International Meeting on Soil Fertility Land Management and Agroclimatology. Turkey, 2008. p:209-215

Analyzing the Soil Texture Effect on Promoting Water Holding Capacity by Polyacrylamide

Buket Yetgin Uz[1*], Sabit Erşahin[2], Elif Demiray[1], Ayşe Ertaş[1]

[1] Gaziosmanpasa University, Agricultural Faculty, Department of Soil Science, 60240 Tokat, Turkey.

[2] Ordu University, Agricultural Faculty, Department of Soil Science, 60240 Ordu, Turkey

* e-mail:buketyetgin@hotmail.com,

Tel: (356)25216168, ext:2196

Fax: (356) 2521488

ABSTRACT

Polyacrylamide (PAM) has been widely used to improve soil water holding capacity and control infiltration rate of the soils. However, limited studies have been conducted on the interactions between soil water holding capacity and PAM rates in different soil textures. This study targeted to analyze the relations between soil texture and water holding capacity as a response of increasing PAM applications rate. PAM rates of 0.03, 0.1, 0.13, 0.16, 0.23, 0.33 and 0.67% by weight were applied to clay loam, clay and sandy loam soils. Water holding capacity (θ) at field capacity ($\theta_{0.01\ MPa}$ for sandy loam and $\theta_{0.033MPa}$ for clay loam and clay) and wilting point ($\theta_{1.50\ MPa}$) were measured with a pressure plate apparatus. The values of water holding capacity were regressed as a function of PAM rate, and the slope and intercepts of regression lines for clay loam, clay and sandy loam soils were compared to decide the homogeneity of these functions. Increasing PAM rate significantly increased the water holding capacity in all three soils ($P<0.05$). The regression lines obtained for sandy loam, clay loam, and clay were all significantly different from one to another, revealing that soil texture has a significant effect on the function of PAM in promoting water holding capacity in these soils. Therefore, we concluded that soil texture should be considered in optimizing the results from PAM applications.

Key Words: PAM, water holding capacity, soil texture, field capacity, wilting point.

INTRODUCTION

Many researcher have used Polyacrylamide (PAM) as a soil conditioner since 1950s (Ajwa and Trout, 2006). It has been long known that Polyacrylamide (PAM) could develop aggregates and soil structure, reduce crust hardness, disrupt massive structures, increase infiltration rate and as a result prevent the erosion (Ben-Hur and Letey, 1989; Ben-Hur et al, 1990; Bjorneberg et al., 2003; Ajwa and Trout, 2006).

In general, studies involving PAM have been carried out to control irrigation-induced soil erosion on clay loam and silt loam soils with low aggregate stability (Ajwa and Trout, 2006). In soil surface layers with low infiltration rate due to high density, high strength, fine pores, and low saturated hydraulic conductivity, addition of Pam could be effective in increasing infiltration rate, hydraulic conductivity, and porosity by improving or maintaining aggregates stability (Ben-Hur et al., 1990). McElhiney and Osterli (1996) reported that when PAM applied to fine-textured soil in San Joaquin Valley, infiltration rate increased due to improved development of more stable aggregates.

Conversely, addition of PAM to furrow irrigation water applied to sandy loam soils with low infiltration due to surface seal formation in the San Joaquin Valley did not show any increase in infiltration rate (Trout and Ajwa, 2001). Polyacrylamide (PAM) was also used to improve plant growth for enhancing seedling emergence, reducing crust hardness, and increasing soil physical properties (Cook and Nelson 1986, Helalia and Letey, 1989, Aly and Letey, 1990). Busscher et al., (2007) used PAM and organic matter as amendments to improve physical properties of loamy sand soils of E and Ap horizons which contain cemented subsurface hard layers that restrict root development and yield even if soil water content is at field capacity in coastal plains of South Eastern USA.

