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The Effect of Organic Waste and Synthetic Conditioner Applications on Consistency Limits

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Abstract

This study was carried out to determine the effects of wheat straw (WS), hazelnut husk (HH), humic acid (HA) and polyacrylamide (PAM) treatments on consistency limits (liquid limit (LL), plastic limit (PL), plasticity index (PI)) in two soils with sandy loam and clayey loam in texture. Soil samples used in the study were taken from two different areas of land (0-20 cm) from Samsun province's Bafra district. WS (0, 2%, 4%), HH (0, 2%, 4%), HA (0, 200 and 1000 ppm) and PAM (0, 30 and 90 ppm) were used in this study that was conducted in a split plots experimental design with three replications. According to the results; it was determined that the liquid limit, plastic limit and plasticity index values increased with the application of organic and synthetic conditioners in both soil texture, and the effect was realized as WS>HH>HA>PAM. It was observed that the highest dose application was the more effective in both soil texture, except for PAM.

Keywords: Hazelnut husk, humic acid, liquid limit, plastic limit

Organik Atık ve Sentetik Düzenleyici Uygulamalarının Kıvam Limitleri Üzerine Etkisi

Öz

Bu araştırma, kumlu tın ve killi tın tekstüre sahip iki toprakta buğday samanı (WS), fındık zurufu (HH), hümik asit (HA) ve poliakrilamid (PAM) uygulamalarının kıvam limitleri (likit limit (LL), plastik limit (PL), plastiklik indeksi (PI)) üzerine etkilerini belirlemek üzere yürütülmüştür. Çalışmada kullanılan toprak örnekleri, Samsun ili Bafra ilçesinde tarla tarımı yapılan iki farklı araziden (0-20 cm) alınmıştır. Bölünmüş parseller deneme deseninde yürütülen çalışmada buğday samanı (0, %2, %4), fındık zurufu (0, %2, %4), hümik asit (0, 200 ve 1000 ppm) ve PAM (0, 30 ve 90 ppm) topraklara üç tekerrürlü olarak uygulanmıştır. Sonuç olarak, likit limit, plastik limit ve plastiklik indeksi değerlerinin her iki toprak tekstüründe de organik ve sentetik düzenleyici uygulaması ile arttığı, etkininin WS>HH>HA>PAM şeklinde gerçekleştiği tespit edilmiştir. Her iki toprak tekstürün de PAM hariç en yüksek doz uygulamasının daha etkili olduğu görülmüştür.

Anahtar kelimeler: Fındık zurufu, hümik asit, likit limit, plastik limit

INTRODUCTION

The liquid limit is defined as limit water content values when a dry soil flows under the influence of a small external force due to the increasing water content, while the plastic limit is defined as the water content values when the soil starts to crumble while losing its water. The numerical difference between the liquid limit and the plastic limit is called the plasticity index (Dexter and Bird, 2001; Gülser and Candemir, 2006).

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The liquid limit (LL), plastic limit (PL), and plasticity index (PI) are defined as consistency limits and are important parameters in the evaluation of some properties of soil when used for agricultural or engineering purposes. These parameters gain value depending on the dominant clay mineral type of the soil, the clay content, the type of exchangeable cations, and the amount of organic matter (Odell et al., 1960; Farrar and Coleman, 1967).

Canbolat and Öztaş (1997), in a study in which they examined the relationships between soil consistency limits and some physicochemical properties, revealed significantly positive correlations between the clay content, organic matter content, lime content, cation exchange capacity and the liquid limit and plastic limit values, and significantly negative correlations with sand content. Yakupoğlu and Özdemir (2006), as a result of the study in which they applied biosolids and tea waste to soils eroded at different levels, reported that the additions of organic material significantly increase the liquid limit (LL) and plastic limit (PL) values of the soils, and such increase depends on the increased erosion levels, the type of waste and the applied dose for the liquid limit, and the type of clay mineral, clay content, exchangeable cation type, and organic matter amount for the plastic limit. Similarly, Kara et al. (2018), as a result of the study in which they examined the effect of applying gyttja as a conditioner on clayey loam textured soil with low percentage of lime content on the liquid limit (LL) and plastic limit (PL) values of the soils; they found that the organic matter (OM), liquid limit (LL) and plastic limit (PL) values of the soil increased depending on the application dose of gyttja. This study was carried out to examine the effects of organic waste and synthetic conditioner applications on consistency limits in two soil texture with sandy loam and clayey loam in texture.

