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Effects of Liquated Humic Substances on Runoff, Soil Losses by Runoff and by Splash under Artificial Rainfall Conditions

Sıvılaştırılmış Hümik Maddenin Yapay Yağış Koşulları Altında Yüzey Akış, Yüzey Akış ve Sıçrama ile Oluşan Toprak Kayıpları Üzerine Etkileri

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Key Words:

Humic substance, runoff, soil loss, splash loss, artificial rainfall

ABSTRACT

Soil, one of the most important natural resources, is lost by water and wind erosion. Addition of organic materials into the soils is commonly used for reducing soil and water losses. In this study liquated humic substances were applied at different doses (0, 5, 10, 20 and 40 ml l^{-1}) to investigate its effects on runoff and soil losses caused by runoff and splash under artificial rainfall conditions on soil surface. Liquated humic substances were sprayed by a hand type pomp uniformly on the surface of the soil samples in the erosion pans (30 x 30 x 15 cm; at a slope of 9 %) and then simulated rainfall (40 mm h^{-1}) was applied to these pans for 1 hour. The results indicated that, increases in humic substances doses reduced runoff (24-45 %), soil losses by runoff (7-97 %) and by splash (3-37 %), significantly (P < 0.01).

Anahtar Sözcükler:

Hümik madde, yüzey akış, toprak kaybı, sıçrama kaybı, yapay yağış

ÖZET

En önemli doğal kaynaklardan olan toprak, su ve rüzgâr erozyonuyla kaybolmaktadır. Toprak kayıplarını azaltmak için topraklara çeşitli organik materyaller ilave edilmektedir. Bu çalışmada, yüzey akış, yüzey akış ve sıçrama ile oluşan toprak kayıpları üzerine hümik maddelerin etkilerini incelemek için toprak yüzeyine yapay yağış koşullarında altında farklı dozlarda (0, 5, 10, 20 ve 40 ml l^{-1}) sıvılaştırılmış humik maddeler uygulanmıştır. Sıvılaştırılmış humik maddeler, erozyon kapları içinde (30 x 30 x 15 cm; % 9 eğimli) bulunan toprak yüzeyine yeknesak olarak bir el pompasıyla püskürtülmüş ve daha sonra 1 saat yapay yağış (40 mm h^{-1}) uygulanmıştır. Araştırma sonuçları; sıvılaştırılmış humik madde dozlarındaki artışların, yüzey akışı (% 24-45), yüzey akış (% 7-97) ve sıçramayla (% 3-37) oluşan toprak kayıplarını önemli düzeylerde azalttığını göstermiştir (P < 0.01).

INTRODUCTION

Erosion is not only the transport of detached soils in simple terms; it is also a very complex mechanical function in nature. Thus, soil erosion has posed a serious threat to the national food production, the security of ecology and environment, and socio economic sustainable development in the future (Bian et al., 2009). Soils are eroded not only by runoff but also by raindrop splash (Taysun, 1989). For the protecting soils, against water erosion, various types of organic materials (plant wastes, paper mill wastes, tobacco wastes, etc.) are commonly applied to soil. Organic materials on soil surface protect soil from erosion and organic materials improve soils structure, and increase fertility (Akalan, 1974).

