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RESEARCH PAPER

Effects of soil conditioner and humic acid applications on the development of some soil quality parameters

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Abstract

This study was conducted under greenhouse conditions in order to determine the effects of polyvinyl alcohol (PVA), polyacrylamide (PAM) and humic acid (HA) applications on the improvement of some soil quality (erosion ratio and coefficient of linear extensibility) parameters. Surface soil samples with three different textures (clay, loam and sandy loam) were used in the study. In the greenhouse, PVA, PAM and HA were applied to soil samples at doses of 500, 100 and 500 ppm, respectively, and incubated in four different periods (0, 15, 30 and 45 days). During the incubation, irrigation was performed when 50% of the available moisture in the soil samples was decreases. As a result of the analysis and evaluation made on the soil samples after the incubation, it was determined that PVA, PAM and HA applications reduced the erosion ratio and linear extensibility values in all three soil groups and that the conditioners were more effective in the soil in clay texture category. It was observed that the conditioners were ranked as PVA>PAM>HA in terms of the said effectiveness. It was observed that PVA's first period applications were more effective on erosion resistance and PVA's second period applications were more effective on coefficient of linear extensibility.

Introduction

The demands created by the increasing population and developing economies and the widespread use of inappropriate production techniques in agricultural systems cause degradation of soil quality, the emergence of certain environmental problems and a decrease in the crop production (Verhulst et al., 2010; Martinez-Blanco et al., 2011). Soil conservation has traditionally emphasized the processes involved in keeping soil in place for agricultural production (Blanco & Lal, 2008). Development of agricultural practices and management of soil resources should take into account land use models, cultivation practices, and consequences on the environment (Dickinson, 2015). Accelerated erosion caused mainly by human activities in nature is the most important factor of soil degradation. Erosion causes a decrease in yield in soils and the loss of soil's organic matter, clay content, plant nutrients, soil water, and fertile topsoil to be cultivated, and significantly restricts plant development (Özdemir, 2013).

Soils are subjected to shrinkage and expansion processes as a result of successive drying and wetting processes depending on their basic properties such as mechanical composition, clay content, clay type, and organic matter content. Cracks that occur due to swelling and shrinkage events cause damage to plant roots and young seedlings, negatively affect the water and air balance of the soil, increase moisture loss, decrease the effectiveness of irrigation water, and cause deterioration of the soil structure (Sönmez & Öztaş, 1988; Dengiz & Gürsoy, 2019). Therefore, revealing the swelling and shrinkage potentials of soils is very important in terms of applications related to soil management. In the studies conducted, it has been found that it is possible to apply organic polymers to improve the structural stability of the soil (Harris et al., 1966), and that artificial polymers can be used to improve the physical properties of soils in a short time (Levy, 1996). To this end, in recent years, studies on various soil stabilizers of organic origin such as polyvinyl alcohol (PVA), polyacrylamide (PAM) and humic acid (HA) have been intensified. Most of these studies show that the application of synthetic organic polymers and humic acid to the soil surface even at very low concentrations has positive effects on the structural properties of the soil (De Boodt, 1993; Sojka & Lentz, 1994; Zhao & Xu, 1995; Nadler et al., 1996; Imbufe et al., 2005; Gizgin, 2020; Civelek, 2021; Fahramand et.al., 2014).

Synthetic polymers are effective in increasing hydraulic conductivity and porosity, improving water-holding capacity (Shanmuganathan & Oades, 1982), and increasing resistance to erosion (Wood & Oster, 1985). In the studies conducted in this respect, polymers such as ammonium lauryl sulphate, liquefied humic substance (Ritchey et al., 2012), polyvinyl alcohol and polyacrylamide (Yılmaz & Uysal, 2010; Yönter, 2010) are focused on. (Cochrane et al., 2005) found that phosphogypsum (PG), polyacrylamide (PAM) and (PG + PAM) applications under simulated rainfall conditions significantly reduced soil losses in splash erosion, while Sinkpehoun and (Yönter, 2018) found that liquefied humic substance applications did the same thing. In their study, (Piccolo et al., 1997) reported that the application of humic acid to the soil reduced soil loss by 36% and increased aggregate stability and water-holding capacity.

