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EFFECT OF MULCHING ON REDUCING SOIL DISAGGREGATION RATES UNDER SIMULATED RAINFALL

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ABSTRACT: Water erosion accounts for one of the main environmental problems worldwide, triggering sediment disaggregation, transport and deposition processes. The highest harmful effects are recorded in uncovered soils and the smallest in areas with vegetation cover, whether alive or dead. Vegetation cover promotes a decrease in soil disaggregation rates and sediment transport. Seeking to study the effects of dead soil cover, the aim was to evaluate the hydraulic conditions and the relationships of soil disaggregation and runoff resistance with the presence of mulching in interrill erosion in reference Latosols of the State of Alagoas. The research was conducted at the Federal University of Alagoas - Arapiraca Campus. The experimental design used was completely randomized. Soils collected under natural conditions were: Dark red Latosol (LVe), Yellow Red Latosol (LVa), and Yellow Latosol (LA) at depths from 0.0 to 0.20 m. The evaluation of interrill water erosion rates was carried out in laboratory under simulated rainfall, under the conditions of uncovered soil, soil cover with Elephant Grass plant residues (*Pennisetum purpureum* Schum.), at doses of 0.00; 0.40 and 0.80 kg m^{-2}. For all soils, the size distribution of soil aggregates in diameter, weighted average diameter, and the water stable aggregates index (WSAi) were determined. Variables were submitted to analysis of variance, when necessary, and regression and comparison of means was performed using the Tukey test at 5% probability. There was no statistical difference for the three soils under study in the % of aggregates > 0.5mm and weighted average diameter. LVa had the highest soil disaggregation rate, followed by LVe and the lowest LA. The lowest soil loss occurred for LA in relation to the other soils. The increase in soil cover considerably reduced soil losses and disaggregation rates.

KEYWORDS: Erodibility; Soil management; Soil structure; Aggregate stability.

EFEITO DA COBERTURA MORTA NA REDUÇÃO DAS TAXAS DE DESAGREGAÇÃO DO SOLO SOB CHUVA SIMULADA

RESUMO: A erosão hídrica responde por um dos principais problemas ambientais do planeta, desencadeando os processos de desagregação, transporte e deposição dos sedimentos. Os efeitos mais danosos são registrados em solos descobertos e os menores em áreas com cobertura vegetal, seja viva ou morta. Esta cobertura promove uma diminuição nas taxas de desagregação do solo e no transporte de sedimentos. Buscando estudar os efeitos da cobertura morta sobre o solo, objetivou-se avaliar as condições hidráulicas e as relações de desagregação do solo e de resistência ao escoamento com a presença de cobertura morta na erosão em entressulcos em Latossolos de referência do Estado de Alagoas. A pesquisa foi conduzida na Universidade Federal de Alagoas – Campus Arapiraca. O delineamento experimental utilizado foi inteiramente casualizado. Os solos coletados em condições naturais foram: Latossolo vermelho escuro (LVe), Latossolo vermelho amarelo (LVa), e o Latossolo amarelo (LA) nas profundidades de 0,0 a 0,20 m. A avaliação das taxas de erosão hídrica em entressulcos foi realizada em laboratório sob chuva simulada, nas condições de solo descoberto, cobertura do solo com resíduos vegetais de Capim elefante, *Pennisetum purpureum* Schum., nas doses de 0,00; 0,40 e 0,80 kg m^{-2}. Realizou-se para todos os solos a determinação da distribuição de tamanho dos agregados do solo em classes de diâmetro e diâmetro médio ponderado, o índice de estabilidade de agregados em água (IEA). As variáveis foram submetidas à análise de variância, quando necessário foi feita a regressão e a comparação de médias pelo teste de Tukey a 5% de probabilidade. Não houve diferença estatística para os três solos estudados na % de agregados > 0,5mm e diâmetro médio ponderado. O LVa apresentou a maior taxa de desagregação de solo, seguida do LVe e o LA a menor. A menor perda de solo ocorreu no LA em relação aos demais. O incremento de cobertura reduziu consideravelmente as perdas de solo e as taxas de desagregação de todos os solos.

