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Full Length Research Paper

The relationships between soil erosion and crust strengths to polyvinylalcohol (PVA) applications on different types of soils in Menemen Plain, Turkey

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This study was carried out to determine the effect of polyvinylalcohol (PVA) on water erosion and crust strengths at different doses (0, 6.70 and 33.50 kg ha^{-1}) under laboratory conditions with two replications. The PVA solutions were sprayed on soil samples and two consecutive rain storms (65 mm h^{-1}) were applied on the experimental soils. Erosion plot was weighted under a platform that has 4 infrared lamps (250 W) at 16 h between two consecutive simulated rainfalls. The results showed that the PVA treatments decreased runoff and soil loss significantly in Typic Xerofluvent, soils in 1st and 2nd simulated rainfall, and Aquic Xeropsamment soils in the second rainfall applications.

Key words: Crust strength, rain simulator, runoff, soil loss, soil stabilizers.

INTRODUCTION

Soils, which are one of the most essential natural resources for humans, are quickly eroded by water and wind effects, and are unconsciously used by humans. Unfortunately, eroding of soils is impossible to recreate soils. After heavy rainfall, a hard layer (crust) is formed on the soil surface due to wind and sunshine effects. These layers have negative impact on agriculture systems in terms of crop production. Therefore, a number of measures are being developed to prevent the forma-tion of crust, and protection of agricultural lands. One of these measures is the use of a number of soil conditioners and polymers on soils.

The most important properties of these materials link soil particles to the land and protect soil against erosion by providing continuity to the regulation of the soil's structure (Haris et al., 1966; De Boodt, 1979). Polymers, for that purpose, have been used in the 1950's following World War II (Chepil, 1954). In some studies, it was found that polyvinylalcohol (PVA) affected crust strengths (Page and Quick, 1979). Barry et al. (1991) determined that the soil improvement materials increased the soil surface resistance from 1.5 to 5.5 times than the controls, whereas the applications of PVA in soil loss were 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 the controls. Zhang and Miller (1996) found that surface material treatments (64%), gypsum treatments (28%) and gypsum + surface material treatments (88%) reduced soil loss, respectively and these applications also reduced crust formation than the 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 (2006) found that polymers, applied at very low rates, prevented crust formation but increased runoff and soil loss. Shrestha et al. (2006) emphasized that the average moving sediments were reduced by 95% with some different polymers applications implemented on water, roads and ponds. Yönter (2010) sprayed polyvinylalcohol (PVA) and polyacrylamide (PAM) on 6 soils surfaces at different doses (0, 6.70, 13.40 and 26.80 kg ha^{-1}) in the erosion plots (30 x 30 x 14 cm; at a slope of 9%). The simulated rainfall (60 mm h^{-1}) was applied on erosion plots for 1 h. In this study, it was found that increases in PVA and PAM doses reduced runoff and

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Table 1. Means of soil samples in the 7th approximation soil classification system (Altınbaş et al., 1990; Soil Survey Staff, 1998).

Sample number	Mean of soil sample in the 7th approximation soil classification system
1	Typic Xerofluvent, loamy on sandy, mixed (calcerous), thermic
2	Typic Xerofluvent, clay on sandy, mixed (calcerous), thermic
3	Typic Xerofluvent, clay, mixed (calcerous), thermic
4	Typic Xerofluvent, loamy on clay, mixed (calcerous), thermic
5	Typic Xerofluvent, loamy, mixed (calcerous), thermic
6	Aquic Xerofluvent, clay, mixed (calcerous), thermic
7	Aquic Xerefluvent, loamy on sandy, mixed (calcerous), thermic
8	Aquic Xerofluvent, loamy, mixed (calcerous), thermic
9	Aeric Halaquept, loamy, mixed (calcerous), thermic
10	Aeric Halaquept, loamy on sandy, mixed (calcerous), thermic
11	Aquic Xeropsamment, mixed, thermic
12	Typic Xeropsamment, mixed, thermic

erosion by runoff and splash significantly ($p<0.05$ and 0.01). Many researches put forward have shown that there are significant relationships between soil erosion and crusting. Erpul and Çanga (1999) determined that consecutive rainfall applications increased runoff and soil loss, and decreased percolation by crusting significantly. Yönter (2006), in his study, applied two consecutive rainfalls at different intesities (50, 75, 100 and 125 mm h^{-1}) on soil samples and it was found that crust strengths were effective on runoff, and runoff was effective on soil loss significantly ($p \leq 0.05$).