The determination of the degrees of contribution or effect of the components affecting the swelling and shrinkage potential or the susceptibility to erosion in the soil is very important in terms of creating an ideal plant development medium, reducing water losses, controlling erosion, and planning an appropriate land management. This study was conducted to determine the effects of polyvinyl alcohol (PVA), polyacrylamide (PAM) and humic acid (HA) applications on the erosion ratio and coefficient of linear extensibility (COLE-bar) parameters for soils with clay (C), loam (L) and sandy loam (SL) texture.

Materials and Methods

The research was carried out on surface (0-20 cm) soil samples taken from Ondokuz Mayıs University Faculty of Agriculture, experiment area (41°36'-36°18' N) and Ondokuz Mayıs University, Bafra application field (41°55'-35°86'; 41°50'-35°82' E). In the greenhouse experiment, three different soil conditioners were used: humic acid, polyvinyl alcohol and polyacrylamide. As humic acid, commercially-available material containing 15% humic matter was used. Fluka-labeled material, which is insoluble in organic solvents and especially soluble in hot water, is used as polyvinylalcohol. As polyacrylamide, water-soluble PAM obtained from the company ACROS was used.

Surface soil samples taken from the land were dried in the shade and then passed through a 4.75-mm sieve (ASTM, 1974) and used in the experiment. Soil samples were weighed on the basis of their oven dried weights and transferred to 1-kg pots. PVA, PAM and HA were applied to the labelled pots at doses of 500, 100 and 500 ppm, respectively (Özdemir et. al., 2015; Yakupoğlu & Öztaş, 2016; Aksakal & Öztaş, 2010), by mixing PAM and HA with pure water, and by turning PVA into a solution at 80 ˚C in pure water. The study, which is based on four different periods (0, 15, 30, and 45 days), was set up on 30 September 2020 in the greenhouse of the Department of Soil Science and Plant Nutrition. During the experiment, irrigation was done when 50% of the available moisture in the soil was decreases. After the end of each period, soil samples were dried in the air and crushed by hand and made ready for analysis.

Soil texture was determined by Bouyoucos hydrometer method (Demiralay, 1993); soil reaction (pH) by pH meter in soil-water mixture of 1:2.5 (Kacar, 2016); electrical conductivity value by a glass-electrode electrical conductivity tool in soil-water mixture of 1:2.5 (Kacar, 2016); lime content of soils by Scheibler calcimeter method (Kacar, 2016); soil organic matter by Walkley-Black method (Kacar, 2016); field capacity (Demiralay, 1993); cation exchange capacity by Bower method (Kacar, 2016). The coefficient of linear extensibility values of the soils were determined from the change in the size of the rods with a diameter of approximately 1 cm and a length of 10 cm prepared with the help of a syringe after the soil samples were turned into paste (Schafer & Singer, 1976); erosion ratio values were determined using some physical analysis results of the soil (Özdemir, 2013).

Statistical evaluation of the data obtained as a result of the research was made using SPSS computer package program. Duncan test was used for multiple comparisons (IBM SPSS statistics 21.0).

Some of the physical and chemical properties of the soil samples used in the study conducted under greenhouse conditions, determined before the experiment, are given in Table 1.

As can be seen from the examination of this table, the soil sample (sample no. 1) taken from the Ondokuz Mayıs University Faculty of Agriculture experiment area is a soil with clay texture, neutral reaction, low lime and medium organic matter content; the soil sample taken from Ondokuz Mayıs University Bafra Application field (sample no. 2) is a soil with loamy texture, slightly-alkaline reaction, medium lime and high organic matter content; and the other soil sample taken from Ondokuz Mayıs University Bafra Application field (sample no. 3) is a soil with sandy loam texture, moderate alkaline reaction, moderate lime and low organic matter content. The pH values of the soils are below 8.5 and there is no alkalinity problem in the soils (Soil Survey Staff, 1993).

