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Interaction effects of polyacrylamide application and slope gradient on potassium and nitrogen losses under simulated rainfall

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ABSTRACT

Soil nutrient loss through erosion depletes farmland productivity and environmental quality. Polyacrylamide (PAM) is often applied to control soil erosion from water but its effectiveness on different nutrients is not clear. This study tested the influence of PAM application rate, PAM molecular weight, and soil slope gradient on K^+ and N losses as well as their interactive effects under simulated rainfall in the laboratory. Experimental treatments consisted of four PAM application rates, two PAM molecular weights, and three soil slope gradients. Results indicated that compared with the control treatment, PAM application generally reduced K^+ and NH_4^+ concentrations and mass loss in runoff, except at the application rate of 2.0 g m^{-2}, though NO_3^- concentration and mass loss increased. Polyacrylamide application reduced K^+, NH_4^+, and NO_3^- concentrations in sediment and generally increased their mass losses with sediment except at a slope gradient of 25°. After PAM application, mass losses of K^+, NH_4^+ and NO_3^- from soil surface generally increased with increased PAM application rate, and the averaged percentages lost with sediment were 77.7%, 15.7%, and 12.1% of the mass losses from the soil surface, respectively. The concentrations and mass loss of K^+, NH_4^+, and NO_3^- in runoff increased with the increase of slope gradient. However, concentrations in sediments decreased and mass loss increased with the increase of slope gradient. The effects of PAM molecular weight on K^+, NH_4^+, and NO_3^- concentrations and their mass losses in both runoff and sediment were not significant. Statistical analysis demonstrated that there existed a significant interaction effect between PAM application rate and soil slope gradient on K^+ and NH_4^+ mass losses from soil surface. Its contribution to the variation of K^+ and NH_4^+ mass losses was 0.86 and 0.50, respectively. The effectiveness of PAM application on constraining nutrient loss is related to nutrient ion type, PAM application rate, and slope gradient. A high PAM application rate is not suitable for the control of soil nutrient loss on a steep slope.

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1. Introduction

Non-point source pollutants from farmland are a significant source of environmental pollution. The loss of soil nutrients such as N, P, and K^+ from farmland not only decreases soil productivity but also contributes to the contamination or eutrophication of water bodies in the catchment area (Entry et al., 2002; Lentz and Westermann, 2010). Nutrients in farmland can be lost to drainage areas in two forms: as a dissolved form and in a sediment-bound form. This means that non-point source pollutants can be reduced if soil and water losses are constrained (Lentz et al., 2001).

Linear water-soluble anion polyacrylamide (PAM) with high molecular weight is often used to improve the structure of soil and decrease runoff and soil loss. Polyacrylamide can adsorb non-point source contaminants by electrostatic force for cationic charge sites or by the bridging function of polyvalent cations such as Ca^{2+} for negative charge sites (Entry and Sojka, 2003; Green and Stott, 1999; Sojka et al., 2007). Its influence on reducing the mass loss of soil nutrients is not well documented because of complicated interactions among nutrient ions, PAM, and soil (Entry et al., 2002).

A great many of research results have demonstrated that PAM application can reduce the concentrations of non-point source pollutants such as N, P, and organic matter in irrigation runoff (Bjorneberg et al., 2000; Krauth et al., 2008; Lentz et al., 1998, 2001). The experimental results of Entry and Sojka (2003) showed that PAM application reduced NO_3^- concentration in runoff by 85% and total P by 90%, and the mass export of NH_4^+, NO_3^-, total P, K^+, Ca^{2+}, and other ions was reduced 10 to 40 times in PAM-treated irrigation furrows. Lentz and Sojka (1994) showed that NO_3^- and total P mass losses by irrigation tailwater were reduced by about 83% and 84%, respectively, after PAM application. Soupir et al. (2004) indicated that aqueous PAM application at the rates of 1.7–6.7 kg ha^{-1} reduced total N concentration and its loading, and PAM application efficacy decreased with the increase of PAM application rate. Wang et al. (2011) reported that PAM application decreased K^+ and NH_4^+ concentrations both in runoff and sediment but increased their mass losses. In contrast, Lentz et al. (1998, 2001) reported that

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Table 1
Total soluble salt (TSS) and chemical elements in the tested soil.

Items	TSS	Total			Soluble								
		N	P	K^+	N	P	K^+	Ca^{2+}	Mg^{2+}	Na^+	SO_4^{2-}	HCO_3^-	Cl^-
	g kg^{-1}				mg kg^{-1}								
Conc.[a]	0.67	0.10	0.52	12.00	13.32	1.78	84.90	60.12	36.47	52.88	86.46	183.05	53.17

[a] Concentration.

