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Full Length Research Paper

Effect of Agri-SC as a soil conditioner on runoff, soil loss and crust strengths

Gökçen Yönter* and Bülent Yağmur

Ege University, Faculty of Agriculture, Department of Soil Science and Plant Nutrition. 35100 Izmir, Turkey.

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This study was carried out to determine the effect of Agri-SC as a soil conditioner at different doses (0, 18.50, 37.00, 55.50 and 74.00 l ha^{-1}) on water erosion and crust strengths under laboratory conditions with three replicates. The Agri-SC solutions were sprayed and two consecutive simulated rainfalls (60 mm h^{-1}) were applied on a loamy soil sample into the erosion plots. Erosion plots were waited under a platform including four infrared lamps (250 Watt) at 16 h between two consecutive simulated rainfalls. Results showed that the Agri-SC treatments decreased runoff, soil loss and crust strengths significantly ($p \leq 0.01$) in each of the two simulated rainfalls compared with controls in the experiment.

Key words: Agri-SC, crust strength, rain simulator, runoff, soil loss, soil stabilizers.

INTRODUCTION

Soils, which are one of the most essential natural resources for human life, are quickly eroded by water and wind effects and unconscious uses by human. Unfortunately, instead of eroding soils is impossible to recreate soils. In natural conditions, heavy rainfalls forms hard layers, which is named crust on soil surface, based on wind and sunshine effects. Agriculture systems in terms of crop production are affected by crust formation negatively.

Many researchers have been put forward that there are significant relationship between soil erosion and crusting. Erpul and Çanga (1999) found that, consecutive rainfall applications increased runoff and soil loss, and decreased percolation by crusting, significantly. Yönter (2006) found that crust strengths were effective on runoff and also, runoff was effective on soil loss significantly ($p \leq 0.05$) with the application of two consecutive rainfalls at different intensities (50, 75, 100, and 125 mm h^{-1}) on soil samples, respectively.

Therefore, a number of measures are being developed to prevent the formation of crust, and protection of agricultural lands. One of these measures is the use of the number of soil conditioners and polymers on soils. The most important properties of these materials links soil particles to the land and to protect against erosion by providing continuity to regulate the structure of the soil (Haris et al., 1966; De Boodt, 1979). Polymers, for that purpose, have been used in the 1950s following World War II (Chepil, 1954). In some studies, it was found that polyvinyl alcohol (PVA) affected crust strengths (Page and Quick, 1979). Barry et al. (1991) found that, the soil improvement materials increased the soil surface resistance than controls between 1.5 to 5.5 times, whereas, the applications of PVA in soil loss was found to be a value close to the controls. Borselli et al. (1996) found that crust strengths were increased on soils treated with gypsum than controls. Zhang and Miller (1996) found that surface materials treatments by 64%, gypsum treatments by 28%, and gypsum + surface material treatments by 88% reduced soil loss, respectively and these applications also reduced crust formation than controls, significantly. In general, polymers applications decreased soil loss significantly (Teo et al., 2001; Takuma et al., 2003). In some studies, runoff on plots treated with polymers started more early than controls and rainfall basin activity was found at higher levels (Wu et al., 2005). Ben Hur (2006) found that, polymers applied at very low rates, prevented crust formation, whereas,

*Corresponding author. E-mail: g.yonter@hotmail.com. Tel: + 90 232 311 1514 / 23, Fax: + 90 232 388 92 03.