PALAVRAS-CHAVE: Erodibilidade; Manejo do solo; Estrutura do solo; Estabilidade de agregados.

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INTRODUCTION

Water erosion is one of the main environmental problems worldwide, with negative impact on ecosystem services, agricultural production, drinking water and carbon stocks (Panagos et al., 2015; Pinto et al., 2020). This process is characterized by the physical soil disaggregation caused by erosive agents, such as rainfall and surface runoff, and consists of three processes: disaggregation, transport and deposition of soil particles (Machado et al., 2013).

The study of the erosion process can be divided, according to the origin of the sediment, into interrill erosion, in furrows and in gullies, which represent a global erosion process called gross erosion (Casalí et al., 2009). However, soils erode not only due to water action, but also due to advanced deforestation and, in some cases, due to steep slopes.

In the state of Alagoas, human action is an aggravating factor, especially in reference Latosols, found in much of the *Agreste* region and in the Coastal Tablelands of the state, where deforestation was severe for the implementation of areas under sugarcane. This monoculture requires high mechanization, compacting the soil, reducing pores and consequently accelerating the process of soil surface sealing, favoring the erosion process (Silva and Ribeiro, 1997; Volk and Cogo, 1998).

One of the most effective alternatives for controlling the erosion process is the application of live or dead cover on the soil surface. Vegetation cover reduces soil disaggregation rates and sediment transport, and provides protection against erosion agents through three effects: i) intercepting the direct impact of raindrops and dissipating their kinetic energy, preventing particle disaggregation and the formation of a surface seal; ii) reducing the transport capacity of surface flow, with decrease in flow velocity; and iii) increasing flow depth, which directly influences the dissipation of raindrop impact energy, reducing the soil disaggregation rate (Cantalice et al., 2009).

Given the scarcity of studies that relate management systems to soil losses and considering the importance of Latosols for the agricultural sector in the state of Alagoas, the aim of this study was to evaluate the hydraulic conditions and the relationships between soil disaggregation and runoff resistance with the presence of mulching in interrill erosion in reference Latosols in the state of Alagoas.

MATERIAL AND METHODS

This study was carried out at the Federal University of Alagoas – Arapiraca Campus. A completely randomized design (CRD) was used, in a 3 x 3 factorial scheme, with 3 replicates, totaling 27 experimental plots. Treatments corresponded to three soil types, Yellow Latosol (LA), Yellow Red Latosol (LVa) and Dark Red Latosol (LVe), and three vegetation covers with Elephant grass straw, *Pennisetum purpureum* Schum., at doses of 0.0; 0.4 and 0.8 kg m^{-2}.

Soils were collected in the following municipalities of the state of Alagoas: Rio Largo (LA), Arapiraca (LVa) and Limoeiro de Anadia (LVe), under natural conditions at depth of 0.0 to 0.20 m, and were classified according to the Brazilian Agricultural Research Corporation (EMBRAPA, 2013) (Table 1). Soils were chemically and physically characterized according to Teixeira et al., (2017) (Table 2).

Table 1. Collection locations of reference Latosols in the state of Alagoas.

Latosol unit	Location	Coordinates	
LA[1]	Rio Largo	S 9º 27' 54.2232"	W 35° 50' 4.293"
LVa[2]	Arapiraca	S 9º 50' 35.3652"	W 36º 34' 34.266"
LVe[3]	Limoeiro de Anadia	S 9º 42' 40.4568"	W 36º 30' 34.693"

[1] Yellow Latosol, [2] Yellow Red Latosol, [3] Dark Red Latosol.

Table 2. Chemical, mineralogical and granulometric characterization of reference Latosols.

