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Influence of Polyacrylamide (PAM) on the Soil and Water Conservation Effects of White Clover (*Trifolium repens L*)

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In order to explore the technology of soil and water conservation in coastal saline soil area, improve the prevention and control of soil erosion, white clover (*Trifolium repens L*) combined with different dosage of polyacrylamide (PAM) was applied to the soil and water conservation in plot tests, and the influence of PAM on the soil and water conservation effects of white clover (*Trifolium repens L*) was examined. The results showed that compared to the only planting white clover, the addition of 1-5 g/m^2 PAM reduced soil erosion by 516.0-1326.3 t/(km^2·a), which were 29.5-75.8% of the yearly soil erosion; inhibited soil evapotranspiration by 24.3-43.4%; improved the total rain water interception by 18.0-44.1 mm; and decreased the cumulative percentage of water loss (CP) by 0.4-4.7% in the 30th day after the plants harvest. From the aspects of reduction efficiency of erosion modulus and reduction efficiency of evapotranspiration, the optimistic dosage of PAM was 1 g/m^2. The synergy of PAM mainly focus on the early stage of white clover. In addition, PAM may still slightly prevent the water loss after the plants harvest.

1. Introduction

The soil erosion problem is very serious in coastal area of Jiangsu in China because the soil there has a sand and saline property (Zhao et al. (2013)). Plants are the most important for soil and water conservation. Zhao et al. (2004) used Arbor-bush-grass combined plants to prevent the soil erosion in coastal saline soil regions, and these plants may not only solve the soil erosion problem but also achieve remarkable economic benefits. Chang et al. (2001) treated soil and water losses on red soil orchard slopes with eight different conservation treatments, and found that planting Bahia grass on level bench terrace ridge was the most effective method to preserve soil and water. As an important pasture, white clover (*Trifolium repens L*) is used in soil and water conservation increasingly for its wide adaptability, barren and so o n ((Čustović et al. (2014); Long et al. (2003)).

Polyacrylamide (PAM), as a sort of polymer material, has been widely used in soil erosion control and soil structure improvement since 1970’s in view of its low cost, convenient application and remarkable effects (Entry et al. (2013); Lado et al. (2015); Lentz (2003); Levy and Warrington (2015); Sojka and Lentz (1997); Sojka et al. (1998)). Lentz and Sojka (1994) summarized that 1.3 kg·ha-1 PAM might reduce furrow sediment loss by 80-99% and increase not infiltration by -8-57%. Bjorneberg et al. (2000) found that 2 to 4 kg·ha-1 PAM reduced runoff and soil erosion significantly. Fox and Bryan (1992) tested the performance of PAM conditioner on tilled and undisturbed soils under simulated rainfall, and they found runoff generation and soil loss were reduced significantly, especially when application it combined with raking. It can be seen that PAM has shown good effects on soil and water conservation.

To further improve the protection of soil and water, white clover combined with PAM was applied to the soil and water conservation in coastal saline soil. And to explore the influence of PAM, the soil and water conversation effects of white clover with different dosage of PAM was compared to that of only white clover through measuring the erosion modulus, evapotranspiration rainfall interception capacity and cumulative percentage of water loss.

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2. Materials and methods

2.1 Experiment materials

The experimental district was located in Dongchuan Farm of Dongtai in Jiangsu. The slope ratio of the district was 1:3. The experimental district was divided into 5 plots in a line and each plot occupied an area of 100 m^2 (10 m×10 m). To avoid interference by the adjacent plot, a one-meter wide division zone was set between each adjacent plot, and 0.5 m high concrete plates were buried at both sides of the plots. The top of the plate was 0.2 m above the soil surface after settlement. The basic physical and chemical properties of the soil are shown in Table 1.

Table 1: Physical and chemical properties of soil (0 ~ 35 cm) in the test area

Mineral composition (%)			Porosity	Bulk density	Salt	Organic matter	pH
Sand	Aleurite	Clay	(%)	($\times10^3$ kg/m^3)	(g/kg)	(g/kg)	
37.3	62.1	0.4	52.7	1.41	4.47	6.2	8.27

PAM was white granular solids manufactured by Shanghai Weizhuo Chemical Co., Ltd. And white clover was from the local area.

2.2 Experiment method

PAM was sowed into the soil by mixing it with soil in ratio of 1:5 in the meantime of sowing white clover. The dosage of PAM was 0, 1, 3, 5 g/m^2, respectively, and each dosage repeats for twice. The blank plot without white clover and PAM was taken as the control check (CK).

