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Effects of Simulated Rainfalls With Different Intensities on Crust Formation and Soil Erosion by Water

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Abstract: In this study, the effects of simulated rainfalls with different intensities (50, 75, 100 and 125 mm h⁻¹) on crust formation and soil erosion by water were investigated as using a rain simulator (Vejeet 80100) under laboratory conditions. Erosion plots, 30×45×15 cm sized and perforated, were placed into coarse s and (7 cm thick) and soil samples sewed by 8 mm (5 cm thick). After rainstorms applied, erosion plots were waited under an infrared lamps platform which has 4 lamps during 24 h. Than crust strengths were measured by a hand penetrometer (EL 516-030). 2nd simulated rainfalls were again applied on erosion plots (at the same intensities). According to research, increased intensities had increased runoff, soil loss and crust strength. It was found that crusting had significantly effected on runoff but no effected on soil loss.

Key words: Rain intensity, runoff, soil loss, crust formation, crust strength

INTRODUCTION

On soil surface raindrops, crushed the soil aggregates by it's kinetic energies, are frequently forming crusting. While infiltration ratio decreases by crusting, runoff increases, therefore soils are eroded by water. In addition, crust formed by raindrops, due to harder, prevents the germination and vegetation of cultural plants on soils. Morin and Winkel (1996), expressed that crust on soil surface is being become by raindrop impact (structural), or sediment accumulate. And to determine the relative importance of two precesses, they had carried out an experiment with rainfall simulation under laboratory conditions. Clay and sandy soil samples were used in experiment. According to results, the main difference had the longer time needed to reach the low infiltration rates both of soils. Biolders *et al.* (1996) carried out a study to determine effects of tillage on morphology and distribution of surface crust in an Oxic Paleustult from southern Togo (West Africa). In this study, 217 mm natural rainfall exposed on plots (1 m²). Micromorfological analyses were made and surface topography was measured 3 times. According to study, crust formation divided 2 parts; (i) runoff crust and (ii) erosion crust. Shainberg *et al.* (1992) carried out an experiment to evaluate the relative importance of aggregate stability in seal formation. In this experiment the effects of raindrops impact energy, ESP, electrolyte concentration in the applied water and addition of PAM on aggregate stability and seal formation were studied on 3 smectitic soils using laboratory drip type rain simulator. According to research, disintegrate aggregates needed 9 mm rain, but seal

formation needed > 40 mm rain. Researchers explained that crusting follows as: (i) soil aggregates crush, (ii) soil surface impaction and (iii) clay dispersion on soils.

As crusting, the cultivation of soils are frequently needed, hence labor and coasts are increased. To prevent of crust formation, some soil conditioners and polymers have been applied on soils. These materials changes the soil properties to decrease erosion and crusting. Some researches found that physical and chemical properties of soils with rain and runoff have important effect on crust formation.

Magunda *et al.* (1997) applied consecutive simulated rainfalls (63 mm h⁻¹ and 3 times) on soil samples (Udic Haploboroll, Typic Hapludalf, Mollic Kandudalf and Typic Palehumult). End of this study, it was found that consecutive simulated rains had decreased infiltration ratio and surface roughness and also significantly increased soil loss.

Mamedov *et al.* (2000) applied 4 kinetic energies of rainstorms (3.6, 8.0, 12.4 and 15.9 KJ m⁻³) with a drop type rain simulator on soil samples (Clay loam Calcic Haploxeralf, Sandy clayey Vertisol, Chromic Haploxerert and heavy clayey Vertisol). According to results, increased kinetic energies had increased runoff and soil loss significantly. Artificial rainfall with different intensities (70 and 90 mm h⁻¹) were applied on loess soils has different slope degree and soil surface conditions. According to results, rain intensities and slope degree had significantly effected on runoff and soil loss (Zheng *et al.*, 2001).

