Effectiveness of polyacrylamide (PAM) for wind erosion control

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ABSTRACT: Polyacrylamide (PAM) has been shown to be very effective in controlling water erosion from furrow irrigation, but it has not been evaluated for its effectiveness in controlling wind erosion. Laboratory and field wind tunnel tests using several formulations and rates of PAM were conducted to determine its possible use for forming wind erosion-resistant surfaces (crusts). Tests showed that PAM is no more effective than natural rainfall for wind erosion control under general agricultural conditions.

Key words: Polyacrylamide, PAM, wind erosion, wind erosion control.

The use of vegetative and nonvegetative mulches to control wind erosion is not new. Wheat straw and prairie hay (Chepil et al. 1963a; Chepil et al. 1963b; Chepil et al. 1960), cotton gin trash (Fryrear and Armbrust 1968), and feedlot manure (Woodruff et al. 1974) are effective in controlling wind erosion if application rates are high enough and materials are well anchored to the soil surface. According to Chepil and Woodruff (1963), desirable nonvegetative surface mulches are:

1) indispersible in water and durable, yet porous to allow rainfall percolation;
2) weak enough to allow seedling emergence;
3) sticky indefinitely if used alone for permanent cover; and
4) easy to apply.

Commercially available nonvegetative materials for temporary wind erosion control have been tested (Armbrust and Dickerson 1971; Lyles et al. 1969; Lyles et al. 1974). Field and laboratory studies indicated that 25% of the manufacturer's recommended rate was effective if material (a) covered the total soil surface, (b) was diluted and applied at the recommended rate with coarse-spray nozzles, and (c) was applied with fine-spray nozzles at the recommended dilution (Lyles et al. 1969). Armbrust and Dickerson (1971) identified additional desirable characteristics: (a) cost was less than $123/ha ($50/a); (b) mulch initially prevented wind erosion and reduction at least 2 months; (c) there were no adverse effects on plant growth and emergence; and (d) the material was easy to apply.

Polyacrylamide (PAM) has been shown to greatly reduce irrigation-induced soil erosion at numerous locations (Sojka and Lentz 1996a). It can be applied as a liquid or as a dry powder through furrow and sprinkler irrigation. Sojka and Lentz (1996b) also reviewed the origins, properties, conservation benefits, mode of action, environmental impacts, and user considerations of PAM.

The objective of this studv was to evaluate various PAM formulations for their effectiveness in controlling wind erosion by their effect on (a) the amount of loose erodible material on the soil surface after treatment, (b) the freestream threshold velocity, and (c) abrasion of the treated surface in the laboratory and in the field.

Methods

Laboratory tests. Haynie very fine sandy loam (fine-sandy, mixed, mesic, Pachic Haplustolls) and Smolan silty clay loam (fine, montmorillonitic, mesic, Pachic Argiudolls) surface layers [0 to 10 cm (0 to 4 in)] were brought to a laboratory, passed through a 0.64-cm (0.25-in) sieve, and air-dried in a greenhouse. Air-dried soil was placed in trays 1.48 m (58.5 in) long, 0.16 m (6.1 in) wide, and 0.04 m (1.5 in) deep. Polyacrylamide formulations were applied to the soil surface at 25, 50, 100, 200, and 400% of the rate recommended by the supplier and at the dilution recommended and allowed to dry in the greenhouse. Untreated soil (no PAM or rain) and soil exposed to rain only (no PAM) served as checks. All treatments were replicated four times. Formulations, recommended rates, recommended dilutions, molecular weights, and costs are shown in Table 1.

Table 1. Polyacrylamide (PAM) formulations, recommended rates, and recommended dilutions tested in the wind tunnel*

Formulation	Recommended Rate	Recommended Dilution	Molecular weight (x 10^6 Mg mol^{-1})	Cost
Liquid PAM	9.3 l/ha (1 gal/A)	1:1000	16-17	$5.81/l ($22.00/gal)
HMW Dry PAM in H_2O*	5.6 kg/ha (5 lb/A)	1:1000	16-17	$9.91/kg ($4.50/lb)
HMW Dry PAM + Rain	5.6 kg/ha (5 lb/A)	0.5 cm rain[†]	16-17	$9.91/kg ($4.50/lb)
LMW Dry PAM in H_2O	5.6 kg/ha (5 lb/A)	1:1000	8-10	$9.91/kg ($4.50/lb)
LMW Dry PAM + Rain	5.6 kg/ha (5 lb/A)	0.5 cm rain	8-10	$9.91/kg ($4.50/lb)
Rain Only	—	0.5 cm rain	—	—

* HMW and LMW are high and low molecular weights, respectively.
† Simulated rain was applied after dry formulations to activate the material.

