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ORIGINAL ARTICLE

EFFECT OF ADDITION OF NANO SAWDUST TO SOIL ON STABILITY AND SUSTAINABILITY OF SOIL AGGREGATES

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Abstract: A laboratory experiment was conducted in the laboratories of the College of Agriculture, University of Anbar, to study the effect of wetting and drying cycles (DW) and sawdust extract. Soil samples were taken from one of the fields of the College of Agriculture and were distributed in size greater than 9.5, 4, 2, 1, 0.5, 0.25 and less than 0.25. mm, containers with a diameter and height of 100 mm were filled with 800g of soil with the same size distribution as the main soil sample. Injecting sawdust extract equivalent (SDE) to 5% of the organic matter in the soil with three types of addition. Then the containers were exposed to 5 DW and incubation at a temperature of 22°C. MWD, ρb, f and some other characteristics were estimated. The results showed that nano-crushed (NCSDE) increased MWD upon rapid wetting significantly compared to the extract as a solution (SSSDE) and without application (WOSDE) in DW_1, MWD values started low when SSDE was added and then increased significantly by 179, 180.5 and 146.3% from DW_3 to DW_5, respectively. As for slow wetting, the effect of SSDE supplementation was higher than that of NCSDE and WOSDE supplementation. And at all DW cycles, it was noted from the SEM images and in the DW_1 cycle that the WOESDE type of addition shows sharp-angled soil aggregates and small aggregates appear cumulatively. In DW_3 and when WOSDE is added in a spherical shape but at acute angles, clusters of acute lamellar shape accumulate on top of it, while NCSDE shows its large spherical aggregates with smooth edges and the aggregates of the SSDE type appear lamellar with large and small aggregates with sharp edges, in DW_5 the soil aggregates of the WOESD type appear spherical and of large size, while the addition of NCSDE shows their aggregates in not large sizes. And the addition of SSDE shows its clusters in relatively large sizes, often spherical, with lumpy clusters and smooth edges.

***Key words*: Sawdust extract, Aggregate, Sustainable, MWD, SLV, bulk density.**

Cite this article

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1. Introduction

The Iraqi soils are weakly constructed soils and many physical soil problems are affected by soil structure. Soil aggregation is a complex process, due to the interaction of many factors, bio and abiotic, as well as processes that affect soil properties, such as mineral composition, soil texture, microorganism's activities and environment and management factors as tillage [Bronick and Lal (2005)].

The soil structure reflected the agricultural system that is used in general [Mahmood *et al.* (2020)]. Kalhoro *et al.* (2017) explained when they study soil loss and lands of different use, the formation of soil aggregates and their stability has a high correlation coefficient and is positively related to the organic carbon content of the soil and the biomass of the roots of different plants and that the small aggregates formed larger soil aggregates by linking them with organic matter. Rahman *et al.* (2018) clarified that the decomposition and re-mineralization of carbon by microorganisms bind the soil aggregations during the incubation period and that the cycles of hydration and drying raise the soil aggregation through physical processes such as shrinkage, expansion and biological processes. The DW cycles modify the hydraulic transmission and thus increase the hardness and stability of the aggregates due to the expansion and contraction

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in the soil size and the reorganization of the soil particles and voids. DW cycles increased MWD but decreased biomass carbon proportionately [Ebreesum and Abbas (2020)].

Nano-fertilizers, due to its high surface area to volume ratio are more effective than most of the latest polymeric-type conventional fertilizers [Abed and Sallume (2020), AL-Juthery *et al*. (2020)]. They could also allow the slow release. This technology, therefore, offers excellent platform for sustainable and novel nutrient delivery systems that penetrate the nanoporous surfaces of plants encapsulated nanoparticles [AL-Juthery *et al*. (2018)], nanoclays and zeolites, increased efficiency in terms, restoration of soil fertility and plant health and reduction of environmental pollution and agroecology degradation [Ali *et al.* (2021), Redeef *et al*. (2021)].

Kabir *et al.* (2017) expounded that the change in the stability of soil aggregates is similar to the change in the organic matter in the soil for both layers' soil studied according to the difference in land use according to the order, pasture lands with good conditions > pastures with bad conditions > abandoned land > dry agricultural lands and index MWD of pasture soils with good conditions was significantly higher than the rest of the land uses. Hu *et al*. (2018) found that when studying different crushing forces, they are fast initial wetting, slow initial wetting, aggregation shaking before initial wetting DW cycles, DW cycles have a significant effect on the stability of soil aggregation as positive and other negative effects, as soil aggregation becomes more susceptible to fracture with increasing clusters size, upon rapid wetting, the MWD of the studied aggregation increased by more than 5% in the first two DW cycles and then decreased by more than 15% after 15 cycles of wetting and drying. However, when wetting slow and mechanical shaking before wetting had a negative effect only, the MWD decreased at slow wetting. The shaking was significant with more than 53 and 69%, respectively.

Xu *et al*. (2017) found that MWD decreased logarithmically with increasing DW cycles and that MWD decreased by about 50% in the first cycle, but after 10 DW cycles only 6:1 of the initial value was left. Nascente *et al.* (2015) concluded that the type of vegetation cover is of great importance in bulk density and that the lowest densities were found in the no-till farming system and that the type of vegetation cover has an effect and a positive correlation was found between the stability of soil aggregate index and the total organic carbon in soil and a negative correlation between the total soil organic carbon and bulk density of the first ten centimeters fromthe soil surface. Tuo *et al.* (2017) reported that organic matter, in turn, helps the growth of some fungal hyphae, which leads to the expansion of soil particles as a result of the pressure of the developing hyphae and thus an increase in the ratio of voids. There was a slight effect of NPK and FYM fertilizers on the soil bulk density and total porosity and the bulk density of the soil slightly increased with the depth of the soil, but the total porosity tended to the opposite. Knowledge of the influence of roots on soil properties remains debatable and limited [Erktan *et al.* (2016), Ali *et al.* (2017)]. Al-Mohammadi and Al-Nuaymy (2021) showed that a significant increase was noticed in MWD of soil with fast wetting, where it raised for 5, 10 and 15% wooden sawdust extract levels. The interaction was significant in the second DW cycle for the same wooden sawdust extract levels in comparison with zero applied treatment where they were 123.62 and 173% ,respectively, soil samples tested with an electron scanning microscope, the samples to which wooden sawdust extract was applied became granular and aggregated surfaces, while the untreated samples were smooth, with no granular surfaces and sharp edges.