Splash erosion and physical characteristics of splash have been examined in some recent studies. Barcelonna and Rienzi (2003) applied artificial rainfall (57 mm h^{-1}; 1.340 j m^{-2}) on soil samples obtained from pastures and from trays with conventional tillage (clay loam Typic Argiudoll). The researchers reported that runoff decreased while splash increased during the experiment, respectively. Frauenfeld and Truman (2004) applied artificial rainfall (57 mm h^{-1}) to the trays for 70 minutes. Runoff (R), soil loss (E), splash water (Sw) and splash sediment (Ss) values were measured at intervals of 5 minutes. The highest r^2 values were found between R and E (r^2=0.98-0.99) and between Ss and E (r^2=0.28-0.81) in this study. Kehl et al., (2005) tested the characteristics of the tilled soils under laboratory and land conditions by applying simulated rainfall. According to the results, relationships were found between the different results of aggregate stability and organic matter content whereas, no relationships could be found between splash and the parameters of soil loss. Teo et al. (2006) applied artificial rainfall at various intensities (5 to 8.5 cm h^{-1}) on soil samples, where they applied doses of PAM both as dry and as solutions at various rates under laboratory conditions. The researchers found that, PAM was very effective and significantly reduced runoff sediment and splash sediment. Bhattacharyya et al., (2008) found that Borassus mats on bare soil significantly (P<0.05) reduced soil splash height by 31% and splash erosion by 50% under natural rainfall conditions. In another study, it was found that Borassus mat-cover on bare soil significantly (P<0.05) reduced total soil splash erosion by 90% compared with bare plots under natural rainfall conditions (Bhattacharyya et al., 2009). Yönter (2010) sprayed PVA and PAM (0, 6.70, 13.40 and 26.80 kg ha^{-1}) on 6 soils, which have different physical and chemical properties into the splash erosion pans (30x30x15 cm sized and at a slope of 9%) and applied artificial rainfall (60 mm h^{-1}) for a 1 hour. Author reported that increases in PVA and PAM doses reduced runoff, soil loss by runoff and by splash, significantly and respectively (p<0.05 and 0.01). Gholomi et al, (2012) determine the efficiency of straw mulch, applied at a rate of 0.5 g m^{-2} in changing the runoff commencement time, runoff amount, splash erosion, and sediment yield from eroded mid-sized plots at different rainfall intensities under laboratory conditions and they used simulated rainfall intensities of 30, 50, 70, and 90 mm h^{-1} and a slope of 30% in three replicates. The results of the research also showed that the straw mulch had a significant effect in changing runoff and soil erosion characteristics at a confidence level of 99%. The maximum increase in runoff commencement time (110.10%) was observed for the rainfall intensity of 90 mm h^{-1}. The runoff coefficient had a maximum reduction at rainfall intensities of 30 and 90 mm h^{-1}. The maximum decrease in sediment yield (63.24%) also occurred at the rainfall intensity of 90 mm h^{-1}. Liu et al., (2015) applied different intensities rainfalls (85, 95, 110 and 125 mm h^{-1}) on saline-sodic soil (at a slope of 6 degrees, 11 degrees, 22 degrees and 35 degrees). Researchers emphasized that the effects of slope gradient and rainfall intensity on sediment losses, runoff and splash were interconnected. Vaezi et al., (2017) applied simulated rainfalls of 10, 20, 30, 40, 50, 60 and 70 mm h^{-1} on 42 micro plots (1x1.4 m; at a slope of 10%). It was found that at the lower rainfall intensities (20-30 mm h^{-1}), raindrop impact was the dominant factor controlling soil loss from the plots (68%) while at the higher rainfall intensities (40-70 mm h^{-1}) soil loss was mostly affected by increasing runoff.

