Effect of Sawdust Extract, Wetting and Drying Cycles on of Aggregates Soil Stability and Saturated Hydraulic Conductivity

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Abstract: A laboratory experiment was conducted, in the laboratories of the College of Agriculture-University of Anbar, for disturbed soil samples taken from one of the fields in the previous College of Agriculture, Baghdad University, latitude 33.2 south, and longitude 44.24 east. Wooden sawdust extract (WSE) was added to soil in 5, 10, and 15% levels in an equivalent proportion of soil organic matter (SOM) content for nine cycles of wetting-drying (WDC). A factorial three replications experimental design was statistically analyzed. A significant increase was noticed in the mean weight ed diameter (MWD) of soil at fast wetting, where it raised for 5, 10, and 15% WDS levels. The interaction was significant in the second WDC for the same WSE levels in comparison with zero addition treatment where they were 123.62 and 173 % respectively, meanwhile 10 and 15 % WSE levels significantly superior to 5% level by 38 and 69 %. Whereas slow wetting MWD gradually to be 37 and 86% starting from third till ninth WDC successively compared to second WDC. The effect of WDCs on the saturated hydraulic conductivity (ks) of aggregates greater than 9.5mm was significant in this trait, as it increased by 13, 8, 13, 19, 18, and 18% for the 2ed, 4th, 6th, 7th, 8th, and last WDC, respectively. It also found a clear effect of the add-on levels in the saturated water conductivity (SWC) within 9.5 – 4 mm aggregates. There was a significant increase in equivalent add-on levels of 5, 10, and 15% with 8.4, 32.9, and 74.2% successively. There was a significant increase of 5, 10, and 15% equivalent addition levels of 8.4, 32.9, and 74.2% respectively compared to the level of non-addition of WSE extract. Soil samples tested with an electron scanning microscope, the samples to which WSE were added became granular and aggregated surfaces, while the untreated samples were smooth, with no granular surfaces and sharp edges.

1. Introduction

Most of Iraq's agricultural soils, many of which have problems, include deteriorating soil structure. The soil's periodic exposure to wetting and drying, due to irrigation operation and conditions caused by climate change, is one of the most common processes. [1]; [ 2] defined soil construction as a key indicator of soil quality and the agricultural system in general. Li[3] considered that the organic content of polysaccharides, humic acids, and fulvic acids was more important for the aggregate's stability rather than the compounds and total substances that make up the organic matter. On the other hand, [4] confirmed a positive significant correlation between organic soil carbon and mean weight diameter (r=0.87).

The wetting and drying cycles that occur in the rhizosphere are important in the formation of soil aggregations because they help to increase the binding among roots and clay particles by resulting in secretions [5]; [ 6]. The addition of straw to the soil has stimulated the activity of microbes, increasing the stability of the aggregates, by increasing the cohesion forces and soil hydrophobicity of water. They emphasized that the net effect of wetting and drying cycles, was less than the addition of straw, and the interaction effect of two factors has been more complex, and this complexity is the result of the wetting and drying cycles in soil properties, the dynamics of microbial communities, and what
happens to linkages and aggregation factors. Dlapa [7] revealed a positive linear correlation relationship of \( r = 0.786 \) value between organic carbon and stability of soil aggregates, but the relationship is negative with the increase in calcium carbonate and soil pH with \( r \) values of 0.652 and 0.608 successively. Rawlin [8] explained that soil’s stability of aggregations is an important physical indicator of soil quality, as they are affected by changing hydration properties and organic carbon storage over time, and reducing soil susceptibility to water and wind erosion. The stability of aggregates also depends heavily on the content of organic matter and the activity of soil microbiology, such as fungal threads that bind soil particles together and form accumulations. Al-Nuaymy [9] in a study on the sustainability of desert soils, noted that unused Iraqi soils are of a sustainable or high-sustained class, when using the mean weighted diameter index and water-stable soil aggregates when steaming samples, and were unsustainable to high-sustainable when wetting by water-logging, which was detected by [10] in their study about wooden sawdust injection in loamy silty clay soil.

Al-Nuaymy [11] concluded that soil aggregates are not only affected by continuous fertilization but also by fertilizer type, the water-stable aggregates, and mean weight diameter induced by nitrogen-phosphorus fertilization, and increased yield of which biomass or different fungal hypha that led to such induction. The two mentioned nutrients have no direct influence on the stability of aggregates, although differences in root properties depending on land use, they are similar in their effect on the stability of soil aggregates. However, knowledge of the role of roots with soil properties remains limited and debatable [12]; [13]; [14].

2. Materials and Methods
A laboratory experiment was conducted, in the laboratories of the College of Agriculture-University of Anbar, for disturbed soil samples taken from one of the fields in the previous College of Agriculture, Baghdad University, Abu Ghraib site, latitude 33.2 south, and longitude 44.24 east. Conducted a particle size distribution of soil aggregations using several graded sieves starting from 9.5, 4, 2, 1, 0.5, and 0.25 mm respectively, the soil was then packed according to the weighted percentages resulting from the size distribution of its aggregates, in PVC cylindrical containers with a thick 10 cm in diameter wall and 10 cm high, one end of the cylinder was closed with pieces of gauze that allow water to pass through during wetting.