Effects of soil conditioners on erosion and crusting were generally investigated in past studies. However, the objectivies of this study were to:

(1) Determine the effects of polyvinylalcohol (PVA) on runoff during the 1st and 2nd simulated rainfall.
(2) Determine the effects of PVA on soil loss during the 1st and 2nd simulated rainfall.
(3) Determine the effects of PVA on crust strengths.
(4) Compare effects of consecutive artificial rainfalls on runoff and soil loss.
(5) Determine the relationships between runoff, soil loss and crust strengths to PVA applications on soil surfaces under laboratory conditions in different soil types.

MATERIALS AND METHODS

The selection and preparation of soil samples

A total of 12 experimental soils of each soil family (Altinbaş et al., 1990; Soil Survey Staff, 1998), located in the Agriculture Faculty's Research Farm of Ege University in Menemen-Izmir-Turkey (latitudes 38°34'12.96"-38°35'17.00" N; longitudes 27°01'01.74"-27°02'40.19" E), based on soils spread areas, were used for the simulated rainfall experiment under laboratory conditions. Moreover, the soil's sample types are given Table 1. It seems that there are different soil types with 5 soil families (Typic Xerofluvent, Aquic Xerofluvent, Aeric Halaquept, Aquic Xeropsamment, and Typic Xeropsamment). In addition, polyvinylalcohol (PVA) was used in the simulated rainfall experiment as a soil conditioner and experimental material. Thus, soil samples were taken from an area in the Western Anatolia region of Turkey (Figure 1), where the Mediterranean climate prevailed with a long-term mean annual temperature of 17.9°C. Nonetheless, the long-term mean annual precipitation was 689.8 mm (DMI, 2009).

In this experiment, around 50 to 80 kg of 12 soil samples (0 to 30 cm) were taken and dried at normal atmospheric conditions in laboratory conditions. A part of the experimental soils that was air-dried passed through a 2 mm sieve (Richards 1954) in order for it to be used in some pysical and chemical analyses, while the other part of the experimental soils also passed through an 8 mm sieve for erosion research (Mollenhauer and Long, 1954; Byran, 1969). 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 organic content (Black, 1965) of the soil samples were analyzed. However, aggregate stabilities of the soil samples were analyzed by Yoder's Wetting Sieved Methods (U.S. Salinity Lab. Staff, 1954) and were calculated using Kempler's formula (Black, 1965).

Preparation and application of treatments

In this study, 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 by very coarse sand layers (5 cm) in this experiment, and these layers were smoothed with hand carefully. After a fine cloth (cheese cloth) was laid on the sand layer, erosion plots were filled by soil samples, which passed through an 8 mm sieve. In the following step, polyvinyalcohol (PVA: $[(-CH_2CH(OH)-]n)$ as hydrophilic polymers were weighted in doses of 1 and 5 g, then dissolved in 1000 mL of pure water at 65°C in a sand oven (Stefenson, 1973; Polyakasa, 1980). Different doses of PVA (6.70 and 33.50 kg ha^{-1}; 90 ml to the plots), and pure water of 90 mL for control were sprayed on the soil surfaces from a 30 cm height and these erosion plots were weighted under a platform, including 4x250 watt infrared lamps for 16 h.