PAM application did not significantly reduce NO_3^- concentration and mass loss in furrow runoff. Oliver and Kookana (2006) also found that PAM application did not significantly reduce total N and particulate P concentrations in runoff but did reduce their mass losses by 56% and 94%, respectively. Furthermore, the experimental results of Soupir et al. (2004) demonstrated that dry PAM application at the rate of 20.2 kg ha^{-1} increased total N concentration and its mass loss with sediment.

Polyacrylamide application affects runoff by preventing soil surface sealing and increasing water viscosity (Li et al., 2010; Sojka et al., 2007). This reduces soil loss by changing runoff erosivity and soil erosion resistance (Lee et al., 2008; Sojka et al., 1998). Water erosivity, sediment delivery capability, and soil erosion resistance all affect the net outcome of soil nutrient losses. Existing research on the effect of PAM application on nutrient loss has mainly focused on furrow irrigation or construction sites. Sprinkling irrigation involves heavier water drop impact and steeper slope gradients than furrow irrigation. The effects of PAM application under these conditions and the interaction effects between PAM application and slope gradient on soil nutrient losses are not well understood. The objective of this study is to determine the influences of PAM application rate, PAM molecular weight, and slope gradient on the mass losses of K^+, NH_4^+, and NO_3^- from sloping farmland and their interaction effects under simulated rainfall in the laboratory.

2. Materials and methods

2.1. Soil collection and preparation

Experimental soil was collected from a depth of about 20 cm in uncultivated land (natural soil without industrial or domestic wastes) in the East Campus of China Agricultural University, Beijing, China (40°0′ N, 116°21′E, Alt. 52 m). The soil basic physical and chemical properties were measured in the laboratory according to standard methods and instrument instruction manuals (Bao, 2008; Burt, 2004). The soil texture was loam according to USDA soil taxonomy with 471 g kg^{-1} sand (0.05–2.0 mm), 422 g kg^{-1} silt (0.002–0.05 mm), and 107 g kg^{-1} clay (<0.002 mm). Illite was the main clay mineral and it accounted for 48% of soil clay minerals. Kaoline and chlorite accounted for 11% and 9%, respectively. The other clay minerals were a mixture of montmorillonite

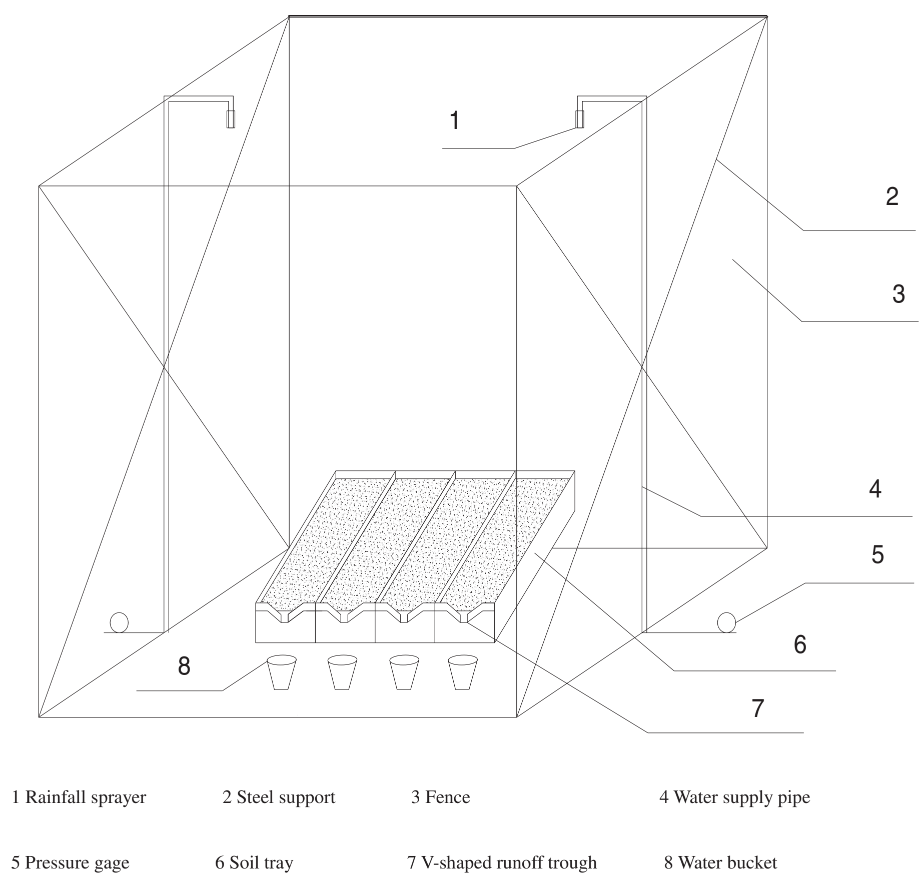

Fig. 1. Schematic diagram of experimental apparatus.

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