MATERIALS AND METHODS

Material

This study was carried out on soil samples taken from the Bafra application area of Samsun Ondokuz Mayıs University and the Black Sea Agricultural Research Institute's Bafra experimental field and its surface (0-20 cm). In the study, wheat straw (WS) and hazelnut husk (HH) were used as organic waste, while humic acid (HA) and polyacrylamide (PAM) were used as synthetic conditioners. Organic wastes were used by passing through a 2 diameter sieve. These wastes and conditioners were obtained from different institutions and organizations. The wheat straw used in the study has 53.46% organic C and 0.65% total N content, and its C/N value is 82.25. The pH and P contents of wheat straw were determined as 5.69 and 2055.00 ppm, respectively. Hazelnut husk has 46.93% organic C, 1.86% total N content, and its C/N ratio is 25.23. The pH and P contents of the hazelnut husk are 6.16 and 6291.52 ppm, respectively. The applied PAM is of technical quality, and HA is a commercially available material containing 15% active substance.

In the study carried out under greenhouse conditions as a pot experiment and in a split plots experimental design, organic residues (0, 2% and 4%); humic acid (0, 200 and 1000 ppm) as a synthetic conditioner; and PAM (0, 30 and 90 ppm) were used with three replications. During the experiment, the air temperature was kept between 25-30 ^{0}C with the air conditioner and irrigation was done when fifty percent of the available moisture in the pots was exhausted. Soil samples were incubated for five months and wheat plants were grown in pots after the incubation period. After the wheat plant was harvested (3 months), the relevant analyses were made on the soil samples.

Methods

The particle size distributions of soils were determined by the Bouyoucos hydrometer method (Gee et al., 1986); the soil reaction (pH) in a 1:2.5 soil-water suspension with a pH meter (Rowell, 1996); the electrical conductivity in soil-water suspension with a glass-electrode electrical conductivity meter (Bayraklı, 1987); the lime content of soils by measuring the volume of CO_2 gas released due to hydrochloric acid treated with $CaCO_3$ using Scheibler calcimeter (Kacar, 1994); and the organic matter contents were determined by the Walkley-Black method (Nelson and Sommers, 1983) based on the oxidation of organic carbon.

The LL value of the soils was determined using the "Casagranda" instrument (Sowers, 1965). The PL value was determined according to the amount of moisture the soil had when it was formed into 3 mm filaments and started to disperse (Sowers,

1965). The PI value was found by subtracting the PL value from the LL value (Casagranda, 1932).

The statistical evaluation of the data obtained as a result of the research was performed using the Minitab computer package program. The Duncan test was used in multiple comparisons (Minitab, 2013).

RESULTS AND DISCUSSION

Soil Properties

Some physical and chemical properties of the soils studied are given in Table 1. As can be seen from the examination of this chart, the research soils have clayey loam and sandy loam texture. The lime content of clayey loam soil is 7.24%, organic matter content is 2.09%; the lime content of soil with sandy loam texture was determined as 17.92% and organic matter content as 1.06%. Liquid limit, plastic limit and plasticity index are measured as 36.49%, 24.71% and 11.78% for clayey loam soil and as 22.76%, 16.35% and 6.41% for sandy loam soil, respectively.