Table 1. Some of the physical and chemical properties of the soils used in the research

Sources	Degrees of freedom	Sum of squares	Mean of squares	F value	Level of significance
Soils (A)	2	53034.745	26517.372	12591.002	0.000
Conditioners (B)	2	1637.414	818.707	388.739	0.000
Periods (C)	3	1581.905	527.302	250.374	0.000
A*B	4	42.460	10.615	5.040	0.001
A*C	6	1720.307	286.718	136.140	0.000
B*C	6	125.868	20.978	9.961	0.000
A*B*C	12	650.118	54.177	25.724	0.000
Error	72	151.636	2.106		
General	108	188009.537			

The erosion ratio values of the soils vary between 9.73% and 64.65%, and sample 1 in the clay texture class has the lowest (9.73%) erosion ratio value and sample 3 in the sandy loam texture class has the highest (64.65%) erosion ratio value. It was determined that the coefficient of linear extensibility (COLE-bar) values of the soils varied between 0.010% and 0.212%, the highest value being in sample 1 in the clay texture class, and the lowest values being in sample 3 with the sandy loam texture class.

Results and Discussion

Erosion Ratio

The results of the variance analysis of the erosion ratio values determined after the soil samples in the experiment were subjected to incubation in four different periods by mixing polyvinyl alcohol, polyacrylamide and humic acid are provided in Table 2, and the average changes in the erosion ratio values (mean of the three values) and the results of the multiple comparison (Duncan) test are provided in Table 3. As can be seen from the examination of the variance analysis results in Table 2, the mean of squares ($p<0.01$) of the erosion ratio values of the tested soils were found to be significant. In other words, the soils differed in terms of their erosion ratio values at the end of the experiment.

Again, from the same table, the mean of squares ($p<0.01$) of the conditioners and the applied periods were found to be significant. This result emphasizes that the effects of the conditioners such as polyvinyl alcohol, polyacrylamide and humic acid used in the experiment and the applied periods, on the erosion ratio are different. From the results of the variance analysis, it was determined that soil x conditioner, soil x period, conditioner x period and soil x conditioner x period interaction were also significant.

When the effects of conditioner applications (Table 1 and 3) are examined, it is seen that all three conditioners provide significant decreases in the erosion ratio values of soils depending on the application periods and soil texture. Given the changes, it was determined that the conditioners used were more effective in the soil number 1 in the clay texture class.

Upon examination of Duncan's multiple comparison test results (Table 3) applied to the data for the comparison of the tested soils, applied conditioners and application periods according to the mean of erosion ratio values at the end of the experiment, it is determined that the soils, the conditioners used in the application, and the application periods are ranked as given in Table 3 in terms of the effect they have on the mean of the erosion ratio values. In this grouping, the differences between soils and periods ($p<0.01$) were found to be significant (Values shown with separate letters are significant at 1% level on the basis of the mentioned test).

The average decreases (%) found in the erosion ratio value according to the controls are presented in Figure 1. In all three soils, the decreases occurred with polyvinyl alcohol were much higher.

The mean decreases (%) caused by the applications of polyvinyl alcohol, polyacrylamide and humic acid in the erosion ratio of the soils showed significant differences between the said conditioners. The decreases (%) caused by the periods related to these three conditioners in the erosion ratio of the soils are given in Figure 2. As it can be understood from these data, the efficiency of the conditioners decreases as the period time increases.

Erosion ratio value is a parameter used to evaluate the resistance of soils to erosion, and soils of which this ratio value is below 10 are considered to be resistant to erosion while those of which this ratio value is higher than that are considered to be susceptible to erosion (Morgan, 2009; Özdemir, 2013). When the tested soils are evaluated in this respect, it can be initially considered that sample 1 is resistant to erosion and samples 2 and 3 are susceptible to erosion. The applied conditioners decreased the ratio value depending on the application periods and increased the resistance of the soils to erosion, but they could not be sufficient in soil no. 2 and 3 in terms of causing a decrease below the limit value (<10) given for resilience. On the other hand, when the test findings are examined accordingly, it can be stated that the erosion ratio values are affected by the type of conditioner used (as PVA>PAM > HA) and the

Table 2. The results of the variance analysis of the erosion ratio values of the soils