Page and Quick (1979) applied the different ratio of 18 type polymers on a sandy loam soil sample (0, 6, 13.4, 27,

54, 108 and 216 kg ha⁻¹) and soil samples were waited under an infrared lamps platform (300 Watt) over at night. Researchers applied 25 mm simulated rainfall during 45 min and soil samples were waited again under the lamps platform at 70 hand they measured the crust strength. It was found that PVA applications increased crust strengths than other polymers (2-142%) and control, but 216 kg ha⁻¹ of PVA also decreased the crust strength (46%). Levin *et al.* (1991) applied to artificial rain (3 mm diameter) from different heights (0.4, 1.0 and 1.6 m) on soil samples (Typic Chromoxerent, Typic Rhodoxeralf and Calcic Haploxeralf) which were treatment with phosphogypsum (PG) and phosphogypsum+polyacrylamide (PG+PAM). It was found that increased heights had decreased infiltration ratios but soil loss had also increased and PG+PAM applications had decreased soil loss. Levy *et al.* (1992) sprayed the different ratios of PAM and PS on Typic Chromoxerent and Typic Haploxeralf and applied consequent artificial rain (60 mm h⁻¹; 5 times). Researches emphasised that PAM applications had increased the permeability but decreased the soil loss.

Ben-Hur (1994) sprayed PAM (20 kg ha⁻¹) and PS (40 kg ha⁻¹) on erosion plots with prepared on a silty loam and a clayey Vertisol and applied simulated rainfall (100 mm h⁻¹). He found that runoff on control and polymers applicated plots had decreased significantly (39-53%). In addition crusting had effected on increasing runoff on control. Levy and Rapp (1999) sprayed PAM and PS on a silty loam soil (Calcic Haploxeralf) into placed erosion plots (120 mm diameter; 78 mm height) and applied artificial rainfall (40 mm h⁻¹). Crust strength were measured by a hand penentrometer (3.24 mm diameter prob), after applied artificial rain and waited erosion plots in dried room at 30°C until soil-water decreased by 95%. It was found that very height crust strength on control than others. In the other study, polymers were sprayed on Oxisols, Vertisols and Aridisols from Hawaii Islands and applied consequent simulated rainfalls (5.5 and 7.0 cm h⁻¹). According to research, it was found that interval relationships with rain intensities and polymers applications.

MATERIALS AND METHODS

This study was conducted at Ege University of Soil Science. Department in Turkey in 2005. As experimental

materials, a sandy clayey loam (44.88% sand, 27.48% silt and 27.64% clay) and a sandy loam (60.40% sand, 16.00% silt and 23.60% clay) soil samples were used to simulated rainfall. In this samples skeleton (%) (Soil Survey Staff, 1951), texture (%) (Bouyoucos, 1962), pH (US Salinity Lab. Staff, 1954), total salt (%) (Soil Survey Staff, 1951), lime (%) (Çağlar, 1949) and organic material (%) (Black, 1965) were analysed. In experiment, a rain simulator (Veejet 80100) (Bubenzer and Meyer, 1965) and perforated erosion plots (Abraham and Rickson, 1989; Grill *et al.*, 1989) were used to under laboratory conditions. Erosion plots were into placed by sand (7 cm thick) and soil sewed by 8 mm (5 cm thick) and firstly applied the simulated rain (1st) with different intensities (50, 75, 100 and 125 mm h⁻¹) during 1 h and than each plots were waited under a infrared lamps platform (250 Watt) until dried duration 24 h. Crust strengths on soil samples surface in erosion plots were measured by a hand penentrometer (EL 516-030), finally 2nd simulated rain applied on erosion plots again (at the same intensities) (Page and Quick, 1979; Levy and Rapp, 1999). Runoff and sediment samples were taken in each 10 min during rainstorms (1st and 2nd) and calculated soil loss after drying in an oven (105°C, at 24 h) (Bubenzer and Meyer, 1965; Abraham and Rickson, 1989; Grill *et al.*, 1989).