After collecting sawdust, the organic extract was prepared from a carpentry plant in Heet district, Anbar province. It was placed in a pile (50 kg), crushed by a coffee grinder to increase the smoothness of sawdust to reduce the duration of fermentation, and was subjected to aerobic decomposition, Sawdust was placed on top of a piece of polyethylene, then added nitrogen with 2% urea (46% N) and phosphorus by 0.05%, of triple superphosphate fertilizer (20% P) [15].

The pile is continuously witted, in the form of a spray with constant stirring, every 3 or 4 days with polyethylene cover, to raise the reaction temperature, speedup of the decomposition process and until the mother material is not diagnosed, as well as the temperature of the reaction inside the pile is reduced from 65°C to 45°C or below, by constantly following them, using the thermometer as an indicator to reach the end of the interaction, Which ended two months after the decomposition began, after which these decaying organic waste, was exposed to air dry up for three days. After then, they extracted by adding KOH solution and soaking it for 24 hours in the solution and then separating the solution from the deposit by centrifuge using a washer-dryer, after putting the solution in a perforated bag inside the dryer.

The extract is added to the soil, after the extract solution is concentrated to the necessary amount of solution, to deliver soil moisture to field capacity limits. In this way, the proportion of dry extract in the solution is equivalent to the amount of the quantity before extraction which equivalent to 5,10, and 15% an organic matter of soil weight. By drip the necessary amount of solution from an inverted bottle. The solution height was titrated according to its viscosity to give a discharge of 2 ltr. h-1, water was only added to the drip control treatment as well. The wetting of the samples was performed with the capillary feature, placing the soil cylinder over a 10 cm height column of fine sand, After the water
column was installed using the Marot bottle. The wetting process lasted to the point of saturation for about 16 hours.

The samples were then left to lose water until they reached the field capacity limits, which is the first moistening cycle. After that, all samples were incubated at 22°C for 3 days, after which the cylinders were removed and placed on the ground horizontally and left to dry on air for 3 days, then re-wetted to the point of saturation for another 16 hours for the rest of the cylinders that will remain to the subsequent 9 wetting-drying cycles. While the containers on which the analysis will be performed, cut from the sides longitudinally, using a knife heated at a high temperature, taking into account not touching the soil at the edge of the knife, then put the soil sample on the sieves 9.5, 4, and 2 mm after drying it on air, sieved, and prepared to calculate the MWD and some chemical properties. MWD was calculated by taking 25 gm of sieved aggregates through 9.5 mm sieve, that stable on the 4 mm sieve, to estimate, as proposed by [16] modified by [17] described by [18], using the wet sieve through the set of 4, 2, 1, 0.5 and 0.25 mm diameters sieves.

Two primary wetting methods were used for soil samples when analyzing the MWD, the first one is fast moistening, as the sieve kit is put in water first. Then the soil samples are placed directly on the 4 mm sieve, after 5 minutes of soil immersion in water, the wet sieve device is turned on for 10 minutes, then the remaining soil is quantitatively transported on each sieve by washing with water to moisture cans to dry in the oven at 105°C. The second is slow moistening by modifying the steam hydration method described by [19] modified by [9], The soil aggregates exposed to steam by placing a 4 mm sieve, over a cylindrical water tank of 210 mm height and 180 mm in diameter, filled at a height of 140 mm, and the sieve was covered with a lid, with the same diameter as the sieve, with a 5cm diameter in the middle to insert soil aggregates through it and as shown in figure 1, the tank was placed on a high-temperature gas stove for 20 to 30 minutes, this bite of time is sufficient to bring the moisture of soil aggregates to the limits of field capacity, and the reservoir is refilled when the water reaches a height of 70 mm, to reach the required limit [9], the sieve is then lifted from the cylinder, placed at the top of the sieve set in the wet sieve and the device is turned on for 10 minutes, while the MDW is calculated in both ways from the equation below:

\[
MWD = \sum_{i}^{6} w_i x_i \ ...............1
\]

MWD is the mean weighted diameter (mm), wi percentage weight of the remaining soil on the sieve, and xi sieving diameter rate (mm).

The hydraulic conductivity of soil aggregates (KS) was measured after estimating its particle size distribution according to [20] by taking one of the stable aggregates on a 9.5 mm sieve, between 4-9.5 mm, as well as the aggregates of 2-4 mm diameter. The length and width of these aggregates are measured, then immersed in paraffin wax, and encapsulated in silicon into a regular capsule shape.
Then the two sides end with a funnel connected to 2 tubes one to move the water from the top and the other to get out of the water with a constant water column of 150 cm and a constant 60-minute time, while the method of collecting flowing water was modified by weighing a quantity of dry cotton and then stuffing it at the end of the water exit tube and the difference between the two weights represents the volume of water flowing. While the hydraulic conductivity \( K_s \) is calculated by the equation below according to [20]:

\[
K_s = \frac{4\nu L}{\Delta H \pi d^2}
\]