In recent years, some researchers have been different kinds of organic and humic substances for preventing soil erosion. Mbagwu and Piccolo (1989) applied liquated humic substances (0, 0.1, 1 and 10 g kg^{-1}) on soils which have different physical and chemical properties. They reported that liquated humic substances increased soils aggregate stabilities by 40-141%, significantly (p<0.05). In other study, it was found that the applied humic substances (100 and 200 kg ha^{-1}) on Mediterranean soils reduced soil erosion by 40% (Piccolo and Mbagwu, 1997). Piccolo et al., (1997) applied liquated humic substances (0, 3, 6, 30 and 60 gl^{-1}) on soils which placed into the erosion pans (2x0.5x0.01 m; at a slope of 15%) and applied rainfall simulation of 40 mm h^{-1}. The results indicated that humic substances decreased soil loss by 36 %, significantly (p=0.05). Brandsma et al., (1999) reported that the applied soil conditioners (Agri-SC, Soil-Tex, humus, Kiwi-Green) on a loamy sand soil reduced soil erodibility. Margherita et al., (2006) examined that 25 kg m^{-2} of fresh waste water sludge, composted waste water sludge and fresh waste water sludge + humic substances on Xeric Torriorthent soils at a slope of 15 %. They found that these applications increased aggregate stabilities of soils and decreased soil erosion. Tejade and Gonzalez (2006) applied 10000 kg ha^{-1} of 4 organic materials (cotton gin, olive oil extraction, sewage sludge and organic municipal solid) on Typic Xerofluvent soil and applied 60 and 140 mm h^{-1} of artificial rainfall for 45 minutes with a rainfall simulator. According to the study, organic materials reduced soil loss by 30-33 % in 60 mm h^{-1} and by 19-25 % in 140 mm h^{-1}, respectively. Ritchey et al., (2012) gave 20 kg ha^{-1} of PAM, 0.3 kg ha^{-1} of ammonium laureate sulfate, 5 kg ha^{-1} of liquated humic substance and 5 kg ha^{-1} of gypsum on prepared parcels (1x1 m sized). Authors reported that liquated humic substance decreased runoff by 51 % and soil loss by 37 %, respectively. Sadeghi et al., (2015) applied on erosion treatments to determine efficiency of straw mulch, manure and TA-200 polyacrylamide with respective rates of 50, 300 and 500 g m^{-2} in changing sediment concentration and soil loss. The experiments were performed under laboratory conditions with simulated rainfall intensities of 30, 50, 70 and 90mm h^{-1} and a slope of 30 %. The results showed that the straw mulch decreased soil erosion at rate of

45.60% compared to the control plots and performed better than manure (8.98% reduction) and PAM (4.74% reduction). The results showed that the maximum reduction in sediment concentration and soil loss for all soil amendments occurred at the rainfall intensity of 90mm h^{-1} with the rates of 58.69 and 63.24% for straw mulch, 14.65 and 13.14% for manure and 20.15 and 23.44% for TA-200. Yönter and Uysal (2017) sprayed liquated humic substances (0, 5, 10, 20 and 40 ml l^{-1}) on 4 soils, which have different physical and chemical properties into erosion pans (30x45x14 cm sized and at a slope of 9%) and applied artificial rainfall (40 mm h^{-1}) for a 1 hour. Authors reported that liquated humic substances reduced runoff and soil loss, and increased drained water amounts, significantly ($p<0.01$).

The objective of this research was to determine the effects of liquated humic substances at different rates on runoff, soil loss by runoff and by splash using a rain simulator under laboratory conditions.

MATERIAL and METHODS

Soil sampling and analyses

In this study, a surface soil sample (0-30 cm) taken from Bornova plain was used. 3 bags of soil samples (about each of 50 kg) were taken and dried under laboratory condition. A small portion of soil samples were passed through 2 mm sieve for determining soil's physical and chemical properties (Richards, 1954), and the rest was passed through 8 mm sieve for using in erosion experiment (Mollenhauer and Long, 1964). Skeleton (Anonymous, 1993), bulk density (Hunt and Gilkes, 1992), texture (Gee and Bauder, 1986), clay and silt rates (%) (Neal, 1938), dispersion rate (%) (Middleton, 1930), percolation rate (%) (Lal, 1988), erosion rate (%) (Akalan, 1967), pH (Pansu and Gautheyroux, 2006), soluble salts (%) (Anonymous, 1993), lime (%) (Nelson, 1982) and organic material content (%) (Nelson and Sommers, 1982) were analyzed. In addition, aggregate stability of soil samples was determined using Yoder type wet sieving methods analysis (Kemper and Rosenau, 1986).