	Soil properties								
Soil number	Sand, %	Silt, %	Clay, %	Texture class	pH (1:2.5)	EC dS/m	$CaCO_3$, %	OM, %	CEC me/100g
1	31.70	23.14	45.16	C	6.97	0.1497	2.22	1.54	65.48
2	36.18	41.57	22.25	L	7.40	0.4924	8.47	3.02	38.26
3	58.91	29.34	11.75	SL	7.92	0.1173	8.26	0.77	31.66
Soil number	Parameters								
				ER, %	COLE				
1				9.73	0.212				
2				42.41	0.024				
3				64.65	0.010				

Table 3. The mean erosion ratio values of the soils and Duncan multiple comparison test results

Soils	Conditioners	Periods				Soil
		1	2	3	4	averages
	PVA	2.01	0.65	1.39	2.00	
1	PAM	3.95	4.64	7.49	7.42	5.53c
	HA	7.14	7.76	9.79	11.14	
	PVA	28.33	34.24	34.85	34.87	
2	PAM	40.17	41.43	41.63	38.44	38.89b
	HA	37.05	44.27	50.67	50.8	
	PVA	55.66	40.49	70.12	44.42	
3	PAM	51.49	57.52	78.57	82.08	59.29a
	HA	63.26	54.87	74.95	61.57	
Periods averages		32.38cd	31.80d	41.16a	32.93bc	
Conditioner Averages	PVA	29.33c				
	PAM	35.74b				
	HA	38.65a				

The averages shown in separate letters are different from Duncan multiple comparison test

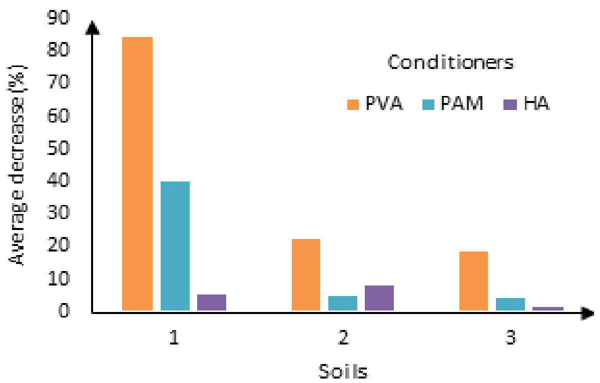

Figure 1. Average decreases (%) determined in the erosion ratio value on the basis of conditioners

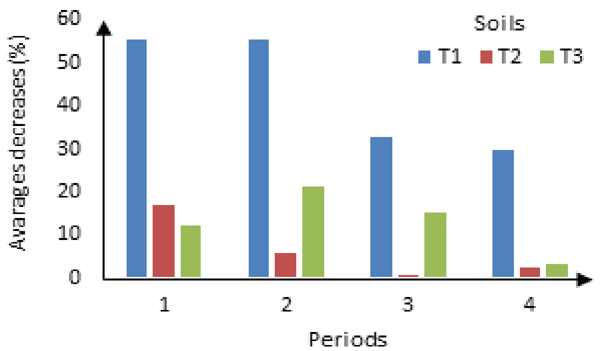

Figure 2. Average decreases determined in the erosion ratio value over the periods on the basis of control (%)

application periods as 2 > 1 > 4>3 (Table 3). In their study, (Yılmaz & Uysal, 2010) examined the effects of polyvinyl alcohol and polyacrylamide applications on **runof**f and soil loss. As a result of the research conducted on 3 soil samples with sandy loam textures with PVA and PAM solution, the researchers found that the mentioned polymers significantly reduced the runoff and soil loss, but that PVA was more effective than PAM. (Tümsavaş, 2005), who investigated the effects of different doses of PVA application in agricultural soils, found that PVA application at a dose of 500 mg/L was an effective dose in protecting the soils against erosion.

Coefficient of Linear Extensibility (COLE-bar)

Variance analysis results of the COLE-bar values determined after the incubation of the tested soils over four different periods by mixing polyvinyl alcohol, polyacrylamide and humic acid are given in Table 4, and the average changes in COLE-bar values (average of three values) and multiple comparison (Duncan) test results are given in Table 5. As can be seen from the examination of the variance analysis results in Table 4, the mean of squares ($p<0.01$) of the COLE-bar values of the tested soils was significant. In other words, the soils differed in terms of their COLE-bar values at the end of the experiment.