Rainfall event simulation

In this experiment, a laboratory type of rain simulator (Veejet 80100

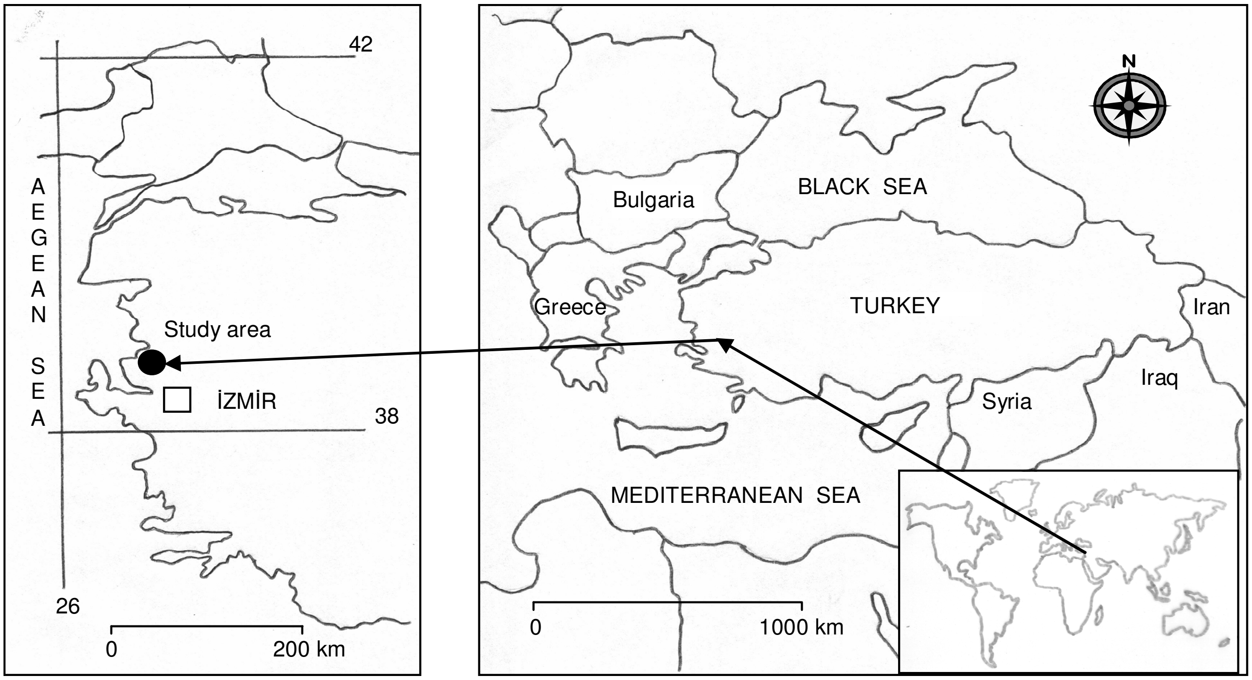

Figure 1. A map of location showing the areas where the experimental soils were taken from (Delibacak et al., 2009).

types nozzle) (Bubenzer and Meyer, 1965; Taysun, 1986) was used for simulated rainfall. After preparation and application of treatments, the 1st simulated rainfall (65 mm h^{-1}) was applied to erosion plots at 9% slope for 1 h from a height of 2.50 m (Bubenzer and Meyer, 1965). Then, runoff start times were measured by using a stopwatch before they were recorded (Taysun et al., 1984; Taysun, 1986). During the artificial rainfall experiments, runoff and sediment samples were taken for each 10 min. After simulated rainfall, these plots were again weighted under an infrared lamp platform at 24 h, and the crust strenghts 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, the 2nd simulated rainfall (65 mm h^{-1}) was applied on these plots. The same methods were used again to measure runoff and sediment. However, tap water (EC: 875 µmhos/cm; SAR: 2.50%) was used in this experiment.