Polyacrylamide (PAM) was also used to improve plant growth by increasing water holding content of soil and by preventing nutrients loss through leaching. Polyacrylamide is an acrylate polymer (-[$CH_2CHCONH_2$]-[CH2CHCOOK]-) formed from acrylamide subunits that is readily cross-linked. When water touches this cross-linked chain, it passes into the molecule by osmosis and rapidly inside the polymer net. With this property, it is highly water-absorbent, and forms a soft gel (Anonymous, 2008a).

PAM, used for agricultural purposes, has been marketed by some private companies in Turkey (Anonymous, 2008b; Anonymous, 2008c). PAM can hold water 400 times of its own volume. When applied in correct doses and conditions, it can conserve water up to 70% by holding water that would normally be lost by drainage and evaporation. This is especially important, considering the fact that our water reserves are limited. In addition, PAM may save 15-30% on fertilizer by absorbing plant nutrients and by preventing nutrients loss with leaching (Anonymous, 2008b; Anonymous, 2008c).

Pam rates applied to soil may need to be adjusted based on soil properties, slope, and type of erosion targeted (USDA-NRCS, 2001). Older Pam formulation required hundreds of kilograms of PAM per hectare. However, PAM with newer longer-chain polymers is more effective even in lower rates (Wallace and Wallace, 1986). There are studies available on PAM rates to be applied in irrigation water toward prevention of erosion by improving infiltration. Many researchers found that application of 20 kg ha^{-1} PAM prior to sprinkler irrigation increased infiltration rates and reduced runoff and erosion (Shainberg et al., 1990; Smith et al., 1990 and Stern et al., 1992). According to Aase et al. (1998), PAM, as low as 2 kg ha^{-1}, might be adequate to effectively reduce runoff. El-Morsy et al. (1991) found that 10 mg l^{-1} concentration of a cationic soluble polymer significantly increased the infiltration rate in sprinkler irrigation under laboratory conditions.

Soil texture must be taken into consideration in calculation of PAM rates to be applied to soil in order to improve water use efficiency. However, limited studies have been conducted on the interactions between soil water holding capacity and PAM rates in different soil textures. This study targeted to analyze the relations between soil texture and water holding capacity as a response to increasing PAM applications rate.

MATERIALS and METHODS

Soil Analysis

Soils used in this study were identified, based on their texture; as 1) clay loam, 2) clay, and 3) sandy loam. Soils were collected from topsoil (0-30 cm) in Kazova region of Tokat in Turkey. Soils were air dried and sieved through a 2-mm sieve. Particle-size distribution of the soils was measured with a Bouyocous hydrometer in laboratory (Gee and Bouder, 1986) (Table 1).

Table 1. Particle-size distribution of the soils used with PAM

Soil ID	Particle size			Texture class
	%clay	% silt	%sand	
1	38.40	32.50	29.10	clay loam
2	53.40	18.75	27.85	clay
3	16.80	22.50	60.70	sandy loam

Dry granular PAM in rates of 0.03, 0.1, 0.13, 0.16, 0.23, 0.33 and 0.67% by weight were mixed with soils. It was not possible to apply PAM in higher doses because it roughens the soil samples and disrupts the soil structure in a degree that hinders soil analysis. The experiment was conducted with three replicates. Soil with no PAM was used as a control for each texture type. Water content of all treatments at field capacity ($\theta_{0.01MPa}$ for sandy loam and $\theta_{0.033\ MPa}$ for clay loam and clay) and at wilting point ($\theta_{1.50\ MPa}$) were measured with a pressure plate apparatus (Klute, 1986). Then, plant available water content (θ_{PAW}) was calculated, subtracting $\theta_{1.50\ MPa}$ from $\theta_{0.01Mpa}$ and/or $\theta_{0.033\ MPa}$ .The bulk density (ρ_b) was measured by core methods (Blake and Hartge, 1986). The total porosity (f) was calculated by following equation;

$$f = 1 - \frac{\rho_b}{\rho_s}$$

Where, ρ_b is bulk density (g cm$^{-3)}$ and ρ_s is the particle density, which was simply assumed as 2.65 g cm^{-3}.

