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WIND ERODIBILITY AS INFLUENCED BY RAINFALL AND SOIL SALINITY

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Wind erosion has been observed on some fields shortly after a rainstorm. Chepil (4) noted that some of the coarse soil grains left loose on the surface following rainfall contributed to the initial stages of wind erosion. Such coarse grains remain on the surface after dispersal of surface soil by raindrop impact and splash (3, 4). Crust formation associated with rainfall presumably would reduce wind erosion by increasing bulk density and lowering aggregation (8). Soil crusting is also associated with soil salinity (2, 3, 7, 9, 10).

Wind erodibility of soils following rainstorms of various intensities and relatively short durations have not been studied extensively. Little, if any, information exists on the influence of various salts on a soil's susceptibility to movement by wind.

Reported here are the combined effects of added salts, rainfall intensity, and rainfall duration on wind erodibility and mechanical strength of a sandy soil.

MATERIALS AND METHODS

The experimental variables are listed in table 1. The study was a factorial experiment in a completely random design with three replications of each combination.

The various salts were added to a Pratt loamy fine sand (table 2) and thoroughly mixed in a cement mixer to produce an electrical conductivity (ECe) of about 12 mmhos./cm., as determined from a saturation extract. The soils were aged at least 4 weeks in covered containers, air dried, remixed in a cement mixer to break up clods and provide a uniform starting point, and placed in perforated trays 8 in. wide, 48 in. long, and 2 in. deep. Identical handling procedures were used on the nonsaline soil.

The soil surface was smoothed by passing a straightedge across the top of the trays before exposure to the various rainfall treatments in a raintower. After drying, soil in each tray was exposed in a wind tunnel (5) for 5 minutes at a free-stream velocity of 15 m./sec. and checked for erosion loss by weight reduction. Immediately

TABLE 1

Experimental variables

Variable	Symbol
Salt composition	
Nonsaline (no salt added)	S_0
Sodium chloride (NaCl)	S_1
50–50 mixture by weight, calcium chloride ($CaCl_2$) and magnesium chloride ($MgCl_2$)	S_2
45–35–20 mixture by weight, NaCl, $CaCl_2$, and $MgCl_2$	S_3
Rainfall duration	
15 minutes	D_1
30 minutes	D_2
60 minutes	D_3
Rainfall intensity	
0.69 inch per hour	I_1
2.14 inches per hour	I_2

TABLE 2

Some physical and chemical characteristics of Pratt loamy fine sand

Sand, %	87.3
Silt, %	6.2
Clay, %	6.5
Electrical conductivity of saturation extract, mmho./cm.	0.22
Cation exchange capacity, mq./100 g.	2.9
Exchangeable sodium, mq./100 g.	0.08
Exchangeable calcium, mq./100 g.	1.40
Exchangeable magnesium, mq./100 g.	0.53
Exchangeable potassium, mq./100 g.	0.10

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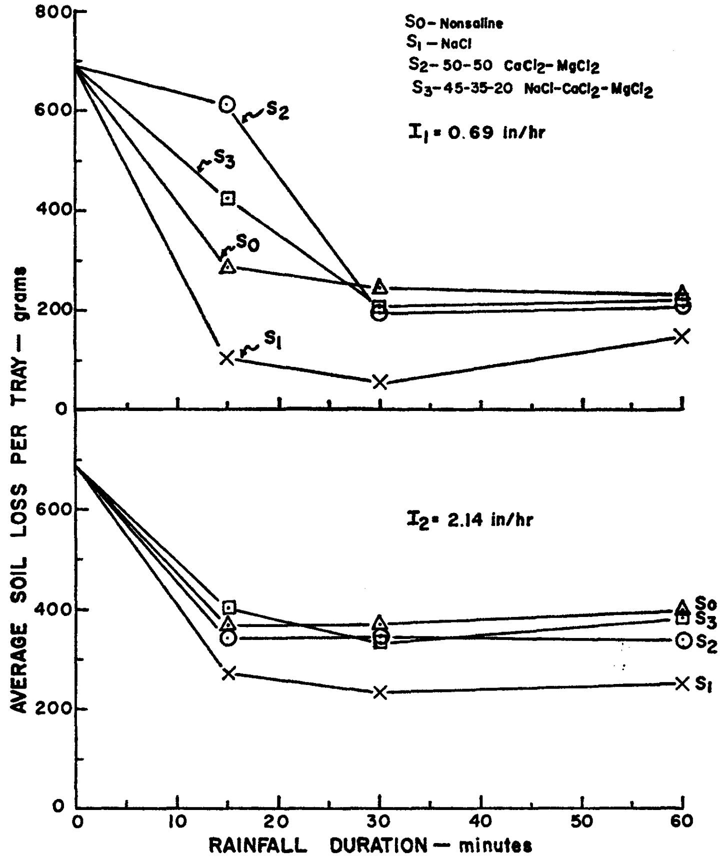

FIG. 1. Average soil loss by wind from trays previously exposed to rainfall intensities of 0.69 (upper) and 2.14 (lower) in. per hour for indicated durations.

