual decrease in moisture content until the time period 8 days, in which there was a clear drop. This drop continued with the same slope for the times 12 and 14 days at the end of the measurement period. This is due to the variation in the level of addition of the improver and its effect on increasing the moisture retention period. This depends on the efficiency of the improver and its direct role in improving soil structure and the formation of aggregates that increase moisture retention, or the direct effect in reducing the capillary movement of water by making the surfaces of particles and aggregates hydrophobic, which limits capillary rise, or through the process of covering the soil surface with clay sludge and hindering capillary movement due to the lack of homogeneity in the capillary tubes between the sandy soil and the Vertisol layer, which depends on the concentration of the improver added to each treatment.





**Figure (1) Effect of soil conditioner factor and rainfall moisture treatments on pw % values for the 14-day period.**

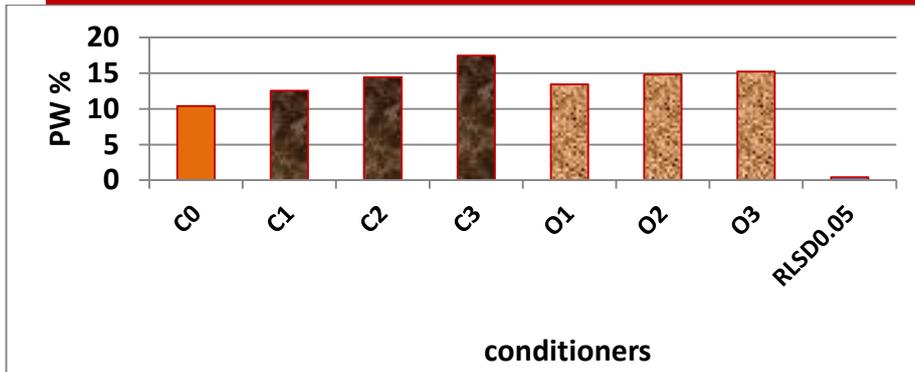
Table (4) shows the highly significant effect of the enhancer factor on %PW values, when comparing these treatments, significant differences were found between all treatments (Figure 2). C3 and O3 achieved the highest %PW values at 17.483% and 15.236%, respectively. It is also evident that there are significant differences between all levels of addition. The variance increases with increasing levels of addition for both enhancers compared to the control treatment, which achieved the lowest values at 10.376%. The percentage increases were 68.494, 46.838, 42.993, 39.003, 29.548, and 20.807% for C3, O3, O2, C2, O1, and C1, respectively.

This is due to Vertisol's ability to increase moisture retention and reduce evaporation from the soil surface. Adding clay in suspension form allowed clay particles to penetrate the soil body, coating the sandy soil particles and closing the pores. This, in turn, increases the soil's ability to retain moisture and restricts water upwelling by capillary action through the formation of a mulching film, this reduces the capillary action of water due to the lack of homogeneity between the pores of sandy and clay soils, this increases soil moisture retention, this positively impacts the activity of microorganisms. It also promotes vegetation growth (both vegetative and root) with increasing levels of Vertisol application (Karbout *et al.*, 2015a, 2015b; Abd El-Hady and Eldardiry, 2016; Al-Madhi, 2018).

Clay also plays another role, as it limits the downward movement of water, it is characterized by its large surface area. Clay particles absorb water. Soil expands when moistened and contracts when dry. Adding clay deposits to the soil surface, reduces total evaporation as the clay deposit level increases. The increased ability of soil to retain moisture is attributed to the reduction of upward water movement by capillary action due to the clay particles closing some soil pores and causing them to swell significantly (Hartage and Horn 2016; Alghamdi *et al.*, 2024).

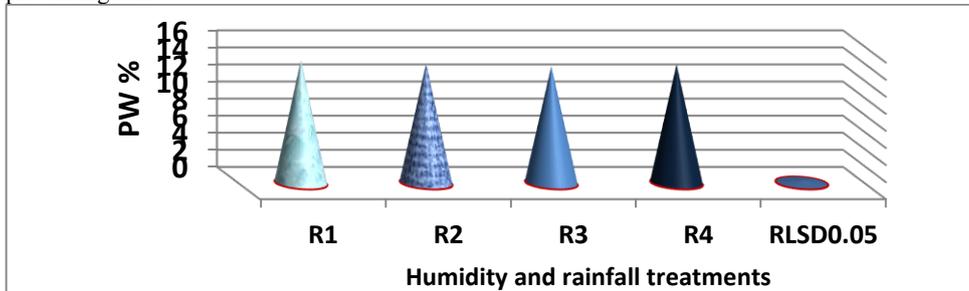
Clay particles have a high surface area, and when added to coarse-grained sandy soil, they increase the number of small pores in the soil at the expense of large pores, thus increasing the soil's ability to retain moisture and making nutrients more available (Tahir and Marschner, 2016). Herawati *et al.* (2021) showed that adding clay to sandy soil increased its moisture retention capacity by 17.59%, representing a 122.69% increase compared to the control treatment.

