SOIL-SURFACE CRUST AND PLOW-LAYER DIFFERENCES WHICH MAY AFFECT RUNOFF QUALITY [1]

E. M. White and E. J. Williamson
Plant Science Department (Soils)
South Dakota State University, Brookings, South Dakota 57006

ABSTRACT

Soil surface crusts and plow layer samples were analyzed to determine if difference existed which could influence runoff quality. Average contents of N, PO_4-P, NO_3-N, NH_4-N, and organic matter are slightly larger in soil surface crusts than in the plow layer. The difference between the two remained nearly constant for N or PO_4-P during a 5-year period. However, the average contents of both the crust and plow layer increased due to fertilizer addition and mulch-tillage. Mulch-tillage and fertilizer application apparently did not increase the amounts of nutrients in the crust more than the relative amount in the plow layer. Thus, runoff quality probably is not affected specifically by surface crust properties which develop with mulch tillage, although it may be altered by changes in the entire plow-layer. Sediment in runoff was enriched by about 1.3 to 1.5 time the nutrient amount found in the plow layer.

INTRODUCTION

Runoff from cultivated soil contains nutrients derived from precipitation, soil, fertilizer, and growing crops or their residues. Nutrient loss in runoff may be increased if the crop residues are left on or in the soil surface where they are in contact with the runoff water. However, the residues on the surface reduce runoff and soil erosion so that the total loss of nutrients probably is less than if the residues are incorporated in the soil. Nutrient loss may be less if the surface crust is leached of readily available nutrients and not mixed with the plow layer by tillage.

LITERATURE REVIEW

Soil crusts form by rain-drop impact, which breaks down soil aggregates, causes compaction, and may release fine particles that either wash into the soil pores and plug them or collect on the soil surface (McIntyre, 1958). Evans and Buol (1968) showed that vesicular (closed) pores form just beneath the surface, and in some crusts, a pronounced gradation in texture develops. Runoff tends to remove the finer soil fraction and leave the coarser fraction (Ellison, 1945). Young and Wiersma (1973) reported in a laboratory

[1]Contribution from South Dakota Agricultural Experiment Station as Journal Series 1401.

study that 80 to 85% of the sediment was transported to rill gullies before it was removed by erosion. Bodman and Harradine (1938) reported that the clay content of the top 68 mm of some loam or clay loam soils decreased about one percent due to downward migration of clay in percolating water. The beating and splashing action of raindrops probably is restricted to the surface layer that is about 3 times thicker than the raindrops (Mutchler and Larson, 1971).

The soil surface-crust properties also may be affected by photochemical destruction of humic materials (Il'in and Orlov, 1973). Radiation bleaching of minerals, which occurs in lunar soil surfaces (Cohen and Hapke, 1968), probably is too slow to alter soil crusts significantly. Summer showers, which wet only the upper soil, may stimulate microbial decomposition of organic matter and leach nutrients from the crust. Leaching of nitrogen may be compensated for by algal fixation of atmospheric N in the moistened surface (Reddy and Giddens, 1975; Hutcheson and Olson, 1967). In addition, algal crusts may retard erosion (Booth, 1941). Nutrient losses by leaching also may be counteracted by nutrients added in the showers (Junge, 1958; Junge and Werby, 1958; Matheson, 1951) and in atmospheric particulates (Morgan et al., 1970). Nutrients may be added to the crust in plant exudates and rain leachates of live or dead plant material (Unambu-Oparah, 1972; Timmons et al., 1970).

METHODS

Soil surface crusts, 1- to 2-cm thick, and plow layers were sampled at 27 locations in runoff plots on three different dates, September 3, 1969, April 12, 1973, and September 18, 1973. The runoff plots (Williamson and Kingsley, 1974) are located near Garden City in eastern South Dakota, have a 5% slope, and Poinsett silt loam soils (Argiborolls). Average annual precipitation is about 500 mm with about three-fourths occurring during the growing season.