Al-Nuaymy and Al-Alusi (2016) attributed the determination of the sustainability class in the last two types of soil aggregate sustainability in most of the cases to the fact that the shattering forces were at the highest under wetting by immersion, while only weak binding forces were affected when humidification with steam, which made the sustainability classes of soil aggregate at higher levels with this method of wetting. Also, a significant decrease in bulk density when injecting the soil with sawdust extract, for the two fractionation treatments and the complete added quantity significantly compared without injection, as a decrease of 3.05% and 8.29%, respectively [Al-Nuaymy and Al-Alusi (2020)].

2. Materials and Methods

Sawdust extract collected from one of the woodworking factories (1:400C:N) was prepared. Grind 50 kg of sawdust with a high-speed mill to increase its fineness to reduce its decomposition time. sawdust was left aerobic decomposition after the sawdust was piled on top of a piece of polyethylene. Nitrogen was added to the stack at 2% of the dry weight using urea (46% N), while Triple Super Phosphate (20% P) was used as a source of phosphorous with a phosphorus percentage of 0.5% of the dry weight of the stack [Al-Hadithi (1997)]. The sawdust was mixed with fertilizers in the pile, then the mixture was wetted with water spray, while the stack was continuously stirred to homogenize its moisture. Cover the stack with polyethylene to raise its temperature is to increase the decomposition of the pile and to maintain its moisture.

Re-stirring the stack and mixing twice a week, while continuing to stir and mix, with the collected extract returned to the stack again until a change from the mother material of sawdust to a material with a loosened texture of dark color. The temperature of the stack was measured with a soil thermometer. The temperature at the beginning of the reaction was 65°C, then it decreased to 45°C. After the complete decomposition, it took 75 days for the sawdust to decompose. Then the decomposing sawdust was re-spread over the polyethylene and left for three days to air dry. The lysate was immersed in 0.1N KOH solution for 24 hours. After that, the solution is separated from the decomposing material by centrifugation by placing the soaked in a mesh bag inside a washing machine towel, then turning on the dryer and until the solution exits from the drain tube of the dryer, dry substance amount in the extract was considered by drying 100 ml of the extract and the weight of the remainder after drying in an oven at a temperature of 40°C, then the isolated extract was divided from the decomposed material into two parts, one of the two parts was dried by air and at a temperature of the room used for drying between 30-35°C. The amount of extract applied to the soil was calculated to depend on 5% of organic matter of the dry soil, then the extract solution was applied as an equivalent amount of dry matter to it in the decomposed material, which was added as a solution of sawdust extract (SSDE), while the same method of calculating of the extract was followed when applied the extract as a powder, the dried part of the extract was taken and grinding as nano-crushed laboratories in the Laboratories of the Ministry of Science and Technology in the Republic of Iraq using the QM ISp04 planetary ball mill device.

It was added in the soil to reach the field capacity, as the properties of the new solution differed from the original extract solution in terms of color and viscosity, as it had a low viscosity and a transparent golden color (nano crushed sawdust extract (NCSDE)), as well as to the control treatment (without sawdust application).Water was added to it in the quantity necessary to reach the field capacity, where water and two extract solutions were applied to the cylinder by dripping liquids from a bottle that was below the surface of the soil so that it gave drainage of 200 $ml.h^{-1}$.

A distributed soil sample was taken from one of the fields of the College of Agriculture, the quantity was spread and left to dry air, a size distribution was carried out by passing it through a set of sieves with holes 9.5, 4, 2, 1, 0.5 and 0.25 mm, then filled cylinders with a height of 100 mm and a diameter of 100 mm as well. By placing a filter paper, covered with a piece of gauze and tied with a waterproof adhesive tape at one end, then the soil was added to the cylinder after weighing 800g of soil. Then the size-distributed soil in the original sample was re-collected in the same proportions as the size distribution of the original soil sample after carefully mixing it on a piece of polyethylene.

Soil sample containers were wetted by capillary action by placing the soil cylinder on top of a column of 100 mm height of fine sand and then fixing the water column using a Maclaurin bottle and continued as shown in Fig. 1 to sufficient moisture to deliver soil moisture to the field capacity after adding a solution of sawdust extract to it, this is the first DW cycle. Then all the samples were incubated at a temperature of 22°C for 3 days, then the cylinders were taken out and placed on the ground horizontally and left to air dry for 3 days, then rehydrated to saturation for 16 hours for the rest of the cylinders, which will remain for the subsequent 5 cycles of DW. The soil vessel that will be subjected to analysis will be cut longitudinally on both sides with a knife heated to a high temperature, taking care not to touch the soil with the edge of the knife.

Soil texture was estimated according to the method proposed by Gee and Bauder (1986), while the bulk soil density was estimated by the method of encapsulating the aggregates with paraffin wax and the true soil density using the pycnometer vial as reported in Black *et al.* (1965). While the porosity was calculated from the equation below.

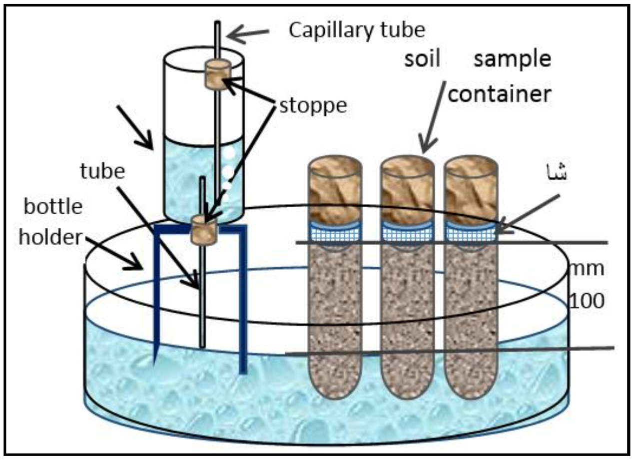

Fig. 1: Method of wetting samples to reach saturation using a Maclaurin bottle used in the DW cycles

$$f = \left(1 - \frac{\rho b}{\rho s}\right) * 100 \quad (1)$$

The electrical conductivity of the soil and some chemical soil analysis were estimated from the soil coming down from a 2 mm sieve, using an EC-Meter and the degree of soil interaction was estimated with a pH-Meter as mentioned in Richards (1954) and the lime was determined by the gravimetric method according to US Salinity Laboratory Staff (1954) and the organic matter was estimated as mentioned in Allison (1965).