Experimental treatments

The 7 cm coarse gravel (1-16 mm diameter) was placed into erosion pans (30x30x15 cm sized and at a slope of 9%). These type erosion pans were used also some researchers (Çetin, 1992; Erpul and Çanga, 1999; Yönter, 2010; Özdemir et al., 2017). After laying a permeable clothe on the coarse gravel layer, soil samples sieved from the 8 mm were placed into erosion pans. To determine the effects of liquated humic substances on runoff, soil loss by runoff and by splash, the liquated humic substances were used in this study. These substances were obtained from liquated humic material produced from leonardite by a company that produces chicken feed. After liquated humic substances were weighted in doses of 0, 5, 10, 20 and 40 g, it's mixed in 1000 ml of pure water (Yönter and Uysal, 2017). Different doses of (0, 5, 10, 20 and 40 ml l^{-1}; 100 ml) liquated humic substances were sprayed by a hand type pump on the soil surface from a 50 cm height and the erosion pans were left for 48 hours to dry soil surface under laboratory conditions. In the following step, to measure the splash sediments, a total of 24 splash containers (diameter = 14.5 cm) were placed on each side and direction of the erosion pans and container (diameter = 14.5 cm) was placed under the platform (at a slope of 9%), where the erosion pan was placed, in such a way that it would be protected from raindrops in order to measure runoff and runoff sediment and this container was connected to the erosion pan by a plastic pipe. Thus, runoff sediment and splash sediment could be measured at the same time during the experiment (Figure 1).

Figure 1. The experiment design and a rain simulator from left to right direction.

Artificial rainfall experiments

In this study, 40 mm h^{-1} of artificial rainfall which is similar to the erosive rainfall intensity commonly occurs in the Mediterranean region (Zanchi and Torri, 1980), was applied from 2.50 m height during 1 hour (Taysun, 1986; Yönter, 2010; Yönter and Uysal, 2017) using a laboratory type rainfall simulator (Bubenzer and Meyer, 1965). The State of Meteorological Services, reported the highest rainfall intensities in 2010 year as 43 mm and 34.2 mm between 18^{00} to 19^{00} and 19^{00} to 20^{00} hours in Menemen, respectively (DMİ, 2013). Tap water was used (EC: 875µS/cm; SAR: 2.50 %) in the experiment.

Parameter measurement and analysis of the data

Containers were left for 48 hours for settlement of sediment within the containers and then runoff was flushed down by a plastic pipe to the cups and 0.01 was weighed on a precision balance and then recorded. After being transferred to the glass beaker, sediments by runoff and by splash were dried at 105 ^{0}C and recorded (Taysun, 1986; Yönter and Uysal, 2007; Yönter, 2010). A completely randomized experimental design with two replications was used for statistical analysis of the data. Data were analyzed by using an SPSS statistical package program (Anonymous 1999) in this experiment.

RESULTS and DISCUSSION

Physical and chemical properties of liquated humic substance and soil sample used in the experiment are given in Tables 1 and 2. According to soil analyzes in this experiment, skeleton percent of soil sample was found 9.76 and classified as “fewer”. Skeleton material in the soil keeps the soil surface from raindrop erosion by breaking the kinetic energy of the rainfall. (Taysun, 1986; Yönter and Taysun, 2004). Bulk density was found 1.35 g cm^{-3}. Clay rate was found 3.14 %. Increasing clay rates shows that sand + silt percent’s increases, while clay percent decreases, therefore, it’s indicates the susceptibility to erosion of the soils (Taysun, 1989). Silt rate was found 1.60 %. It is considered that silt rates of soils, which are greater than 2.50 %, are not susceptible to erosion (Taysun, 1989). Suspension percent was found 10.72 %, and dispersion percent was found 58.72 %, which are the most important indicators of erosion in soils. Taysun (1989) reported that low suspension and low dispersion fractions show good aggregation, thus soils with these properties is resistant to erosion.

Table 1. Some physical and chemical properties of the experimental soil.

pH	7.62
Soluble Salts (%)	0.044
Lime content (%)	18.38
Organic Matter (%)	2.13
Sand (%)	37.12
Silt (%)	38.72
Clay (%)	24.16
Textural Class	Loam
Bulk Density (g cm^{-3})	1.35
Clay Rate (%)	3.14
Silt Rate (%)	1.60
Suspension (%)	10.72
Dispersion (%)	58.72
Dispersion Rate (%)	18.26
Erosion Rate (%)	18.06
Skeleton (%)	9.76
Aggregate Stability (%)	32.96

Table 2. Chemical properties of liquated humic substance.