Table 1. Some characteristics of the soils used in the research
Çizelge 1. *Araştırmada kullanılan toprakların bazı özellikleri*

	Soils	
	OMU	BSARI
Sand, %	59.42	23.86
Silt, %	29.88	42.30
Clay, %	10.70	33.82
Texture Class	SL	CL
pH (1:2.5)	7.96	7.59
EC dS m^{-1} (1:2.5)	0.418	0.425
$CaCO_3$,%	17.92	7.24
OM, %	1.06	2.09
Consistency limits (Pw)		
Liquid limit (LL), %	22.76	36.49
Plastic limit (PL), %	16.35	24.71
Plasticity index (PI), %	6.41	11.78

$CaCO_3$: lime content, OM: organic matter content, EC: electrical conductivity, Pw: Percentage weight OMU: Ondokuz Mayıs University's Bafra Experimental Field, BSARI: Black Sea Agricultural Research Institute's Bafra Experimental Field

Consistency Limits

Liquid Limit (LL)

In the study carried out under greenhouse conditions, the changes in the liquid limit values were determined after harvest in soils that were mixed and incubated with the different doses of conditioners (WS, HH, HA and PAM) and where wheat plants were grown are shown in Figure 1. As can be seen from this Figure, except for PAM applications in sandy loam textured soil, the applied conditioners provided significant improvements in liquid limit values. These increases were higher in Black Sea Agricultural Research Institute's Bafra Experimental Field with high clay (33.82%) and organic matter content (2.09%) and low lime content (7.24%). The liquid limit (LL) values of the soil samples ranged from 22.76% to 44.81%, and the lowest LL value was determined in the sample with sandy loam texture in the second dose application of the PAM conditioner, and the highest LL value was determined in the soil with clayey loam texture and in the second dose application of wheat straw.

Soils with an LL value of less than 30% are considered to have "low" plasticity, while those with an LL value between 30-50% are considered to have "medium" plasticity and those with more than 50% are considered to have "high" plasticity (Demiralay and Güresinli, 1979). Accordingly, it can be stated that Ondokuz Mayıs University's Bafra Experimental Field with sandy loam texture (LL values lower than 30%) have low plasticity; Black Sea Agricultural Research Institute's Bafra Experimental Field with clayey loam texture (LL values between 30-50%) have moderate plasticity.

It is determined that there are significantly negative correlations between the liquid limit values, the lime content (-0.964**) and pH (-0.549**) of soils, while significantly positive correlations were established between and organic matter content (0.714**) at the level of 1%.

Deng et al. (2017) determined in their study that there are significant positive correlations

Table 2. Some chemical properties of organic wastes used in the study
Çizelge 2. *Çalışmada kullanılan organik atıkların bazı kimyasal özellikleri*

Organic waste	pH (1:10)	EC (1:10), dS m^{-1}	OC, %	Total N, %	C/N	Ash, %	P, %
WS	5.69	2.848	53.46	0.65	82.25	7.84	0.205
HH	6.16	2.058	46.93	1.86	25.23	19.09	0.629

WS: wheat straw, HH: hazelnut husk, OC: organic carbon

between organic carbon and LL and PL values. Similarly, many researchers have found that there are statistically significant positive correlations between the liquid limit and plastic limit values of soils and their clay contents (Aksakal et al., 2013; Spagnoli et al., 2018) and organic matter contents (Canpolat and Öztaş, 1997; Gülser and Candemir, 2006).

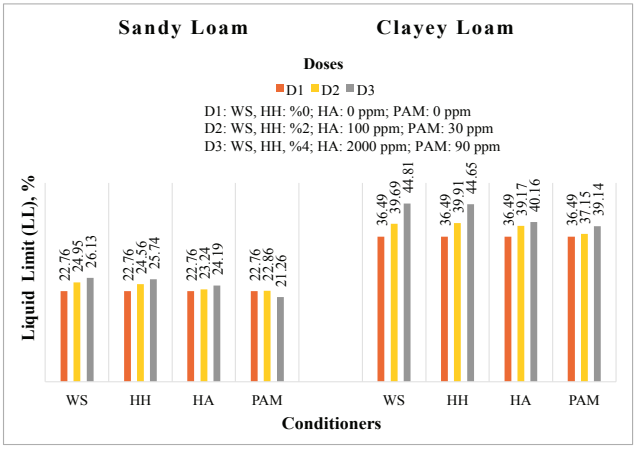

Figure 1. Changes in the liquid limit values due to applications compared to control (WS: wheat straw, HH: hazelnut husk, HA: humic acid, PAM: polyacrylamide)
Şekil 1. *Uygulamaların likit limit değerlerinde kontrole göre meydana getirdiği değişimler*