\( K_s \) is the hydraulic conductivity; \( \nu \) is the volume water flux through soil aggregates (cm\(^3\). Sec\(^{-1}\)), \( L \) is cylinder length (cm), \( \Delta H \) is the hydraulic head (50 cm), \( d \) aggregate diameter (cm). Soil separates calculated according to [21], while the electrical conductivity of the soil, and some chemical soil analyses of the soil coming down from a 2 mm sieve, was estimated using the EC-Meter, the degree of soil interaction (pH) was estimated using pH-meter and according to the method mentioned in [22], and gypsum was estimated using deposition by acetone, Table 1 shows some physical and chemical values.

| Separates of soil | Class of texture | Electrical conductivity dS.m\(^{-1}\) | pH | Gypsum lime | O.M. in soil aggregates >9.5mm | O.M. in soil aggregates 4-9.5mm |
|------------------|------------------|--------------------------------------|----|-------------|-------------------------------|-----------------------------|
| silt             | clay             | sand                                 |    |             | gm.kg\(^{-1}\)                | gm.kg\(^{-1}\)              |
| 478              | 376              | 146                                  | 8.1| 7.66        | 2.2                           | 252                         |
|                  |                  | silty clay loam                      |    |             | 11.239                       | 8.74                         |

Control treatment samples were treated by sawdust extract, with a precise electronic microscope (PEM). The working principle of this device is to survey the surface of the soil sample exposed to the test, in addition to the ability to give a full analysis of the desired elements under the focus of the examination of the PEM device. The data were statistically determined by the method of designing factorial experiments, the first factor represents the wetting-drying cycles and the second is the levels of Sawdust extract with three replications. The data were compared according to significant differences between means by the L.S.D. test using GenStat program in statistical analysis. On the other side, the best regression model was used in the significance of organic matter (OM) to show the effectiveness of OM in a physical trait or otherwise. The data were also analyzed by the analysis of the tablet data which designed for banking works, to adapt the data to the requirements of the analysis, the cycle time was expressed in hours. On condition that one replicate per cycle is one hour less than the other, the other is one hour higher than the third one.

3. Results and Discussion

3.1. Effect of WSE on MWD of soil

3.1.1. At fast wetting MWD

It is noted from Table 2, that the WDC has a significant effect on the MWD when using immersion wetting, it increased by 33% in the second cycle compared to the first one, and the rest of the cycles were not affected significantly compared to the same cycle. While the MWDf in the fourth, sixth, seventh, and final cycle decreased significantly compared to the second round by 29, 17, 16, and 26% respectively, while there was no significant impact between the third and the ninth cycles, except for the significant increase between the 9th and 4th WDCs by 23%. This may be due to increased fulvic and humic acids, which increases the expansion of soil aggregates as well as the effect of WDCs. Table 2 shows that the addition of SWE has a significant effect on the MWDf, at levels 5, 10 and 15% increased with the equivalent of organic matter, with an increase of 21, 27.12, and 23.9% compared to
the zero addition of the extract. In terms of the interaction between the WDC with the WSE levels, for the first WDC, it should be noted that there is no significant difference between the add-on level of 5 and 15% of the organic equivalent, as opposed to the non-addition, the level of 10% of the equivalent, increased in the MWDf significantly at fast moistening, with an increase of 52%.

The effect was not significant between WSE levels 5 and 10% also between levels 10 and 15%, as well as between 5 and 15%, on the other hand, the interference in the second WDC was significant to the levels of addition 5, 10 and 15% of WSE compared to non-addition with rates of 62, 123 and 173% respectively. The level of 10 and 15% was also distinguished from the level of 5% significantly with an increase of 38 and 69%. The effect was not significant between 10 and 15% WSE levels. Interaction has an insignificant effect within the single cycle, the third cycle and up to the ninth cycle of WDC levels as compared to control, or between the addition levels themselves.

This increase is due to the presence of the hemic acid, which works to form humic-clay complexes, which in turn bind clay particles to other soil components. Besides, some organic compounds are hydrophobic which reducing the velocity of water entering soil aggregates, allowing air to gradually exit, which saves the soil from crashing [23]; [24]. On the other hand, the absence of significant difference between 10% and 15% levels of organic matter equivalent, or between the level 5% and the 15% levels of organic equivalent at other time, which may be since the new growths of biomass and hyphae are not enough to bind the primary soil particles, [24], as well as [25] indicated that several grams of fine roots or decaying soft organic residues would contain low levels effective of organic matter for microbiology, as it contained a lot of water.

Table 2, at the same time, shows that the best correlation and prediction of the MWDf at fast wetting, was in the second WDC when comparing the R2 coefficient of the equation, followed by the 3rd WDC, but the third cycle was more reliable compared to the rest of the cycles, and the extract of organic matter affects significantly the physical properties of the soil, as their effect was evident on the MWDf at the fast wetting of the second and third WDC, with R2 value of 95.14% and 40.85% respectively, while the least value at 5th WDC cycle which was 6%.

