

Effect of Gypsum and Polyacrylamide Application on Erodibility of an Acid Kunigami Mahji Soil

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Abstract: Acid soil covers one third of the world arable lands. Excess Al and H⁺ in acid soil are not favorable for most plants. Calcium carbonates and gypsum (CaSO₄) are used to improve chemical status of the acid soil. However, application of Ca cation may sometimes enhance dispersion and deteriorate soil physical properties. Presenting study discusses effect of non-ionic polyacrylamide (PAM) application on erodibility of a gypsum amended Japanese acid soil.

Acid Kunigami mahji soil (Hapludult), pH(H₂O):4.4, from Okinawa, Japan was used in this study. The soil was sieved through 3 mm mesh screen and packed into an acrylic plastic box of 30cm×50cm×10cm in depth with bulk density of 1.15 Mg/m³. Prior to the simulated rainfall, a 2.5t/ha of gypsum and/or 15 kg/ha of non-ionic PAM were applied onto soil surface. Intensity of the simulated rainfall were 40 mm/hr. During a rainfall, surface runoff was collected periodically, and after the halt of rainfall sediment concentration, pH, and electric conductivity (EC) of surface runoff was measured.

Gypsum application enhanced runoff significantly. It caused quick and more surface runoff than without the amendment. During rainfall, electrolyte concentration of the runoff was greater than 15 mmol/L, and this concentration was greater than the critical coagulation concentration of the clay fraction of the soil material, however the soil became dispersive with gypsum application. When only non-ionic PAM was applied prior to the rainfall, it could reinforce soil structure. The PAM application could thus improve infiltration of gypsum amended Kunigami mahji soil and the soil could storage more rainfall. Gypsum application caused greater sediment concentration (10 g/L) than that without the gypsum amendment (5g/L). Applying PAM made gypsum-amended soil to show lower sediment concentration of surface runoff.

Keywords: acid soil, gypsum, dispersion, aluminum, erodibility, polyacrylamide, PAM

1 Introduction

Acid soil covers one third of the world arable lands. Aluminum toxicity is a serious problem in acid soil regions (Noble *et al.* 1988). It is well known, lime, gypsum, and calcium carbonate can remove Al from the acid soil and reduce the problem of Al toxicity. Because of its higher solubility in water, gypsum can decrease the Al status and increase the Ca status of subsoil by the surface application (Pavan *et al.* 1984). Gypsum has been recognized as a dispersion-restricting agent. Many studies have shown the effects of gypsum on the infiltration of saline and sodic soils (Shainberg *et al.* 1989). Gypsum is also reported to be effective in preventing soil loss from lower exchangeable percentage (ESP) soils (Miller 1987; Zhang and Miller 1996). However, less is known about the effect of gypsum amendment on the physico-chemical properties of soils of variable charge. Roth and Pavan (1991) and Nishimura (1996) reported enhancement of the dispersion of acid soils following the application of Ca salt. A possible mechanism for the enhancement of dispersion caused by gypsum amendment might be that the exchangeable Al monomers and/or polymers, which act as binding agents, are displaced from exchange sites by Ca²⁺ (Roth and Pavan 1991). Details of this suggested mechanism, however, was not clear.

Polyacrylamide (PAM) has been studied to improve soil structural stability (Saybold 1994). Many studies of effects of anionic PAM (Zhang and Miller (1996), Nadler *et al.*(1994)) and cationic PAM

(Helalia and Letey 1988) on soils containing permanently charged clay have been reported. However, effects of non-ionic PAM have not been studied extensively. The ionic-PAMs are adsorbing on either negatively or positively charged clay surface. Non-ionic PAM interacts with soils by adsorbing onto clay surfaces through Van der Waals forces (Saybold 1994). This would be benefit on applying PAMs on to variable charged clay. Since contribution of ionic PAMs depends on clay charges and the charges of the variable charged clay varies with pH, however the effect of non-ionic PAM might be independent to pH dependent charges.

It is important to attain both chemical improvement and soil conservation, since potential agricultural productivity of many of the acid soil areas is quite important. Agricultural land reclamation in Okinawa, Japan moved surface soil and forced the acid Kunigami mahji subsoil to be surface soil for agricultural production. This subsoil-derived surface soil has both serious acidity and erosion problems. Presenting study discusses possibility of polyacrylamide (PAM) application to reduce soil loss from a gypsum amended Japanese acid soil.