Abbreviations: PVA, Polyvinyl alcohol; **PAM,** polyacrylamide; **PPA,** polypropylene acid; **PTA,** polythene alcoholic; **UR,** urea-formaldehyde poly-condensate; **LSD,** least significant difference.

increased runoff and soil loss. Shrestha et al. (2006) emphasized that, average sediments moving are reduced by 95% with some different polymers' applications on water, roads and ponds implemented. Yönter and Uysal (2010) sprayed PVA and polyacrylamide (PAM) at different ratios (0, 6.70, and 33.50 kg ha^{-1}) on sandy clay loam and sandy loam soil samples. In the research, it was found that polymers (PVA, and PAM) reduced runoff, soil loss and crust strengths significantly ($p<0.01$). Wu et al (2010) applied different consistencies of 3 amendments; polypropylene acid (PPA), polythene alcoholic (PTA) and urea-formaldehyde poly-condensate (UR) to China's Loess and determined their effects on soil physical properties and on runoff-sediment yield under laboratory and outdoor artificial rainfall simulations. As a result of this study, it was found that these materials reduced runoff, soil loss and crust formation.

In recent years, Agri-SC as a soil conditioner has been used also for the improvement of soil properties, and to prevent erosion, and crust formation on soils. Fullen et al. (1993) applied Agri-SC on the erodibility of loamy sand soils. Factors measured included runoff and erosion, soil structure, crust strength, splash susceptibility, aggregate stability, soil micro morphological properties, response to compaction and penetrometer resistance. Results showed that Agri-SC decreased runoff and erosion rates, bulk density, splash erosion, crust strength and penetrometer resistance, and increased pore space and aggregate stability. The effects on crust strength, aggregate stability and bulk density were statistically significant. Sutherland and Ziegler (1998) applied laboratory rainfall simulation on soils to determine splash detachment from soil treated with 0 (untreated control), 0.3, 3.0, 30, and 300 l ha^{-1} of Agri-SC. Results indicated that the quantity of sediment splashed was significantly lower for Agri-SC application rates of 0.3 and 3.0 l ha^{-1}.

MATERIALS AND METHODS

The experimental soil sample from the agriculture faculty's research fields of Ege University in Bornova-Izmir-Turkey (latitude: 38°27'07.72" N; longitude: 27°13'33.34" E), was taken to use the simulated rainfall experiment under laboratory conditions. In addition, Agri-SC was used in the simulated rainfall experiment as a soil conditioner. Soil sample taken from the area is in the western Anatolia region of Turkey, where the Mediterranean climate prevails with a long-term mean annual temperature of 17.9°C. Long-term mean annual precipitations is 689.8 mm (DMI, 2009).

In the first step of this experiment, around 50 to 80 kg of soil sample (0 to 30 cm) was taken and dried at normal atmospheric conditions in the laboratory conditions. A part of the experimental soil, which was air-dried, was sieved with a 2 mm sieve (Richards 1954) and used in some physical and chemical analyses, and other part of the experimental soil was also sieved with a 8 mm sieve for erosion research (Mollenhauer and Long, 1964; Byran, 1969). Some physical and chemical characteristics of the soil were determined as follows, respectively; texture (Bouyoucos, 1962), pH, (US Salinity Lab. Staff, 1954), dispersion rate (Middleton, 1930), erosion rate (%)(Akalan, 1967), lime (%) (Schlichting and Blume, 1966), soluble total salt (%) (Soil Survey Staff, 1951), and the organic content (Black 1965) of the soil sample were analyzed. Aggregate stabilities of the soil samples was analyzed by Yoder's Wetting Sieved Methods (U.S. Salinity Lab. Staff, 1954) and calculated using Kempler's formula (Black 1965).

In this experiment, a laboratory type rain simulator (Veejet 80100 types nozzle) (Bubenzer and Meyer, 1965) and the perforated erosion plots sized 30×45×15 cm (Taysun 1986; Abrahim and Rickson, 1989; Gril et al., 1989) were used. Erosion plots were filled with a 5 cm very coarse sand layers in this experiment, and this layers were smoothed by hand carefully. After a fine cloth (cheese cloth) was lay on the sand layer, erosion plots were filled by soil samples sieved with an 8 mm sieve.