Soil	pH (H_2O)	Fe	Cu	Zn	Mg	M.O.	Clay	Silt	A.G.	A.F.	C.T
		Ppm				%	g/Kg				
LA[1]	4.8	388.6	0.02	2.2	20.2	1.73	185	213	251	302	F.Aren.[4]
LVa[2]	4.7	137	0.35	2.97	5.22	0.95	164	25	529	293	F.Aren.
LVe[3]	4.3	42.05	2.61	8.64	263	2.34	328	52	424	293	F.Arg.Ar[5]

[1] Yellow Latosol, [2] Yellow Red Latosol, [3] Dark Red Latosol. [4] Sandy Loam, [5] Sandy Clay Loam.

The size distribution of soil aggregates was performed in diameter classes and weighted mean diameter (WMD) of samples, using methodology described by Tisdall and Oades (1979). For this purpose, 50 g of soil were used, considering the moisture content present, and dispersant NaOH 1 mol L^{-1}. The material was dried at 105ºC, weighed and the mass of aggregates was determined.

Samples were placed in a set of sieves with mesh diameters of 4.76; 2.0; 1.0; 0.5 and 0.25 mm, placed in shaker at 45 RPM for 10 minutes. The materials retained in each sieve were dried in an oven and the soil mass was weighed. The water stable aggregates index (WSAi) was determined using methodology described by Kemper and Rosenau (1986).

The evaluation of interrill water erosion rates was carried out in laboratory under simulated rainfall, as recommended by the Water Erosion Prediction Project (WEPP). Rainfall was applied to experimental plots of 1 m^2 (0.5 m in width and 1 m in length) by a rainfall simulator built according to specifications of Meyer and Harmon (1979). The rainfall simulations had average intensity of 90 mm h^{-1}.

The liquid discharge (q) per width unit was determined from runoff collections in plastic containers at the end of the collection gutter at 5-minute intervals. The runoff surface velocity (Vs) was determined by the time taken by a dye (methylene blue) to travel the distance between two fixed points on the plot (expressed in m s^{-1}), subsequently enabling the determination of the average runoff velocities by the product of the surface runoff velocities by a correction factor (a = 2\3).

The runoff depth (h) was determined by the equation derived by Singh (1983) for the kinematic solution of the Saint-Venanton equations. The interrill soil disaggregation rate (Di) and soil losses (Ps) were determined according to Bezerra and Cantalice (2006). The surface runoff coefficient was calculated by the ratio between the surface runoff rate (ES – mm h^{-1}). The rainfall intensity was determined based on the volume collected by 10 rain gauges, randomly distributed around the experimental plot. The infiltration rate (Ti – mm h^{-1}) was calculated by the difference between the rainfall intensity and the surface runoff rate:

The interrill water erosion variables in this experiment were submitted to regression analysis and analysis of variance in a completely randomized experimental design. Means were also compared using the Tukey test at 5% probability. For this purpose, the SISVAR 5.6 statistical software (Ferreira, 2014) was used.

RESULTS AND DISCUSSION

The values of hydraulic variables are described in Table 3. All treatments presented Re number > 4000 and Fr < 1, therefore, it could be inferred that all surface flows were subcritical turbulent. Cantalice et al. (2005) also found flow regime in erosion furrows in uncovered and recently prepared soil conditions, and characterized it as being transitional from subcritical to subcritical turbulent.

Table 3. Hydraulic characteristics of runoff generated by simulated rainfall on different Elephant Grass straw doses, *Pennisetum purpureum* Schum., in three reference Latosols in the state of Alagoas.

Dose (kg m^{-2})	**Q** (m^3 s^{-1})	**Vm** (m s^{-1})	**h** (m)	**Re**	**Fr**
			Yellow latosol		
0.0	0.0687	0.0123	0.00018	12.5063	0.9441
0.4	0.0289	0.0138	0.00025	11.9027	0.4950
0.8	0.0239	0.0133	0.00027	13.1697	0.4396
			Yellow-red latosol		
0.0	0.0428	0.0115	0.00027	11.3522	0.8384
0.4	0.0262	0.0172	0.00047	12.0182	0.3936
0.8	0.0233	0.0118	0.00052	11.9703	0.3503
			Dark-red latosol		
0.0	0.0428	0.0092	0.00022	9.0189	0.9928
0.4	0.0285	0.0113	0.00040	11.1323	0.4836
0.8	0.0336	0.0187	0.00044	11.4251	0.4461

Q – liquid discharge per width unit; Vm – Mean velocity; h – Flow height; Re – Reynolds number and Fr – Froude number.