2 Methods

2.1 Soil

Kunigami mahji soil, an acid red-yellow soil in southern Japan (Typic Hapludult), was used in this study. The soil was collected from a depth of 20 cm to 40 cm (B horizon) in a non-cultivated field in Nakijin, Okinawa, and sieved through a 3 mm mesh screen. Clay mineralogy was dominated by kaolinite, and smaller amounts of gibbsite, vermiculite and goethite were detected by X-ray diffraction. Organic carbon was determined using a total carbon analyzer (LECO Corp., St. Joseph, MI, USA). The electrical conductivity of the soil at a soil:water ratio of 1:1 was 0.025 dS m^{-1} , which is equivalent to $0.349 \text{ mmol L}^{-1}$ in ionic strength by Marion-Babcock equation (Sposito 1989). Other selected soil properties are given in Table 1. The exchangeable sodium percentage of the soil was below 0.1 and most of the exchange sites were occupied by Al monomers and/or polymers and protons (Table 2).

Table 1 Properties of kunigami mahji soil

Texture	LiC (Sand:324, Silt:337, Clay:339 [$\text{g} \cdot \text{kg}^{-1}$])
Specific Surface Area [$\text{m}^2 \cdot \text{g}^{-1}$]	100
Particle Density [$\text{Mg} \cdot \text{m}^{-3}$]	2.74
Organic Carbon [$\text{g} \cdot \text{kg}^{-1}$]	2.5
pH	4.25(H_2O), 3.65(KCl) (1:2.5 soil-water ratio)
Electric Conductivity [$\text{ds} \cdot \text{m}^{-1}$]	0.025 (1:5 soil-water ratio)
Cation Exchangeable Capacity [$\text{mmol}_c \cdot \text{kg}^{-1}$]	265 (KCl extraction)
Saturated Hydraulic Conductivity [$\text{cm} \cdot \text{sec}^{-1}$]	9×10^{-3} (at $\rho_b=1.15 \text{ Mg} \cdot \text{m}^{-1}$)
Soil Color	2.5YR4 or 5/8

Table 2 Changes in exchangeable cations folloing to gypsum amendment

Gypsum application [t/ha]	Na^+ [$\text{mmol}_c \cdot \text{kg}^{-1}$]	K^+ [$\text{mmol}_c \cdot \text{kg}^{-1}$]	Mg^{2+} [$\text{mmol}_c \cdot \text{kg}^{-1}$]	Ca^{2+*} [$\text{mmol}_c \cdot \text{kg}^{-1}$]	Al^{3+*} [$\text{mmol}_c \cdot \text{kg}^{-1}$]
0	2.7	2.3	0.77	0.13	36
2.5	2.5	1.4	0.28	16.8(+15.6)	28(-16)

*:number in brackets are increase/decrease in exchangeable cations

2.2 Rainfall experiment

Rainfall experiment has conducted in the Arid Dome of the Arid Research Center of Tottori University, Japan. Raindrops were generated from nozzles of 12m high from the sample soil surface, and

the drops were expected to reach terminal velocity. An 85% of drops were smaller than 2mm. Mean rainfall intensity was 40 mm/hr.

The plastic acrylic box of 50cm×30cm×10cm was used in this study. Soil was packed to a 5cm deep over a 5cm thick sand and gravel layer. The box has drains at the bottom and effluent was collected. A flume was connected to lower end of the soil surface, and runoff and sediment were collected periodically. After the halt of rainfall all the runoff was oven dried and dry weight of sediment was weighted. Initial moisture condition of the soil was water content of approximately 10 weight%. Prior to the simulated rainfall, 2.5t/ha of gypsum and/or 15 kg/ha of non-ionic PAM were applied onto soil surface. Molecular weight of the non-ionic PAM used in this study was 1.3×10^7 g • mol⁻¹, and ratio of hydrolysis was around 2%. The PAM was applied by spraying a 0.05 weight% dilute solution onto soil surface.

3 Result And Discussion

3.1 Effects of gypsum and non ionic PAM application on runoff

Fig.1 shows effects of gypsum and non ionic PAM application on runoff from Kunigami mahji soil. Gypsum application promoted runoff without PAM. It was suspected removal of Al, which could act as binding agent, of the sample soil was the reason of enhancement of runoff (Nishimura *et al.*, 1999). Non ionic PAM application had significant effect on reducing runoff. Without gypsum, PAM application made rainfall duration to have runoff twice to that without PAM. Beginning of runoff was earlier with gypsum application however, applying both gypsum and non ionic PAM made time to begin runoff similar to that to have no chemical amendment. In addition, PAM reduced steady runoff rate during a rainfall.