The NH_4-N and NO_3-N was extracted with 2 N KCl (Bremner, 1965) within a day after the soils were sampled and refrigerated. Extracts were refrigerated until the N could be determined by steam distillation (Bremner, 1965) and nezzlerization (Jackson, 1958). Other methods are: Organic matter — Walkley-Black; total N — titrimetric macrokjeldahl; total PO_4-P — $HClO_4$ digestion and ascorbic acid reduction (Watanabe and Olsen, 1965); and particle size — pipette on organic matter and salt-free samples (Day, 1965).

RESULTS AND DISCUSSION

The soil-crust samples in comparison to plow-layer samples have higher contents of organic matter, total PO_4-P, total N, NH_4-N, and NO_3-N except for the one sampling date (Table 1). The smaller

organic matter contents for the April in comparison to the September sampling dates probably is because roots from the previous season have decayed. The Walkley-Black method depends on the oxidation of organic matter to CO_2 so that microbial decay of easily oxidized root components would decrease rapidly the amount of organic matter measured by the method. The mulch-tillage practices had little effect on the organic matter distribution between the crust and plow layer in the 5 year period.

Although total N and total PO_4-P increased in the 5 year period, relative differences between the soil crust and plow layer are similar for the three sampling dates. The possible losses and additions of nutrients discussed in the literature review must be equal or insignificant. Increases in total N must cause a narrowing of the carbon-nitrogen ratio in the soils because the organic matter content has remained constant. However, the narrower C/N ratio apparently has had no effect on the NH_4-N or NO_3-N content of the

TABLE 1

Means for Organic Matter, Total-N, Total PO_4-P, NH_4-N, NO_3-N, and Clay Contents of Soil Surface-Crusts and Plow-layers Sampled at the Same 27 Locations on Three Dates

Sample Date†	Soil Layer Crust	Plow	Signif.§	Sample Date	Soil Layer Crust	Plow	Signif.§
	Organic Matter %				Total Nitrogen %		
1	4.04	3.89	**	1	.170	.166	N.S.
2	3.77	3.67	†	2	.212	.205	*
3	3.98	3.79	**	3	.210	.201	*
	NH_4-N ppm				NO_3-N ppm		
1	8.31	4.91	**	1	17.64	5.67	**
2	7.99	6.01	†	2	17.35	10.47	**
3	4.96	4.40	N.S.	3	10.89	17.27	*
	Total PO_4-P ppm				Clay ($<2\mu$ size) %		
1	629.1	568.3	**	1	25.7	26.0	N.S.
3	655.4	573.6	**				

† Sample dates were 1. September 3, 1969, 2. April 12, 1973, and September 18, 1973.

§ Statistical Significance: **, p = .01; *, p = .05; †, p = .10; N.S. not significant.

soil. These soluble ions would be removed readily from the crust in runoff. The main effect of the nitrogen may have been to decompose relatively stable high C/N ratio organic matter that had accumulated in the soils when fertilizer use was limited prior to 1969.

The smaller clay content of the crust in comparison to the plow layer was not significant because a few samples had 30 to 50 percent clay. These samples probably were collected from slight depressions where the crust accumulated fine particles eroded from adjacent areas. The surface crust should have less clay because the average sediment eroded from the plots had 9 percent more clay than the average plow layer soil (Table 2).

TABLE 2

Average Clay, Fine Silt, Coarse Silt, Sand, Organic Matter, N, and Total PO_4-P Content of Runoff Sediment From Cultivated Runoff Plots

Source	Samples Averaged	Average Content	Sediment/Soil ratio	
			Crust	Plow layer
Clay, %	52	35.1	1.36	1.34
Fine silt, %	52	32.0	1.65	1.69
Coarse silt, %	52	21.7	.69	.71
Sand, %	52	11.2	.46	.46
Total N, %	46	.291	1.39	1.45
Organic matter, %	50	5.6	1.40	1.48
Total PO_4-P, ppm	51	750.	1.10	1.31

Average organic matter, nitrogen and PO_4-P contents of the runoff sediment are larger than those in either the crust or plow layer samples. Ratios between the amounts in the sediment and in the crust or plow layer samples on the last sampling date are respectively: organic matter, 1.40 or 1.48; PO_4-P, 1.14 or 1.31; nitrogen, 1.38 or 1.45; and for clay, 1.36 or 1.34. Thus the enrichment of the sediment in comparison to the soil contents is quite uniform. However, from the ratios, PO_4-P is more apt to be from the plow layer than the crust.