Soil erosion was measured and calculated by nail method according to standard SL 419-2007. The total volume from April to September was used to represent the annual soil erosion volume, which was expressed as the erosion modulus. Evapotranspiration was measured by Markov bottle method. In the specific steps, the undisturbed soil columns (depth 1.5 m, diameter 0.4 m) were taken and placed in PVC measuring barrels (the soil surface is planted with grass), which were connected to the Markov bottle via a flexible plastic tube, then the water levels of undisturbed soil columns were controlled the same as the underground water levels of the experiment plot by Markov bottle, and then the change of water volume in the Markov bottle was the soil evapotranspiration. The evapotranspiration rate was measured in the early stage (March 25th-May 31st), the middle stage (June 1st-July 31st) and the late stage (August 1st-September 30th). When there was no rainfall for seven consecutive days, the 7 d average evapotranspiration was regarded as the stage evapotranspiration rate. Rainfall interception was measured and calculated by the difference between the rainfall volume and the surface runoff volume based on the standard SL 419-2007, and it was measured during rainfall when surface runoff was formed. Water loss amount of undisturbed soil samples 15 cm below the soil surface was measured by cutting ring method. It was measured for consecutive 30 days after white clover harvest.

The reduction efficiency of erosion modulus (E) and the reduction efficiency of evapotranspiration (EE) were calculated by equation (1) and (2):

$$E = (EM_0-EM)/W \tag{1}$$

where E is the reduction efficiency of erosion modulus, EM_0 and EM are the soil erosion modulus without and with PAM, respectively, W is the mass PAM.

$$EE = (EV_0-EV)/W \tag{2}$$

where EE is the reduction efficiency of evapotranspiration, EV_0 and EV are the evapotranspiration without and with PAM, respectively, W is the mass PAM.

The cumulative percentage of water loss (CP) of the i-th day was calculated by the equation (3):

$$CP_i= (M_0-M_i)/ (M_0-M_e) \tag{3}$$

where CP_i is the i-th day cumulative percentage of water loss, M_0, M_i and M_e are the mass of cutting ring with initial saturated soil; the mass of cutting ring with soil on the i-th day and the mass of cutting ring with dry soil sample (drying at 105℃).

3. Results and analysis

3.1 Effects of PAM dosage on soil erosion modulus

Fig. 1 shows the effects of PAM dosage on soil erosion modulus.

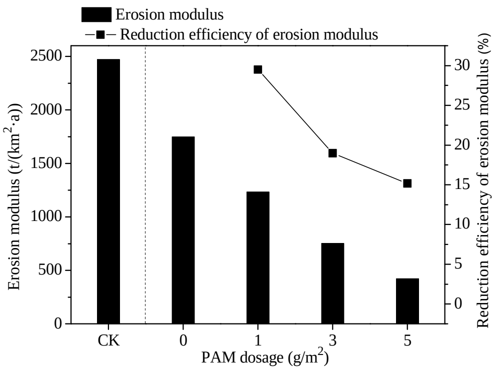

Figure 1: Effects of PAM dosage on the erosion modulus

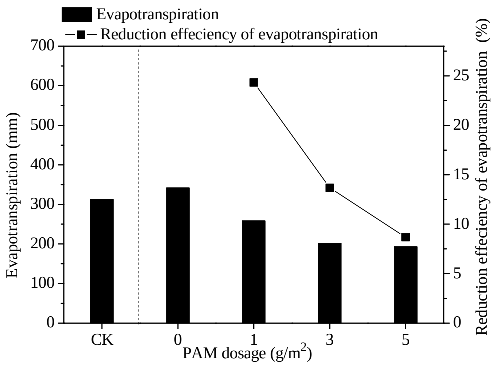

Figure 2: Effects of PAM dosage on evapotranspiration

It can be seen that the soil erosion modulus of CK and the plot only planted with white clover was 2472.4 and 1749.5 t/(km^2•a) respectively; the latter is reduced by 29.2% compared to the former, suggesting that white clover itself has good effects in preventing soil erosion. With the increase of PAM dosage, the soil erosion modulus decreased continuously. Compared to the plot only planted with white clover, the soil erosion modulus of the three plots added with different doses of PAM are reduced by 516.0-1326.3 t/(km^2·a), accounting for 29.5-75.8% of the total annual erosion volume. However, with the increase of PAM dosage from 1-5 g/m^2, the value of E decreased, which were equal to 29.5%, 19.0% and 15.2%, respectively. Therefore, from the aspects of E, the optimal dosage of PAM was 1 g/m^2.

3.2 Effects of PAM dosage on evapotranspiration

Fig. 2 shows the effects of different doses of PAM on evapotranspiration.