As for the effect of emulsified lubricating oil, it is due to the indirect effect of increasing moisture content, this results from the formation of hydrophobic soil particle surfaces and aggregates. This limits the upward capillary movement of water within the soil body, especially the capillary movement of water in all directions within the soil body, this reduces surface evaporation loss (Dheyab, 2019). Furthermore, it plays a role in improving soil structure, it works by binding soil particles together, forming aggregates, and reducing pore size. Consequently, it increases the soil's ability to retain moisture and reduces evaporation potential, this is achieved by limiting capillary water movement, this is due to the formation of hydrophobic soil particle surfaces (Dheyab, 2017).



**Figure (2) Effect of the conditioners factor on the average PW % values.**

The results of the F-test (Table 4) demonstrate a highly significant effect of humidity and rainfall on PW% values. Figure (3) shows significant differences among all treatments. R1 achieved the highest PW% value at 14.455%. This was followed by R2, then R4, and finally R3, with values of 14.048, 13.941, and 13.711%, respectively. These treatments showed decreases of 5.147, 3.555, and 2.815%, respectively, compared to R1. This is attributed to the differences in the treatments received, whether through irrigation (R1) or rainfall (R2 and R3). The current year's rainfall (R4) and its impact on microbial growth and increased activity, consequently, an increase in biomass and its role in promoting Soil water retention, by its direct effect on increasing organic matter content, as well as the role of living organisms and plant roots, promote their growth in improving soil structure and building soil aggregates, work to bind the particles of sandy soil, thus redistributing pores and increasing water retention and preventing loss.



**Figure (3) Effect of humidity and rainfall parameters on the average PW % values.**

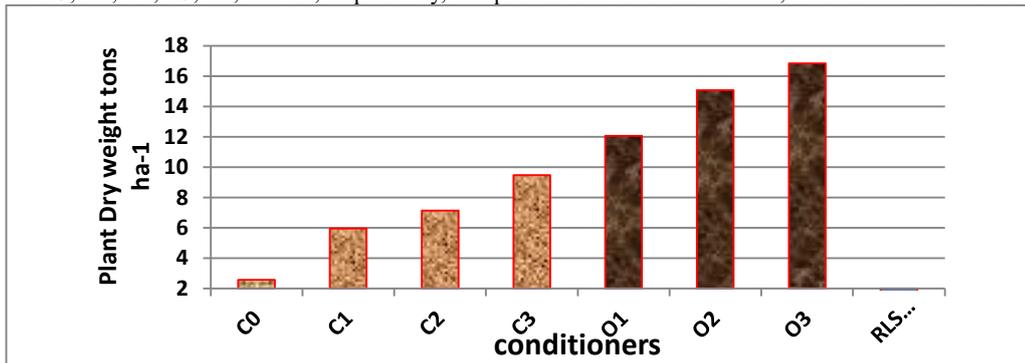
The results of the statistical analysis of the F-test (Table 4) show no significant differences in the interaction between the enhancer factor and the moisture modulus factor on PW % values.

**Effect of conditioners on the dry weight of desert plants:**

The results of the F-test (Table 4) show a highly significant effect of the plant enhancer on the dry weight of desert plants. Figure (4) shows significant differences between all treatments compared to the control, with treatment O3 achieving the highest dry weight of 16.845 tons ha<sup>-1</sup>. The order of the treatments is as follows:

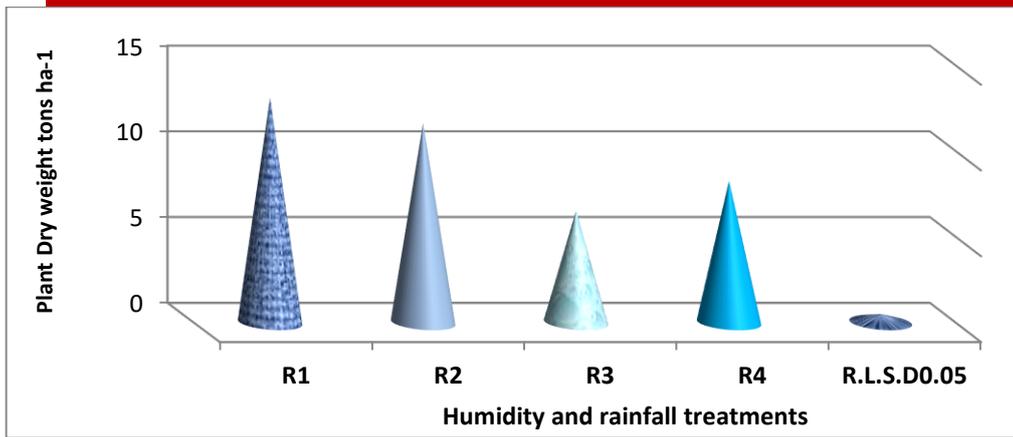
$$O3 > O2 > O1 > C3 > C2 > C1$$

At a rate of 16.845, 15.073, 12.068, 9.481, 7.146, 5.968, 2.580 tons ha<sup>-1</sup>, with percentage increases of 5.529, 4.842, 3.677, 2.674, 1.769, 131.317 for O3, O2, O1, C3, C2, and C1, respectively, compared to the control treatment, which achieved the lowest plant dry weight of 2.580 tons ha<sup>-1</sup>.