The measurement of parameters and analysis of the data

At the end of the rainfall applications (1st and 2nd), the runoff containers were left for 24 h in order for the sediment to settle down in the containers. Then the sediment samples were dried in an oven at 105°C, after which the runoff and sediment amounts were recorded and tabulated (Taysun, 1986; Yönter and Uysal, 2007). A completely randomized experimental parcel, designed with 2 replications, was used for statistical analysis of the data. Data were analyzed by using an SPSS statistical package program (SPSS, 1999) in this experiment.

RESULTS AND DISCUSSION

Soil characteristics

Some pyhsical and chemical properties of soil samples in used the experiment are given in Table 2. The experimental soils have different physico-chemical properties. Differences in physical and chemical properties of soils affect soil erosion differently (Akalan, 1974; Taysun, 1989). As a known, dispersion rates and erosion rates are the most important indicates of soil erosion. In the experiment, dispersion rates varied from 32.59 to 47.74% in Typic Xerofluvent soils, varied from 24.81 to 49.92% in Aquic Xerofluvent soils, varied from 38.37 to 61.83% in Aeric Halaquept soils, and 20.89% and 35.53% were taken from Aquic Xeropsamment and Typic Xeropsamment soils, respectively. Erosion rates also varied from 47.12 to 94.77% in Typic Xerofluvent soils, varied from 70.39 to 94.01% in Aquic Xerofluvent soils, varied from 56.26 to 56.79% in Aeric Halaquept soils, and 87.53% and 72.48% were taken from Aquic Xeropsamment and Typic Xeropsamment soils, respectively (Table 2). It is considered that, soils have no resistance to erosion, when dispersion and erosion ratios are higher than 15 and 10%, respectively (Akalan 1974; Taysun 1989). However, aggregate stabilities were found to be very low in experimental soils. If the clay content is lower than 20% and silt content is lower than 12%, soils could become powder (Taysun, 1989). For this condition, aggregate stabilities of soil samples were found very low especially in Typic Xeropsamment soils. According to results, all of the soil samples in used this experiment have no resistance to erosion.

Runoff start times

Runoff start times, runoff, soil loss and crust strengths

Table 2. Some physical properties of soil samples in used experiment.

Soil Families	Sample No	pH	Total salt (%)	$CaCO_3$ (%)	OM (%)	Sand (%)	Silt (%)	Clay (%)	Texture	DR (%)	ER (%)	AS (%)
Typic Xerofluvent	1	7.60	0.049	6.37	1.72	46.92	46.00	7.08	L	38.37	94.77	5.07
	2	7.75	<0.030	4.42	1.60	73.92	21.00	5.08	SCL	32.59	62.23	5.61
	3	7.70	0.063	11.49	1.41	13.92	53.00	33.08	SiCL	37.40	47.12	14.17
	4	8.00	0.079	7.79	2.50	26.92	52.00	21.08	SiL	47.74	60.63	8.37
	5	7.70	<0.030	5.67	1.14	59.38	33.00	7.72	SL	44.20	74.70	4.92
Aquic Xerofluvent	6	7.60	0.052	6.90	1.28	53.28	34.00	12.72	L	49.78	81.14	10.25
	7	7.30	0.035	6.09	0.71	53.28	40.00	6.72	SL	24.81	94.01	9.30
	8	7.75	0.073	23.60	1.62	17.00	50.64	32.36	SiCL	49.92	70.39	3.50
Aeric Halaquept	9	7.95	0.210	6.98	1.28	38.56	45.00	16.44	L	38.37	56.79	3.07
	10	7.45	0.098	4.52	0.81	82.26	9.00	8.72	LS	61.83	56.26	2.79
Aquic Xeropsamment	11	7.80	<0.030	3.77	1.07	83.28	14.00	2.72	LS	20.89	87.53	7.30
Typic Xeropsamment	12	8.05	<0.030	4.68	0.90	77.28	16.00	6.72	LS	35.53	72.48	4.24

