EFFECTS OF POLYACRYLAMIDE, COVER CROPS, AND CROP RESIDUE MANAGEMENT ON WIND EROSION

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Abstract

Wind erosion results in reduced land productivity and environmental hazards. Wind erosion may be controlled through tillage, maintenance of a surface cover of growing crops or of crop residues, and by surface application of cementing agents. We investigated the effects of multiple densities of growing winter small grains and frost-killed summer forage grass seedlings, different post-harvest sorghum stubble management techniques, and surface application of several different rates of polyacrylamide (PAM) on in-field wind erosion in the Southern Great Plains of Texas, USA. We found cover cropping with winter small grains to reduce soil loss by 2-3 orders of magnitude at all planting densities. Frost-killed summer forage grass seedlings initially reduced soil loss by 1-2 orders of magnitude at all densities, but the 5 kg ha^{-1} planting density lost effectiveness with time. Certain management systems of standing sorghum stubble also reduced soil loss. Surface application of PAM was not found to reduce in-field soil loss at any application rate

Additional Keywords: PAM, surface cover, forage, sorghum

Introduction

Wind erosion is responsible for the degradation of over one-half billion hectares of land worldwide and also results in sandblast injury to crop seedlings and the production of fugitive dust that obscures visibility, pollutes the air, imperils transportation, fouls machinery, and endangers human health. Wind erosion may be controlled through tillage, maintenance of a surface cover of growing crops or crop residues, and by surface application of cementing agents. The importance of maintaining a cover of growing vegetation or residue has been recognized for several decades (Call, 1936). In addition to controlling wind erosion, the maintenance of surface residues helps conserve water by increasing infiltration and decreasing runoff (Onstad and Otterby, 1979). While many crops produce sufficient residue to protect the surface, tillage and weathering reduce the amount of residue remaining during the fallow season (Skidmore *et al*., 1979). Standing residue is much more effective at reducing erosion than flattened residue (Bilbro and Fryrear, 1994), but in semi-arid regions, drought often limits the production of residue (Merrill *et al*., 1999) and sparse surface residues have been shown to actually increase wind erosion in some cases (Sterk, 2000). Where residue production in insufficient to protect the surface, tillage can be and is often implemented to control erosion (Fryrear and Bilbro, 1984).

Tillage of soils in semi-arid areas reduces soil organic matter and wet aggregate stability resulting in the disintegration of soil aggregates and the increase of erodible particles less than 0.84 mm in size (Unger, 1999). In recent years, many soil conditioning compounds that may increase aggregate stability have been investigated (Nadler *et al*., 1996). One of these soil conditioners is polyacrylamide (PAM), a high molecular weight compound that has been shown to decrease water erosion and increase infiltration in furrow irrigated fields (Lentz and Sojka, 2000). The effectiveness of PAM at increasing wet and dry aggregate stability varies with soil type and the specific PAM formulation applied. Armbrust (1999) investigated the effects of PAM on wind erosion control and determined that PAM reduced the amount of loose erodible material available for erosion in laboratory trials, but did not reduce the erodibility of the soil in field tests. We investigated the effects of multiple densities of growing winter small grains and frost-killed summer forage grass seedlings, different post-harvest sorghum stubble management techniques, and surface application of several different rates of polyacrylamide (PAM) on in-field wind erosion in the Southern Great Plains of Texas, USA.

Materials and Methods

Field site

The United States Department of Agriculture, Agricultural Research Service (USDA-ARS) Big Spring Field Station (BSFS) is located near Big Spring, Texas, USA (32° 16'N, 101° 29'W) and is very near the southern terminus of the Great Plains region of North America. The climate is warm, semi-arid, and, on average, less than 500 mm of rain is received in a bimodal pattern with late spring and early fall maxima. The winters and early spring tend to be dry and windy. The primary soil at the BSFS is Amarillo fine sandy loam, fine-loamy, mixed,

superactive, thermic Paleustalf that has 0.2 % organic carbon and very low wet aggregate stability. The fragile nature of the soil, frequent high winds during the fallow season and the minimal surface residue resulting from the continuous cotton (*Gossypium hirsutum* L.) production in the area all contribute to occasionally severe wind erosion events.