TABLE 3

Summary of analysis of variance for all the soil loss data

Main Effect	Variance Ratio (F)	Inter-actions	Variance Ratio
Rain intensity (I)	12.2*	ID	4.0†
Salts (S)	8.7*	IS	1.5‡
Rain duration (D)	5.7*	SD	1.5‡
		SID	1.6‡

* Significant at the 1% level.
† Significant at the 5% level.
‡ Not significant.

upwind from a tray of test soil, a tray of erodible silica sand provided a source of saltation flow to more closely simulate the natural wind erosion process. The wind-tunnel floor outside the trays was covered with 2.5-cm.-diameter spheres to simulate a rough surface.

The effect of added salts and rainfall on the mechanical strength of the surface soil layer was determined by recording the maximum force necessary to pull ¼-in. glass spheres from a ⅜-in. soil depth (center of sphere) after rainfall exposure and drying. Sixteen force measurements were made for each treatment combination.

Salt content (ECe) of three 0.67-inch soil depth increments from the trays was determined from samples taken immediately following rainfall and again after drying.

EXPERIMENTAL DATA AND OBSERVATIONS

The average soil loss by wind at each level of the variables studied is shown in fig. 1. The variance ratios for the variables and their interactions are summarized in table 3. The control soil loss (from trays not exposed to rainfall) is not included in the analysis.

The significance of the rain intensity times rain

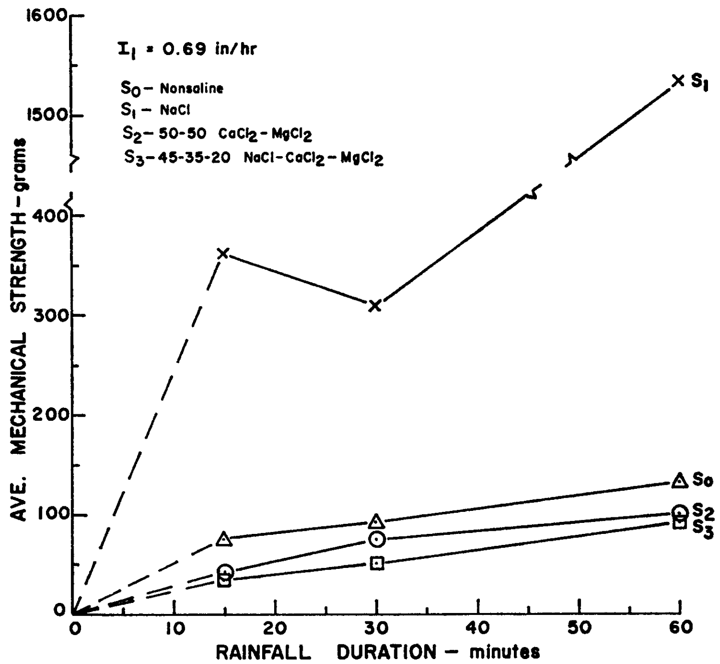

FIG. 2. Average mechanical strength of saline or nonsaline soil previously exposed to a rainfall intensity of 0.69 in. per hour for indicated durations.

duration interaction restricts interpretation of the main variable effects. Consequently, the data were regrouped according to rainfall intensity and specific intensity-duration combinations and additional analyses of variance were performed. Loss by wind from sodium chloride-treated soil (S_1) was significantly less (44 to 48 per cent) than from soil treated with the other salts. Except for the low-intensity, short-duration treatments, soil losses did not differ significantly among the other three salts. Except for S_2 and S_3 at 15-minute-rainfall duration, soil loss was lower with the lower intensity (I_1) for all the salt-duration combinations. Rainfall duration significantly influenced soil loss only for the 15 min. exposure at the low rainfall intensity.

Generally, the effects of rainfall intensity and duration on mechanical strength were about as expected, i.e., increasing strength with both increasing intensity and duration (figs. 2 and 3). The sodium chloride-treated soil (S_1) was markedly stronger than soils not treated (S_0) or than those treated with other salt combinations (S_2, S_3), regardless of rainfall intensity or duration.