Parameters	Liquated humic substance
pH	9.06
Total organic matter (%)	5.00
Total (Humic + Fulvic) Acid (%)	15.00
Soluble K_2O (%)	1.00

Dispersion rate was calculated 18.26 %. It is considered that if dispersion rate in soils greater than 15 %, and erosion rate in soils greater than 10%, soils can be erodible, if not, soils can be resist. (Akalan, 1974; Taysun, 1989). In the study, aggregate stability was found 32.96 %. Since Bornova plain soil has high clay content, aggregate stability was also high. Soil reaction was measured 7.62 as slightly alkaline classes. Water soluble salt content of the experimental soil was measured 0.044 %, and showed no salinity. Lime content was measured 18.38 % as texture + marl. Organic matter content in the experiment soil was measured 2.13% as moderate humus classes (Schlichting und Blume, 1965). On the other hand, liquated humic substance was strong alkaline, containing high amounts of organic matter (Table 2). Runoff, soil losses by runoff and by splash are given in Table 3. According to Table 3, the highest runoff was measured from 5 ml l^{-1} of the humic substance treatments, whereas the lowest runoff was measured from 40 ml l^{-1} of the humic substance treatments compared with controls.

Also the highest soil loss by runoff was measured from 5 ml l^{-1} of the humic substance treatments, whereas the lowest soil loss by runoff was measured from 40 ml l^{-1} of the humic substances treatments compared with controls. Similarly to soil loss by runoff, the highest soil loss by splash was measured from 5 ml l^{-1} of the humic substance treatments, whereas the lowest soil loss by splash was measured from 40 ml l^{-1} of the humic substance treatments compared with controls, respectively. In briefly, the results indicated that, liquated humic substances reduced runoff (24 to 45 %) and soil losses by runoff (7 to 97 %) and by splash (3-37 %) as compared to the control, respectively. Our findings were agreed with the results reported by the others (Piccolo and Mbagwu, 1997; Piccolo et al., 1997; Tejade and Gonzalez, 2006; Bhattacharyya et al., 2008 and 2009; Ritchey et al., 2012; Sadeghi et al., 2015). Some researchers reported that organic amendments increased aggregate stabilities of soils and decreased soil erosion, significantly (Mbagwu and Piccolo, 1989; Margherita et al., 2006). Also, Yönter and Uysal (2017) reported that liquated humic substances reduced runoff and soil loss, and increased drained water amounts, significantly ($p<0.01$). Some researchers explained that humus is rapidly reacting with neutralized polyvalent cations (Ca^{+2}, Mg^{+2}, Al^{+3}) at the clay surface to form polyvalent metal clay complexes and reactive acidic groups are distributed over heterogeneous humic macromolecules and are stabilized by chelation of polyvalent cations to combine with clay particles (Greenland, 1977; Theng, 1982), since, these materials reduced runoff and soil losses. Liquated humic substances reduced runoff (R = -0.769**), soil loss by runoff (R = -0.901**), and by splash (R = -0.801**), significantly in the study (Table 4). Similar statistical results of this research were reported by some researchers (Piccolo and Mbagwu, 1997; Piccolo et al., 1997; Yönter, 2010; Yönter and Uysal., 2017). In addition, the highest R values were found between runoff and soil loss by runoff (R = 0.803**) and between soil loss by splash and soil loss by runoff (R = 0.769**). These findings were supported by some authors (Frauenfeld and Truman, 2004; Gholomi et al., 2012; Sadeghi et al., 2015; Vaezi et al., 2017).

Table 3. Runoff, soil losses by runoff and by splash.

Application Rate (ml l^{-1})	Runoff (mm h^{-1})			Soil loss by runoff (g m^{-2})			Soil loss by splash (g m^{-2})		
	1	2	Mean	1	2	Mean	1	2	Mean
0	17.44	14.84	16.14 b	26.56	24.11	25.34 c	88.55	116.10	102.33 c
5	10.85	13.63	12.24 ab	23.44	23.67	23.56 c	100.44	97.33	98.89 bc
10	10.84	11.99	11.42 a	9.11	13.44	11.28 b	102.99	82.66	92.83 abc
20	10.80	10.27	10.54 a	7.44	3.47	5.46 a	63.67	69.56	66.62 ab
40	10.68	7.00	8.84 a	0.22	1.11	0.67 a	56.55	73.00	64.78 a

[1: 1st replication; 2nd replication]

Table 4. Correlations between application rates, runoff, soil loss by runoff and soil loss by splash.