From the same table, it is seen that the mean of squares ($p<0.01$) of the conditioners and the applied

Table 4. The results of the variance analysis on the coefficient of linear extensibility values of the soils

Sources	Degrees of freedom	Sum of squares	Mean of squares	F value	Level of significance
Soils (A)	2	0.446	0.223	53037.205	0.000
Conditioners(B)	2	0.001	0.000	86.502	0.000
Periods (C)	3	0.019	0.006	1521.654	0.000
A*B	4	0.000	0.000	29.097	0.000
A*C	6	0.006	0.001	227.794	0.000
B*C	6	0.000	8.169E-05	19.418	0.000
A*B*C	12	0.001	0.000	24.903	0.000
Error	72	0.000	4.207E-06		
General	108	0.993			

Table 5. Coefficient of linear extensibility values of soils (mean) and Duncan multiple comparison test results

Soils	Conditioners	Periods				Soil averages
		1	2	3	4	
1	PVA	0.13	0.11	0.17	0.18	0.156a
	PAM	0.16	0.13	0.17	0.18	
	HA	0.15	0.13	0.18	0.18	
2	PVA	0.02	0.01	0.03	0.03	0.028b
	PAM	0.02	0.02	0.04	0.03	
	HA	0.02	0.01	0.03	0.03	
3	PVA	0.01	0.00	0.02	0.01	0.012c
	PAM	0.01	0.01	0.02	0.02	
	HA	0.00	0.00	0.01	0.01	
Periods average		0.058c	0.047d	0.080a	0.076b	
Conditioner Average	PVA	0.062c				
	PAM	0.067ab				
	HA	0.067b				

The averages shown in separate letters are different from Duncan multiple comparison test

periods were also found to be significant. This result indicates that the effects of the conditioners such as polyvinyl alcohol, polyacrylamide and humic acid used in the experiment and the applied periods, on the COLE-bar are different. From the results of the variance analysis, it was found that soil x conditoner, soil x period, conditioner x period and soil x conditioner x period interaction were also significant.

As can be seen from the examination of the average changes in the COLE-bar values (Table 1 and 5), all three conditioners applied caused significant changes in the coefficient of linear extensibility values of the soils depending on the periods. The change in question occurred at a higher level in the soil number 1 with clay texture class.

Upon examination of Duncan's multiple comparison test results (Table 5) applied to the data for the comparison of soils, applied conditioners, and application periods according to the COLE-bar value averages at the
end of the experiment, it is seen that the soils differ in terms of their COLE-bar averages at the end of the experiment. Again, according to the aforementioned test, it was seen that the conditioners used differed also in terms of the effect they had on the mean COLE-bar values at the end of the experiment.

On the other hand, the differences between the periods were also found to be significant in the same grouping (The values shown in separate letters are significant at 1% level on the basis of the mentioned test).

The mean changes (%) in the coefficient of linear extensibility value on the basis of the controls are provided in Figure 3. As can be seen from these data, the change (decrease) obtained with polyvinyl alcohol in soil no. 1, which has clay texture class, was at a higher level. While there was a decrease in the samples treated with only polyvinyl alcohol and humic acid in the soil no. 2, only the humic acid provided an effective decrease in the soil no. 3.

The average changes (%) caused by polyvinyl alcohol, polyacrylamide and humic acid applications in the coefficient of linear extensibility of the soils showed significant differences among the mentioned conditioners. The changes (%) caused by the periods related to these three conditioners on the coefficient of linear extensibility of the soils are presented in Figure 4.

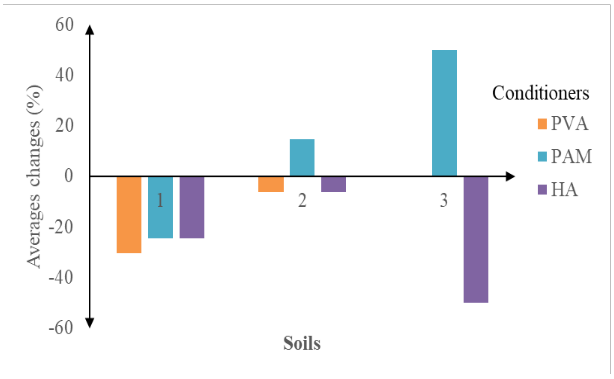

Figure 3. Average changes in COLE-bar value determined on the basis of conditioners (%)