RESULTS AND DISCUSSION

Runoff and soil loss: Increases in runoff, soil loss and crust strengths are based on increases in rain intensities both 1st and 2nd simulated rain (Table 2). According to Table 1, soil samples have different properties, thus runoff and soil loss are differently effected by this properties. Especially, physical and chemical properties of soil sample no 1 had effected on runoff, soil loss and crust strength (Table 2 and 3). After crusting, while rain intensity had increased, runoff from sample 2 was more increased than sample 1. During experiment, on sandy clayey loam soil surfaces (no 1) were observed cracks after waiting under infrared lamps as runoff in 2nd rainstorm less than 1st rainstorm. In generally, runoff, soil loss and crust strengths were increased based on rain intensities (at increased ratio). This findings are similar to some studies (Magunda *et al.*, 1997; Mamedov *et al.*, 2000; Zheng *et al.*, 2001). According to Table 3, increased rain intensities increased the crust strengths, also crusting had effected on runoff and soil loss. This findings are supported by Ben-Hur (1994), Levy and Rapp (1999).

Table 1: Some physical and chemical properties of soil samples

Sample No.	Skeleton (%)	Sand (%)	Loam (%)	Clay (%)	Texture class	pH (%)	Total salt (%)	Lime (%)	Organic material (%)
1	11.16	46.39	26.36	27.28	Sandy Clayey loam	7.60	0.078	17.19	2.76
2	18.79	72.40	21.60	6.00	Sandy loam	5.83	0.030<	0.22	0.34

Table 2: Runoff and soil loss from before and after crusting

Intensity (mm h ⁻¹)	Sample No.	Runoff (mm h ⁻¹)		Soil loss (g m ⁻²)	
		B.C	A.C	B.C	A.C
50	1	24.38	15.74	174.73	180.96
	2	16.73	19.62	94.69	140.79
75	1	47.66	41.99	506.80	543.23
	2	37.47	44.93	621.37	793.47
100	1	64.19	62.20	919.30	1039.33
	2	54.84	61.70	988.39	1003.16
125	1	101.77	90.00	1638.37	2188.36
	2	70.71	73.73	1420.91	1624.98

B.C: Before crusting (1st rainstorm) A.C: After crusting (2nd rainstorm)

Table 3: Measured crust strengths from plots

Intensity (mm h ⁻¹)	Sample No.	
	1	2
50	2.42	1.84
75	2.72	2.45
100	3.32	2.52
125	3.56	2.65

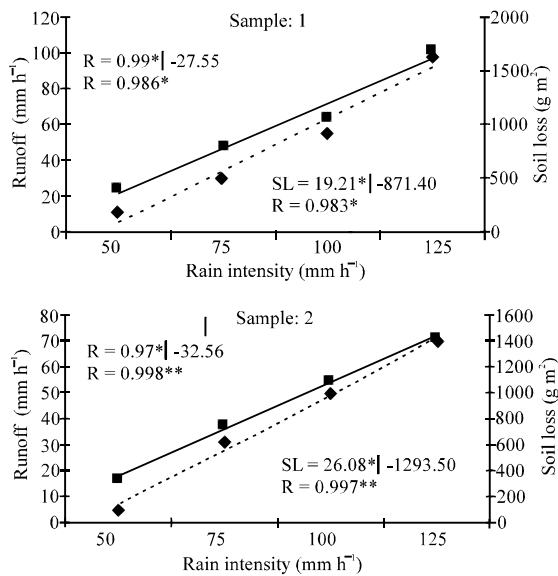


Fig. 1: 1st rain storm effects on runoff and soil loss (R: Runoff; SL: Soil loss)

According to Fig. 1, rain intensity effected on runoff and soil loss significantly in sample 1 ($R = 0.986^*$ and $R = 0.983^*$) ($p \leq 0.05$) but in sample: 2, its effected on runoff and soil loss significantly ($R = 0.998^{**}$ and $R = 0.997^{**}$) ($p \leq 0.01$). However 2nd rain storm had effected on runoff and soil loss in sample 1 ($R = 0.998^{**}$ and $R = 0.963^{**}$) significantly ($p \leq 0.01$) and its effected significantly ($p \leq 0.05$) on runoff in sample: 2 ($R = 0.986^*$) but it didn't effected on soil loss (Fig. 2). Magunda *et al.* (1997) found that rain storms had increased soil loss significantly. Increased kinetic energies had increased soil loss significantly (Mamedov *et al.*, 2000). According to other