After drying, trays were placed in a wind tunnel to determine the loose erodible material on the surface, freestream threshold velocity, and abrasion resistance. The trays were placed 10 m (32.8 ft) downwind from the air inlet to the wind tunnel. The tunnel was 0.76 m (30 in) wide and 1.0 m (39.3 in) high.

Loose erodible material (LEM) was determined by exposing the trays for 5 min to a freestream wind speed of

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Table 2. Polyacrylamide (PAM) formulations, rates, and dilutions used in field experiments*

Formulation	Rate	Dilution
Liquid PAM	18.6 l/ha (2 gal/A)	1:1000
HMW Dry PAM in H_2O*	11.2 kg/ha (10 lb/A)	1:1000
HMW Dry PAM + Rain	11.2 kg/ha (10 lb/A)	0.5 cm rain†
Rain Only	—	0.5 cm rain

* HMW = high molecular weight.
† Simulated rain was applied after dry formulations to activate the material.

Table 3. Effect of PAM formulations on loose erodible material, threshold wind velocity, and abrasion of Haynie very fine sandy loam tested in wind tunnel*

Formulation	Loose erodible material g/tray	Threshold velocity m/s	Abrasion g soil/g abrader
Check	174 a*	9.7 d	0.20 b
Rain Only	14 c	19.4 b	0.19 b
Liquid PAM	42 b	16.8 c	0.40 a
HMW† Dry PAM + Rain	7 c	21.5 b	0.21 b
LMW Dry PAM + Rain	7 c	25.3 a	0.16 b
HMW Dry PAM in H_2O	7 c	21.7 b	0.34 a
LMW Dry PAM in H_2O	7 c	21.9 b	0.38 a

* If same within-column letter appears, differences are not significant at the 5% level by Duncan's multiple range test.
† HMW and LMW are high and low molecular weights, respectively.

13.4 m/s (30 mph). Soil loss was determined by weighing the trays before and after exposure. Wind speeds were measured 16 cm (6.3 in) above the tunnel floor with a pitot-static tube and pressure transducer.

Freestream threshold velocity (U_{fst}) was determined by measuring the soil loss from the trays after a 3-min exposure to a freestream wind speed of 7 m/s (15.6 mph) and increasing the wind speed in 1.0 m/s (2.2 mph) increments until soil loss was > 10.0 g (0.02 lb) for three exposures. The cumulative soil loss was plotted against wind speed to determine the U_{fst} at which soil loss was 10.0 g (0.02 lb). Ten grams was selected to be sure that a change in weight of a tray was due only to wind-removed soil.

Abrasion was determined by exposing the trays, from the LEM determination, to a freestream wind speed of 13.4 m/s (30 mph) and 1.3 kg (29.5 lb) of sand [0.297-0.42 mm diameter (0.012-0.017 in)]. Sand was placed 9 m (29.5 ft) upwind of the trays. Abrasion by saltating sand grains was determined by weight loss/weight of abrader.

Field tests. PAM formulations were applied to plots, each 3 X 10 m (10 X 33 ft) in size, of Haynie very fine sandy loam soil that had been rototilled to produce a highly erodible surface. PAM formulations, rates, and dilutions used are given in Table 2. Liquid materials were applied with a farm sprayer with coarse-spray nozzles. Dry materials were applied with a hand-held spreader and simulated rain [0.5 cm (0.2 in)] was applied with the farm sprayer. Untreated plots (no PAM or rain exposure) and "Rain Only" plots (no PAM) were included. Plots were replicated three times.

Plots were exposed when the soil surface was dry to a 17.3 m/sec (38.7 mph) wind velocity using a portable wind tunnel that was 0.91 m (3 ft) wide, 0.91 m (3 ft) high, and 9.1 m (30 ft) long. Wind velocity was measured with a Kurz anemometer located 8 m (26 ft) downwind and 0.46 m (1.5 ft) above the soil surface. Soil loss was measured with two modified Bagnold catchers, located 0.3 m (1 ft) from the tunnel walls at the downwind end of the wind tunnel. The catchers are 0.61 m (2 ft) high with a 1-cm (0.375-in) wide sampling slot.