3.1.2. MWD at slow wetting MWDs
Table 3 showed that WDC significantly affected the MWDs with values graduated from 27% to 136%, starting from 2nd to 9th WDC respectively. Compared to the first cycle, the MWDs also gradually
increased by between 37% and 86% from the third cycle to the ninth cycle, respectively. Compared to the second cycle, a significant increase is observed in the MWDs values of between 27 and 72% from the fourth cycle to the ninth cycle, respectively, compared to the fourth cycle, while the ninth cycle had a significant effect on the MWDs with an increase of 21, 19 and 10% compared to the fifth, sixth and seventh cycles, orderly, this rise in MWDs values may be caused by the homogeneity of steam wetting, as water vapor will condense simultaneously on soil aggregates [9]. In general, slow wetting allows the soil air trapped between the pores to gradually exit.

It is clear from Table 3 that ratios of SWE have increased significantly the MWDs, with a ratio of 22 and 21% of the equivalent addition ratios of 10 and 15% compared to the zero-addition of SWE, there is also a significant difference of 27 and 26% for the addition ratios 10 and 15% compared to the level of 5%, while there was no significant difference between the addition ratios 10 and 15%. It was noted that there was no significant effect between the add-on levels 5 and 10%, this was the same in the ninth cycle, as the MWDs at steam wetting increased by 30 and 29% for the additional level of 10 and 15% compared to control treatment, while it was 38 and 57% for the same add-on level compared to the added level of 5%, there were no significant differences between 10 and 15%, this may be due to increased biomass of micro-organisms, which have become larger due to incubation periods, and thus increase of cementing compounds due to microbial activity. On the other hand, in slow wetting, only very weak soil aggregates will be affected, as opposed to fast wetting, as very strong and weak soil aggregates will be affected.

At the same time, on the other hand, the best mathematical model in the sixth cycle in addition to the 6th, 7th, 8th, and 9th WDC, with determination coefficients of 65.54, 42.58, 52.34, and 56.79% successively. While the results were reliable at the probability level of 5% in the seventh cycle, and the probability level of 1% in the last two cycles, there is some difference in the results when tested by the LSD method, and between the analysis of the best regression model related to organic matter, as observed in the seventh cycle, there is no significant difference while the predictive relationship indicates that it was significant at 5% at R2 factor of 42.58%.

Table 3. The effect of SWE and WDC on MWD by slow wetting and their statistical relationship

| WDC | 0% | 5% | 10% | 15% | Average WDS  |
|-----|----|----|-----|-----|-------------|
| 1   | 1.09 | 1.29 | 1.77 | 1.47 | 1.404       |
| 2   | 1.64 | 1.62 | 2.09 | 1.81 | 1.788       |
| 3   | 2.09 | 1.69 | 2.1  | 1.86 | 1.933       |
| 4   | 2.19 | 2.29 | 2.82 | 2.52 | 2.454       |
| 5   | 2.54 | 2.55 | 2.82 | 3.07 | 2.748       |
| 6   | 2.47 | 2.62 | 2.89 | 3.14 | 2.782       |
| 7   | 2.89 | 2.74 | 3.18 | 3.23 | 3.010       |
| 8   | 2.58 | 2.02 | 3.47 | 3.73 | 2.950       |
| 9   | 2.92 | 2.75 | 3.81 | 3.8  | 3.320       |
| Average WSE | 2.736 | 2.770 | 2.176 | 2.269 |
| LSD (p≤5%) | 2.736 | 0.04458 | WDC =0.3111 | Interaction = 0.6222 |

| WDC | Equation | R2  | p-value  |
|-----|----------|-----|----------|
| 1   | MWD1 = 1.000 + 0.162 WSE | 0.1139 | 0.270   |
| 2   | MWD2 = 1.543 + 0.098 WSE | 0.0982 | 0.321   |
| 3   | MWD3 = 2.005 + 0.029 WSE | 0.0075 | 0.788   |
| 4   | MWD4 = 2.077 + 0.151 WSE | 0.1389 | 0.240   |
| 5   | MWD5 = 2.285 + 0.185 WSE | 0.3259 | 0.053   |
| 6   | MWD6 = 2.223 + 0.223 WSE | 0.6554 | 0.001** |
| 7   | MWD7 = 2.643 + 0.1467 WSE | 0.4258 | 0.021*  |
| 8   | MWD8 = 1.725 + 0.490 WSE | 0.5237 | 0.008** |
| 9   | MWD9 = 2.393 + 0.371 WSE | 0.5679 | 0.005** |
Concerning the effect of WSE when comparing slow with fast wetting, it is noted that this effect in the first three cycles is higher than the next following cycles, on the contrary, when slow wetting, WSE has a significant effect in the last four cycles. Due to the type of resulting compounds, from the interaction of WSE with soil residues and materials, as well as activity, age, and type of microbes which secreted various compounds with time, and with the nutrients needed for the growth of these microorganisms, or maybe because of components type with the power needed for decomposition. As the fast wetting has a higher powerful destruction force than slow moistening, which requires more powerful cementing agents but Logically, the resulting compounds at the beginning of the addition will be stronger, with larger and more complex carbon chains.