In the following step, Agri-SC was weighed in doses of 0, 0.5, 1.0, 1.5, and 2.0 ml, and then mixed in 1000 ml of pure water. Different doses of Agri-SC (18.50, 37.00, 55.50 and 74.00 l ha^{-1}; 500 ml to the plot), and pure water of 500 ml for controls were sprayed on the soil surfaces from a 30 cm height and these erosion plots were waited under a platform, which included 4 x 250 Watt infrared lamps during 16 h. After the application of these methods, first, artificial rainfall (60 mm h^{-1}) was applied to the plots at 9% slope for 1 h from a height of 2.50 m (Bubenzer and Meyer, 1965). Then, runoff start times were measured and recorded by using a stopwatch (Taysun et al., 1984; Taysun, 1986). During the simulated rainfall experiment, runoff and sediment samples were taken at each 10 min. After simulated rainfall, these plots were again waited under an infrared lamps platform at 24 h, and crust strengths were measured by a hand type penetrometer (EL 516–030) (Page and Quick, 1979; Levy and Rapp, 1999; Yönter, 2006; Yönter and Uysal 2010). Finally, second artificial rainfall (60 mm h^{-1}) was applied on these plots again. The same methods were also used to measure runoff and sediment. In this experiment, tap water (EC: 875 µmhos/cm; SAR: 2.50%) was used. At the end of the rainfall applications (first and second), the runoff containers were left for 24 h in order for the sediment to settle in the containers. Then, the sediment samples were dried in an oven at 105°C. Runoff and sediment amounts were recorded and tabulated (Taysun, 1986). A completely randomized experimental parcel, designed with three replications was used for statistical analysis of the data. Data were analyzed by using an SPSS statistical package program (SPSS, 1999) in this experiment.

In this study, it was aimed to determine the effects of different doses of Agri-SC on water erosion and crusting under laboratory conditions.

RESULTS AND DISCUSSION

Soil characteristics

The experimental soil properties are given in Table 1. Soil sample was a neutral reaction, and its soluble salt percent was very low. The lime percent level of soil was very high and it contained very low organic material. The soil was loam textured. Skeleton percent level was found very low. Dispersion ratios and erosion ratios, which are the most important indication of soil erosion, were found as 25 and 27%, respectively. It was considered that, soil has no resistance to erosion, when dispersion and erosion ratios are higher than 15 and 10%, respectively (Akalan 1974; Taysun 1989).

Runoff

Runoff, soil loss and crust strengths from the experiment

Table 1. Some physical and chemical properties of soil sample.

Soil property	Value
pH	7.31
Soluble salt in water (%)	0.080
Lime (%)	17.28
Organic material content (%)	1.66
Sand (%)	44.00
Silt (%)	36.00
Clay (%)	20.00
Texture	Loam
Skeleton (%)	2.20
Clay ratio (%)	4.00
Silt ratio (%)	1.80
Suspension (%)	14.00
Dispersion (%)	56.00
Dispersion ratio (%)	25.00
Erosion ratio (%)	27.21
Aggregate stability (%)	4.85

Table 2. Mean runoff start times, runoff, soil loss and crust strengths taken from plots treated with Agri-SC and LSD tests results.

Treatment (l ha^{-1})	1st simulated rainfall (mm h^{-1})		Crust strength (kgf cm^{-2})	2nd simulated rainfall (mm h^{-1})	
	Runoff (mm h^{-1})	Soil loss (g m^{-2})		Runoff (mm h^{-1})	Soil loss (g m^{-2})
Control	31.62 a	276.52 a	1.92 a	48.70 a	701.76 a
18.50	30.95 ab	244.45 b	1.91 ab	41.98 b	611.55 b
37.00	30.54 b	219.85 c	1.88 bc	37.51 c	445.10 c
55.50	19.99 c	125.78 d	1.86 cd	36.84 d	259.15 d
74.00	18.40 d	100.44 e	1.84 d	29.44 e	243.61 e
$LSD_{(0.05)}$	0.875	5.752	0.032	0.519	5.130