Loose erodible material (LEM) was determined by exposing the surface for 5 min to the wind and weighing the amount of material caught in each catcher. Abrasion was determined by introducing 1.5 kg (3.3 lb) of sand [0.297 to 0.42 mm diameter (0.012-0.017 in)] at the upwind end of the wind tunnel. Exposure time was 5 min. Material caught in the catchers was passed through a 0.297-mm (0.012-in) sieve with finger pressure to assure that any soil aggregates were broken, and the amounts of abrader and soil were determined by weighing. Crust strength was measured with a penetrometer with a 1 cm^2 (0.14 in^2) flat tip at five locations in each plot.

Results and discussion

Laboratory tests. Even though soil losses were less on the Smolan soil than on the Haynie soil, the effects of the PAM formulations were the same; therefore, only the Haynie results will be discussed. Application of PAM formulations to the soil surface significantly reduced the amount of loose erodible material (LEM) (Table 3). PAM binds the surface particles to form a crust. Although the dry formulations performed better than the liquid formulation, the effects were not different from results of applying 0.5 cm (0.2 in) of simulated rain. The rate of application of PAM made no difference (Table 4).

The threshold wind velocity (U_{fst}) required to initiate soil movement was increased by all PAM formulations (Table 3). Only the LMW Dry + Rain formulation required a higher U_{fst} than 0.5 cm (0.2 in) rain. Applying less or more than the recommended rate was of no benefit (Table 4).

Abrasion by sand was increased by any PAM formulation applied as a liquid (Table 3). None of the formulations was less abraded than the Rain Only treatment. Two and four times the recommended rate decreased abrasion, compared to the lower application rates (Table 4), but were no different than the Rain Only treatment. The surface crusts formed by PAM were not well anchored to the soil below the crust and were penetrated easily by salting particles.

Field tests. Applying PAM to the soil surface at two times the recommended rate had no significant effect on loose erodible material, abrasion, or crust strength (Table 5). Rainfall [0.5 cm (0.2 in)] on the night after PAM treatments were applied may account for the check plots (no PAM or rain) having a crust, which reduced the loose erodible material. Results agree with tests conducted at Big Spring, Texas, with similar PAM formulations[1].

[1]Personal correspondence from D.W. Fryrear, Big Spring, Texas.

Table 4. Effect of rate of application of PAM formulations on loose erodible material, threshold wind velocity, and abrasion of Haynie very fine sandy loam tested in the wind tunnel*

Rate*	Loose erodible material g/tray	Threshold velocity m/s	Abrasion g soil/g abrader
0	174 a[†]	9.7 c	0.20 b
25	47 b	17.3 b	0.35 a
50	36 b	18.7 ab	0.31 a
100	33 b	19.6 ab	0.29 a
200	31 b	20.4 ab	0.20 b
400	35 b	21.3 a	0.19 b

* Percent of recommended rate.
[†] If same within-column letter appears, differences are not significant at the 5% level by Duncan's multiple range test.

Table 5. Effect of field application of PAM on loose erodible material, abrasion, and crust strength on Haynie very fine sandy loam

Treatment	Loose Erodible Material kg/ha	Crust Abrasion g soil/g abrader	Strength kg/cm²
Check	9 a*	0.10 a	0.67 a
Rain Only	25.6 a	0.14 a	0.48 a
Liquid PAM	34.4 a	0.19 a	0.58 a
HMW Dry in H_2O[†]	23.6 a	0.16 a	0.83 a
HMW Dry + Rain	28.4 a	0.18 a	0.56 a

* If same within-column letter appears, differences are not significant at the 5% level by Duncan's multiple range test.
[†] HMW = High molecular weight.

Summary

Application of PAM formulations will protect the soil surface from wind erosion if the treated area can be protected from incoming saltation particles. Application of twice the recommended rate gave maximum resistance to abrasion, but the crusts formed by 0.5 cm (0.2 in) of simulated rain were more resistant to abrasion than PAM crusts. Because of the added cost of materials, the large volumes of water needed to apply the materials, and the need to ensure that saltation does not enter the treated area, PAM cannot be recommend as a wind erosion-control practice for general agricultural situations.

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