3.2. Effect of SWE on KS
Table 4 shows the effect of WDC on KS of aggregates greater than 9.5 mm, and notes that the WDC have a significant effect in this trait, increasing by 13, 8, 13, 19, 18 and 17% for 2nd, 4th, 6th, vx7m not significant at third and fifth WDC compared to the first cycle, the KS within this range has also increased morally by 6 and 7% for the 8th and 9th WDCs, respectively, as compared to second WDC. KS also increased by 8, 14, 16 and 16%, for the last five cycles orderly compared to the third cycle, as well as 9, 10 and 11%, KS for the seventh, eighth and ninth cycles respectively compared to the fourth cycle, and for the same cycles and by 6 and 87%, respectively compared to The fifth round, in the seventh and eighth WDCs, the increase was significant and by 6 and 7% respectively compared to the sixth cycle. Concerning the addition ratios, it is noted that they did not have a significant effect except for the 5% equivalent level by 3% compared to the zero-addition, whereas it was 21% at the equivalent level of 15% compared to the additional rate of 10%. Concerning interaction, it is observed in the 1st WDC from the same figure that KS has increased significantly by 29% for the 5% equivalent addition level, compared to the non-addition, at the same time, it decreased significantly at the equivalent level of 10%, by 26%. On the other hand, the KS decreased significantly at the equivalent addition level of 10 and 15% with 43 and 28%, respectively, compared to the level of 5%. While the KS increased by 26%, at the equivalent level of 15% compared to the application level of 10%

Table 4 shows that KS decreased significantly at the 10 and 15% levels by 32% compared to control treatment (non-addition), as well as decreased by 32 and 29% for the same levels, compared to the additional level of 5%. Inversely, the KS of soil increased at the level of equivalent addition 15%, compared to the level of addition 10%, and by 14%, in the second WDC, while the third cycle exhibited similar behaviour to the second cycle, as it decreased at the level of addition 10 and 15%, with a decrease of 30 and 14%, compared to the zero addition. At the same time, the KS decreased by 23%, at the equivalent level 10%, compared to the level of 5% addition equivalent, while it increased in the equivalent 15% at a rate of 22%. It is also observed that there is a negative effect of the WSE on the KS on 9.5 mm diameter aggregates, at the probability level of 5%, for the 2nd, 3rd, and 4th WDCs with a determination factor (R2) of 49.63, 38.76 and 34.39%, respectively, and with a high degree of confidence, while the eighth WDC was of 76.51% R2 at 0.1% probability level and with a very high degree of confidence.

Table 5 shows the effect of WDC on the KS of soil aggregates of 9.5 - 4 mm in diameter, as they increased significantly at the second and ninth WDC by rates of 6.9, 14.8, 21.3, 18, 24.7, 25.4, 27.3, and 23.4% in comparison with the first one, the KS also increased within this range of aggregate diameters, with rates of 7.3, 13.4, 10.3, 16.7, 17.2, 18.9 and 15.3% for the last seven WDCs respectively, compared to the 2nd cycle. It was also observed that there is a significant increase for the fourth, sixth, seventh, eighth, and ninth WDCs, with increasing rates of 5.7, 8.7, 9.3, 10.9, and 7.5%, successively in comparison with the third cycle. While there was a significant increase, by 3. 4 and 4.9% for the seventh and eighth WDC, compared to the fourth cycle, while the increase in KS was significant, at the sixth, seventh and eighth cycle by 5.7, 6.3 and 7.8%, Compared to the fifth cycle, and the last three WDCs did not have any significant effect on the KS at aggregates 9.5- 4 mm.
Table 6. also shows a clear positive effect of WSE on the KS within 9.5 – 4 mm aggregates in probability level of 0.1%, for the first eight cycles with R2 values of 91.79, 93.10, 88.87, 87.56, 88.33, 83.73, 89.54, and 78.18% respectively with very high confidence degree, while the determination coefficient was 53.76% for the ninth WDC in 1% probability level.

From Table 6, there is no effect of the nine WDCs and the level of SWE addition, as well as the interaction between them on the KS within the 4-2 mm soil aggregations. On the other hand, when analyzing using the predicted significance of WSE, Table 6 indicates a positive effect of WSE at the first, second and last WDC with a determination factor (R2) of 20.06, 12.99, and 11.31% respectively.

3.3. The effect of physical soil properties on each other under the influence of WDC and the addition of SWE

Table 7 stated the regression equations according to the analysis of the panel data models, which were conducted in two ways, the first was an analysis of the data of the small squares, and the other was an analysis of the effect of the random cross-sector RCS, in this method of statistical analysis, all variables are entered, and at procession analysis, the program will exclude the variables that make no difference in results, i.e. they do not affect the dependent

Variable, whereas the independent variables that formed the equation are the most important, according to the statistical tests accompanying the analysis. It is clear from the table above and in equation 1 that the SRC of soil aggregates greater than 9.5 mm does not affect significantly, any physical properties of soil under study.