Main weight diameter (MWD) was estimated by taking 25 g of sieved soil aggregates of 9.5 mm and settled on a 4 mm sieve to estimate MWD as suggested by Yoder (1936) modified by Van Bavel (1949) and described by Kemper and Chepil (1965) using a wet sieving device through the set of sieves in the order of 4, 2, 1, 0.5 and 0.25 mm. For primary per-wetting, two methods were used, namely, rapid wetting by placing the set of sieves with water first, then inserting soil samples directly onto the 4 mm sieve and after 5 minutes of immersion of the soil with water, the sieving device is turned on for 10 minutes. By washing them with water, into cans and oven-dried at 104 degrees Celsius. The second method of wetting is slow, where the soil aggregates are exposed to water vapor after the modification proposed by Al-Nuaymy and Al-Hadithi (2013) to the method proposed by Kemper and Rosenau (1986) as in Fig. 2 to suit the size and weight of the aggregates.

By placing a 4 mm sieve on top of a cylindrical water tank with a height of 210 mm and a diameter of 140 mm (Fig. 2) and covering the sieve with a lid of the same diameter as the sieve, in the middle of this lid is a hole with a diameter of 50 mm. It is refilled again to the same water level when the water reaches one-third of the height of the tank, then it is placed on a gas stove at a high temperature for 30 minutes and this is a period sufficient to deliver the soil moisture to the field capacity. Wet and run for 10 minutes. MWD is calculated in both ways using the following (Yoder 1936) equation:

$$MWD = \sum_{i=1}^{6} wi\,xi \quad (2)$$

The MWD is main weight diameter (mm), wi is the weight of the soil remaining on the sieve i and xi is the diameter of the sieve holes i.

slaking valueSLVthen the following [Ben-*et al.* Hur (2009)] equation is obtained :

$$SLV = MWD_{slow} / MWD_{fast} \quad (3)$$

3. Results and Discussion

3.1 MWD at fast initial wetting

Table 2 shows the effect of the type of sawdust extract applied to the soil under the influence of DW cycles. It is noted that the application of sawdust extract had a significant effect on MWD, as NCSDE increased by 34% by 34%. The addition, while the effect of NCSDE was higher than that of SSDE and significantly in MWD with an increase of 24.5%, the reason for the increase in the weighted drop rate after adding the sawdust extract is due to the fulvic and humic acids caused by the decomposition of sawdust [Bidegain *et al.* (2000)] which work to increase the expansion of soil agglomerations [Al-Mohammadi and Al-Nuaymy

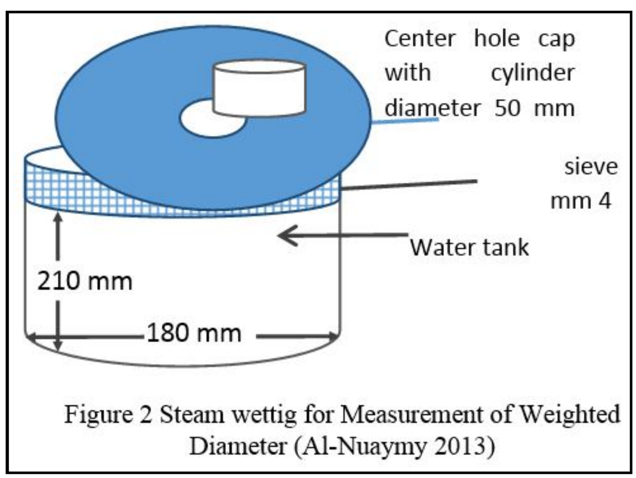

Fig. 2: Steam wettig for Measurement of Weighted Diameter **(Al-Nuaymy 2013)**

(2021)].

It is clear from Table 2 that the DW cycles also increased from MWD and were at the highest at the third cycle, as MWD increased significantly 38.3, 103, 74.9 and 47.8% from DW_2 to DW_5, respectively, compared to DW_1, while the increase in MWD was 47.5 and 26.4% for the two cycles DW_3 and DW_4 compared to DW_2 and the MWD decreased significantly in DW_5 compared to DW_3 . The reason for the increase in the increase of DW cycles is due to the ratio of $CaCO_3$ in the soil and water, which is one of the binding materials (Table 1). With the increase in water, the expansion and contraction of the soil due to successive wetting and drying will work on the movement of soil particles and their re-spread and contact with the largest possible number of $CaCO_3$ particles, while the return of the decline after the third cycle is attributed to the successive expansion and contraction of the soil, which works to break the less strong soil bonds. Perhaps also, the secreted acids from some microorganisms and the decomposition of organic matter and living mass may help dissolve or weaken some of the bonds and bridges between soil particles by increasing the DW cycles.

It is noticed from the same Table 2 that the interaction effect of the DW cycles and the type of SDE applied to the soil, as it is noted that in the first cycle, NCSDE significantly affected the limits of two times (by 175%) compared to the two types of application, SSDE and WOSDE, which did not differ significantly from each other. In DW_2 even DW_5, the change was not significant in MWD, but the application of NCSDE was the highest for each cycle separately. It is also noted that the MWD when adding NCSDE started high in DW_1 and maintained its high until the end of DW_5, at the same time it is noted that the MWD values started low at the application of SSDE then increased significantly by 179, 180.5 and 146.3% from DW_3 to DW_5, respectively, while it also increased significantly at WOSDE with increasing rates of 51.1, 238.5, 136.2 and 91.8% from DW_2 to DW_5, respectively, but the non-addition reached its peak at the third cycle and then decreased to its lowest values in DW_4 and DW_5. The reason for the increase in MWD is due to the presence of humic acid, which works on the formation of humic-clay complexes, which works to bind soil particles with each other by expanding the aggregates when they absorb water again in the next wetting process, which in turn binds the clay particles to other soil components according to Emerson's (1959) model of aggregates formation mechanics. The decomposition and re-mineralization of carbon by microorganisms bind the soil assemblies during the incubation period [Rahman *et al.* (2018)]. In addition, some organic compounds and some secretions of living organisms that grew when incubating are hydrophobic, which leads to a reduction in the speed of water entering the soil aggregates, allowing the air to exit gradually, which preserves the soil from destruction [Al-Nuaymy (2013), Al-Muhammadi and Al-Nuaymy (2021)].