are given in Table 2 for each of the two simulated rainfalls. Runoff varied from 31.62 mm h^{-1} to 18.40 mm h^{-1} and 48.70 mm h^{-1} to 29.44 mm h^{-1} in the first and second simulated rainfall experiments, respectively. From Table 1, it is understood that soil has skeleton and organic material contents at lower levels. Therefore, runoff was found with higher amounts (Taysun, 1986; Yönter and Taysun, 2004). The second simulated rainfall increased runoff than the first simulated rainfall experiments. It might be that crust formation affected runoff (Erpul and Çanga, 1999; Yönter, 2006; Yönter and Uysal, 2010). The effects of the Agri-SC treatments on runoff were found statistically significant according to the least significant difference (LSD) test ($p \leq 0.05$) in Table 2. The results showed that Agri-SC decreased runoff significantly compared with the controls (Figure 1, Tables 3 and 4). Also residual effects of Agri-SC continued on runoff during the second simulated rainfall (Table 3). Similar findings were found by Fullen et al. (1993).

Soil loss

Soil loss in the experiment varied from 276.52 g m^{-2} to 100.44 g m^{-2} in the first simulated rainfall experiments. In the second simulated rainfall experiments, soil loss varied from 701.76 g m^{-2} to 243.61 g m^{-2}. In general, soil loss can be reduced by using soil conditioners (Zhang and Miller, 1996; Teo et al., 2001; Takuma et al., 2003). The effects of the Agri-SC treatments on soil loss were found statistically significant according to the LSD test ($p \leq 0.05$) in Table 2. According to the experiment, Agri-SC also reduced soil loss significantly in each of the simulated rainfall experiments compared with the controls

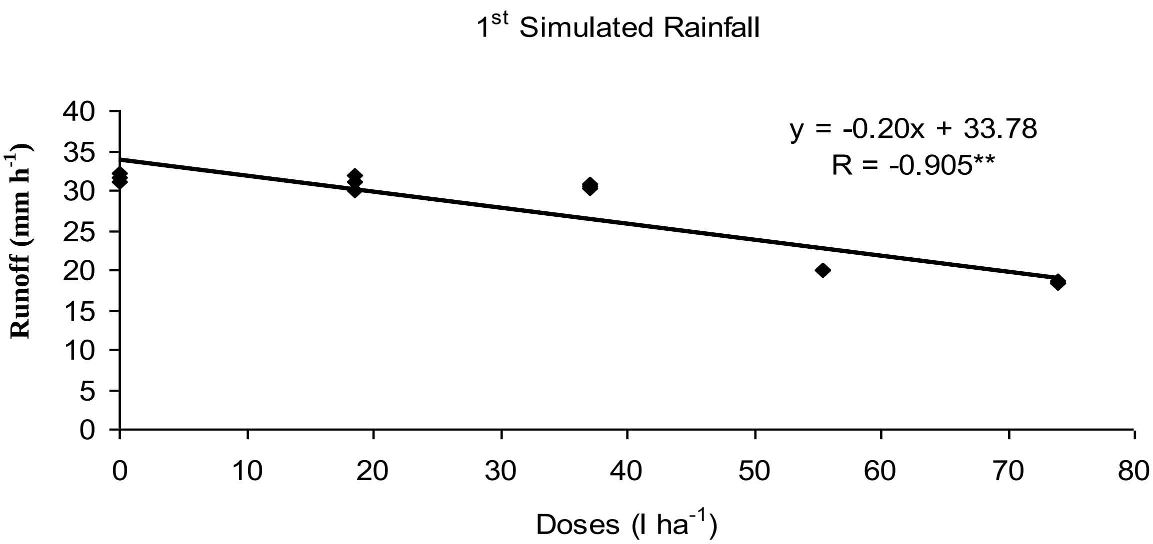

Figure 1. The relationships between Agri-SC application doses to runoff in the experiment.