Bar graphs show the salt concentration (ECe) in three depth increments of soil from trays for the S_1 salt treatment immediately after rainfall exposure (fig. 4) and after drying (fig. 5). Similar data from the other salt treatments are omitted. As expected, the water-soluble salt moved in response to the amount of water received during the rainfall (fig. 4) and to drainage or evaporation during drying (fig. 5).

INTERPRETATIONS AND DISCUSSION

At high-rainfall intensities a dense, compact layer (crust) forms beneath surface particles that are mobilized by raindrop impact and splash. It is these loose surface particles that are subsequently moved by wind. Soil mechanical strength (which reflects degree of compaction, dispersion and cementing) was not related to wind erodibility of salt-treated soils following rainfall and drying. The nonsaline soil indicated an unexpected positive correlation between soil loss and mechanical strength (fig. 6). The expected correlation, if any, would be negative. Apparently, mechanical strength of salt-treated soils was not a good indicator of erodibility because strength was not related to the quantity of loose particles at the surface.

Wind erodibility of nonsaline soil following rainfall and drying was increased more by rain-

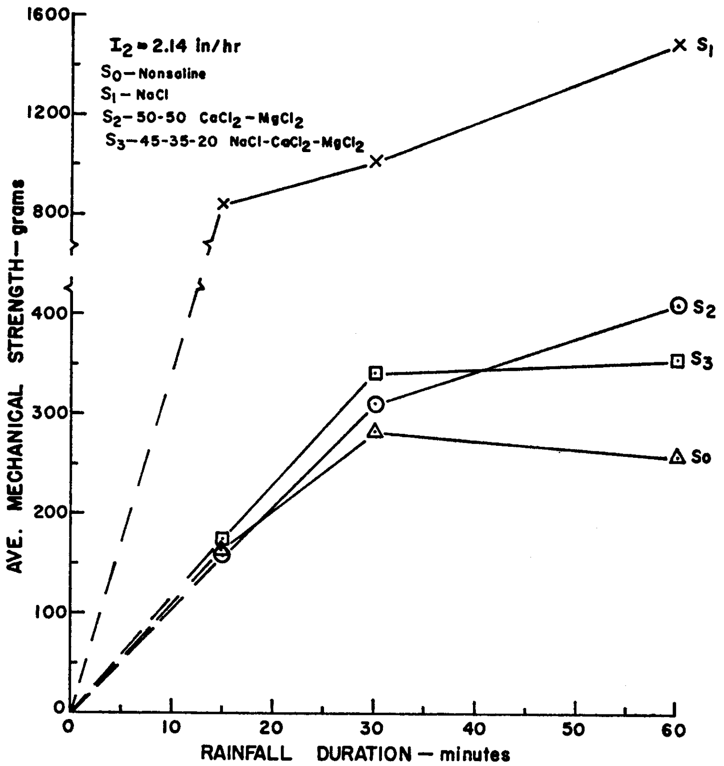

FIG. 3. Average mechanical strength of saline or nonsaline soil previously exposed to a rainfall intensity of 2.14 in. per hour for indicated durations.

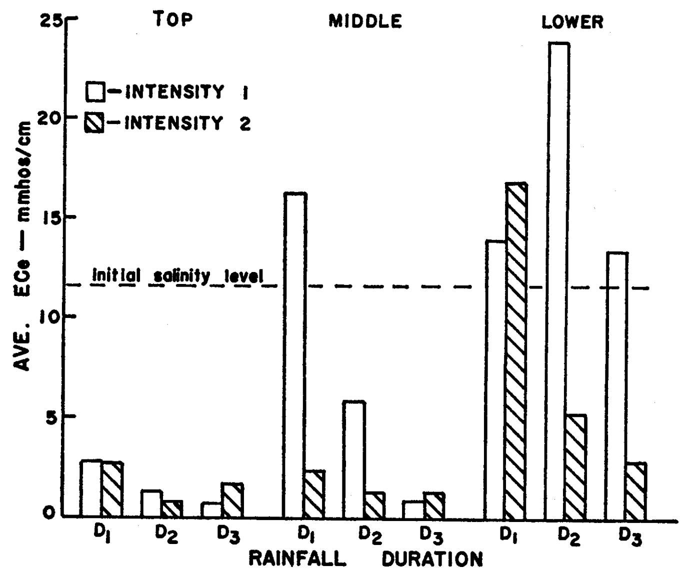

FIG. 4. Average electrical conductivity of a soil saturation extract from three soil depth increments (top, middle, lower) *immediately* after exposure to indicated rainfall intensities and durations. The salt treatment was sodium chloride (S_1). The symbols are identified in table 1.