These secretions may either dissolve the binding materials or may increase the effectiveness and strength of the binding depending on its type. This depends on the soil moisture percentage, whose decrease may limit the activity of these organisms before re-wetting [Amezketa (1999), Nimmo (2004)], as well as the accumulation, is the product of rearranging soil particles, coagulation and the effectiveness of the broiler materials for the content of organic carbon, as

Table 1: Some physical and chemical properties of soil.

Separates of soil			Class of texture	$EcdS.m^{-1}$	pH	Gypsum	lime	O.M. in soil aggregates	
clay	silt	sand						>9.5 mm	9.5 -4 mm
$gm.kg^{-1}$			silty loam			$gm.kg^{-1}$			
18.4	51.2	28.5		6.8	7.7	2.6	15. 8	19.7	9.4

Table 2: Effect of application type of SDE and DW cycle on MWD with fast per-wetting.

DW cycleApplica-tion type	DW_1	DW_2	DW_3	DW_4	DW_5	AvSDE
WOSDE	0.257	0.527	0.87	0.607	0.493	0.551
NCESD	0.697	0.67	0.883	0.773	0.667	0.738
SSDE	0.253	0.47	0.707	0.73	0.623	0.557
AV DW	0.402	0.556	0.82	0.703	0.594	
L.S.D.	SDE = 0.1056		DW cycle = 0.1363		Interaction= 0.2362	

well as for the content of clay, calcium carbonate and roots the plants [Kalhoro *et al.* (2017)]. Also, the effect of the interaction between DW cycles varies from one type of application of organic materials to another type of application due to the difference in the dynamics and nature of interactions between these different materials [Rahman *et al.* (2018)].

3.2 Sustainability of soil aggregates according to MWD values upon rapid wetting

Table 3 shows the types of sustainability of soil assemblies based on the values of MWD upon rapid wetting and it is clear that adding sawdust extract did not change the type of sustainability despite the high percentage of increase in MWD when applying and not applying the extract. The organic matter extract was not enough to change the sustainability class, while the DW cycles raised the sustainability class to the highest level and at the sustainable class under another use, from DW_2 to DW_5 compared to the unsustainable class at the DW_1 cycle. The reason for raising the sustainability class from the lowest to a higher level can be attributed to the fact that the increase in hydration led to an increase in the activity and effectiveness of microorganisms, while the activity of these microorganisms was not in DW_1 about the interference. it is noted that the sustainability class at DW_1 was unsustainable in the two types of addition SSDE and WOSDE and it rose to sustainable when another use of the rest of the DW cycles, except for DW_5 when no application, as for the application type NCSDE, all DW cycles were within the category of sustainable when using another. And the reasons that affected the MWD have affected the values of the sustainability classes for their adoption of the classification on it.

While the decrease after the third cycle is attributed to the group of bond-dissolving acids that result from the activity of the accumulated microorganisms [Amezketa (1999)], especially those acids that dissolve in water and thus spread better when not added because the soil solution will be more diluted than the soil solution when the extract is added. On the other hand, the effectiveness of microorganisms may differ from one cycle to another due to the different reactions referred to above. The passage of time is important in this because it may lead to the dominance of one species at the expense of other species until its death or the inhibition of its work from the rival organisms that differ among themselves in the outputs of their secretions.

3.3 MWD at slow initial wetting

It is observed from Table 4 the effect of the type of ESD addition and DW cycles on MWD when the soil samples are initially wetted with steam (slow wetting). WOSDE and the application of SSDE were significantly distinguished from NCSDE with an increase of 16.8%. Table 3 shows that MWD increased linearly significantly from DW_2 to DW_5 compared to DW_1 with percentage increases, respectively, of 22.8, 47.6, 73.6 and 98.7%. MWD also increased by 20.3,

Table 3: Sustainable Soil aggregate when estimated by MWD with fast per-wetting depend on Shulka *et al.* (2004).

	DW_1	**DW_2**	**DW_3**	**DW_4**	**DW_5**	**Average SDE**
WOSDE	Unsustainable	Sustainable with another land use	Sustainable with another land use	Sustainable with another land use	Unsustainable	Sustainable with another land use
NCSDE	Sustainable with another land use	Sustainable with another land use	Sustainable with another land use	Sustainable with another land use	Sustainable with another land use	Sustainable with another land use
SSDE	Unsustainable	Unsustainable	Sustainable with another land use	Sustainable with another land use	Sustainable with another land use	Sustainable with another land use
Average DW	Unsustainable	Sustainable with another land use	Sustainable with another land use	Sustainable with another land use	Sustainable with another land use	

Table 4: Effect of application type of SDE and DW cycle on MWD with slow per-wetting.

DW cycle / Applica-tion type	**DW_1**	**DW_2**	**DW_3**	**DW_4**	**DW_5**	**Av SDE**
WOSDE	1.127	1.273	1.887	2.03	2.733	1.81
NCESD	1.28	1.677	2.053	2.353	2.377	1.948
SSDE	1.657	2.037	2.057	2.67	2.96	2.276
AV DW	1.354	1.662	1.999	2.351	2.69	1.81
L.S.D.	SDE = 0.1294		DW cycle = 0.1671		Interaction= 0.2894	

41.5 and 61.9% from DW_3 to DW_5, respectively, compared to the DW_2 cycle and by 17.6 and 34.6% for the DW_4 and DW_5 cycles, respectively, compared to the DW_3 cycle and increased by 14.4% at DW_5 compared to DW_4, due to this increase the biomass of microorganisms, which increased by increasing the incubation periods, which gave enough time to increase the secretion of carnivores thanks to the microbial activity. On the other hand, slow wetted affect the cracking of weak soil aggregates only as it allows air to gradually exit the pores and reduces air pressure inside the aggregates. Slow absorption also reduces the difference in water absorption between the outer surfaces of those aggregates and their internal parts, thus reducing their fragmentation.

Table 3 shows that the interaction of the effect of the type of SDE addition and DW cycles in MWD when the soil samples were initially wetted with steam was also linear, but the effect of SSDE variety was higher than that of NCSDE and WOSDE application and at all DW cycles except for DW_5, where MWD decreased from both types NCSDE and SSDE. However, in DW_1, the MWD increased at SSDE type 29 and 34.3% compared to the two types of application NCSDE and WOSDE, respectively, while at DW_2, it was noticed that the SSDE type increased MWD significantly by 32 and 60% compared to the two types of application NCSDE and WOSDE, although that MWD increased in the three application significantly compared to the first and second cycles, the difference was not significant for the types of addition at DW_3. Also, MWD increased significantly with an increase of 15.9 and 31.5% for the SSDE type in comparison with NCSDE and WOSDE in DW_4, while in DW_5, the MWD increased significantly with the SSDE type with an increase of 15 and 24% for the two types of application WOSDE and NCSDE, respectively.