RESULT and DISCUSSIONS

According to the results of laboratory analysis, bulk density of loamy and sandy soils reduced with PAM addition compared to the control while there was a small increase in bulk density of clayey soil. Conversely, porosity increased with increasing PAM rates for clay loam and sandy soils. However, macro pore size increased in clay soil while it decreased in clay loam and sandy loam soils (Table 2).

Table 2. Analysis results of clay loam (1), clay (2), and sandy loam (3) soils

Soil property	Soil ID	PAM Rates % (by weight)							
		0.00	0.03	0.10	0.13	0.17	0.23	0.33	0.67
ρ_b (g/cm^3)	1	1.48	1.48	1.46	1.47	1.45	1.44	1.40	1.41
	2	1.39	1.38	1.39	1.39	1.38	1.39	1.41	1.42
	3	1.50	1.49	1.49	1.48	1.47	1.48	1.46	1.39
f	1	0.44	0.44	0.45	0.44	0.45	0.45	0.47	0.47
	2	0.48	0.48	0.48	0.47	0.48	0.47	0.47	0.46
	3	0.44	0.44	0.44	0.44	0.44	0.44	0.45	0.48
Macro	1	9.17	7.54	5.65	5.67	5.18	5.67	6.90	1.11
pore size	2	-6.99	-6.88	-7.72	-7.74	-7.20	-9.34	-10.93	-16.17
(%)	3	16.77	16.03	14.77	13.58	12.61	8.84	9.37	6.01

ρ_b: bulk density f: porosity

The effect of increasing PAM rates on water retention of soils were shown in Fig. 1 through 3. Volumetric water content at field capacity increased linearly with increasing PAM rates in all soil texture types. The greatest increase in water content was in soil 3 (55%) at 0.67% (by weight) PAM rate compared with its control. Application of 0.67% of PAM resulted in only 15% increase in water content at the field capacity in the Soil 2. This smaller increase may be attributed to increase in macro pore size by aggregation of clay particles by granular PAM. Sivapalan (2001) reported that, in sandy soil, amount of water retained at 0.01 MPa pressure increased 23% and 95% with addition of 0.03 an 0.07 %PAM, respectively, resulting in reduction in deep percolation. At 1.5 MPa pressure more water was retained by soil due to the presence of PAM. However, no significant increase in the amount of water released from the soil was observed. According to the results of pot experiments, soybean plants in soils treated with PAM at rate of 0.07% showed better growth compared to those in control soils that suffered from moisture stress due to insufficient available water content (Sivapalan, 2001). Therefore, the researcher concluded that the difference between the soil moisture content at 0.01and 1.5 MPa is not representative of the available water content for soybean plants.

Greatest increase in volumetric water content at wilting point occurred in sandy soils (55%) treated with 0.67% by weight PAM. On the other hand, with the same PAM treatment, volumetric water content of loamy and clay soils decreased (-11% and -16%, respectively).

Available water contents of loamy and clay soils showed highly significant increase (108% and 105%, respectively) with the highest PAM rate applied due to increase in water content at FC and decrease in water content at WP. Meanwhile, plant available water content (θ_{PAW}) of sandy soil increased by 55% since water content at WP increased. Hemyari and Nofziger (1981) observed that addition of PAM in the rate of 0.4% (by weight) to loamy sand and sandy loam soils resulted in higher water retention compared to their untreated counterparts. However, PAM had only little effect on water retention in clay and loamy soils.