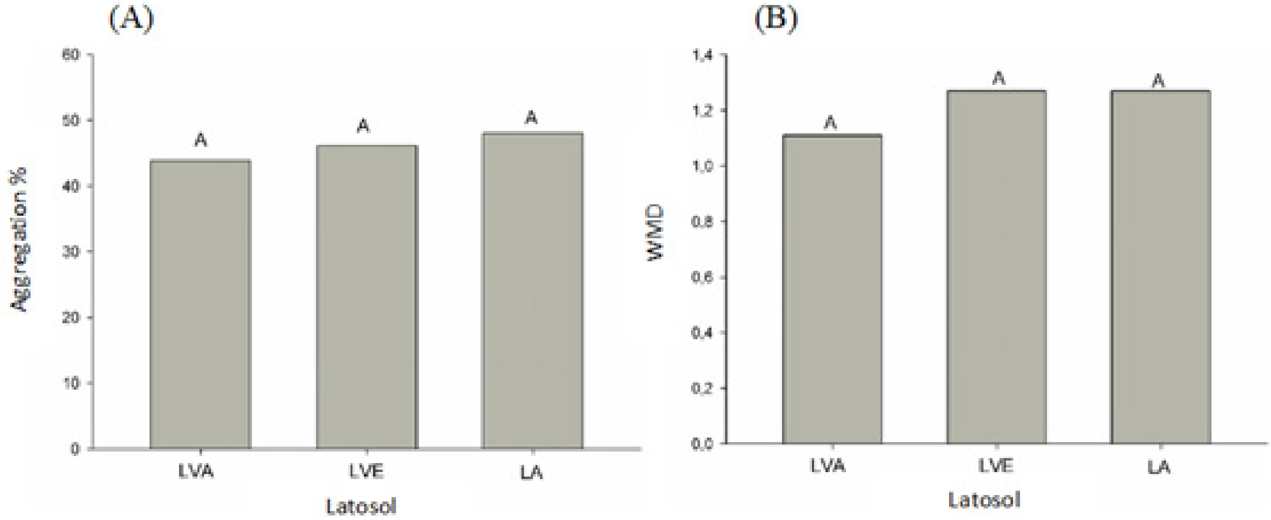
However, it was observed that with the increase in the straw dose, the Froude values decreased. This occurred because the presence of mulching generates a resistance action to the flow, promoted by the roughness of its shape. Thus, increase in the flow height and increase in gravitational forces are reflected, which decreases the Froude number. These results corroborate those found in soil disaggregation (Cassol et al., 2004) and surface runoff studies (Cantalice et al., 2009).

All soils under study were collected in fallow areas, without periodic turning, probably for this reason there was no statistical difference among them for the aggregation percentage of > 5 mm in water (Figure 1A). Soils with greater aggregation can be considered superior, having a more organized and developed structure, with proportional macro and micropores, facilitating root growth and water storage, and are less erosive than soils with lower % of aggregates > 0.5 mm, which are submitted to continuous agriculture (Salton et al., 2008).

It is noteworthy that macroaggregates are influenced by the type of soil management. Troleis et al. (2017) state that there was no statistical difference in particle aggregation in the experiment conducted due to the use of the conventional planting system, in addition to the fact that the experimental area had been a crop area for many years. According to Ayer et al., (2015), in their natural state, Latosols present great stability and resistance to erosion.

There was no statistical difference among Latosols in relation to WMD, possibly due to the soil characteristics and the way it is used (Figure 1B). This result was similar for the three soils under study, where natural vegetation predominates. The factors that influenced the soil aggregate percentage also affected WMD, since soils with little disturbance are more structured and, consequently, less susceptible to erosion. The lowest values were observed in systems with only crops, where soil turning is routine, under conventional system. Long-term studies have indicated that WMD is lower than in no-tillage, according to Wendling et al. (2005). Ayer et al. (2015) found that the areas least susceptible to water erosion are forests, floodplains and urban areas, the latter with high water losses due to soil impermeability.