The same reasons that affected MWD at rapid wetting are the same as those that affected MWD at slow wetting, in addition to the DW cycles reorganizing the fine soil structure and the equilibrium state of the micro-aggregations will shape the structure of the aggregate by increasing the DW cycles [Hu *et al.* (2018)]. Also, the reason for the superiority of the SSDE treatment over the NCSDE treatment may be due to the type of microorganisms developing. These growths may differ when adding sawdust extract to the extracted solution directly from those growths on the dried and powdered extract in a nano form re-substituted again with water. Wetting, drying and the adding agent to the organic matter are more complex than the effect of the two factors separately [Cosentino *et al.* (2006)]. This complication results from whether the DW cycles increase or weaken the bond strength between the components [Amezketa (1999)]. The effectiveness of microbial communities may also influence and contribute to interdependence.

It is noteworthy that the MWD values were significantly higher at slow wetted than fast wetted. The difference is due to eliminating the problem of air blockage and pressure caused by the rapid wetting method. Steam wetted also contributes to the homogeneity of moisture and reduces the problem of cracking as a result of the difference between the parts of the earthen masses in the speed of water absorption and the expansion of the outer part of the mass in a way that is different from the inner part so that the masses break. The water vapor will reach the parts of the assemblies at about the same time [Al-Nuaymy (2013)]. This reduces both the pressure of the air trapped within the assemblies and reduces the problem of the difference in expansion between parts of a single block or group. In general, slow wetting gives the soil air trapped in the pores an opportunity to gradually exit, to reduce the pressure caused by air confinement within the aggregates and blocks and the cracking process decreases. Whereas, that significant effect of the NCSDE treatment in the rapid wetting compared to the rest of the study applications is due to dew, while the superiority of the SSDE treatment to the other two treatments at slow wetting may be due to the type of bonds produced. Emerging from the application of NCSDE, it does not withstand rapid wetting, while its positive effect appears at slow wetting.

3.4 Sustainability of soil aggregates according to MWD values at slow wetting

Table 5 shows the sustainability classes of soil assemblies based on MWD values at slow hydration. The sustainability cultivar has increased in general by two taxonomic levels at slow wetting compared to rapid wetting that increased by one taxonomic level. It is also noted that the SSDE treatment has increased its taxonomic level from sustainability by management. The high addition coefficients of NCSDE and WOSDE to sustainable, on the one hand, notes that the first, second and third DW cycles were at the taxonomic level, sustainable with high management and rose to sustainable and high sustainable at DW_4 and DW_5, respectively.

Concerning the interaction, it is noted that with the application type WOSDE, its taxonomic levels tended to the same direction as the average DW cycles, while when adding NCSDE, it was noted that it was sustainable with high management in the first and second cycles and is sustainable for the rest of the DW cycles, while with the addition type SESD it was the taxonomic level of DW_1 is sustainable with high management and has risen to the taxonomic level of sustainable for DW_2 and DW_3 and at the taxonomic level of sustainable for DW_4 and DW_5 and of course, the same reasons that affected MWD are the same that affected the sustainability classes.

3.5 Slaking value

Table 6 shows the effects of the application type and the DW cycles in slaking value (SLV). It is noted that SLV affected by the application type decreased by 27.5% at NCSDE compared to WOSDE, while SLV increased significantly in the SSDE treatment by 28.5% compared to the WOSDE treatment, the SLV decreased thanks to the DW cycles in general, but this decrease was not significant except at DW_3 and DW_4 cycles, with a decrease of 47.9 and 28.8%, respectively, compared to DW_1. When reviewing the results based on the application type, it is noted that SLV was not affected by the DW cycles significantly when NCSDE was treated, while SLV decreased from its highest values in the first cycle when SSDE was added and significantly by 58.9, 50 and 35% in the third to fifth cycles on the At the same time, SLV decreased significantly at DW_2 and DW_3 with decrease rates of 52 and 57.7% compared to the first cycle and then returned to rise insignificantly in the last two cycles.

The SLV is the product of dividing MWD at slow wetting to MWD at fastwetting. Therefore, the effect of the two values will affect the SLV. Also, the reason for the decrease of SLV when adding NCSDE and its rise at SSDE may be attributed to the nature of the pores formed, as can be observed from Tables 2, 4 and Figs. 3, 4 and 5 are small pores, more numerous and twisted when adding NCSDE, which causes a delay in the entry of air into the assemblies on the one hand and on the other hand, the air trapped as bubbles in the capillary ducts will slow the entry of water (bottleneck characteristic) while it is less numerous and large in size when the extension type in SSDE.

Table 5: Sustainable Soil aggregate when estimated by MWD with Slow per-wetting depend on Shulka *et al.* (2004).

	DW_1	**DW_2**	**DW_3**	**DW_4**	**DW_5**	**Average SDE**
WOSDE	Sustainable with high management input	Sustainable with high management input	Sustainable with high management input	sustainable	Highly sustainable	Sustainable with high management input
NCSDE	Sustainable with high management input	Sustainable with high management input	sustainable	sustainable	sustainable	Sustainable with high management input
SSDE	Sustainable with high management input	sustainable	sustainable	Highly sustainable	Highly sustainable	sustainable
Average DW	Sustainable with high management input	Sustainable with high management input	Sustainable with high management input	sustainable	Highly sustainable	

Table 6: Effect of application type of SDE and DW cycle on slaking value.