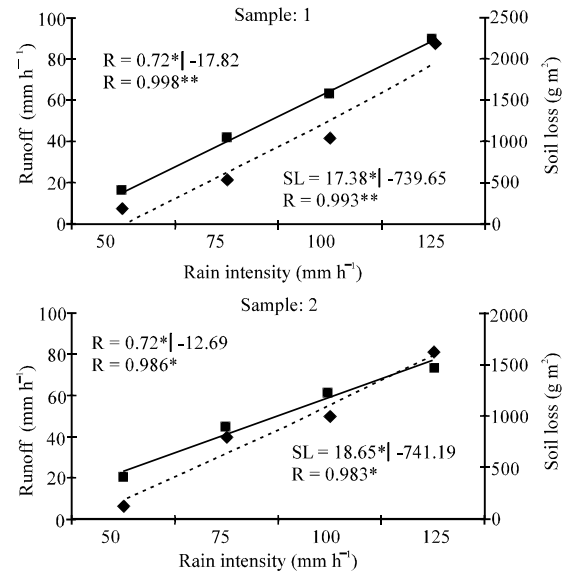


Fig. 2: 2nd Rain storms effects on runoff and soil loss (R: Runoff; SL: Soil loss)

study, rain intensity had significantly effect on soil loss (Zheng *et al.*, 2001).

Crusting effects on runoff and soil loss: Table 3 shown that effects of rain storms on crust strength. According to Table 3, increased rain intensity increased crust strength differently based on soil properties. The greatest crust strengths were taken in sample 2. In additional increased crust strengths increased runoff and soil loss both of soil samples (Table 1 and 2). It has been shown effects of crust strengths on runoff and soil loss at Fig. 3 and 4.

According to Fig. 3 and 4, crust strength increased significantly runoff ($R = 0.975^*$ and $R = 0.953^*$) ($p \leq 0.05$) but it didn't effect on soil loss in both of soil samples. In sample 2, runoff was significantly increased than sample 1 during 1st rain storm but contrary effects was observed 2nd rain storm. It has been found that crust strength had effect on runoff significantly ($p \leq 0.05$) as statistical (Ben-Hur, 1994; Levy and Rapp, 1999).

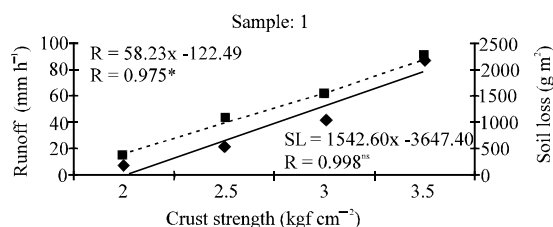


Fig. 3: Crust strengths effects on runoff and soil loss at sample 1

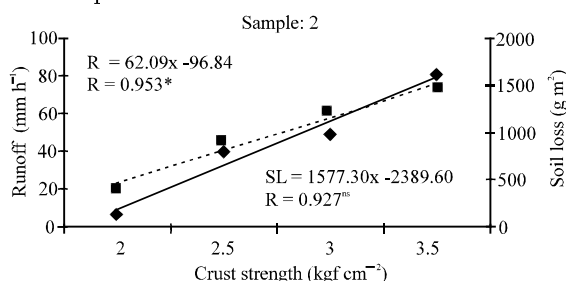


Fig. 4: Crust strength effects on runoff and soil loss at sample 2

CONCLUSIONS

In this study rainfall intensities effects on crust formation, runoff and soil loss and crusting effects on runoff and soil loss were investigated using a rain simulator under laboratory condition. Different rain intensities (50, 75, 100 and 125 mm h⁻¹) were applied on erosion plots (30×45×15 cm) placed soil samples (Sandy clayey loam and sandy loam). After applying rain storms erosion plots were waited under infrared lamps during 24 h crust strength was measured by a hand penetrometer. Than 2nd rain storms (at the same intensities) were applied on erosion plots again. Runoff and soil loss from before and after crust formation were evaluated by statistical. According to this results, it was found as follows: (i) rain intensities had effected on runoff, soil loss and crust formation, (ii) Also crust formation had effected on runoff significantly but no effected on soil loss.

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