Figure 1. Aggregation percentage of > 5 mm in water (A) and Weighted Mean Diameter (WMD) (B) for Red-Yellow Latosol (LVa), Dark Red Latosol (LVe) and Yellow Latosol (LA)



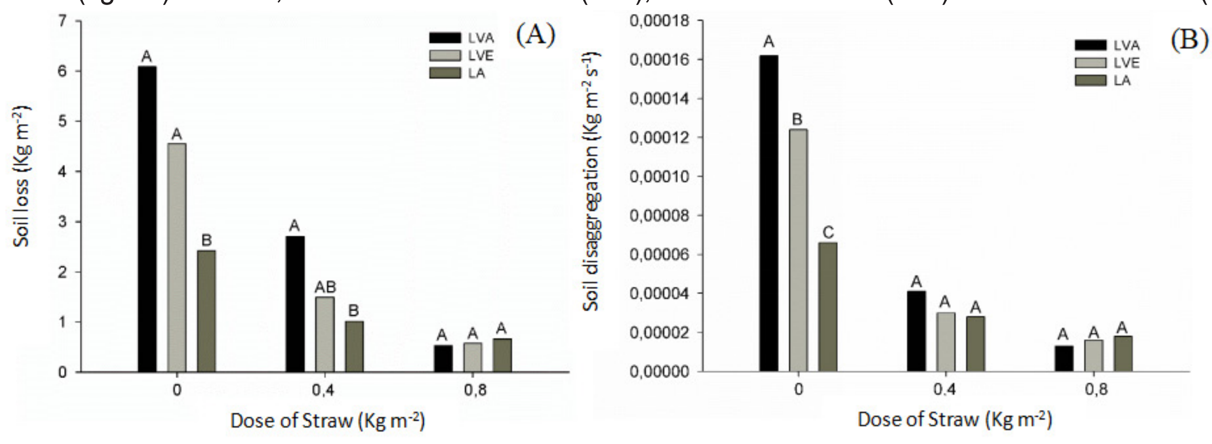
Means followed by the same letter do not differ significantly by the Tukey's test at 5% level.

After applying 60 min of simulated rainfall, it was found that without cover and with cover of 0.4 kg m^{-2}, Red Yellow Latosol (LVa) and Dark Red Latosol (LVe) presented greater accumulated soil loss compared to Yellow Latosol (LA) (Figure 2A). This result is possibly due to the fact that Yellow Latosol has higher Fe and Al contents. Nunes and Cassol (2011) found that soils with lower interrill erodibility were those with higher clay content and that presented high iron and aluminum oxide contents and lower degree of dispersion of the clay plus silt fraction in water. However, there was no statistical difference among Latosols under study with 0.8 kg m^{-2}, demonstrating the effective benefit of vegetation cover against the erosive impacts of rainfall on unprotected soils.

Bertol et al. (2017), in a study on water erosion under three washing methods in *Eucalyptus benthamii* cultivation, observed that water losses did not differ statistically among treatments, while soil losses varied over time ($p < 0.05$).

Soil disaggregation was greater in Red-Yellow Latosol, followed by Dark Red Latosol. Yellow Latosol had the lowest disaggregation rate compared to the other soils. In treatments with vegetation cover, there was no statistical difference (Figure 2B).

Figure 2. Cumulative soil loss due to interrill erosion (A) and cumulative soil disaggregation due to interrill erosion (B) during 60 min of simulated rainfall of 90 mm h^{-1}, in environment of uncovered soil (0), with 0.4 and 0.8 (kg m^{-2}) of straw, for Red-Yellow Latosol (LVa), Dark Red Latosol (LVe) and Yellow Latosol (LA).