DW cycleApplica-tion type	**DW_1**	**DW_2**	**DW_3**	**DW_4**	**DW_5**	**AvSDE**
WOSDE	5.15	2.47	2.18	3.51	5.6	3.78
NCESD	1.92	2.73	2.33	3.11	3.61	2.74
SSDE	7.38	5.47	3.03	3.69	4.76	4.86
AV DW	4.82	3.56	2.51	3.43	4.66	
L.S.D.	SDE = 1.08		DW cycle =1.395		Interaction= 2.416	

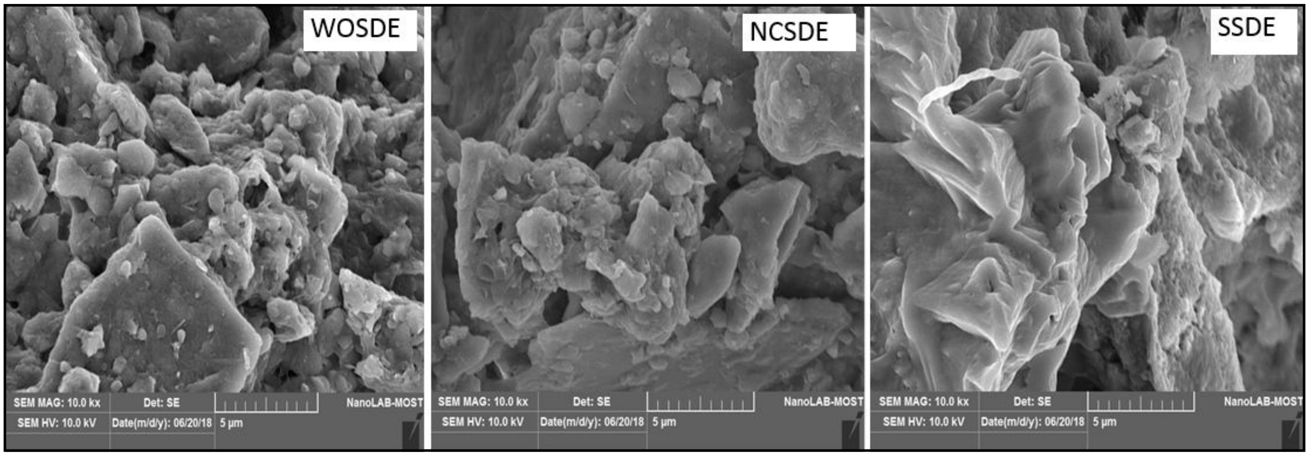

Fig. 3: SEM image for Application type of ESD to soil samples throw first DW cycle with 5 μm

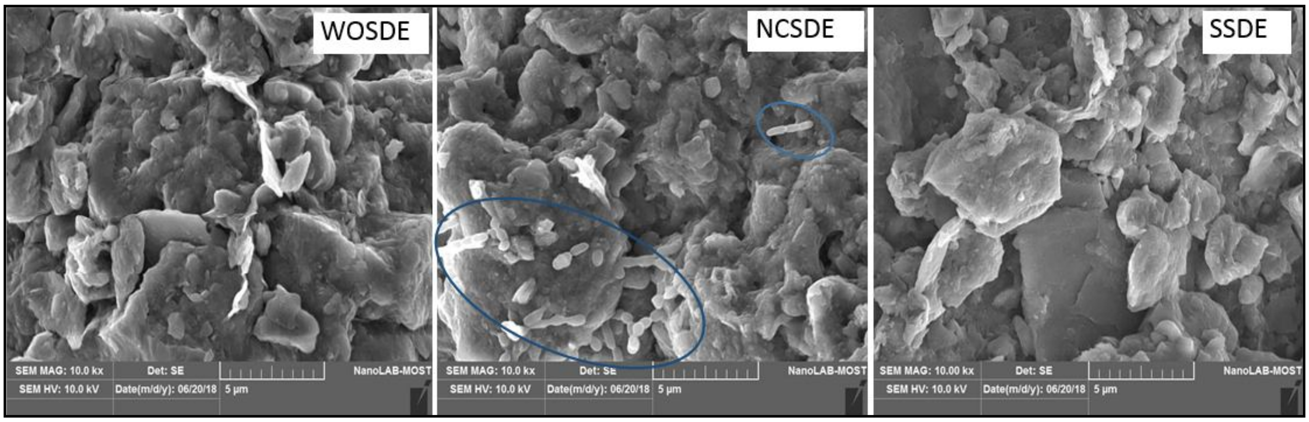

Fig. 4: SEM image for Application type of ESD to soil samples throw third dry-wetting cycle with 5 μm

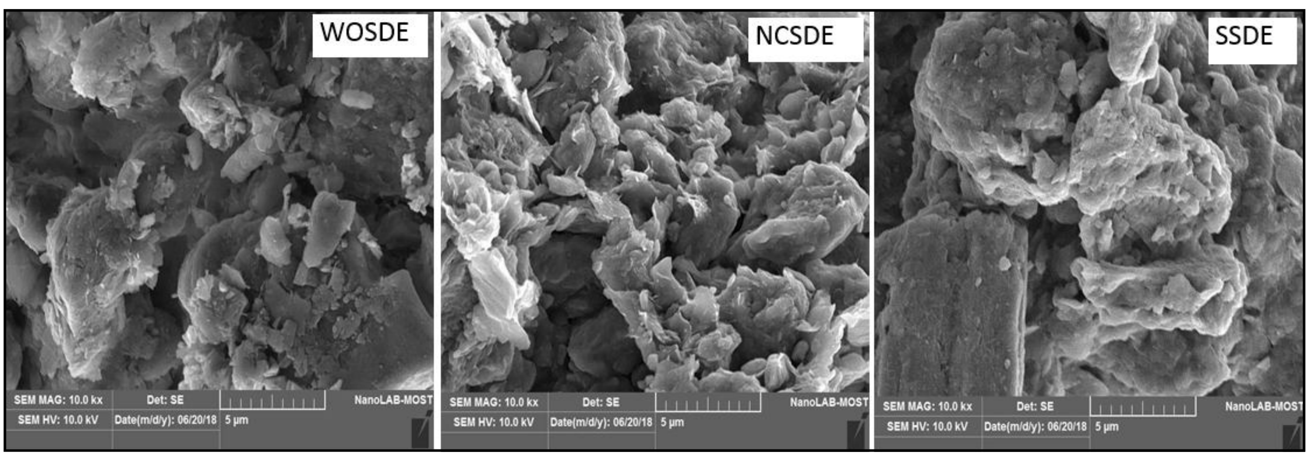

Fig. 5: SEM image for Application type of ESD to soil samples throw fifth DW cycle with 5 μm

3.6 Bulk soil density ρb

Table 7 shows the effect of type application and the DW cycles on ρb and it appears from the table that the application type decreased significantly for the two types of application, NCSDE and SSDE, with a decrease of about 8.6 and 5.3%, respectively, compared to WOSDE, the reason for the decrease in ρb is due to the improvement that occurred on the construction of soil as reflected by the rise in the MWD and soil porosity (Figs. 3, 4 & 5).