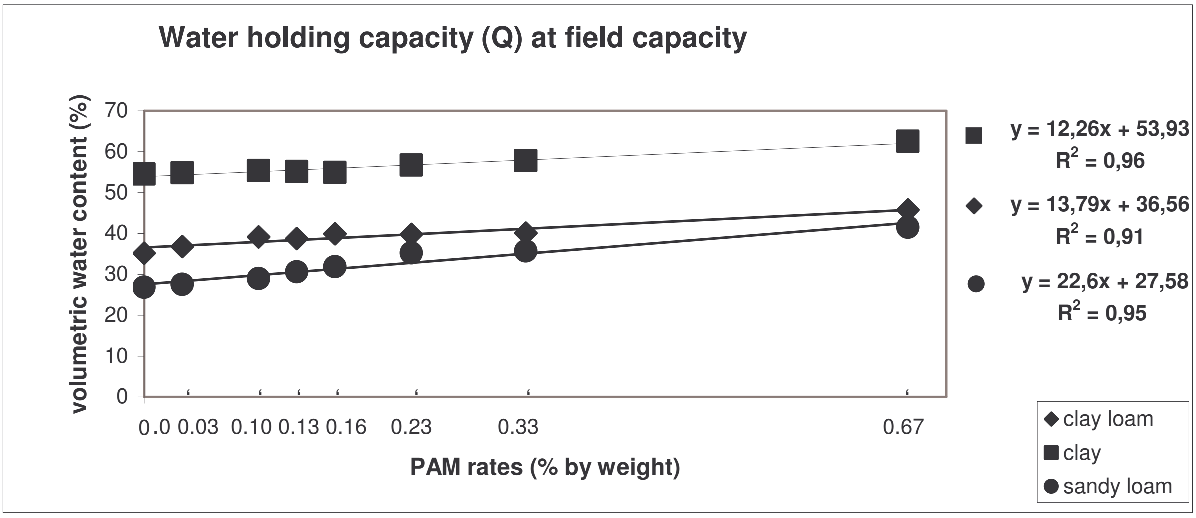

Fig. 1. Response of volumetric water content at field capacity to increasing PAM rates in clay loam, clay, and sandy loam.

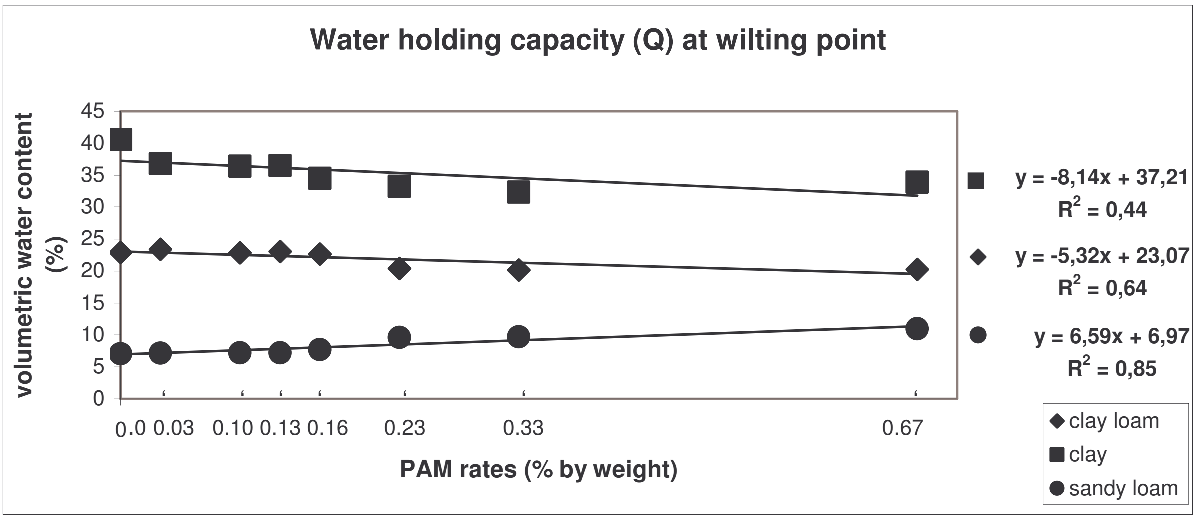

Fig. 2. Response of volumetric water content at wilting point to increasing PAM rates in clay loam, clay, and sandy loam.