Implementation of experiments

Eight approximately square plots >1 ha in size were utilized for the winter small grain and frost-killed summer forage grass investigation. In September of 2000, we planted barley (*Hordeum vulgare* L.) cv. Tambar 404 in 0.3 m spaced drill rows at rates of 0, 5, 10, and 20 kg ha^{-1} in two replicates each. Eight other approximately square plots >1 ha in size were planted with a sorghum (*Sorghum bicolor* (L.) Moench) and sudan grass (*Sorghum sudanense* (Piper) Stapf.) cross cv. Sweeter 'n Honey in groups of 3 x 0.15 m spaced drill rows on 1 m spacings at rates of 0, 3, 6, and 12 kg ha^{-1} in two replicates each. A killing freeze in early November killed the sorghum-sudan grass cross at an average height of 0.15 m. A five sampler gang (0.05, 0.1, 0.2, 0.5, and 1.0 m above the surface) Big Spring Number Eight (BSNE) sediment sampler was placed in the centre of each plot to guarantee a fetch of >50 m from a protected or differing surface. A 20 ha field was planted with sorghum in 1 m spaced rows at a rate of 60000 plants ha^{-1} in July and harvested in January leaving standing stalks 0.5 m tall. The field was divided into 12 plots of equal size (>1.5 ha) and the following four treatments applied in three randomized complete blocks; (1) the standing stalks were mowed to within 0.1 m of the ground and the plots were disked twice to incorporate the residue; (2) the standing stalks were mowed to within 0.1 m of the ground and no tillage operations were conducted; (3) the standing stalks were left at full height and no tillage operations were conducted; and (4) 0.25 m tall beds were listed onto the standing stalks. As in the winter small grain investigation, BSNE samplers were placed in the center of each plot area.

A 4 ha field with standing rye (*Secale cereale* L.) residue on the north half and clean-tilled fallow on the south half was divided into 10 plots 12 m wide oriented north – south and separated by raised borders. Each plot contained a 150 m long fallow sub-plot and a 150 m long residue covered sub-plot. In late August of 2000, PAM was applied to two randomized complete blocks at rates of 2.5, 5, and 10 kg ha^{-1} in water at 950 l ha^{-1} and as a dry granule at the 10 kg ha^{-1} rate. The PAM was incorporated with a rotary hoe to protect it from ultraviolet radiation. A 35 mm rain event in mid October activated the dry application and smoothed the tilled surfaces in all sub-plots. BSNE samplers were placed in the centre of each sub-plot area and the samples collected for analysis when the wind direction resulted in a fetch of at least 50 m from the raised borders. Surface soil samples were collected before PAM application and after the application and activation for analysis of dry and wet aggregate stability using the methods of Kemper and Rosenau (1986). In April 2002, a finely ground formulation of PAM was applied to the same experimental design at rates of 0, 0.5, 1, 2, and 4 kg ha^{-1} in saturated ammonium sulfate solution at 100 l ha^{-1}. Portable soil trays placed in the field received the same spray treatments and were brought into the laboratory for rainfall simulator testing of aggregate stability, loose sand abrader production, and dust production testing.

Analysis

After each wind event resulting in soil erosion, the BSNE samplers were collected and the trapped sediments were oven dried at 60°C and weighed. The weights were entered into the data processing routine developed for the development and validation of the Revised Wind Erosion Equation (RWEQ) (Fryrear *et al*., 1998) in order to get point estimates of soil loss in terms of kg m^{-2}. Treatment effectiveness was evaluated using analysis of variance with PROC GLM for randomized complete block designs and PROC MIXED for split plot designs in SAS v.8.2 (SAS, 1986). Wind erosion events vary greatly in intensity and comparison among multiple events requires that the soil loss from each treatment be normalized to the unprotected control soil loss. The Soil Loss Ratio (SLR) is commonly used to compare treatment effectiveness at controlling erosion. The SLR is the soil loss from any treatment divided by the soil loss from the control. SLRs were calculated for development of the graphical representation of the data.