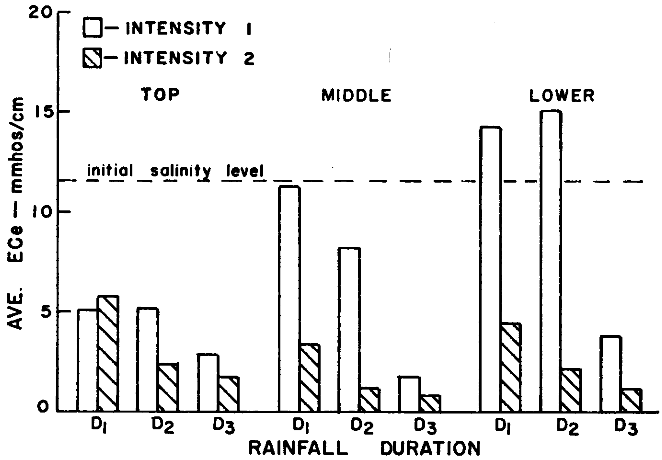

FIG. 5. Average electrical conductivity of a soil saturation extract from three soil depth increments (top, middle, lower) *after drying* following exposure to indicated rainfall intensities and durations. The salt treatment was sodium chloride (S_1). The symbols are identified in table 1.

fall intensity than by amount (fig. 7). Ellison (6) reported that soil splash from raindrop impact is directly proportional to rainfall intensity. Thus, for nonsaline soils (especially sands) the quantity of loose particles generated at the surface by rainfall would increase with rainfall intensity.

Saline soils (ECe > 4 mmhos./cm. and exchangeable sodium percentage, ESP, <15) become "normal" soils after excess soluble salts are leached out (10). That would apply to S_2 and S_3, and very likely explains their general lack of difference in either wind erodibility or mechanical strength, compared with nonsaline soil.

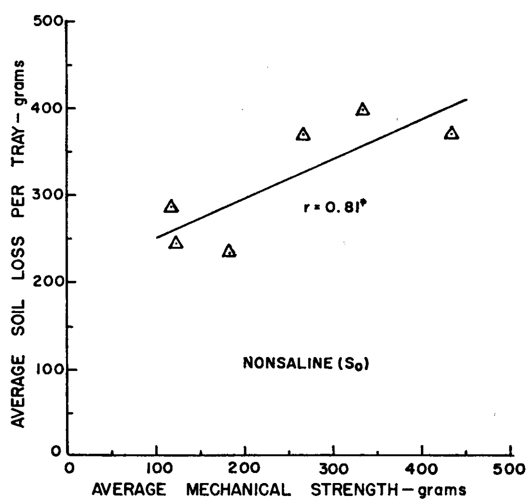

FIG. 6. Average soil loss by wind from nonsaline soil as related to its mechanical strength created by rainfall and subsequent drying.

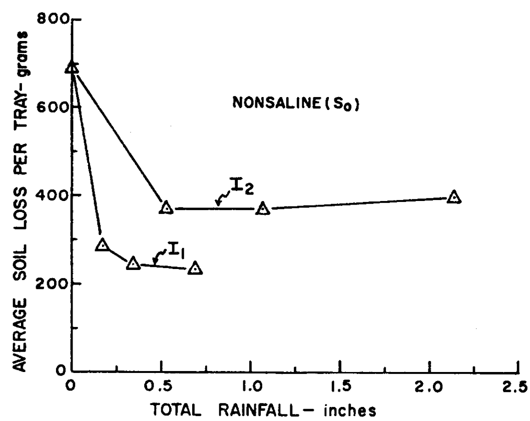

FIG. 7. Effect of total rainfall on average soil loss by wind from nonsaline soil previously exposed to intensities of 0.69 (I_1) or 2.14 (I_2) in. per hour.