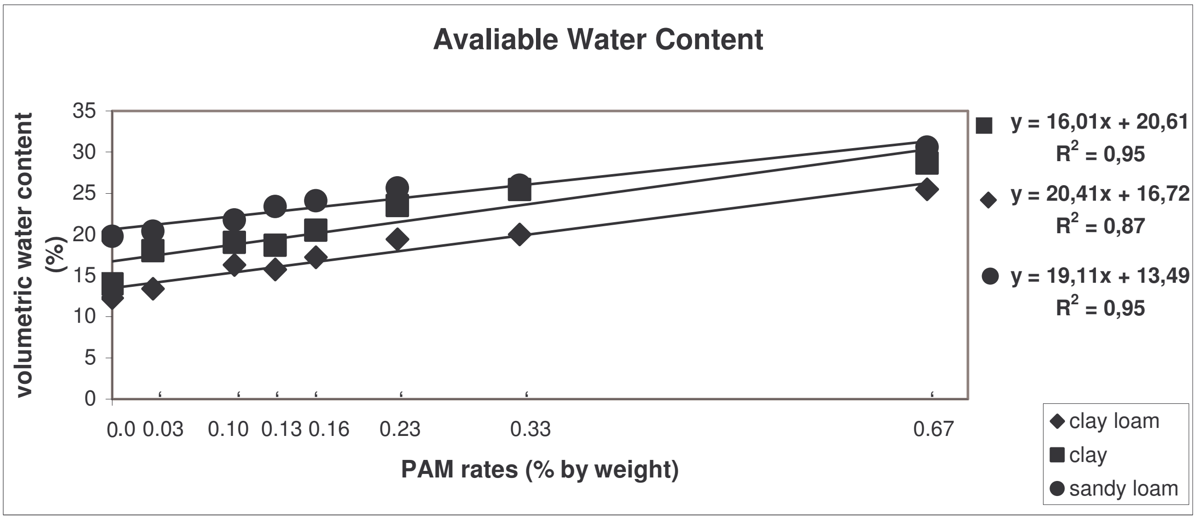

Fig. 2. Response of plant available water content to increasing PAM rates in clay loam, clay, and sandy loam.

To evaluate the soil texture effect on efficiency of PAM, linear regression analyses were conducted between values of water content and PAM rates at θ_{FC}, θ_{WP}, and θ_{PAW}; and then the regression lines representing clay loam, clay, and sandy loam were compared by their slopes (Kleinbaum et al., 1998). At both field capacity and wilting point, the slopes for clay and sandy loam were significantly different, while those for the clay loam and clay were the same. This revealed that sandy loam responded differently to increasing PAM rates than clay and clay loam. At plant available water content, the slopes for all the three soils were the same, indicating that addition of PAM affected water holding capacity of these soils in a similar way. We suggest that soil texture should be considered in application of PAM with the purpose of increasing water holding capacity of the soils. In a small quantity (0.07% by weight) of PAM addition to sandy soil can increase water use efficiency about 19 times due to the fact that more water is retained by PAM and used by plants (Sivapalan, 2001). This suggests that PAM could conserve more time, more money and energy required for frequent irrigation for plants in sandy soils

REFERENCES

Aase, J.K., D.L. Bjorneberg, R.E. Sojka, 1998. Sprinkler irrigation runoff and erosion control with polyacrylamide - Laboratory tests. Soil Sci. Am. J. 62:1681-1687

Aly, S.M., J. Letey, 1990. Physical properties of sodium- treated soil as affected by two polymers. Soil Sci. Am. J. 54:501-504

Ajwa, H.A., T.J. Trout, 2006. Polyacrylamide and water quality effects on infiltration in sandy loam soils. Soil Sci. Am. J. 70:643-650.