It can be seen from Table 7 that in the DW cycles and the DW_2 cycle, a significant increase in ρb is observed by a rate of 10.3% compared to DW_1 and a significant decrease of 8.5% in the DW_5 cycle compared to the DW_1 cycle. At the same time, ρb decreased significantly for the DW cycles DW_4 and DW_5 by 9 and 22.9. The apparent density also decreased significantly in the DW_5 cycle by 6% compared to the

Table 7: Effect of application type of SDE and DW cycle on bulk density, $Mg.m^{-3}$.

DW cycleApplica-tion type	DW_1	DW_2	DW_3	DW_4	DW_5	AvSDE
WOSDE	1.51	1.7733	1.6267	1.5333	1.2567	1.54
NCESD	1.42	1.38	1.35	1.39	1.4133	1.3907
SSDE	1.5	1.5867	1.4333	1.39	1.3833	1.4587
AV DW	1.51	1.7733	1.6267	1.5333	1.2567	
L.S.D.	SDE = 0.03501		DW cycle = 0.0452		Interaction= 0.07829	

DW_4 cycle, the reason for the decrease in ρb is due to the improvement that occurred in the soil structure as a result of the increase in the MWD and the porosity of the soil (Tables 2, 4 & 10, Figs. 3, 4 & 5), while the reason for the increase in ρb may be attributed to the value of the crash (Table 6), which may cause movement of smaller soil particles in larger soil pores, plus dead biomass after each wetting and drying cycle.

Table 7 shows the interaction between the two factors and it is noted that the NCSDE addition type had lower values in general and more stable than the WOSDE and SSDE types and that ρb was not significantly affected by the increase in DW cycles. While when no addition, the value of ρb was significantly high in the DW_2 and DW_3 cycle, with an increase of 17.4 and 7.8% over DW_1 and significantly decreased in the DW5 cycle by 16.8% compared to DW_1.

Also, ρb decreased significantly from the third to the fifth cycle by rates of 8.3, 13.5 and 29.2% compared to the DW_2 cycle, on the other hand, ρb decreased significantly in the DW_4 and DW_5 cycles by 5.7 and 22.7% compared to the DW_3 cycle, at the same time the apparent soil density decreased significantly in the DW_5 cycle is 18.1%. Regarding the type of SESD addition, ρb was significantly increased in the DW_2 cycle by 5.8%, while it decreased significantly in the DW_4 and DW_5 cycles by 7.3 and 8% compared to DW_1. Also, a significant decrease in ρb was observed from the DW_3 to DW_5 cycle, with rates of 9.7, 12.4 and 12.8%, respectively, compared to the DW_2 cycle. The reasons for the decrease in ρb are due to the change in the soil structure as a result of the increase in the MWD and the change in soil porosity (Table 2, 4, 7 & 10, Figs. 3, 4 & 5), as well as the expansion of the pores as a result of the pressure of the fungal hyphae [Tuo *et al.* (2017)]. On the other hand, the increase in ρb can be attributed to the high value of the decomposition (Table 6), which can lead to the movement of fine soil particles in the large soil pores, to which dead biomass is added after each DW cycle, as well as perhaps also to the filling of the voids with non-dead live mass which often they are of a higher weight than the dead.

3.7 Sustainability of soil assemblies according to ρb values

Table 8 shows the sustainability of the soil based on the apparent density values of the soil as reported by Shukla *et al.* (2004). It is clear that the category of sustainability ranged from highly sustainable to sustainable, whether it was for each factor separately or when the two factors overlap, except when the two factors overlap and within the non-ESD type of addition and when the humidification and drying cycles DW_2 and DW_3, which were unsustainable and sustainable when another use of the two cycles on arrangement.

3.8 Particle density ρs

Table 9 shows the effect of adding ESD and DW cycles on ρs. It is clear that there was no significant

Table 8: Soil Sustainable when estimated by bulk density with depending on Shulka *et al.* (2004).

	DW_1	DW_2	DW_3	DW_4	DW_5	Average SDE
WOSDE	Sustainable	Unsustainable	Sustainable with another land sue	Sustainable	Highly sustainable	Sustainable
NCSDE	Highly sustainable	Highly sustainable	Highly sustainable	Highly sustainable	Highly sustainable	Highly sustainable
SSDE	Sustainable	Sustainable	Highly sustainable	Highly sustainable	Highly sustainable	Highly sustainable
Average DW	Highly sustainable	Sustainable	Highly sustainable	Highly sustainable	Highly sustainable	

effect of the type of addition on ρs, and the humidification and drying cycles did not affect ρs except for the DW_2 cycle, in which ρs is increased by 2.5% compared to the DW_1 cycle, concerning the interference. With an increase of 8.3 and 5% for the two types of addition, WOSDE and NCSDE, respectively. In the DW_2 cycle, the ρs increased at the SSDE type by 4.4 compared to the WOSDE type, at the same time the ρs is decreased at the SSDE type with a decrease of 4.6 and 5.3% for the two types of application, WOSDE and NCSDE, respectively and that was in the DW_3 cycle, while in the DW_4 cycle the ρs at the application type SSDE is decreased by 5.4% compared to the WOSDE type and ρs was not significantly affected in the DW_5 cycle by the type of application. The reason for the change in ρs, whether it was an increase or decrease, may be attributed to an increase in mass with an unimportant change in size or vice versa by changing the size in a significant way and not changing the mass in a significant way as a product of the growing biomass, which depends on the type of addition [Rahman *et al.* (2018)] as well as to the age and type of living organisms and their dominance and the effect of DW cycles on the nature of its growth.

3.9 Soil porosity *f*

Table 10 shows the effect of the type of addition of sawdust extract and the DW cycles in f and it is noted that the two types of addition NCSDE and SSDE have increased f by an increase of 13.3 and 8.6%, respectively, compared to the type of application WOSDE. From the same table it is clear that during the DW_2 cycle, f is decreased by 5.8% compared to W_1, while f is increased significantly by 5.9 and 10.3% for the DW_4 and DW_5 cycles, respectively, compared to DW_1 and the f is increased significantly by 8.1, 12.4 and 17% for the DW_3, DW_4 and DW_5 cycles, respectively by 8.1, 12.4 and 17%. In DW_2, f is increased significantly by 5.9% in the DW_5 cycle compared to the DW_4 cycle.