According to the results of variance analysis, the effect of the mean squares of soils, conditioner types and application doses on the change in the liquid limit values of the study soils ($p<0.01$) was found to be significant. The Duncan multiple comparison test results, which were conducted to examine the conditioner types and the effectiveness of the applied doses, are given in Table 3.

As can be understood from the examination of these data, the effectiveness of hazelnut husk and wheat straw on the LL value of the soils is the highest, and the effectiveness of the PAM conditioner is the least; and it was determined that the LL values increased with the higher dose levels.

Plastic limit (PL)

In the study carried out under greenhouse conditions, the changes in the plastic limit values determined after harvest in soils that were mixed and incubated with different doses of conditioners (WS, HH, HA, and PAM) and where wheat plants were grown are shown in Figure 2. As can be seen from this Figure, except for PAM applications in sandy loam textured soil, the applied conditioners provided significant improvements in plastic limit values. These increases were higher in the samples from Ondokuz Mayıs University's Bafra Experimental Field with high sand (59.41%) and lime content (17.92%) and low organic matter content (1.06%). PL values ranged between 15.01-30.19%, with the lowest PL value recorded in the soil with sandy loam texture and in the second dose application of the PAM conditioner, and the highest PL value recorded in the second dose application of hazelnut husk in the soil with clayey loam texture.

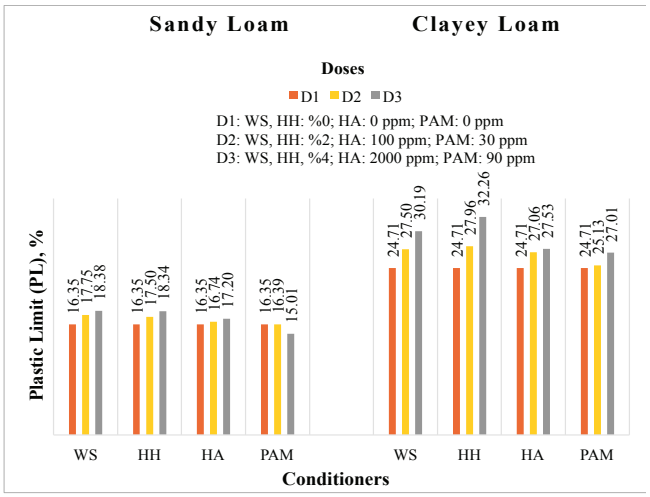

Figure 2. Changes in the plastic limit values due to applications compared to control (WS: wheat straw, HH: hazelnut husk, HA: humic acid, PAM: polyacrylamide)
Şekil 2. *Uygulamaların plastic limit değerlerinde kontrole göre meydana getirdiği değişimler*

Table 3. Duncan test results on the effects of soils mixed with different doses of conditioners on liquid limit values
Çizelge 3. *Farklı dozlarda düzenleyici karıştırılan toprakların likit limit değerleri üzerine etkilerine ilişkin Duncan testi sonuçları*

Conditioners	WS	HH	HA	PAM
Liquid Limit (LL), %	32.47[a]	32.17[a]	31.00[b]	29.95[c]
Doses	D1	D2	D3	
Liquid Limit (LL), %	29.63[c]	31.44[b]	33.26[a]	

(WS: wheat straw, HH: hazelnut husk, HA: humic acid, PAM: polyacrylamide (D1: WS, HH: 0%; HA: 0 ppm; PAM: 0 ppm, D2: WS, HH: 2%; HA: 100 ppm; PAM: 30 ppm, D3: WS, HH, 4; HA: 2000 ppm; PAM: 90 ppm))