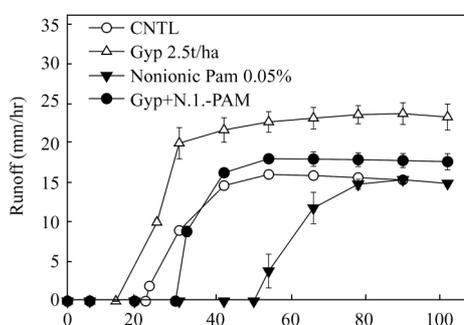


Fig.1 Effects of Polyacrylamide and Gypsum application on runoff of Kunigami mahji soil. Rainfall intensity was 40 mm/hr. Vertical bars show range of measured data

3.2 Effects of gypsum and non ionic PAM application on soil loss

Fig.2 shows sediment concentration of runoff as a function of rainfall duration. Gypsum amended soil showed higher maximum sediment concentration. In terms of maximum sediment concentration,

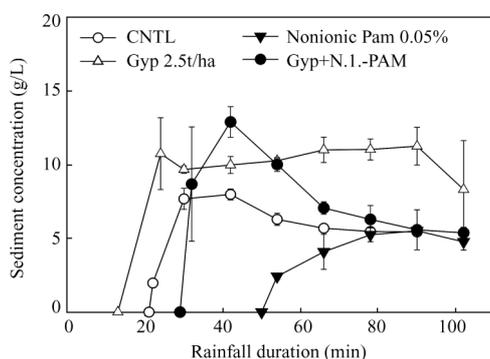


Fig.2 Effects of Polyacrylamide and Gypsum application on sediment concentration of Kunigami mahji soil. Rainfall intensity was 40 mm/hr. Vertical bars show range of measured data

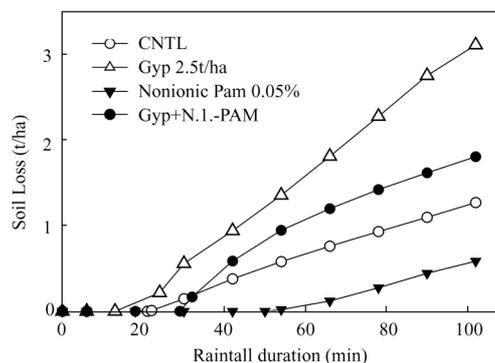


Fig.3 Effects of Polyacrylamide and Gypsum application on soil loss from Kunigami mahji soil. Slope was 5%, and rainfall intensity was 40 mm/hr

PAM application could not reduce the maximum sediment concentration, the peak sediment concentration of gypsum amended soil was similar with or without PAM application. However, final sediment concentration showed distinct contribution of PAM application. Application of PAM reduced final, or steady, sediment concentration of runoff down to that from the soil without gypsum. Soil loss showed contribution of PAM clearly. The soil loss was multiplication of sediment concentration and volume of runoff. The gypsum and PAM applied soil showed greater soil loss after 100 min of rainfall, however this was almost half of the soil loss from gypsum amended soil box(Fig.3).

3.3 Possible mechanism of stabilization of soil structure with both gypsum and PAM application

Fig.4 shows electric conductivity (EC) of runoff. Both the gypsum applied and the gypsum and non ionic applied soils showed higher EC through the experiment. The EC was greater than $1 \text{ dS} \cdot \text{m}^{-1}$ and this was equivalent to electrolyte concentration of 0.01 mol/L of electrolytes (Nakajima 2000). Critical coagulation concentration of kaolinite, which is dominant clay mineral of the soil, is 0.4 and $5 \text{ mmol}_c \cdot \text{L}^{-1}$ for Na and Ca electrolyte solution, respectively (Arora and Coleman 1979). This suggests clay particles of Kunigami mahji soil was flocculative condition during a rainfall of presenting study, and enhancing dispersion of the soil and runoff by gypsum application could not explain by electric double layer theory. It was expected removal of Al cation in the acid soil, which generally has a role to bind particles, was a reason. Thus, the soil structure could be stabilized by supplying binding agent as applying non ionic PAM.

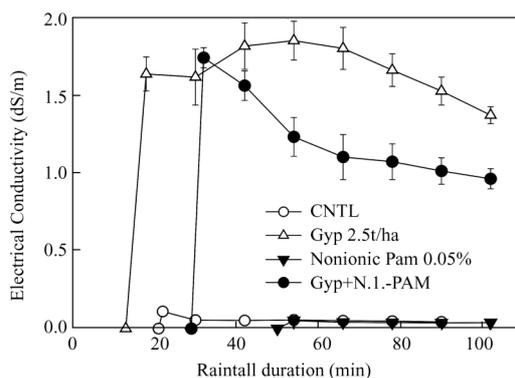


Fig.4 Electric conductivity of runoff of Kunigami mahji soil. Vertical bars show range of measured data

4 Conclusion

Chemical amendment of acid soils is important practice to improve agricultural production in tropic and subtropic areas. However, chemical amendment of acid soil by applying Ca agents may sometimes deteriorate physical properties of the soil. In presenting study gypsum application enhanced dispersion of the acid kunigami mahji soil, and thus runoff and soil loss from the soil. Application of non-ionic PAM reinforced the stability of soil structure that was deteriorated by gypsum application. The study showed possibility to attain chemical improvement and physical condition simultaneously by applying gypsum and organic polymer together.

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