Saline-sodic soils (ECe > 4 mmhos./cm.; ESP > 15), upon leaching, form nonsaline-sodic soils (ECe < 4 mmhos./cm.; ESP > 15) whose particles disperse and develop hard surface crusts as the soil dries (fig. 8). The crusts do not favor entry or movement of water, and soils with such crusts may present tillage problems (10). Factors favoring development of hard surface crusts are: high exchangeable sodium, low organic matter, puddling, and wetting the soil to zero tension (which occurs with rain). The first,

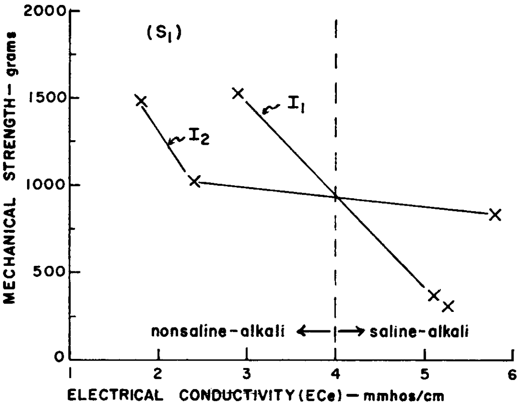

FIG. 8. Effect on mechanical strength of leaching a saline-alkali soil.

second, and fourth factors were present in our sodium chloride-treated soil (S_1) and apparently account for its marked increase in mechanical strength (figs. 2 and 3). Also note that the large increase in mechanical strength occurred even though the test soil clay content was small (table 2). The effect of sodium on mechanical strength of S_3 soil was ameliorated because Ca and Mg are more strongly adsorbed on the exchange surfaces than is Na (1, 10). Therefore, adverse effects of Na are offset if salts present generally contain 50 per cent or more of Ca and Mg as our S_3 soil did.

Although rainfall may reduce wind erodibility of a nonsaline soil 42 to 66 per cent, the minimum loss of 230 g. per tray (equivalent to about 4 tons per acre) per rainfall event following surface drying of treated soil (fig. 1) would be unacceptable; so, other means of control such as maintaining vegetative residues, surface roughening, or establishing wind barriers would be needed.

The amounts of sodium chloride added did reduce wind erodibility, but detrimental effects of NaCl on soil structure, plant growth, runoff, and erosion by water would more than offset benefits gained.

In 16 of 18 salt-rainfall combinations studied, salts did not increase susceptibility of a sandy soil to wind erosion. Therefore, salts added to soil by irrigation with poor quality water should not increase the wind erosion hazard. Our conclusions should probably be restricted to 2:1 lattice type clays.

SUMMARY

The combined effects of added sodium, calcium and magnesium chloride salts, rainfall intensity and rainfall duration on wind erodibility and mechanical strength of a sandy soil were evaluated in a laboratory study. Loss by wind from sodium chloride-treated soil was significantly less than from nonsaline soil or from soil treated with the other salts. With two exceptions, soil loss following low-intensity rain was less than that following high-intensity rain for the salt-duration combinations studied. Except for short-duration rains at low intensity, rainfall duration did not significantly affect soil loss. The sodium chloride-treated soil increased in mechanical strength following rainfall and drying much more than did nonsaline soil or soils treated with other salt combinations, regardless of rainfall intensity or duration.

REFERENCES

(1) Baver, L. D. 1956. "Soil Physics." John Wiley and Sons, 3rd ed., 489 pp.

(2) Bower, C. A. and Hatcher, J. T. 1962. Characterization of salt affected soils with respect to sodium. Soil Sci. 93: 275–280.

(3) Carnes, A. 1934. Soil crusts. Agr. Engin. 15: 167–169.

(4) Chepil, W. S. 1958. Soil conditions that influence wind erosion. USDA Tech. Bul. 1185, 40 pp.

(5) Disrud, Lowell A., Lyles, Leon and Skidmore, E. L. 1969. How wind affects the size and shape of raindrops. Agr. Engin. 50: 617.

(6) Ellison, W. D. 1944. Studies of raindrop erosion. Agr. Engin. 25: 131–136, 181–182.

(7) Jacobs, H. S., Dixon, R. M., Lynn, W. C. and Naddih, B. I. 1964. Irrigation effects on Kansas soils. Kans. Agr. Expt. Sta. Tech. Bul. 134.

(8) Lemos, Petezval and Lutz, J. F. 1957. Soil crusting and some factors affecting it. Soil Sci. Soc. Am. Proc. 21: 485–491.

(9) Reeve, R. C., Bower, C. A., Brooks, R. H. and Gschwend, F. B. 1954. A comparison of the effects of exchangeable sodium and potassium upon the physical condition of soils. Soil Sci. Soc. Am. Proc. 18: 130–132.

(10) U. S. Salinity Laboratory Staff. 1954. Diagnosis and improvement of saline and alkali soils. USDA, Agr. Handbook No. 60, 160 pp.