(OM: Organic matterial; DR: Dispersion ratio; ER: Erosion ratio; AS: Aggregate stability)

obtained from the experiment are given in Table 3, and the statistical test results of the experimental data are given in Table 4. In the 1st simulated rainfall, runoff start times from controls varied from 450 to 2025 second in Typic Xerofluvent soils. In Aquic Xerofluvent soils, it varied from 505 to 1030 second. In Aeric Halaquept soils, it varied from 255 to 960 second. In Aquic Xeropsamment and Typic Xeropsamment soils, runoff start times were obtained 1655 and 1365 second, respectively. In 2nd simulated rainfall, runoff start time from controls varied from 205 to 1185 second in Typic Xerofluvent soils, varied from 165 to 400 second in Aquic Xerofluvent, varied from 150 to 410 second in Aeric Halaquept soils, respectively. Runoff start time in the 2nd simulated rainfall measured 880 and 600 seconds in Aquic Xeropsamment and Typic Xeropsamment soils, respectively. During each of the rainfall applications, PVA (6.70 kg ha^{-1}) treatments delayed runoff start time in all soils when compared with controls. Also, PVA (33.50 kg ha^{-1}) treatments indicated same trends in the experiment. In the experiment, the effect of 33.50 kg ha^{-1} PVA on delaying runoff start time was better than the effect of 6.70 kg ha^{-1} PVA. The effects of PVA treatments on runoff start time were found to be statistically significant according to the LSD test ($p \leq 0.05$). From Table 4, it can be understood that during the 1st simulated rainfall, PVA treatments in Typic Xero-fluvent and Aquic Xerofluvent soils delayed runoff start time, while it delayed runoff start time in Typic Xero-fluvent and Aquic Xeropsamment soils during the 2nd simulated rainfall, significantly ($p \leq 0.01$; 0.05).

Fundamentally, runoff start time taken from this experiment in the 2nd simulated rainfall was earlier than the 1st simulated rainfall applications (Yönter, 2006). In some studies, it was found that polymers delayed runoff start time, thus runoff and soil erosion were reduced (Taysun, 1986; Wu et al., 2005).

Runoff

In the 1st simulated rainfall, runoff taken from control plots varied from 1.63 to 39.26 mm h-1 in Typic Xerofluvent soils, varied from 16.84 to 36.28 mm h-1 in Aquic Xerofluvent soils, varied from 27.31 to 37.47 mm h-1 in Aeric Halaquept soils, 7.45 and 14.49 mm h-1 of runoff were obtained from Aquic Xeropsamment and Typic Xeropsamment soils, respectively. During the 2nd simulated rainfall, runoff varied from 10.21 to 50.03 mm h-1 in Typic Xerofluvent soils, varied from 28.63 to 37.79 mm h-1 in Aquic Xerofluvent soils, varied from 32.80 to 51.67 mm h-1 in Aeric Halaquept soils, 16.81 and 24.24 mm h-1 of runoff were obtained from Aquic Xeropsamment and Typic Xeropsamment soils, respectively. PVA treatments decreased runoff in the1st simulated rainfall in soils compared with control, but increased runoff in soil no: 3 and 5 (Typic Xerofluvent), and PVA treatments in the 2nd simulated rainfall increased runoff in Typic Xerofluvent soils (soil no: 3, 5), Aquic Xerofluvent soils (soil no: 8), in Aquic Xerepsamment and in Typic Xerepsamment soils (soil no: 11 and 12). PVA treatments on runoff were found to be statistically significant according to the LSD test ($p \leq 0.05$). From Table 4, it can be seen that PVA treatments were found to be very effective on reducing runoff in Typic Xerofluvent, Aquic Xerofluvent and Typic Xeropsamment soils in each of the two simulated rainfall, significantly ($p \leq 0.01$; 0.05).