Fig. 2 showed that the total evapotranspiration of CK was 312.9 mm, and the total evapotranspiration of the plot with only white clover was 342.1 mm, which increased by 9.3% compared to CK. This is mainly due to the transpiration of plants increased the total evapotranspiration of soil. With the increase of PAM dosage, the total evapotranspiration decreased first and then exhibited a flattened trend. Compared to the plot only planted with white clover, the three doses of PAM reduced the total evapotranspiration by 24.3-43.4%, suggesting that the inhibition effect of PAM on evapotranspiration was stronger than the promotion effect of plant transpiration. With the increase of PAM dosage, the EE decreased continuously. When the PAM dosage was equal to 1 g/m^2 EE was the largest, equal to 24.3%, which reduced the total evapotranspiration by 83.2 mm compared to the plot only planted with white clover. The inhibition effect on evapotranspiration reached the optimum at this point of time.

Fig. 3 showed the effects of PAM dosage on the evapotranspiration rate in different stages of white clover.

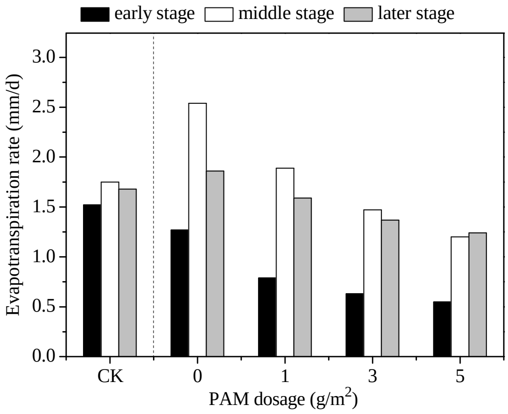

Figure 3: Effects of PAM dosage on the evapotranspiration rate in different growth stages of white clover

Compared to CK, the evapotranspiration rate of the plot only planted with white clover rose significantly in the middle stages. This is because that the continuous growth of leaves increases the transpiration effects gradually. With the increase of PAM dosage, the evapotranspiration rate decreased at all stages. Compared to the plot only planted with white clover, 1-5 g/m^2 of PAM can reduce the evapotranspiration rate by 37.8-56.7% in the early stage, by 25.6-52.8% in the middle stage and by 14.5-33.3% in the late stage. Therefore, the inhibition effects of PAM on the evapotranspiration mainly turned out in the early stage of white clover.

3.3 Effects of PAM dosage on the rainfall interception

Fig. 4 shows the effects of PAM dosage on the rainfall interception of white clover in different stages.

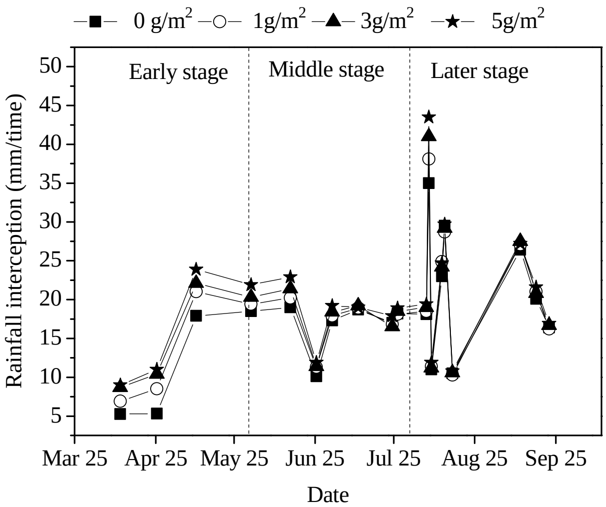

Figure 4: Effects of PAM dosage on the rainfall interception of white clover in different stages

It can be seen that the effects of different doses of PAM on the interception of white clover in a single rainfall exhibited the same trend. Under the same rainfall, the interception capacity of white clover increased with the increase of PAM dosage. With the addition of 1-5 g/m^2 PAM, the total rainfall interception volumes of white clover were increased by 18.0, 29.5 and 44.1 mm, respectively. The effects of PAM on the rainfall interception capacity were different in different growth stages of white clover. The synergistic effect of PAM appeared obviously in the early and middle growth stages of white clover, and the three doses of PAM can increase the rainfall interception by 10.2-21.0%. Till the middle and late stage, along with the growth of white clover, PAM only increased of rainfall interception by 7.3-2.3% and 2.0-4.8%, respectively. In other words, PAM mainly strengthened the rainfall interception capacity of white clover in the early stages, while white clover itself plays the leading role in the middle and late stage.