Table 4. Duncan test results on the effects of soils mixed with different doses of conditioners on plastic limit values
Çizelge 4. *Farklı dozlarda düzenleyici karıştırılan toprakların plastik limit değerleri üzerine etkilerine ilişkin Duncan testi sonuçları*

Conditioners	WS	HH	HA	PAM
Plastic limit (PL), %	22.48[b]	22.86[a]	21.60[c]	20.77[d]
Doses	D1	D2	D3	
Plastic limit (PL), %	20.53[c]	22.00[b]	23.24[a]	

(WS: wheat straw, HH: hazelnut husk, HA: humic acid, PAM: polyacrylamide (D1: WS, HH: 0%; HA: 0 ppm; PAM: 0 ppm, D2: WS, HH: 2%; HA: 100 ppm; PAM: 30 ppm, D3: WS, HH, 4; HA: 2000 ppm; PAM: 90 ppm))

Significantly negative correlations were detected at the level of 1% between PL values and lime content (-0.947**) and pH (-0.528**) values of soils, while significantly positive correlations were found at the level of 1% between the organic matter content (0.734**) and PL values.

According to a study, Qu et al. (2014) stated that there was a statistically significant increase in plastic limit values with the application of different doses of rice husk ash to the soil, while Stanchi et al. (2015) stated that the plastic limit values in the upper soil horizons were higher than the lower horizons, and this situation was related to the organic matter content in the surface layer.

According to the results of variance analysis, the effect of the mean squares of soils, conditioner types, and application doses on the change in the PL value of the study soils ($p<0.01$) was found to be significant. The Duncan multiple comparison test results, which were conducted to examine the conditioner types and the effectiveness of the applied doses, are given in Table 4.

As can be understood from the examination of these data, the effectiveness of HH on the PL value of the soils is the highest, and the effectiveness of the PAM conditioner is the least; and it was determined that the PL values increased with the higher dose levels.

Plasticity index (PI)

In the study carried out under greenhouse conditions, the changes in the PI values determined after harvest in soils that were mixed and incubated with different doses of conditioner (WS, HH, HA and PAM) and where wheat plants were grown are shown in Figure 3. As can be understood from this Figure, except for PAM applications in sandy loam textured soil, the applied conditioners provided significant improvements in PI values. Such increases were higher in the samples from Black Sea Agricultural Research Institute's Bafra Experimental Field with high sand (33.82%) and organic matter content (2.09%) and low lime content (7.24%). PI values ranged between 6.25and 14.48%, with the lowest PI value seen in the soil with sandy loam texture and in the second dose application of the PAM conditioner, and the highest PI value seen in the second dose application of wheat straw in the soil with clayey loam texture.

The PI index value is used as a parameter in the evaluation of tillage time. A high PI value indicates that the risk of sludge formation will increase when the soils are cultivated (Demiralay and Güresinli, 1979; Mueller et al., 2003). Gülser and Candemir (2006) examined the PI values of the soil series in the Ondokuz Mayıs University Campus, and found that the PI values increased with the order of Aksu < Kurupelit < Müzmüllü < Oyumca < İncesu; they stated that the risk of sludge formation during tillage is higher in the İncesu and Oyumca series than in the other series. In light of such findings and considering the PI values of the soils in this study, it can be stated that the risk of sludge formation during tillage is higher in Black Sea Agricultural Research Institute's Bafra Experimental Field with high clay content than in Ondokuz Mayıs University's Bafra Experimental Field with high sand content.

Significantly negative correlations were detected at the level of 1% between PI values and lime content (-0.973**) and pH (-0.575**) values of soils, while significantly positive correlations were found at the level of 1% between such values and the organic matter content (0.657**). Considering relevant studies, Rezaee et al. (2019) examined swelling shrinkage characteristics and plasticity indices in paddy fields, and stated that clay content, cation exchange capacity, organic carbon and saturated water content have significant effects on the value of Atterberg limits in cultivated soils.