According to these findings, it is understood that runoff increased in the 2nd simulated rainfall than in the 1st simulated rainfall (Yönter, 2006). Runoff, based on land slope, detaches the soil particles. Polymers applied on soil surfaces decrease runoff effects, therefore polymers are used commonly to reduce runoff hazards. In the experiment, the effect of 33.50 kg ha^{-1} PVA on decreasing runoff is better than the effect of 6.70 kg ha^{-1} PVA. These findings from the experiment are similar to

Table 3. Mean runoff start times, runoff, soil loss, and crust strengths taken from plots treated with PVA and LSD tests results.

Sample No	Treatments (kg ha^{-1})	1st simulated rainfall			Crust strength (kgf cm^{-2})	2nd simulated rainfall		
		Start time (sec)	**Runoff (mm h^{-1})**	**Soil loss (g m^{-2})**		**Start time (sec)**	**Runoff (mm h^{-1})**	**Soil loss (g m^{-2})**
	0	1320b	19.44a	292.00a	1.48a	235b	37.82a	582.60a
1	6.70	1410b	12.99b	121.55b	1.25b	525a	27.84b	158.66b
	33.50	2420a	2.84c	51.40c	1.09b	315b	19.19c	67.90c
LSD (0.05)		**159.567**	**0.766**	**13.126**	**0.184**	**80.090**	**0.496**	**1.187**
	0	925b	21.41a	194.08a	0.97a	420b	37.31a	399.33a
2	6.70	1655a	11.57b	89.93b	0.97a	435b	31.66b	296.81b
	33.50	1695a	11.44b	88.07c	0.97a	840a	22.66c	118.59c
LSD (0.05)		**56.273**	**0.504**	**1.033**	**0.100**	**45.007**	**0.711**	**0.590**
	0	450c	39.26b	827.70a	1.60a	205c	50.03b	1420.75a
3	6.70	525b	47.75a	651.64b	1.50a	340b	55.93a	1147.77b
	33.50	835a	29.58c	138.67c	1.30b	420a	38.42c	334.59c
LSD (0.05)		**31.718**	**0.612**	**0.927**	**0.191**	**60.939**	**0.505**	**0.946**
	0	600c	37.52a	458.74a	1.33a	240a	46.84a	678.45a
4	6.70	950b	28.10b	213.56b	1.32a	303a	42.54b	659.56b
	33.50	1415a	10.31c	58.88c	1.30a	490b	34.34c	349.62c
LSD (0.05)		**190.947**	**1.015**	**2.564**	**0.073**	**95.438**	**0.741**	**0.888**
	0	2025a	1.63ab	27.19b	1.40a	1185c	10.21b	190.75a
5	6.70	1660a	3.89a	36.07a	1.50a	1380b	11.62a	81.40b
	33.50	-	-	-	1.50a	2550a	0.48c	0.22c
LSD (0.05)		**401.804**	**3.357**	**2.049**	**0.050**	**39.918**	**0.378**	**0.652**
	0	825b	22.36a	277.63a	0.98a	165b	33.87a	444.53a
6	6.70	2685a	3.11b	14.45b	1.08a	600a	19.48b	135.41b
	33.50	-	-	-	1.05a	-	-	-
LSD (0.05)		**381.185**	**5.035**	**12.864**	**0.257**	**323.945**	**2.164**	**1.348**
	0	1030b	16.84a	187.11a	3.25a	400c	28.63a	251.70a
7	6.70	2520a	0.93b	3.34b	3.15a	660b	11.70c	67.49b
	33.50	2550a	1.63b	3.37b	2.25b	825a	21.84b	32.96c
LSD (0.05)		**160.180**	**1.932**	**0.895**	**0.225**	**91.869**	**0.883**	**1.951**
	0	505b	36.28a	536.23b	2.60a	203b	37.79c	719.91c
8	6.70	1045a	30.09b	676.00a	2.75a	205b	40.32b	1036.96a
	33.50	1140a	25.21c	192.74c	2.70a	505a	43.02a	871.03b
LSD (0.05)		**114.007**	**0.828**	**1.321**	**0.291**	**18.374**	**0.213**	**0.618**
	0	255c	37.47a	549.63a	1.68a	150b	51.67a	1232.68a
9	6.70	530b	34.54b	417.90b	1.67a	300a	39.80c	762.28c
	33.50	870a	34.66b	237.11c	1.69a	300a	49.63b	989.56b
LSD (0.05)		**80.090**	**0.648**	**1.448**	**0.140**	**63.649**	**0.655**	**4.763**
	0	960c	27.31a	330.82a	1.50b	410c	32.80a	427.25a
10	6.70	1460b	18.96b	159.55b	1.75a	755b	26.80b	233.12b
	33.50	1585a	11.49c	16.96c	1.67ab	855a	22.68c	113.70c
LSD (0.05)		**90.013**	**0.987**	**0.807**	**0.191**	**63.649**	**0.607**	**0.633**
	0	1655b	7.45a	112.96a	1.50a	880c	16.81b	224.14a
11	6.70	3120a	0.43b	0.07b	1.25b	1225b	20.33a	193.85b
	33.50	-	-	-	1.20b	2475a	0.67c	0.14c
LSD (0.05)		**767.645**	**2.301**	**2.343**	**0.130**	**45.007**	**0.156**	**0.407**
	0	1365b	14.49a	342.07a	1.35b	600c	24.24b	380.15c
12	6.70	1800a	6.45c	85.71c	2.15a	679b	29.39a	586.56a
	33.50	1650c	9.40b	139.70b	2.00a	820a	23.18c	407.71b
LSD (0.05)		**64.691**	**0.466**	**0.663**	**0.184**	**48.194**	**0.556**	**0.318**