Correlations		Application rate	Runoff	Soil loss by runoff	Soil loss by splash
Application rate	R p N	1.000 10	-	-	-
Runoff	R p N	-0.769** 0.01 10	1.000 10	-	-
Soil loss by runoff	R p N	-0.901** 0.01 10	0.803** 0.01 10	1.000 10	-
Soil loss by splash	R p N	-0.801** 0.01 10	-	0.769** 0.01 10	1.000 10

(**:p<0.01; R:coefficient of correlation; p: significant level; N: number of samples)

CONCLUSION

The results of this study indicated that, liquated humic substances reduced runoff and soil loss by runoff and by splash, significantly. Spreading humic substances even at low application rate (20 ml l^{-1}) over the soil surface is an effective practice for controlling runoff and soil losses by runoff and by splash.

REFERENCES

Akalan, İ. 1967. Toprak Fiziksel Özellikleri ve Erozyon. Ankara Üniversitesi Ziraat Fakültesi Yıllığı, (3-4): 490-503.

Akalan, İ. 1974. Toprak ve Su Muhafazası. Ankara Üniversitesi Ziraat Fakültesi Yayın No: 532, Ankara.

Anonymous, 1993. Soil Survey Manual. United States of Department of Agricultural Handbook No: 18. United States Goverment Print Office, Washington.

Anonymous, 1999. SPSS 9 for Windows User's Guide. Copyright 1999 by SPSS Incoorparation SPSS, Chicago, IL.

Barcelonna, C. and E.A. Rienzi. 2003. Changes produced by cover surface on enrichment rate of sediment from a typic argiudoll. Revista de la Facultad de Agronomia (Universidad de Buenos Aires), 23 (2/3): 141-145.

Bhattacharyya, R, K. Davies, M.A. Fullen, A.C. Booth. 2008. Soil conservation using palm-mat geotextiles on loamy sand soils in the United Kingdom. *http://wlv.openrepository.com/wlv/.*

Bhattacharyya, R., M. A. Fullen, and K. Davies. 2009. Utilizing palm-leaf geotextile mats to conserve loamy sand soil in the United Kingdom, Agriculture, Ecosystems & Environment, 130 (1–2): 50-58.

Bian, H.F., L.X. Sheng, G. Yang and J. Jiang. 2009. The Degradation, Prevention and Treatment of Black Soil in Jilin Province. In: Lifeng X (ed), Proceedings of the 5th WSEAS International Conference on Mathematical Biology and Ecology, 10-12 January 2009, Ningbo, 33–38.

Brandsma, R.T., M.A. Fullen and T.C. Hocking. 1999. Soil conditioner effects on soil structure and erosion. Journal of Soil and Water Conservation, 54 (2): 485-489.

Bubenzer, G.D. and L.D. Meyer. 1965. Simulation of rainfall and soils for laboratory research. Transaction of American Society of Agricultural Engineers, 8: 73-75.

Çetin, T. 1992. Toprakların bazı özelliklerinin yana sıçrama kayıplarına (SSE=Side Splash Erosion) etkisi (Yüksek Lisans Tezi). Ege Üniveristesi Fen Bilimleri Enstitüsü, Bornova/İZMİR.

DMİ, 2013. T.C. Orman ve Su İşleri Bakanlığı Meteoroloji Genel Müdürlüğü. http:// www.meteoroloji.gov.tr/veridegerlendirme/il-ve-ilçeleristatistik.aspx. Erişim Tarihi: 23.06.2014.

Erpul, G and M.R. Çanga. 1999. Effect of subsequent simulated rainfalls on runoff and erosion. Turkish Journal of Agriculture and Forestry, 23: 659-665.

Frauenfeld B. and C. Truman. 2004. Variable rainfall intensity effects on runoff and interrill erosion form two coastal plain ultisols in Georgia. Soil Science, 169 (2): 143-154.