**Figure (4) Effect of conditioners on plant dry weight (tons ha<sup>-1</sup>).**

This is due to the effect of both the soil conditioner Vertisol and the emulsified lubricating oil in increasing moisture retention (Figure 2). Consequently, this increases the water available for plant growth and improves soil structure and pore size distribution, reflected positively in the increased moisture content of sandy soils. This effect increases with the application level of both conditioners, promotes biomass growth and increases the dry weight of desert plants. Both clay and the emulsified lubricating oil bind soil particles, form aggregates, and reorganize the geometry of soil pores, this increases the moisture retention capacity of sandy soils (Hall *et al.*, 2010; Ebulue and Ebulue, 2022). In addition, added conditioners promote the growth of microorganisms, and the formation of a biological crust on the soil surface, which increases the soil's ability to retain moisture (Rodriguez-Caballero *et al.*, 2018). Furthermore, adding conditioners increases organic matter and nutrients (Udom *et al.*, 2008; Purwantono *et al.*, 2011). The results of the F-test (Table 4) show a highly significant effect of the humidity and rainfall (R) treatment factor on the dry weight of the plant. Figure (5) shows significant differences between all humidity and rainfall treatments. R1 achieved the highest dry weight value at 13.122 tons ha<sup>-1</sup>, followed by R2, were achieved 11.613 tons ha<sup>-1</sup>, and then treatment R4 achieved 8.260 tons ha<sup>-1</sup>. Finally, R3 recorded the lowest value, reaching 6.524 tons ha<sup>-1</sup> at the midpoint and end of the experiment, respectively. The percentage decreases compared to R1 were 11.499, 50.281, and 37.052% for R2, R4, and R3, respectively.



**Figure (5) Effect of moisture treatments on the desert plant dry weight (tons ha<sup>-1</sup>).**

The results were shown in Table (3), and the statistical analysis of the F-test is shown in Table (4). There was a highly significant interaction effect between soil conditioners and rainfall and moisture treatments on the dry weight of desert plants. The addition of soil conditioners led to a significant increase in plant dry weight. The highest variances were observed at all levels of conditioner addition and for all rainfall and moisture treatments. Table 3 shows that the O3 lubricating oil treatment, interacting with all rainfall and moisture treatments (R1, R2, R3, and R4), was superior in increasing the dry weight of desert plants. This is compared to the levels of Vertisol soil conditioner interacting with the same rainfall and moisture treatments. The results also showed that soil conditioners were superior in increasing plant dry weight compared to the control treatment. O3R1 recorded the highest dry matter weight, reaching 21.540 tons ha<sup>-1</sup>, while The lowest dry weight of plants under the factorial treatment C0R3 was 1.583 tons ha<sup>-1</sup>.

**Table (3) Effect of interaction among the conditioner factor and the moisture and rainfall treatments on the dry weight of the vegetative part of desert plants tons ha<sup>-1</sup>.**

Conditioner	Humidity and rainfall treatments			
	R <sub>1</sub>	R <sub>2</sub>	R <sub>3</sub>	R <sub>4</sub>
C <sub>0</sub>	3.650	3.140	1.583	1.947
C <sub>1</sub>	9.763	9.690	1.913	2.507
C <sub>2</sub>	11.060	10.050	2.567	4.907
C <sub>3</sub>	13.823	11.383	5.517	7.200
O <sub>1</sub>	13.627	12.903	10.230	11.510
O <sub>2</sub>	18.393	16.500	11.397	14.000
O <sub>3</sub>	21.540	17.627	12.463	15.750
RLSD <sub>0.05</sub>	1.427			

The increase in the dry weight of the vegetative part in R1 and R2 is attributed to the increased application rate of the used lubricating oil, particularly when the oil was added, is due to the emulsified lubricating oil penetrating the soil profile and reaching deeper soil layers. This increased surface area and improved soil aggregate stability and resilience to wetting and drying cycles. This was especially true when treatments R1 and R2, which had high water depths, were applied, these depths reached 609 and 249.82 mm, respectively, consequently, the application of these treatments improved the physical and hydraulic properties of the soil.

**Table (4) Statistical Analysis of the F-test.**

Source	d.f	F	
		PW %	Plant dry weight
C	6	361.688 **	381.402 **
R	3	12.278 **	233.761 **
C* R	18	1.315 n.s	7.808 **
C: Conditioners		R: Humidity and rainfall treatments	

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