The statistical analysis, as in the same table and equation 4, shows that the KS of soil aggregates of 9.5-4 mm diameter, increases the MWD at slow wetting significantly at a probability level of 1%, these results are consistent with [26], while reducing KS of soil aggregates greater than 9.5 mm, significantly at a 5% probability level of MWD at fast wetting of the aggregates, as the increase of one unit of KS in these aggregates will reduce the MWD by 114.6 times.

| Table 4. Effect of SWE, WDCs on the KS of greater than 9.5 mm aggregates and their statistical relationship |
|---|---|---|---|---|---|
| WDC | WSE | 0% | 5% | 10% | Average |
|---|---|---|---|---|---|
| 1 | 0.0695 | 0.00899 | 0.00516 | 0.0065 | 0.0069 |
| 2 | 0.0089 | 0.00962 | 0.00602 | 0.00686 | 0.0078 |
| 3 | 0.00826 | 0.00754 | 0.00582 | 0.00711 | 0.0072 |
| 4 | 0.00793 | 0.00875 | 0.00644 | 0.0068 | 0.0075 |
| 5 | 0.00699 | 0.00867 | 0.00535 | 0.00774 | 0.0072 |
| 6 | 0.00951 | 0.00742 | 0.00614 | 0.00815 | 0.0078 |
| 7 | 0.0082 | 0.00923 | 0.00713 | 0.00842 | 0.0082 |
| 8 | 0.00953 | 0.00906 | 0.00714 | 0.00744 | 0.0083 |
| 9 | 0.00913 | 0.00875 | 0.00673 | 0.00859 | 0.0084 |
|平均| WSE = 0.008377 | 0.00867 | 0.006214 | 0.007523 | 0.008217 |
| LSD (p≤5%)| WDC = 0.000027 | WDC = 0.000041 | Interaction = 0.0008217 |
| R2 | p-value |
|---|---|
| 1 | Ks > 9.5 = 0.00819 - 0.000517 WSE | 0.1664 | 0.188 |
| 2 | Ks > 9.5 = 0.010270 - 0.000097 WSE | 0.4963 | 0.011* |
| 3 | Ks > 9.5 = 0.008475 - 0.000517 WSE | 0.3876 | 0.031* |
| 4 | Ks > 9.5 = 0.008998 - 0.000568 WSE | 0.3439 | 0.045* |
| 5 | Ks > 9.5 = 0.007452 - 0.000106 WSE | 0.0086 | 0.775 |
| 6 | Ks > 9.5 = 0.009143 - 0.000535 WSE | 0.2211 | 0.123 |
| 7 | Ks > 9.5 = 0.008605 - 0.000144 WSE | 0.0324 | 0.576 |
| 8 | Ks > 9.5 = 0.010345 - 0.000821 WSE | 0.7651 | 0.000** |
| 9 | Ks > 9.5 = 0.009160 - 0.000334 WSE | 0.1325 | 0.245 |
Table 5. Effect of SWE and WDC on KS of 9.5 – 4 mm soil aggregates and their statistical relationship

| WSE WDC | 0%       | 5%       | 10%      | 15%      | Average WDC |
|---------|----------|----------|----------|----------|-------------|
| 1       | 3.16*10^-4 | 3.73*10^-4 | 5.71*10^-4 | 6.92*10^-4 | 4.88*10^-4 |
| 2       | 3.57*10^-4 | 4.11*10^-4 | 6.08*10^-4 | 7.13*10^-4 | 5.22*10^-4 |
| 3       | 4.12*10^-4 | 4.64*10^-4 | 5.73*10^-4 | 7.93*10^-4 | 5.61*10^-4 |
| 4       | 4.62*10^-4 | 5.09*10^-4 | 6.01*10^-4 | 7.87*10^-4 | 5.92*10^-4 |
| 5       | 4.06*10^-4 | 4.87*10^-4 | 5.78*10^-4 | 8.34*10^-4 | 5.76*10^-4 |
| 6       | 5.03*10^-4 | 5.18*10^-4 | 6.11*10^-4 | 8.04*10^-4 | 6.08*10^-4 |
| 7       | 4.77*10^-4 | 5.46*10^-4 | 6.12*10^-4 | 8.15*10^-4 | 6.12*10^-4 |
| 8       | 5.22*10^-4 | 5.11*10^-4 | 6.25*10^-4 | 8.28*10^-4 | 6.21*10^-4 |
| 9       | 5.58*10^-4 | 5.4*10^-4  | 5.69*10^-4 | 7.39*10^-4 | 6.02*10^-4 |
| Average WSE | 4.469*10^-4 | 4.844*10^-4 | 5.947*10^-4 | 7.784*10^-4 |
| LSD (p<0.05) | WSE =18*10^-4 | WDC =28*10^-4 | Interaction = 55.45*10^-6 |

| Equation | R²     | p-value |
|----------|--------|---------|
| Ks=-0.000095 + 0.000014 WSE | 0.9179 | 0.000** |
| Ks=-0.000009 + 0.000017 WSE | 0.9310 | 0.000** |
| Ks=-0.000035 + 0.000012 WSE | 0.8877 | 0.000** |
| Ks=0.000035 + 0.000014 WSE | 0.8657 | 0.000** |
| Ks=0.000035 + 0.000013 WSE | 0.8833 | 0.000** |
| Ks=0.000035 + 0.000012 WSE | 0.8373 | 0.000** |
| Ks=0.000034 + 0.000010 WSE | 0.8954 | 0.000** |
| Ks=0.000036 + 0.000010 WSE | 0.7818 | 0.000** |
| Ks=-0.000045 + 0.000057 WSE | 0.5376 | 0.007** |