Gee, G.W. and J.V. Bauder. 1986. Particle Size Analysis, Methods of Soil Analysis. Part 1. Physical and Mineralogical Methods, 2nd Edition. No: 9, 383-411, Madison, Wisconsin, USA.

Gholami, L., S.H. Sadeghi and M. Homaee. 2012. Straw Mulching Effect on Splash Erosion, Runoff, and Sediment Yield from Eroded Plot, Soil Science Society of America Journal, 77 (1): 268-278.

Greenland, D.J. 1977. Interactions between humic and fulvic acids and clay. Soil Science, 111: 34-41.

Hunt, N. and R. Gilkes. 1992. Farm Monitoring Handbook. The University of Western Australia: Netherlands, WA.

Kelh M., C. Everding, J. Botschek and A. Skowronek. 2005. Erosion processes and erodibility of cultivated soils in North Rhine-Wesphalia under artificial rain. I. Site characteristics and results of laboratory experiments. Journal of Plant Nutrition and Soil Science, 168 (1): 34-44.

Kemper, W.D. and R.C. Rosenau. 1986. Aggregate Stability and Size Distribution. In A. Klute et al., Methods of Soil Analysis. Part 1. Physical and Minerological Methods, 425-442, 2nd Edition. Agronomy Monograph. Soil Science of America, Madison, USA.

Lal, R. 1988. Soil Erosion Research Methods. Soil and Water Conservation Society, Iowa.

Liu, D., D. She, S. Yu, G. Shao and D. Chen. 2015. Rainfall intensity and slope gradient effects on sediment losses and splash from a saline-sodic soil under coastal reclamation. Catena, 128: 54-62.

Margherita, E., G. Brunetti, C. Garcia-Izquierdo, F. Cavalcante, S. Fiore, N. Senesi. 2006. Humic substances and clay minerals in organically-amended semi-arid soils. Soil Science, 171 (4): 322-333.

Mbagwu, J.S.C. and A. Piccolo. 1989. Changes in soil aggregate stability induced by amendment with humic substances. Soil Technology, 2 (1): 49-57.

Middleton, H.E. 1930. Properties of Soil Which Influence Soil Erosion. United States of Department of Agricultural Technician Bulletin, No: 178.

Mollenhauer, W.C. and D.C. Long. 1964. Influence of rainfall energy on soil loss and infiltration rates: I. Effects over a range of texture. Soil Science of Society American Processing Book, 28: 813-817.

Neal, J.H. 1938. The Effect of The Degree of Slope and Rainfall Characteristics on Runoff and Soil Erosion. Agricultural of Experiments of Strategies Research Bulletin, No: 280.

Nelson, D.W. and L.E. Sommers. 1982. Total Carbon, Organic Carbon and Organic Matter. Methods of Soil Analysis. Part 2. Chemical and Microbiological Properties. 2nd Edition. No:9, 539-579, Madison, Wisconsin, USA.

Nelson, R.E. 1982. Carbonate and Gypsum. Methods of Soil Analysis. Part 2. 2nd Edition. No:9, 181-197, Madison, Wisconsin, USA.

Özdemir, N, E. Öztürk ve Ö.D. Kop. 2017. Organik düzenleyici uygulamalarının yapay yağış koşulları altında toprak kaybı üzerine etkileri. Anadolu Tarım Bilimleri Dergisi, 32 (1): 114-120.

Pansu, M. and J. Gautheyroux. 2006. Handbook of Soil Analysis: Mineralogical, Organic and Inorganic Methods. Springer Verlag, Berlin.

Piccolo, A. and J.S.C. Mbagwu. 1997. Exogenous humic substances as conditioners for the rehabilition of degraded soils. Agro Food Industry Hı-Technology, 8 (2): 2-4.

Piccolo, A., G. Pietramellara and J.SC. Mbagwu. 1997. Reduction in soil loss from erosion susceptible soils amended with humic substances from oxidized coal. Soil Technology, 10: 235-245.

Richards, L.A. 1954. Diognosis and Improvement of Saline and Alkali Soils. United States of Department of Agricultural Handbook 60. United States of Goverment Print Office, Washington.

