Reprinted from *1996 Columbia Basin Agricultural Research Annual Report. Spec. Rpt. 961,* pp. 68-70, 1996
Oregon State University in cooperation with USDA-Agricultural Research Service, Pendleton, OR

FORMATION OF WEAKLY CEMENTED SILICEOUS PANS INDUCED BY LONG-TERM AGRICULTURAL MANAGEMENT

John Baham and Said Al-Ismaily

INTRODUCTION

Soil pans commonly appear on the agricultural landscape of the Colombia Plateau. These features form largely as the result of tire and machine traffic. However, the weathering, migration, and re-precipitation of water soluble silica, (Si_w) may enhance the strength of these pans through cementation of the soil particles. The source of the water soluble Si is most likely a recent (geologically speaking) dusting of volcanic ash. The weathering of Si-rich minerals can be significantly influenced by agricultural practices (e.g. addition of N fertilizers) that acidify the soil. We feel that the potential for the chemical cementation of these pans is largely influenced by agricultural management practices.

This preliminary report includes discussion of 1) the potential and magnitude of Si weathering by agricultural practices, 2) the sources and amounts of readily soluble Si that form the cementing agents, 3) a number of biogeochemical acidification processes involving N cycling, and 4) plant removal. The major goal of this work is focused on the understanding of the formation of these cemented pans, with the implied goal that this understanding will provide us with the knowledge necessary for their management.

MATERIALS AND METHODS

Soil cores were collected from long-term residue management plots during the spring fallow and after harvest (August) in 1995. These plots have been managed under a continuous wheat-fallow system for over 50 years. Four treatment plots were sampled: 1) 80 lbs. N(nitrogen)/acre, 2) 40 lbs. N/acre, 3) manure/straw additions (equivalent to a rate of 80 lbs. N/acre), and 4) a control plot to which no N is added. Field penetrometer readings were measured in each plot in the spring of 1995.

The soil cores were sectioned at 1 inch intervals to 20 inches, and at 4 inch intervals thereafter. Bulk density and water content values were measured in the laboratory. Soil pH_w (pH in H_2O, 1:2) values were measured with a combination glass electrode and a pH meter. Total acidity was determined by the $BaCl_2$- Triethanolamine method. Water soluble silica, Si_w (mg Si/ kg soil) is defined as the amount of Si dissolved in water (5 g of soil in 20 mL of deionized water for 2 hours). This produces a labile pool of Si. Amorphous Si is measured as the amount of Si soluble in 0.5 *M* NaOH at 85 ^oC, for ten minutes. Si was determined colorimetrically.

RESULTS AND DISCUSSION

Soil penetrometer (Fig. 1) and bulk density values taken during the spring from the fallow segment of the management cycle are consistent with the formation of a compacted traffic pan. The maximal expression of the pan occurs at approximately 10-12 inches soil depth (Allmaras et al., 1982). There appeared to be no relation between the treatments and soil strength values taken in the spring when the soil was still moist. Values measured for the soil strength in the fall, after the soil dried, are nearly double those of the spring (Douglas et al., 1983). It appears the strength of the pans is expressed most markedly in the fall when the soil is dry. This observation is consistent with the presence of a cementing agent such as Si.

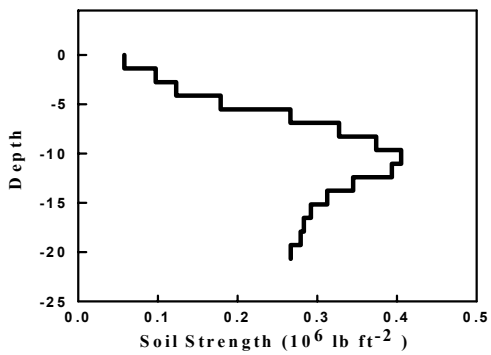

Figure 1. Average soil penetrometer values obtained from the long-term residue management plots, Pendleton OR, spring, 1995.

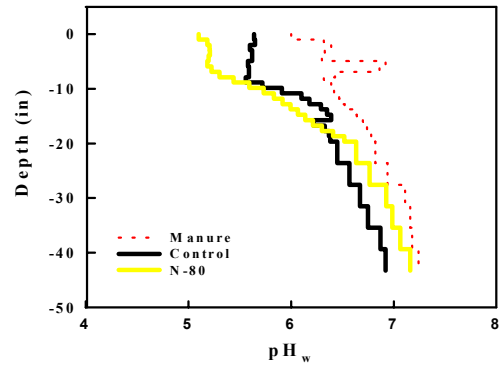

Figure 2. Soil pH_w values for the manure/ straw, N-80, and the control treatments in the long-term residue management plots, Pendleton OR, spring 1995.

The weathering and release of Si is driven by the production of soil acidity. The two main sources of acidity in the dryland wheat agricultural ecosystem are the removal of basic cations in harvest and the nitrification and leaching of excess nitrogen as nitrate. Soil pH_w values (Fig. 2) clearly show that soils that have been fertilized with 80 lbs/acre of reduced N and have yields of wheat on the order of 80 bushels per acre are experiencing acidification of the surface horizons. The manure plot is more basic than the control plot. This is a result of the "liming" effect of return of basic elements to the soil.