Table 4. Correlation coefficients of PVA treatments on soil types.

Soil Types	RST(1)	R(1)	SL(1)	CS	RST(2)	R(2)	SL(2)
Typic Xerofluvent	-	-0.384*	-0.482*	-	-	-0.382*	-0.491**
Aeric Xerofluvent	-	-	-	-	-	-	-
Aeric Halaquept	-	-	-0.703*	-	-	-	-
Aquic Xeropsamment	-	-	-	-	0.999**	-0.936**	-0.998**
Typic Xeropsamment	-	-	-	-	0.978**	-	-

(RST: Runoff start time, R: Runoff, SL: Soil loss, CS: Crust strength, (1): 1st simulated rainfall, (2): 2nd simulated rainfall, **: 0.01, *: 0.05).

those of some researches (Zhang and Miller, 1996; Teo et al., 2001; Takuma et al., 2003).

Soil loss

It is seen that soil loss in the 1st simulated rainfall varied from 27.19 to 827.70 g m-2 in Typic Xerofluvent soils, varied from 187.11 to 536.23 g m-2 in Aquic Xerofluvent soils, varied from 330.82 to 549.63 g m-2 in Aeric Halaquept soils. 112.96 g m-2 and 342.07 g m-2 of soil loss was taken from Aquic Xeropsamment and Typic Xeropsamment soils. During the 2nd simulated rainfall, soil loss varied from 170.75 to 1420.75 g m-2 in Typic Xerofluvent soils, varied from 251.70 to 719.91 g m-2 in Aquic Xerofluvent soils, varied from 427.25 to 1232.68 g m-2 in Aeric Halaquept soils. 224.14 g m-2 and 380.15 g m-2 of soil loss was taken from Aquic Xeropsamment and Typic Xeropsamment soils. During the 1st simulated rainfall, PVA treatments increased soil loss in Typic Xerefluvent (soil no: 5) and Aquic Xerefluvent soils (soil no: 8), whereas during the 2nd simulated rainfall, soil loss were found higher in Aquic Xerofluvent soils (soil no: 8) and Typic Xerepsamment soils (soil no: 12) compared with controls. Generally, increase in PVA treatments was found to be effective on reducing soil loss in each of the two rainfalls significantly ($p \leq 0.01$; 0.05) (Table 4). As a consequence, the effects of the PVA treatments on soil loss were found to be statistically significant according to the LSD test ($p \leq 0.05$).