Ritchey, K.D., L.D. Norton, A. Hass, J.M. Gonzalez and D.J. Snuffer. 2012. Effect of selected soil conditioners on soil properties, erosion, runoff and rye growth in nonfertile acid soil. Journal of Soil and Water Conservation, 67 (4): 264-274.

Sadeghi S. H. R., L. Gholami, M. Homaee and A. K. Darvishan. 2015. Reducing sediment concentration and soil loss using organic and inorganic amendments at plot scale, Solid Earth, 6, 445–455.

Schlichting, E. und H.P. Blume. 1965. Bodenkundliches Praktikum. Verlag Paul Parey In Hamburg und Berlin.

Taysun, A. 1986. Gediz Havzasında Rendzina Tarım Topraklarında Yapay Yağmurlayıcı Yardımıyla Taşlar, Bitki Artıkları ve Polivinilalkolün (PVA) Toprak Özellikleri ile Birlikte Erozyona Etkileri Üzerine Araştırmalar. Ege Üniversitesi Ziraat Fakültesi, Yayın No: 474.

Taysun, A. 1989. Toprak ve Su Korunumu. Ege Üniversitesi Ziraat Fakültesi, Teksir No: 92-III, Bornova.

Tejada, M. and J.L. Gonzalez. 2006. Effects of two beet vinase forms on soil physical properties and soil loss. Catena, 68 (1): 41-50.

Teo, J.A., C. Ray and S.A. EI-Swaf. 2006. Screening of polymers on selected Hawaii soils for erosion reduction and particle settling. Hydrological Processes, 20 (1): 109-125.

Theng, B.K.G. 1982. Clay-polymer interactions: Summary and perspectives. Clays ClayMiner, 30: 1-10.

Vaezi, A.R., M. Ahmadi and A. Cerda. 2017. Contribution of raindrop impact to the change of soil physical properties and water erosion under semi-arid rainfalls. Science of the Total Environment, 583: 382-392.

Yönter, G. ve A. Taysun. 2004. Farklı çaplardaki taş örtü oranlarının yapay yağmurlayıcı koşulları altında su erozyonuna etkisi, Ege Üniversitesi Ziraat Fakültesi Dergisi, 41(3): 185-196.

Yönter, G. ve H. Uysal. 2007. Menemen Uygulama Çiftliği Topraklarında Laboratuvar Koşulları Altında Uygulanan Polivinilalkol (PVA) ve Poliakrilamid'in (PAM) Su Erozyonu ve Kaymak Tabakası Dirençleri Üzerine Etkileri. Ege Üniversitesi Bilimsel Araştırma Proje Kesin Raporu, Proje No: 2005-ZRF-056.

Yönter, G. 2010. Effects of polyvinylalcohol (PVA) and polyacrylamide (PAM) as soil conditioners on erosion by runoff and by splash under laboratory conditions. EKOLOJİ, 19(77): 35-41.

Yönter, G. ve H. Uysal. 2014. Farklı Fiziksel ve Kimyasal Özelliklere Sahip Typic Xerofluvent Topraklara Uygulanan Doğal Katkı Maddelerinin Laboratuvar Koşullarında Yüzey Akış, Toprak Kaybı ve İnfiltrasyon Üzerine Etkileri. Ege Üniversitesi Bilimsel Araştırma Proje Kesin Raporu, Proje No: 2012-ZRF-017.

Yönter, G. ve H. Uysal. 2017. Farklı Fiziksel ve Kimyasal Özelliklere Sahip Topraklara Uygulanan Hümik Maddenin Laboratuvar Koşullarında Yüzey Akış, Toprak Kaybı ve Drene Olan Su Miktarları Üzerine Etkileri. Ege Üniversitesi Bilimsel Araştırma Proje Kesin Raporu, Proje No: 2015-ZRF-058.

Zanchi, C and D. Torri. 1980. Evaluation of rainfall energy in central Italy. In: M.De Boodt and D. Gabriels (Editors), Assessment of Erosion. John Wiley, London, pp. 133-142.