Table 6. Effect of SWE and WDC on KS of 4 – 2 mm soil aggregates and their statistical relationship

| WSE WDC | 0%       | 5%       | 10%      | 15%      | Average WDC |
|---------|----------|----------|----------|----------|-------------|
| 1       | 1.16*10^-7 | 2.28*10^-7 | 2.58*10^-7 | 1.82*10^-7 | 1.96*10^-7 |
| 2       | 1.14*10^-7 | 2.85*10^-7 | 3.24*10^-7 | 1.92*10^-7 | 2.29*10^-7 |
| 3       | 1.89*10^-7 | 2.06*10^-7 | 3.49*10^-7 | 2.08*10^-7 | 8.51*10^-7 |
| 4       | 1.79*10^-7 | 3.34*10^-7 | 3.99*10^-7 | 2.23*10^-7 | 2.83*10^-7 |
| 5       | 2.07*10^-7 | 3.76*10^-7 | 4.26*10^-7 | 2.44*10^-7 | 3.13*10^-7 |
| 6       | 2.18*10^-7 | 3.75*10^-7 | 3.79*10^-7 | 2.24*10^-7 | 2.99*10^-7 |
| 7       | 2.52*10^-7 | 4.16*10^-7 | 4.11*10^-7 | 2.84*10^-7 | 3.41*10^-7 |
| 8       | 2.59*10^-7 | 3.97*10^-7 | 4.14*10^-7 | 2.92*10^-7 | 3.41*10^-7 |
| 9       | 2.63*10^-7 | 3.93*10^-7 | 3.99*10^-7 | 3.19*10^-7 | 3.44*10^-7 |
| Average WSE | 1.994*10^-7 | 4.01*10^-7 | 3.73*10^-7 | 2.41*10^-7 |
| LSD (p=0.05) | WSE=52*10^-8 | WDC =77*10^-8 | Interaction = 1.5517*10^-4 |

| Equation | R²     | p-value |
|----------|--------|---------|
| Ks2-4 = 0.000016 + 0.000001 WSE | 0.2006 | 0.144 |
| Ks2-4 = 0.000016 + 0.000002 WSE | 0.1299 | 0.250 |
| Ks2-4 = 0.000016 + 0.000003 WSE | 0.0180 | 0.677 |
| Ks2-4 = 0.000002 + 0.000000 WSE | 0.0664 | 0.419 |
| Ks2-4 = 0.000003 + 0.000000 WSE | 0.0392 | 0.537 |
| Ks2-4 = 0.000000 + 0.000000 WSE | 0.0009 | 0.928 |
| Ks2-4 = 0.000000 + 0.000000 WSE | 0.0193 | 0.667 |
| Ks2-4 = 0.000000 + 0.000000 WSE | 0.0370 | 0.549 |
| Ks2-4 = 0.000000 + 0.000000 WSE | 0.1131 | 0.285 |
Table 7. The effect of physical soil properties on each other under the influence of WDC and the addition of SWE

| NO. | Bj | MWDf | MWDs | Adj. R² | R² | t | prob. | t | prob. | t | prob. | t | prob. |
|-----|----|------|------|---------|-----|----|-------|----|-------|----|-------|----|-------|
| 1   | 2.82173 | 209.145 Ks (4-2 mm) | 936.001 Ks (9.5-4 mm) | 114.6341 Ks (<9.5 mm) | 7.42% | t | 6.60615*** | -0.3961 | 2.6606** | -2.8756** | Adj. R² | 6.45% | prob. | 0.0001 | 0.6931 | 0.0001 | 0.0005 |
| 2   | 0.39232 | Ks (4-2 mm) | 162.0123 Ks (9.5-4 mm) | 97.0115 Ks (<9.5 mm) | 7.86% | t | 4.7356 | 0.9183 | 2.2223* | -1.23218 | Adj. R² | 5.17% | prob. | 0.0001 | 0.3606 | 0.0284 | 0.2246 |
| 3   | 0.4944 | 474.393 Ks (4-2 mm) | 2482.35 Ks (9.5-4 mm) | 73.04 Ks (<9.5 mm) | 21.15% | t | -0.7645 | 5.7403*** | 1.55086 | 0.1240 | 1.55086 | Adj. R² | 18.80% | prob. | 0.4463 | 0.0001 | 0.124 | 0.0001 | 5.7403*** |
| 4   | 0.4624 | 1014.41 Ks (4-2 mm) | 141.83 Ks (9.5-4 mm) | 173.099 Ks (<9.5 mm) | 3.44% | t | 0.8638 | 1.8131** | -1.9527* | 0.0545 | -1.9527* | Adj. R² | 9.63% | prob. | 0.3904 | 0.0737 | 0.0545 | 0.0737 | 1.8131** |

which differed from that obtained by [26], it is known and obvious that the MWD affects the KS, but studies.