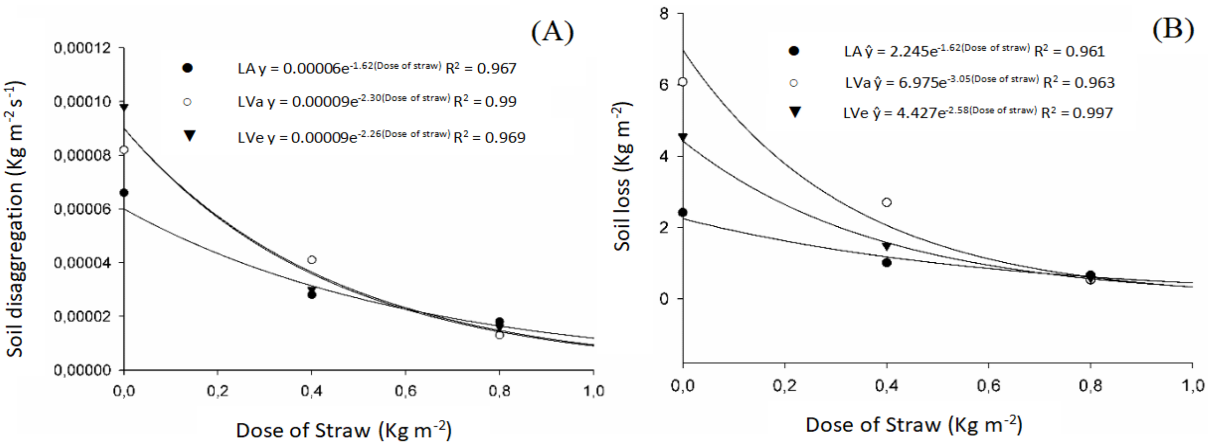


Means followed by the same letter do not differ significantly by the Tukey's test at 5% level.

Corrêa (2002) evaluated the effect of cultivation systems on the stability of aggregates of a Red-Yellow Latosol in Querência, MT, and found a tendency for an increase in the aggregate percentage with diameter greater than 2 mm and in WMD, when the soil organic matter content is increased.

The effect of the application of different straw doses on soil disaggregation rates is observed in Figure 3A. For the Yellow Latosol, it was observed that the curve expressing the dilution of soil disaggregation rates as a function of the increase in straw doses showed $r^2=0.967$, in LVa $r^2=0.99$ and in LVe $r^2=0.969$. It was observed that in the three soils under study, reduction in disaggregation rates was well correlated with the increase in straw doses, showing its efficiency in reducing erosion rates.

Figure 3. Soil disaggregation rates for applied top dressing doses (A) and soil loss for applied top dressing doses (B) in Yellow Latosol (LA), Yellow Red Latosol (LVa) and Dark Red Latosol (LVe).



These data corroborate those of Cantalice et al. (2009), where different sugarcane straw doses were studied with slopes of 5 and 15%, the $r^2=0.36$ on the first slope indicated that there was a limitation in the transport of disaggregated sediment by the impact of raindrops under this condition, however, the increase in straw doses was efficient in reducing erosion rates.

The results of the application of different straw doses on soil losses are verified in Figure 3B. In this figure, it is observed that the soil losses adjustment curves were well correlated, with $r^2 = 0.961$; 0.963 and 0.997 for LA, LVa and LVe, respectively. The increase in straw doses considerably reduced soil losses. Therefore, mulching proved to be efficient, protecting the soil against interrill erosion, since it reduces the impact of raindrops and the consequent obstruction of pores on the soil surface by compression and migration of clays, as reported by Bezerra and Cantalice (2006).

Thus, it could be concluded that: there was no statistical difference for soils under study in the % of aggregates > 0.5 mm and weighted average diameter; Red Yellow Latosol presented the highest soil disaggregation rate, followed by Dark Red Latosol and Yellow Latosol; the lowest soil loss was found for Yellow Latosol in relation to the other soils; the increase in vegetation cover considerably reduced soil losses and the disaggregation rates of all soils analyzed.

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