Table 3. Correlation coefficients of experimental results.

	Parameter	Dose	R1	SL1	CS	R2	SL2
Doses	Pearson correlation	1.000					
	Sig. (2-tailed)						
	N	15					
R1	Pearson correlation	-0.905**	1.000				
	Sig. (2-tailed)	0.000					
	N	15	15				
SL1	Pearson correlation	-0.972**	0.974**	1.000			
	Sig. (2-tailed)	0.000	0.000				
	N	15	15	15			
CS	Pearson correlation	-0.916**	0.836**	0.891**	1.000		
	Sig. (2-tailed)	0.000	0.000	0.000			
	N	15	15	15	15		
R2	Pearson correlation	-0.973**	0.799**	0.899**	0.901**	1.000	
	Sig. (2-tailed)	0.000	0.000	0.000	0.000		
	N	15	15	15	15	15	
SL2	Pearson correlation	-0.977**	0.914**	0.972**	0.889**	0.913**	1.000
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.000	
	N	15	15	15	15	15	15

R1, Runoff in 1st simulated rainfall; SL1, soil loss in 1st simulated rainfall; CS, crust strength; R, runoff in 2nd simulated rainfall; SL2, soil loss in 2nd simulated rainfall; **, 0.01; *, 0.05.

(Figure 2, Tables 3 and 4). Similar findings were found by Sutherland and Ziegler (1998). In addition, the second simulated rainfall increased soil loss than the first simulated rainfall experiments. It might be that crust formation increased soil loss (Erpul and Çanga, 1999; Yönter, 2004; Yönter and Uysal, 2010). However, Agri-SC effects on soil loss continued during the second simulated rainfall (Table 3).

Crust strengths

In the experiment, crust strengths varied from 1.92 kgf cm^{-2} to 1.84 kgf cm^{-2}. The effects of the PVA treatments on crust strengths were found statistically significant according to the LSD test ($p \leq 0.05$) in Table 2. According to the experiment, it was found that while the applied doses of Agri-SC increased, crust strengths decreased

Table 4. Analyses of variance of experimental results.

	Parameter	**Sum of square**	**df**	**Mean Square**	**F**	**Sig.**
R1	Between groups	510.386	4	127.596	550.982	0.000
	Within groups	2.316	10	0.232		
	Total	512.702	14			
SL1	Between groups	70285.995	4	17571.499	1757.677	0.000
	Within groups	99.970	10	9.997		
	Total	70385.965	14			
CS	Between groups	0.012	4	0.003	13.227	0.001
	Within groups	0.002	10	0.000		
	Total	0.014	14			
R2	Between groups	603.581	4	150.895	1852.838	0.000
	Within groups	0.814	10	0.081		
	Total	604.395	14			
SL2	Between groups	505503.333	4	126375.833	15891.574	0.000
	Within groups	79.524	10	7.952		
	Total	505582.857	14			

R1, Runoff in 1st simulated rainfall; SL1, soil loss in 1st simulated rainfall; CS, crust strength; R, runoff in 2nd simulated rainfall; SL2, soil loss in 2nd simulated rainfall.