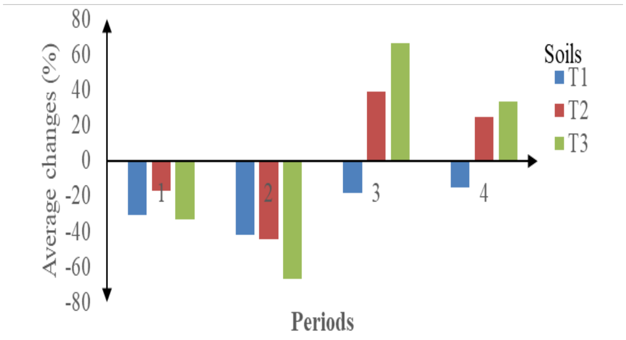

Figure 4. Average changes in COLE-bar value determined over periods on the basis of the control (%)

As it can be understood from these data, the effectiveness of the conditioners decreases after the second period (15 days).

As can be seen from the examination of the test findings, it can be stated that COLE-bar values are affected by the type of the applied conditioners (PVA>HA>PAM) and the application periods (2 > 1 > 4>3), that PVA is the most effective conditioner on COLE bar value, and that period 2 is the most effective period in terms of conditioner effectiveness (Table 3). In other words, it can be said that as the period time increases, the conditioner effectiveness decreases. On the other hand, when the COLE-bar values of the tested soils are examined, it can be stated that there is a significant risk of swelling and shrinkage in the soil number 1 in the clay texture class and that PVA, HA and PAM have significant effects in terms of mitigating this risk.

Özdemir et al. (2016) found in their study that garbage compost, tobacco processing waste and paddy husk compost applied to soils with acid, neutral and alkaline reactions improved the mechanical properties and decreased the COLE-bar values. In the study examining the effects of wheat straw, hazelnut sludge, humic acid and PAM conditioners on the coefficient of linear extensibility of soils, COLE-bar values, (Civelek, 2021) found that COLE-bar values decreased with the application of the conditioners and that there were statistically significant negative correlations between the COLE-bar values and the organic matter content.

Conclusions

As a result of this study that was conducted under greenhouse conditions in order to determine the effects of polyvinyl alcohol, polyacrylamide and humic acid applications on the improvement of erosion susceptibility and coefficient of linear extensibility (COLE-bar) parameters in the soils;

From among the tested soils, soil no. 1 with clay texture was found to be resistant to erosion (ER<10) and soils no. 2 and 3 with loam and sandy loam texture (EO>10) were found to be susceptible to erosion. PVA, PAM and HA applications increased the resistance of soils to erosion by causing significant decreases in the ratio values depending on the application periods and soil texture. Given the changes in the erosion ratio value in soil no. 2 and 3, the conditioners could not be sufficient in terms of causing a decrease below the limit value given for resistance to erosion. It was observed that the applied conditioners were effective as PVA>PAM>HA and the application periods were effective as 1 > 2 > 3>4.

PVA, PAM and HA applications used in the test decreased the COLE-bar values; the conditioner effectiveness was PVA> HA> PAM and the application period effectiveness was as 2> 1> 4> 3; in other words, it can be said that PVA was the most effective conditioner on the COLE bar value and that period 2 was the most effective period in terms of conditioner effectiveness. On the other hand, when the COLE-bar values of the tested soils are examined, it can be stated that there is a significant risk of swelling and shrinkage in the soil number 1 in the clay texture class and that PVA, HA and PAM have significant effects in terms of mitigating this risk.

As a result, it was determined that polyvinyl alcohol, polyacrylamide and humic acid applications increased resistance to erosion in the soils and decreased the swelling-shrinkage feature. It was also determined that the effectiveness depends on the characteristics of the conditioners, soil texture class, and the period duration. It would be helpful to pay attention to this issue in practice.

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Author Contribution

NÖ: Funding, project administration, conceptualization, supervision, writing, reviwed editing; **HK:** Formal analysis, investigation, methodology, writing original draft, resources.

Conflict of Interest

The authors declare that they have known competing financial or non-financial, professional, or personal conflicts that could have supported to influence the work reported in yhis paper.

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