Results and Discussion

A total of 12 wind erosion events occurred during the measurement period of February 2001 through April 2001. By the time the first wind erosion event occurred in February, even the 5 kg ha^{-1} rate plots had greater than 30% vegetative coverage of the soil. The growing winter small grain cover crop reduced wind erosion at all planting rates (p<0.001). While the vegetated plots were different from the fallow plots, they were not significantly different from each other. All the vegetated plots reduced wind erosion by 2-3 orders of magnitude for all events and may have completely eliminated saltation on the plots. BSNE samplers typically collect large amounts of

sediment in the saltation layer (0.05-0.2 m above the ground) with progressively less in the 0.5 m and 1.0 m sampler. From our data, this typical pattern was not apparent in the vegetated plots and often the upper samplers collected more sediment than those in the theoretical saltation layer below. Further, the particle diameters of sediment trapped above an actively eroding soil also tend to decrease with height and the sediment collected over the vegetated plots was relatively uniform at all heights above the surface. We believe that the sediment collected in the BSNE samplers may have been transported from eroding surfaces near the investigation area. As the culms began to elongate around the first of April, it was not unusual for one or more of the saltation layer samplers to be completely devoid of sediment. In addition, an approximately 5 m wide zone of sand deposition approximately 0.15 m deep was observed in the vegetated plots where they bordered the fallow plots. This phenomenon clearly demonstrates the sediment trapping effectiveness of cover crops. Unfortunately, the production of this cover crop had severely depleted the soil moisture to the 2 m depth by early May, the normal time for planting the revenue producing cotton crop in our area.

Soil loss estimates made from BSNE collected sediment samples for the same 12 wind erosion events were used to test the erosion reduction effectiveness of the strip-planted frost-killed summer forage grass. Early in the measurement period, plots protected with the strips of frost-killed forage grass reduced erosion at all planting rates (p<0.001). The level of protection was not as great as with the growing vegetative cover, but erosion was reduced by 1-2 orders of magnitude for all planting rates. By event 5 in early March, the 3 kg ha^{-1} planting rate was beginning to lose its effectiveness (Figure 1) due to natural weathering and degradation of the residue. As the season progressed, the effectiveness of this treatment continued to wane until nearly as much or more soil loss was observed in than in the unprotected control in events 11 and 12. The wind direction in event 11 was within 5° of parallel with the planted strips. We believe that the sediment that had been trapped by the strips on previous events may have all been mobilized in that event resulting in an SLR greater than 1. The other planting rates remained highly effective at reducing erosion throughout the measurement period.

A total of five wind erosion events occurred during the measurement period of February 2003 through April 2003. The effective management of residue remaining from a revenue producing crop is perhaps the most cost effective method of controlling wind erosion. The SLR data presented in Fig. 2 show how effectively wind erosion can be controlled by different management and tillage systems. The data are plotted on a log scale in order for the relative effectiveness of each system to be evident. The data for the first two wind erosion events indicate that the mowed stubble treatment has the highest erosion potential. The tillage of the mowed and plowed treatment resulted in surfaces with protective soil aggregates until a rain in late March disintegrated the aggregates. From that time until the end of the measurement period, all treatments in which any surface residues remained had less soil loss than the mowed and plowed treatment (p<0.006). The most effective treatment for all events was listing beds (displace inter-row soil to raise an in-row bed) on the full height stalks which combined the effects of the crop residue with
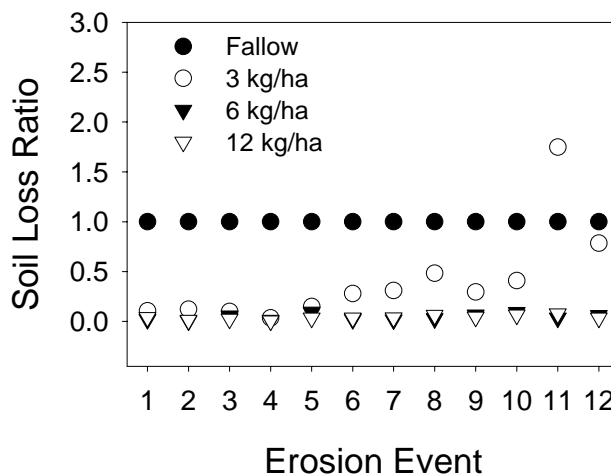