Have not indicated that KS can affect the MWD. Despite this, it makes sense, increasing the KS of soil aggregates larger than 9.5 mm will increase the air pressure inside soil pores, due to increased tortuosity of soil pores resulting from the size of larger aggregates, which leads to a crash, while an increase in KS in aggregates of 9.5-4 mm diameter by one unit will be corresponded by an increase in MWD at slow wetting by 936 times.

It is also noted that the MWD at fast wetting has been positively affected by the conductivity of soil aggregates of 9.5-4 mm diameter, increasing the KS of this volumetric range by one unit, will increase the MDW by 162 times at the probability level of 3%, while the KS did not affect significantly, at this range, in the MWD when wetting by water immersion, the rest of the soil properties under study was excluded from the analysis, and perhaps the volume of the soil in this range of sieves has made the torsion better arranged for its porous channels and this can be observed in figure 4, especially in the 1st and 5th WDCs, that is in picture P2D1, P3D1, P2D5 and P3D5 thus the soil will be connected to water more smoothly and with the least possible pressure of the gas trapped between its pores, thus maintaining the stability of the soil aggregates.

The analysis of the tablet data using the way of random cross-section effect confirmed the very high confidence degree of the significant positive effect of KS for 9.5 – 4 mm diameter aggregates on the steam wetted MWD. Increasing one unit of KS gives an increase in the MWD at slow wetting of 2,482 units, whereas the negative effect of KS on 4-2 mm aggregates and larger than 9.5 was significant in the KS itself. Regarding the fast wetting of soil aggregates, the KS in equation 4 followed the same trend in equation 2, while the analysis excluded the remaining physical soil properties from the regression equation. This is in line with what can be observed from Figure 3, and 4 of the soil aggregates taken under the scanner electronic microscope. The above leads to the conclusion that increasing soil aggregates to 9.5-4 mm diameter is of great importance in maintaining the stability of soil aggregates, as the KS for this range has a positive impact.

3.4. SEM tested samples

Figures 2 and 3 show images of soil samples, examined under a scanning electron microscope (SEM), with a 10-micron section resolution, showing clear differences and on this basis the images were interpreted, as it is found that the soil aggregates in which SWE was added to, was the more granule, as the more concentration of the extract was added, in a form of aggregates. While non-treated with SWE samples appeared, surfaces close to smooth with sharp edges, and the size of the soil aggregates treated with sawdust extract SWE was larger than untreated soil aggregates.

The P1D1 image in figure 3, which represents the control treatment (i.e. without SWE addition) for the first cycle, shows the presence of scattered and larger aggregates, of sharp edges with more voids between aggregates, while P2D1, which represents the addition of SWE equivalent to 5% of WSE, for the same cycle, in which aggregates of sharp edges are observed, but less than the control treatment while the voids were larger, and in the P3D1 image, which represents the addition of SWE equivalent to 10% of WSE, was more obvious, as there was more granulation than the previous two images, for the same cycle, with fewer voids between aggregates, while the P4D1 image, which represents the equivalent of 15% of WSE, shows more granulation and a larger size than the 10% level.
The P1D5 in Figure 2, which represents the control treatment of the fifth WDC, shows the presence of large blocks with sharp edges, with many and distributed pores, while P2D5, which represents the addition of SWE to 5% of WSE, as the granules are blurred, which was scattered, with very few pores as well as the presence of small clear aggregates, this is disagreed with findings of [10], for the same (third) WDC, where the granules were less observed at the beginning of transitional granulation, with fewer pores, with groups of fungi and bacteria in white color, in the image of fungi and bacteria, which are white, formed as a result of the growth and development of organisms over time, as well as the period in which the sample was exposed to an incubation period of 50 days.

Figure 2. images under the SEM of the first WDC, for soil samples P1D1 control treatment, P2D1 add SWE equivalent to 5%, P3D1 add SWE equivalent to 10% WSE, and P4D1 add SWE equivalent to 15% of WSE

Figure 3. images under the SEM of the fifth WDC, for soil samples P1D5 control treatment, P2D5 add SWE equivalent to 5%, P3D5 add SWE equivalent to 10% WSE, and P4D5 add SWE equivalent to 15% of WSE

Many studies, including those found by [27], have shown that many types of fungi are directly related to the construction of internal soil aggregates, and between the particles of coarse & soft sand and coarse silt. In the same figure and in the P3D5 image, which represents the addition equivalent to 10% of WSE, it shows small aggregates, associated with large blocks with smooth edges, while the P4D5 image, which represents the addition equivalent to 15% of WSE, has a clear block structure of smooth edges, the granules were small and multiple sizes.
4. Conclusion

The addition of the sawdust extract with the equivalent of 5% and 10% of the organic matter was the best addition level 15%. The organic matter extract reduces the negative role of drying and moisturizing cycles. The measure saturated water conductivity is measured according to the distribution of volumetric soil aggregates, which affects the values of the weighted diameter. The soil aggregates with the sawdust extract have been shown in the electronic survey more granular, larger, closer to smooth, and more interconnected in clusters than the samples that have not been added.

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