LITERATURE CITED

Bodman, G. B., and E. F. Harradine. 1938. Mean effective pore size and clay migration during water percolation in soils. Soil Sci. Soc. Amer. Proc. 3:44-51.

Booth, W. E. 1941. Algae as pioneers in plant succession and their importance in erosion control. Ecology 22:38-46.

Bremner, J. M. 1965. Inorganic forms of nitrogen. **In** C. A. Black (ed.) Methods of soil analysis. Agronomy 9:1179-1237. Amer. Soc. Agron., Madison, Wisc.

Cohen, A. J., and B. W. Hapke. 1968. Radiation bleaching of thin lunar surface layer. Sci. 161:1237-1238.

Day, P. R. 1965. Particle fractionation and particle-size analysis. **In** C. A. Black (ed.) Methods of soil analysis. Agronomy 9:545-567. Amer. Soc. Agron., Madison, Wisc.

Ellison, W. D. 1945. Some effects of raindrops and surface-flow on soil erosion and infiltration. Trans. Amer. Geophys. Union 26:415-429.

Evans, D. D., and S. W. Buol. 1968. Micromorphological study of soil crusts. Soil Sci. Soc. Amer. Proc. 32:19-22.

Hutcheson, H. L., and E. S. Olson. 1967. A comparison of soil algae in grazed and ungrazed grasslands in eastern South Dakota. South Dakota Acad. Sci. Proc. 46:257 (Abstr.)

Il'in, N. P., and D. S. Orlov. 1973. Photochemical destruction of humic acids. Soviet Soil Sci. 5:75-83.

Jackson, M. L. 1958. Soil chemical analysis. Prentice-Hall, Inc., Englewood Cliffs, N. J.

Junge, C. E. 1958. The distribution of ammonia and nitrate in rain water over the United States. Trans. Amer. Geophys. Union 39:241-248.

Junge, C. E., and R. T. Werby. 1958. The concentration of chloride, sodium, potassium, calcium, and sulfate in rain water over the United States. Jour. Meteorology 15:417-425.

Matheson, D. H. 1951. Inorganic nitrogen in precipitation and atmospheric sediments. Canadian Jour. Tech. 29:406-412.

McIntyre, D. S. 1958. Soil splash and the formation of surface crusts by raindrop impact. Soil Sci. 85:261-266.

Morgan, G. B., G. Ozolins, and E. C. Tabor. 1970. Air pollution surveillance systems. Sci. 170:289-296.

Mutchler, C. K., and C. L. Larson. 1971. Splash amounts from waterdrop impact on a smooth surface. Water Resour. Res. 7:195-200.

Reddy, G. B., and J. Giddens. 1975. Nitrogen fixation by algae in fescuegrass soil crusts. Soil Sci. Soc. Amer. Proc. 39:654-656.

Timmons, D. R., R. F. Holt, and J. J. Latterell. 1970. Leaching of crop residues as a source of nutrients in surface runoff water. Water Resour. Res. 6:1367-1375.

Unamba-Oparah, I. 1972. Evaluation of nutrients in the water exuded by plants. Soil Sci. 114:158-159.

Watanabe, F. S., and S. R. Olsen. 1965. Test of an ascorbic acid method for determining phosphorus in water and $NaHCO_3$ extracts from soil. Soil Sci. Soc. Amer. Proc. 29:677-678.

Williamson, E. J., and Q. Kingsley. 1974. Across slope farming saves rainfall runoff. S. D. Farm and Home Res. 25:14-17.

Young, R. A., and J. L. Wiersma. 1973. The role of rainfall impact in soil detachment and transport. Water Resour. Res. 9:1629-1636.