Antonymous, 2008a. http://www.answers.com/topic/polyacrylamide

Anonymous, 2008b.http://www.optimaltarim.com/

Anonymous, 2008c.http://www.sutut.com/

Ben-Hur. M., J. Letey, 1989. Effect of polysaccharides, clay dispersion, and impact energy on water infiltration. Soil Sci. Am. J. 53:233-238

Ben-Hur. M., J. Letey, I. Shainberg, 1990. Polymer effects on erosion under laboratory rainfall simulator conditions. Soil Sci. Am. J. 54:1092-1095.

Bjorneberg, D.L., F.L. Santos, N.S. Castanheira, O.C. Martins, J.L. Reis, J.K. Aase, R.E. Sojka, 2003. Using polyacrylamide with sprinkler irrigation to improve infiltration. Journal of Soil and Water Conservation, Vol.58, No.5 pp:283-289

Blake, G.R., and Hardge, K.H. 1986. Methods of Soil Analysis. Bulk Density Part1. 2nd Ed. Agronomy9. ASA and SSSA, 363-375, Madison.

Busscher, W.J., J.M. Novak, T.C. Caesar-TonThat, 2007. Organic matter and polyacrylamide amendment of Norfolk loamy sand. Soil and Tillage Research 93:171-178

Cook, D.F., and S.D. Nelson, 1986. Effect of polyacrylamide on seedling emergence in crust-forming soils. Soil Sci. 141.328-333.

El-Morsy, E.A., M. Malik, J. Letey, 1991. Interactions between water quality and polymer treatment on infiltrstion rate and clay migration. Soil Technology 4(3):221-231

Gee, G.W., Bouder, J.W., 1986. Particle Size Analysis. Methods of Soil Analysis. Part1, 2nd Ed. Agronomy 9,Am. Soc. Agron. 825-844, Madison.

Helalia, A.M., J. Letey, 1989. Effects of different polymers on seedling emergence, aggregate stability and crust hardness. Soil Sci. 148:199-203.

Hemyari, P. and D.L. Nofziger, 1981. Super slurper effects on crust strength water retention, and water infiltration of soils. Soil Sci. Am. J. 45:799-801

Kleinbaum, D.G., L.L. Kupper, K.E. Muller and A. Nizam, 1998. Dummy Variables ın Regression, Applied Regression Analysis and Multivariable Methods, 3rd Edition, Pacific Grove: Duxbury Press pp: 317-360.

Klute, A., 1986, Water Retention: Methods of Soil Analysis, Part1, 2nd Ed, Agronomy 9,Am, Soc, Agron. 635-660, Madison.

McElhiney, M. and P. Osterli, 1996 An integrated approach for water quality. The PAM connection-West Stanislaus HUA, CA p: 27-30.

Shainberg, I., D.N. Warrington, P. Rengasamy, 1990. Water quality and PAM interactions in reducing surface sealing. Soil sci.149:301-37

Sivapalan, S. 2001. Effect of Polymer on Soil Water Holding Capacity and Plant Water Use Efficiency. Australian Society of Agronomy.10th Australian Agronomy Conference, "Science and Technology: Delivering Results for Agriculture?" Hobart January 2001.

Smith, H.J.C., G.J. Levy, I. Shainberg, 1990. water- droplet energy and soil amendments: effect on infiltration and ersion. Soil Sci. Soc. Am. J. 54:1084-1087

Stern, R., A.J. Van Der Merwe, M.C. Laker, I. Shainberg, 1992. Effect of soil surface treatments on runoff and wheat yields under irrigation. Agron. J. 84:114-119

Trout, T.J., H. Ajwa, 2001. Polyacrylamide effects on infiltration in San Joaquin Valley sandy loam soils. ASAE annual meeting.

USDA-NRCS, 2001. Anionic polyacrylamide (PAM) erosion control. *In* Natural resources conservation practice standard. USDA Natural Resources Conservation Service, USA.

Wallace, A. and G.A. Wallace, 1986. Effects of very low rates of synthetic soil conditioners on soils. Soil Sci. 141. 324-327.