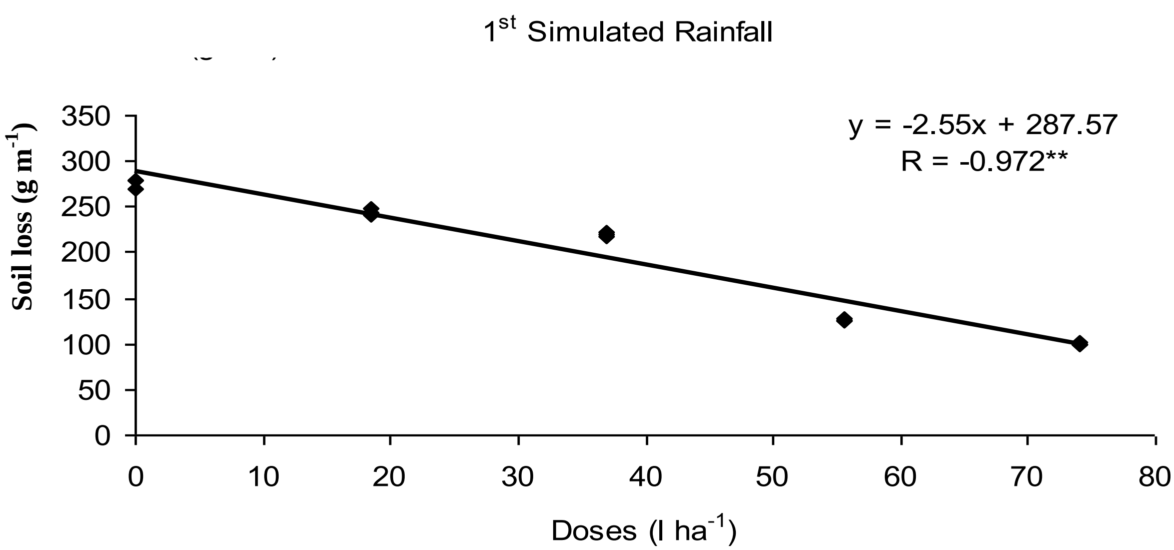

Figure 2. The relationships between Agri-SC application doses to soil loss in the experiment.

significantly (Figure 3, Tables 3 and 4). Similar findings were found by Fullen et al. (1993). Some researchers found that soil conditioners reduced crust formation significantly (Barry et al., 1991; Zhang and Miller, 1996; Ben Hur, 2006; Wu et al, 2010). In addition, crust strengths increased runoff and soil loss significantly (Figure 4).

Conclusion

Our results indicate that the Agri-SC application with very low doses on soil was found to be the most effective to minimize soil erosion by water as runoff, soil loss and crust strengths. For this reason, Agri-SC as an important soil conditioner can be used for reducing soil erosion.

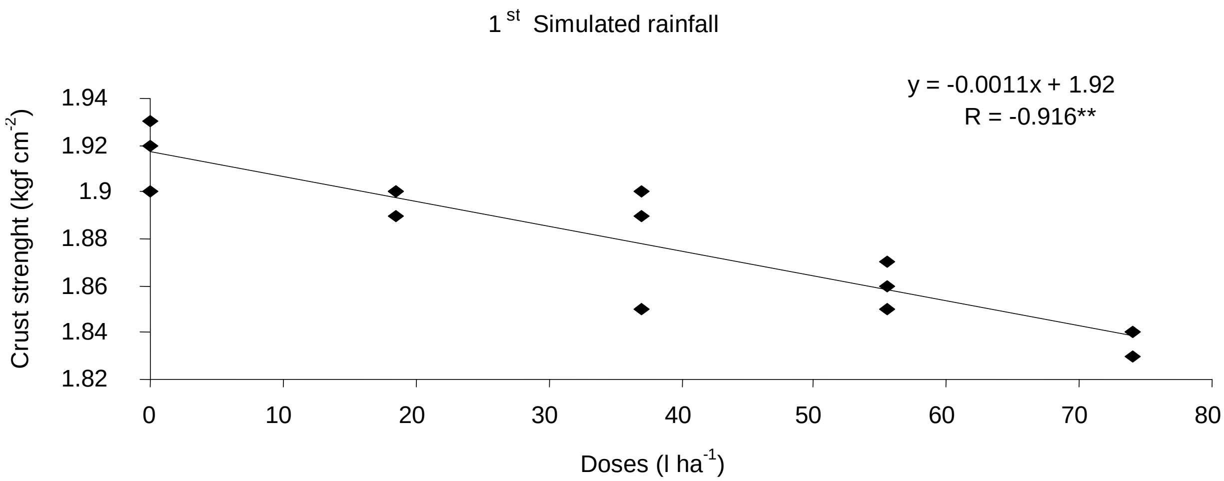

Figure 3. The relationships between Agri-SC application doses to crust strengths in the experiment.