Perhaps more informative are the data for total acidity stored in the soils (Fig. 3). The difference in acidity, produced over 60 years, between the control plot (no N) and the treatment receiving 80 lbs N/acre on an annual basis is equivalent to the amount of acid needed to neutralize approximately 250-350 lbs of pure limestone per acre on an annual basis. This amount of acid is more than sufficient to mobilize Si in the soil profile.

Two major pools of silica comprize the majority of the Si in these soils, water soluble Si (Si_w), and amorphous Si. The extraction procedure used to obtain the amorphous Si values is very aggressive and would be expected to dissolve all Si present in the forms of biogenic opal and volcanic glass. Opal and volcanic glass represent the pool of readily weathereable Si. Since the pool of amorphous Si is several hundred times larger than the water soluble pool (Si_w), the profile distribution of amorphous Si is nearly the same for all of the management conditions. The amorphous Si distribution can be represented as the average value for all of the treatment plots (Fig. 4). Since the total pool of amorphous Si is rather large when compared to

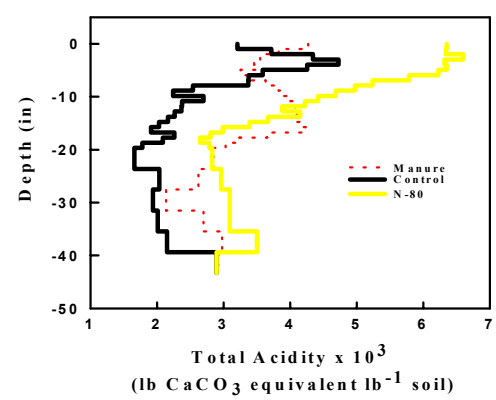

Figure 3. Total acidity for the manure/straw, N-80, and the control treatments in the long-term residue management plots, Pendleton OR, spring 1995.

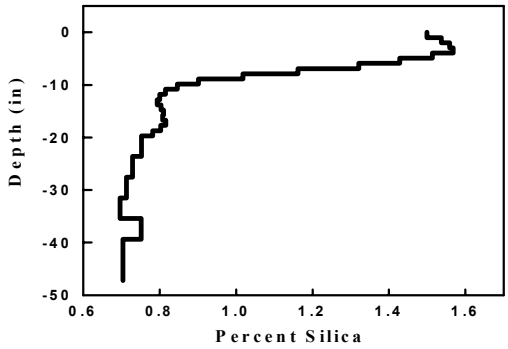

Figure 4. Average concentration of amorphous Si in the four treatment plots, Pendleton OR, 1995.

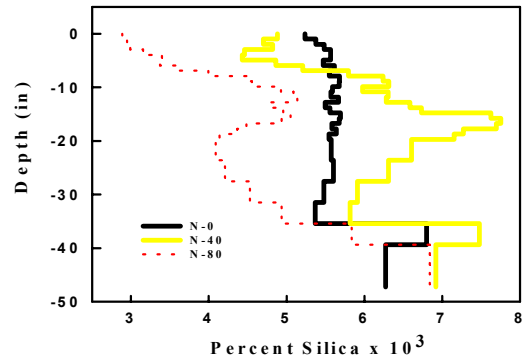

Figure 5. Concentrations of water soluble Si in the soil profile for the control (N-0), N-40, and N-80 management treatments Pendleton OR, 1995.

the annual amount that might be expected to be released by weathering, one does not expect to see a difference in treatments reflected over 50 years. Most of the amorphous Si occurs in the surface of the soil profile. This is likely the result of the deposition of volcanic glass or the biological cycling of Si to the surface of the soil via plant uptake, or some combination of both processes. We expect to learn more about the distribution of amorphous Si by direct examination of the soil in thin section and
scanning electron microscopy.

The water soluble pool of Si is thought to be responsible for the cementation of the soil particles in the layer just below the plow pan (Douglas et al., 1983; Brown and Mahler, 1988). Both of the plots that have received N have obvious "spikes" in their Si_w distributions in the soil layer, which correspond to the lower portion of the plow pan. Values for the concentration of Si_w on a solution basis are very high. This suggests that the source of Si_w is likely due to the weathering of amorphous volcanic glass or biogenic opal Si. The concentration of Si_w is lower in the surface horizons for both nitrogen treatments, suggesting the source of Si_w has been depleted by acid induced weathering. In the case of the higher nitrogen fertilization rate, the Si_w concentration is less than the control to a depth of 1 meter (39 in.). This suggests that weathering has exhausted the sources of Si_w while the total amorphous Si pool remains relatively unchanged (Fig. 5).

CONCLUSIONS

The weathering of soil minerals and release of water soluble Si is accelerated by the production of agricultural acidity. The greatest concentrations of water soluble Si appear to occur at the boundary between the plow zone and the undisturbed soil. This may be the result of the migration of Si to this layer with water when it moves upward as moisture is lost from the soil. The degree to which Si fills the soil pores in this region will be explored in the next phase of our research. We plan to examine soil fabric by thin section and scanning electron microscopy.

REFERENCES

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