Figure 1. Mean soil loss ratios for the four frost-killed summer forage grass planting rates by wind erosion event.
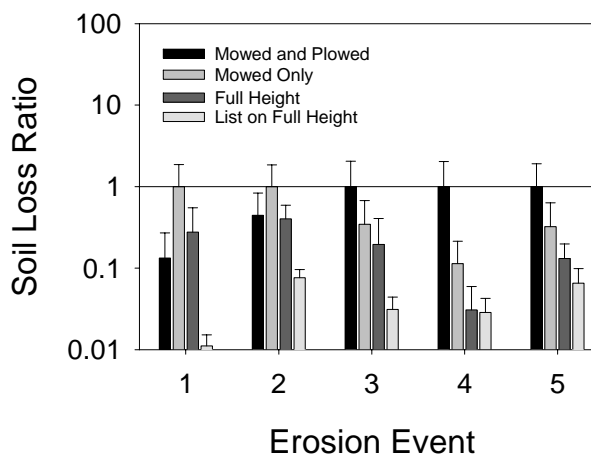

Figure 2. Mean soil loss ratios and standard deviations for the four management options for post-harvest sorghum standing residue. A rain received between events 2 and 3 disintegrated the soil aggregates resulting from plowing the residues into the soil and changed the treatment with maximum soil loss from the mowed only treatment to the mowed and plowed.

oriented soil roughness elements and resulted in 5 % of the soil loss for the mowed and plowed treatment.

Only two wind erosion events with wind directions allowing for 50 m of fetch upwind of the BSNE samplers occurred during the measurement period of January 2001 to May 2001. From the soil loss estimates from these two events, the standing residue was effective at reducing soil loss ($p < 0.004$) but no treatment effects of the PAM applications on soil loss were observed at any application rate or method. This observation is consistent with Armbrust (1999) who found that surface application of PAM had no significant effect on loose erodible material, abrasion, or crust strength. We also found PAM ineffective at increasing either dry aggregate stability or wet aggregate stability. A trend was noted for higher wet aggregate stability in the residue covered plots than the fallow plots, indicating that even small increases in organic matter may positively affect this important parameter. Gravimetric cores collected before PAM application and after the first rain event indicated that PAM did increase infiltration, but the residue was more effective at increasing infiltration. There was an additive effect of the PAM on infiltration observed in the residue covered sub-plots.

From our laboratory investigations with field-sprayed surface applications of PAM on portable soil trays, PAM did not reduce the aggregate disintegration resulting from a 15 minute simulated rain event of 13 mm at any application rate. While PAM did reduce the production of loose sand-sized abrader on the surface of the crust at the 1, 2, and 4 kg ha^{-1} application rates for the first post-application simulated rain event, this effect was not observed for subsequent simulated rain events. Surface applications of PAM also did not reduce dust emissions in wind tunnel tests of post rain event crusted soils.

Conclusions

From our observations, we have concluded that maintaining an actively growing cover crop was the most effective method of controlling wind induced soil loss. Where insufficient rainfall exists to maintain a cover crop, utilizing a strip-planted frost-killed summer grain or forage grass crops offers a very high level of protection without depleting the soil moisture available for a subsequent summer crop. Management of existing crop residues in a standing condition along with listing beds for the following crop is an effective method that does not require additional seed purchase or additional cultural operations and thus is very cost effective. PAM application does not appear to be effective at controlling wind induced soil loss.

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