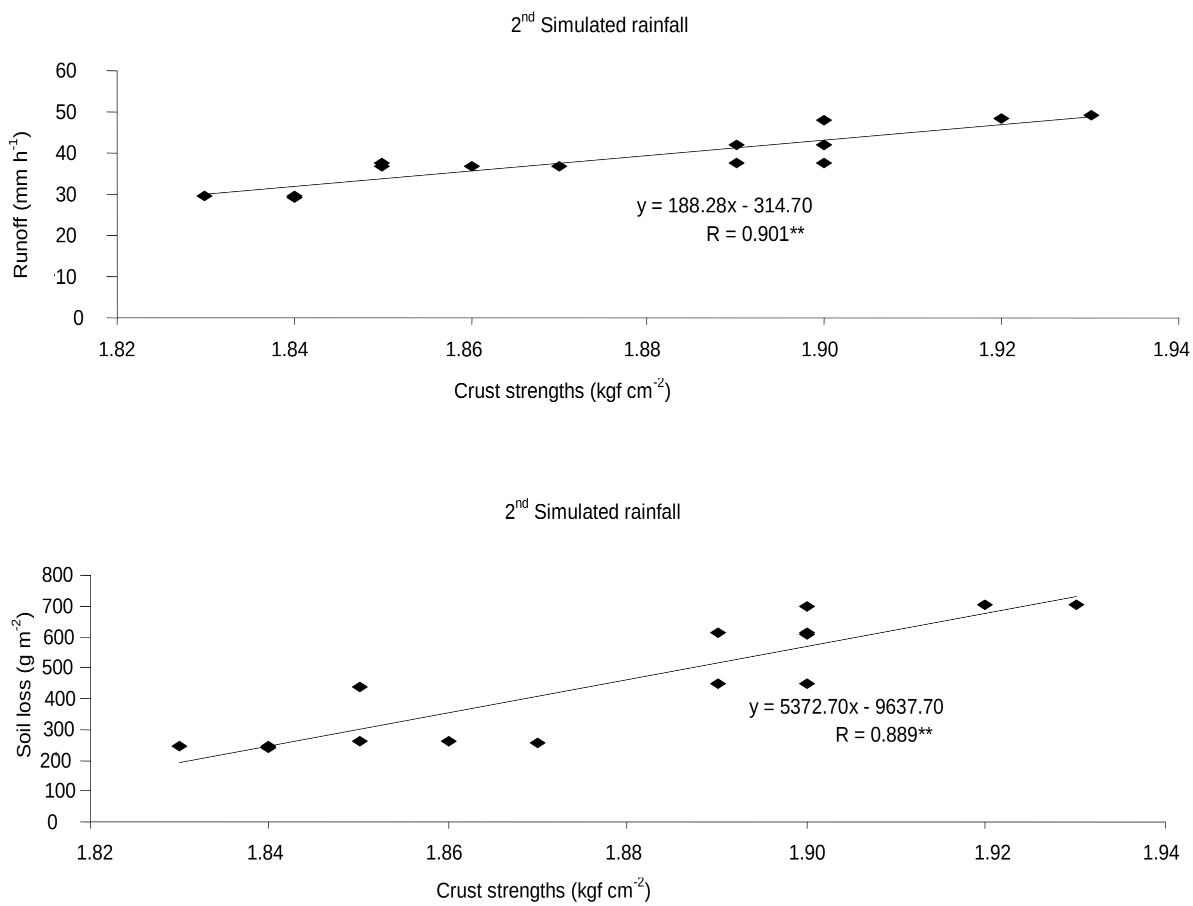

Figure 4. The relationships between crust strengths to runoff and soil loss in the experiment.

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