As for the interference, it is noted in Table 10 and the first cycle that f is increased significantly by 13.45 and 12.7% for the two types of application NCSDE and SSDE, respectively, compared to the type of addition of WOSDE and in the period DW_2, f is increased significantly when the two additions NCSDE and SSDE with percentages of 50.9 and 30.3 compared with WOSDE, f is increased significantly with the two additions NCSDE and SSDE with rates of 26.4 and 11.4% compared to WOSDE in the DW_3 cycle, while in the DW_5 cycle, f is decreased significantly with the two application NCSDE and SSDE with rates of 14.8 and 7.2% compared to the WOSDE application.

In general, it is noted that the type of application NCSDE increased in the period f until od DW_3 cycle and then decreased again, while at the two types of application SSDE and WOSDE it decreased in the period DW_2 from the period DW_1 and then increased to reach its highest values in DW_5 for the type of addition type WOSDE. The factors that affected ρb and ρs will affect its porosity, since the mathematical relationship from which f is calculated depends on the two aforementioned values, that the organic matter, in turn, helps the growth of some fungal hyphae, which leads to the expansion of soil particles as a result of the

Table 9: Effect of application type of SDE and DW cycle on particle density, $Mg.m^{-3}$.

DW cycleApplica-tion type	DW_1	DW_2	DW_3	DW_4	DW_5	AvSDE
WOSDE	2.5092	2.61	2.7108	2.7396	2.5884	2.6316
NCESD	2.5884	2.6748	2.7288	2.6244	2.5164	2.6266
SSDE	2.718	2.7252	2.5848	2.592	2.646	2.6532
AV DW	2.6052	2.67	2.6748	2.652	2.5836	
L.S.D.	SDE = 0.03663		DW cycle = 0.04729		Interaction = 0.08191	

Table 10: Effect of application type of SDE and DW cycle on soil porosity.

DW cycleApplica-tion type	DW_1	DW_2	DW_3	DW_4	DW_5	AvSDE
WOSDE	39.77	32.06	39.98	44.01	51.45	41.45
NCESD	45.12	48.37	50.52	47.03	43.83	46.97
SSDE	44.81	41.76	44.55	46.31	47.74	45.03
AV DW	43.23	40.73	45.02	45.78	47.67	
L.S.D.	SDE =1.621		DW cycle =2.093		Interaction= 3.625	

pressure of the developing hyphae and thus an increase in the percentage of voids [Tuo *et al.* (2017)].

3.10 Soil aggregates under an SEM electron microscope

Figs. 3, 4, 5 display pictures of soil aggregates under the electron microscope and their impact on the DW cycles and the type of soil extract application. From the smallest to the largest, it is not continuous and irregular and the small gatherings are the most and most of the pores visible in the image are of large diameter and less deep and the channels are short and discontinuous. As for the application type NCSDE, most of the large aggregates appear in it in a lamellar shape, while others are spherical and with a larger size than the WOSDE type. As for the small aggregates, they appear spherical and range from the largest to the smallest and appear to be clustered or coagulated in a more regular manner than the WOSDE application type and the largest aggregates are common, while its pores appear larger and deeper and connected to its capillary channels, which seem to be continuous and the reflection of light from them is less than the type of WOSDE application and this may be due to the transparency of the nanopowder solution, which allows light to pass through instead of being reflected.

While the aggregates of the SSDE type of application appear as a single mass, almost sharp-angled and appear as if they are covered with a membrane. This membrane may be a thin layer of sawdust extract solution. The pores are few, but they are large in size compared to the other two types of application and the light reflection in it is higher than the other two types of application and this may be due to the viscosity of the soil extract solution, as it shows some white threads, which may be fungal hyphae or algal hyphae. Fig. 3 explains the effect of the type of application on the MWD of the first cycle in Tables 3 and 7.

Fig. 4 shows the soil aggregates under the electron microscope of the third DW cycle. The aggregates appear when WOSDE is added in a spherical shape, but at acute angles, over which aggregates of sharply angular lamellar shape accumulate with more and less interrupted capillary channels and their pores appear fewer in number, but larger in size and in greater depth compared to the same application type at the first cycle and there are some reflections of white light, which indicates the growth of some organisms [Jong-Shik *et al.* (2013)] concerning the type of application NCSDE, its aggregate appear large spherical in shape with smooth edges with larger and deeper pores and connected capillary channels with the presence of white light reflections and some cluster shapes (indicated with a closed curve), which may be fungal organisms or algae and this may indicate the difference in the type of organisms the developing ones, although the source of the organic extract is the same, while the aggregates of the SSDE type appear in lamellar form and with large and small assemblies with sharp edges and show large-sized pores and connected capillary channels and white light is reflected from them, which may be evidence of bacterial and fungal growth [Jong-Shik *et al.* (2013)]. Fig. 4 explains the results presented in Tables 4, 6, 8 and 10.

Fig. 5 displays the soil aggregates under the electron microscope of the fifth wetting and drying cycle. It is noted that the WOSDE soil aggregates appear spherical in shape, large in size, smooth edges, large and connected capillary channels and large voids and this explains the high values of soil porosity in this treatment (Table 10) with little light reflection (white), while the NCSDE additive type, its aggregates appear in not large sizes, as in the two types of addition, WOSDE and SSDE and in undefined, non-smooth shapes and more adherent to each other and appear as if they are covered with membranes, with large voids and twisted capillary channels and white light is reflected from them more than the other two types of addition, while the type of application is SSDE, so its aggregate appear in relatively large sizes, often spherical, with mass clusters, smooth edges and large pores, but their distribution is not homogeneous and white light is reflected from them less than NCSDE application.

4. Conclusion

It is concluded from this study that the performance of the nano-powdered sawdust extract is better than the performance of the sawdust extract solution in resisting the conditions of crushing and cracking of the soil structure under the conditions of rapid wetting (immersion), while the performance of the same two types of application was opposite under the conditions of slow wetting. The class of soil sustainability varies according to the index used in the classification. In the first cycle, the dominant variety was unsustainable at rapid aggregates wetting and sustainable at high management at slow wetting, while the bulk density was of sustainable to highly sustainable cultivar. In this study the DW cycles had positive effect on the stability of soil aggregates and this is contrary to the prevailing information in this field.

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