3.4 Effects of PAM dosage on CP30

Fig. 5 shows the effects of PAM dosage on CP after the white clover harvest.

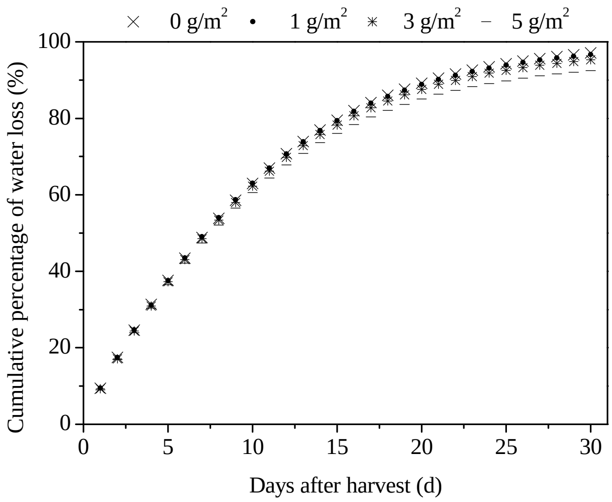

Figure 5: Effects of PAM dosage on CP after harvest

Fig. 5 showed that after the harvest of white clover, the CP increased continuously along with time. With the increase of PAM dosage, the CP declined. On the 30th day after harvest, with the PAM dosage of 0-5 g/m^2, the CP_{30} were 97.1, 96.7, 95.3 and 92.5% respectively. In other words, the CP_{30} can be reduced by 0.4- 4.7%. Therefore, although the white clover was harvested, PAM can still increase the water conservation capacity of soil slightly.

4. Discussions

Fig. 1, 2 and 4 suggest that PAM can enhance the soil and water conservation effects of white clover significantly. This mainly contains two parts, one is the effects of the PAM on the growth of white clover, which can enhance the soil and water conservation capacity of the plant, and the other is the effects of PAM itself on the soil and water conservation. For the first part, it is mainly because PAM can significantly increase the contents of coacervate in the coastal saline soil (Helalia et al. (1988); ZHANG (2012)), and this property of PAM is conducive for the formation of favorable soil environment for the growth of plants, then it can in turn boost the growth of root and improve the water conservation capacity of the plants. When soil is dry, the soil moisture can be released slowly by the osmotic pressure and absorbed by plants; this process prevents the water loss and the useless evaporation (YUAN et al. (2005)). For the second part, it is because PAM is beneficial to the formation of large soil particles (Mortensen (1962)) and porous structure, it thereby enhances the capacity of soil to conserve rain water which consists with Figure 5. In addition, when PAM is dissolved in the soil solution, a certain amount of colloidal substances are formed, which can conserve water by hydration.
Fig. 3 and 4 indicate that the synergistic effect of PAM appears significant mainly in the early stage. This is because that the water conservation capacity of white clover is relatively weak during the initial stage of growth. Therefore, the water conservation in the early stage mainly relies on PAM; while with the continuous consumption of PAM, the capacity of plants turns up gradually.
When PAM dosage is equal to 1 g/m^2, the water conservation efficiency is the highest. This is mainly because that, with the continuous increase of PAM dosage, excessive amount of PAM dissolved in the soil solution exists in form of hydrated state, and the colloidal structure may clog soil capillary and inhibit water evaporation (Lentz (2003)). In addition, the amount of coacervate, sticky particles and small particles not involved in PAM polymerization is reduced, so the water conservation effect of unit mass PAM declines with the increase of PAM dosage.

5. Conclusions

(1) In coastal saline soil districts of Jiangsu Province, PAM can enhance the anti-erosion capacity of white clover. Compared to the experiment plot only planted with white clover, the PAM dosage of 1-5 g/m^2 reduced soil erosion by 516.0-1326.3 t/(km^2·a), accounted for 29.5-75.8% of the total annual erosion volume. Meanwhile, it also reduced the evapotranspiration by 24.3-43.4%, increased the total rainfall interception by 18.0-44.1 mm, and reduced the 30th day cumulative percentage of water loss by 0.4-4.7%. From the aspects of E and EE, the optimistic dosage of PAM was 1g/m^2.
(2) In terms of the capacities of inhibiting evapotranspiration and strengthening rainfall interception, the synergistic effect of PAM appears obviously in the early stage. A suitable dosage of PAM can form

complementary relationship with plants. That is to say, the soil and water conservation mainly relies on PAM in the early growth stage of plant, while it takes advantage of plants in the middle and late stage. In addition, after the white clover harvest, PAM may still slightly prevent the water loss.

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