Demir et al. (2012) found significant positive relationships between liquid limit, plastic limit and plasticity index and clay content, organic matter and lime content in the study they carried out to examine the relationship between soil consistency limits and some soil properties depending on land use in the Uğrak Basin, and stated that there was no significant relationship with silt, sand, pH and EC values.

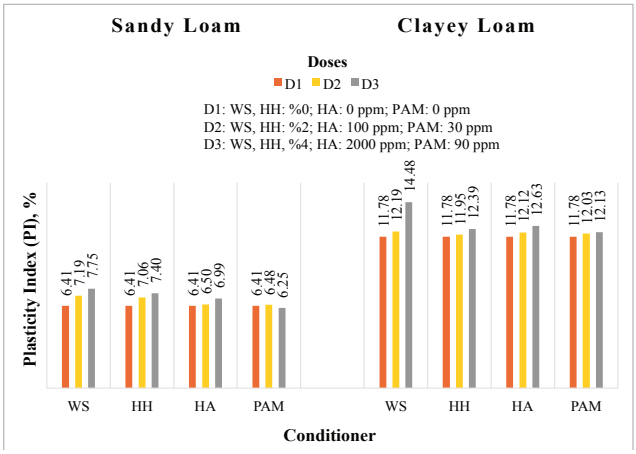

Figure 3. Changes in the plasticity index values due to applications compared to control (WS: wheat straw, HH: hazelnut husk, HA: humic acid, PAM: polyacrylamide)
Şekil 3. *Uygulamaların plastiklik indeksi değerlerinde kontrole göre meydana getirdiği değişimler*

According to the results of variance analysis, the effect of the mean squares of soils, conditioner types and application doses on the change in the plasticity index value of the study soils ($p<0.01$) was found to be significant. The Duncan multiple comparison test results, which were conducted to examine the conditioner types and the effectiveness of the applied doses, are given in Table 5.

As can be seen from the examination of these findings, the effectiveness of WS on the plasticity index value of the soils is the highest, and the effectiveness of the PAM conditioner is the least; and it was determined that the PI values increased with the higher dose levels.

CONCLUSIONS

In this study, in which changes in the consistency limits were examined with the addition of WS, HH, HA and PAM in clayey loam and sandy loam textured soil samples; it has been observed that the aforementioned conditioners added to the soils cause increases in the LL, PL and PI values, but the effect of the PAM conditioner on the consistency limits of the sandy loam in texture soils remained low level. This is probably related to the nature of PAM, the effect of soil texture and the incubation and cultivation process. It has been determined that the effectiveness of organic and synthetic conditioners used on the consistency limits are listed as WS > HH > HA > PAM. It is seen that organic wastes are more effective than synthetic conditioners on consistency limits. This is probably associated with the chemical structure of hazelnut husk and wheat straw and disintegration time (C/N ratio). And the fact that the conditioners were more effective in clay textured soils is probably due to the length of the process (incubation and cultivation) and the decelerated texture disintegration and aeration process. On the other hand, statistically significant positive correlations were found between soil consistency limits and organic matter content, while significant negative correlations were established with lime and pH values. It was determined that the effectiveness of conditioners depends on their own characteristics, and the texture, lime and organic matter content of soils, as well as on the application dose.

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Table 5. Duncan test results on the effects of soils mixed with different doses of conditioners on plasticity index values
Çizelge 5. *Farklı dozlarda düzenleyici karıştırılan toprakların plastiklik indeksi üzerine etkilerine ilişkin Duncan testi sonuçları*

Conditioners	WS	HH	HA	PAM
Plasticity index (PI), %	9.97[a]	9.50[b]	9.40[b]	9.18[c]
Doses	**D1**	**D2**	**D3**	
Plasticity index (PI), %	9.10[c]	9.44[b]	10.00[a]	

(WS: wheat straw, HH: hazelnut husk, HA: humic acid, PAM: polyacrylamide (D1: WS, HH: 0%; HA: 0 ppm; PAM: 0 ppm, D2: WS, HH: 2%; HA: 100 ppm; PAM: 30 ppm, D3: WS, HH, 4; HA: 2000 ppm; PAM: 90 ppm))

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