Soil erosion has posed a serious threat to the national food production, the security of ecology and environment, and the socio-economic sustainable development in the future (Bian et al., 2009). Recently, polymers are being used to prevent soil loss, but in the experiment, the effect of 33.50 kg ha^{-1} PVA on the decreasing soil loss is better than the effect of 6.70 kg ha^{-1} PVA. These findings are similar to those of some researchers (Zhang and Miller, 1996; Teo et al., 2001; Takuma et al., 2003). The PVA treatments decrease runoff and soil loss, owing to the increased macro aggregates and aggregate stabilities of soils (Uysal et al., 1996). However, runoff and soil loss from soil samples in each experiment did not show decreasing trends. The experimental soils in the same soil families have different physico-chemical properties, whereas they might be collected from the same region; thus, these soils affected soil erosion, very differently. Similar findings are also observed by some researchers (Barry et al., 1991; Shrestha et al., 2006; Yönter, 2010).

Crust strengths

In this study, the crust strengths measured from soil surfaces varied from 0.97 to 1.60 kgf cm-2 in Typic Xerofluvent soils, varied from 0.98 to 3.25 kgf cm-2 in Aquic Xerofluvent soils, varied from 1.50 to 1.68 kgf cm-2 in Aeric Halaquept soils. In Aquic Xeropsamment and Typic Xeropsamment soils, 1.50 and 1.35 kgf cm-2 of crust strengths were measued, respectively. From Table 3, it can be seen that PVA (6.70 and 33.50 kg ha-1) reduced crust strengths in Typic Xerofluvent soils (soil no: 1, 2, 3, and 4), in Aquic Xerofluvent soils (soil no: 7), and in Aquic Xeropsamment (soil no: 11), but PVA applications didn't reduce crust strengths in some soil samples (Typic Xerofluvent soils no: 5, Aquic Xerofluvent soils no: 6 and 8, Aeric Halaquept soils no: 9 and 10, Typic Xeropsamment soils no: 12). The effects of the PVA treatments on crust strengths were found to be statistically significant according to the LSD test ($p \leq 0.05$). In addition, PVA treatments were found to be significantly reducing crust strengths only in Aquic Xeropsamment soils ($p \leq 0.01$).

In some studies, it was found that polymers decreased crust strengths (Zhang and Miller, 1996; Ben, 2006), but in some other studies, it was found that polymers increased crust strengths (Page and Quick, 1979; Barry et al., 1991; Borselli et al., 1996) when compared with controls. It was emphasized that crust formation increased runoff and soil loss in some studies (Zhang and Miller, 1996; Erpul and Çanga, 1999; Teo et al., 2001).

Conclusions

As it is known, soil erosion is a threat to our soils; therefore, some measures should be taken to minimize erosion hazards. One of these measures is the use of a number of soil conditioners and polymers on soils. In this experiment, the results of this study indicate that:

(1) The PVA applications with very low doses on soil are found to be the most effective in minimizing soil erosion by water as runoff, soil loss and crust strengths.
(2) Runoff and soil loss taken from the 2nd simulated rainfall applications were higher than the 1st simulated rainfall.
(3) Crust strengths increase runoff and soil loss.
(3) The effect of 33.50 kg ha^{-1} PVA on decreasing runoff, soil loss and crust formation is better than the effect of 6.70 kg ha^{-1} PVA.
(4) Soil types affect soil erosion.
(5) The best performance of PVA applications in runoff and soil loss can be seen in Typic Xerofluvent, (in the each of rainfall simulations), in Aeric Halaquept (at the 1st simulated rainfall for soil loss), in Aquic Xeropsamment (at 2nd simulated rainfall for runoff start time, runoff and soil loss), and in Typic Xeropsamment (at 2nd simulated rainfall for runoff start time) soils. In the study, no performance of PVA applications on crust strengths was taken in the experimental soils. For this reason, polymers solutions can be used for reducing soil erosion.

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