Occluded C in Phytoliths: a Potential Mechanism for Carbon Sequestration in a Pacific Northwest Mollisol

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Introduction:

Limited research has examined influence of organic amendments on soil organic carbon (SOC) and silica (Si) interaction. Silica in the soil solution is taken up by plant roots in the form of monosilicic acid (H_4SiO_4) and subsequently deposited throughout the intra- and extra-cellular structures of their leaf, stem and root systems (Parr and Sullivan, 2005). Deposits of Si in plants have become known as opal phytoliths (Fig.1, b & c). Norgren (1973) reported rates of phytolith production of 300 kg ha^{-1} y^{-1} in Oregon. This high formation rate was attributed to the large amount of readily weatherable volcanic silica in parent material from which these soils developed (Al-Ismaily,1997). Amorphous forms of Si can be dissolved rapidly in acidic soil environments (Milnes and Twidale, 1983). Agricultural practices, such as use of N fertilization, may accelerate dissolution of phytoliths by release of H^+ ions during nitrification of the applied NH_4^+ (Gollany et al., 2005). The objectives were to: i) determine the effect of tillage and N fertilizer on SOC accretion and on Si dissolution; and ii) evaluate the influence of organic amendments on fine organic matter (FOM) distribution and interaction with soluble Si.

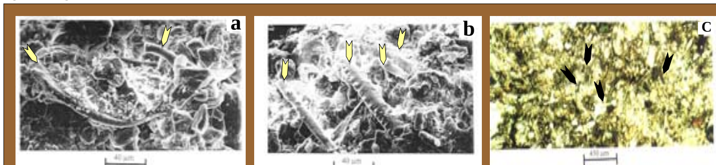


Fig. 1. Scanning electron photomicrographs views: a) fragment of volcanic material surrounded by silt size particles, b) Opal phytoliths from gramineae species, c) Opal phytoliths in a silt matrix (Al-Ismaily, 1997)

Materials and Methods:

- A long-term wheat (Triticum aestivum L.)-fallow experiment with several management practices was established on a Walla Walla silt loam (coarse-silty, mixed, superactive, mesic Typic Haploxeroll) in 1931 (Fig. 2).
  - Crop residue management practices:
    - No burning (NB)
    - Spring burning (SB)
    - Fall burning (FB)
  - Two N rates (0, and 90 kg N ha^{-1})
  - Organic amendments:
    - Manure; (NB_M, 11.2 t ha^{-1} yr^{-1})
    - Pea vines (NB_{PV}, 1.12 t ha^{-1} yr^{-1})

Fig. 2

- A second long-term experiment was established in 1940.
  - Tillage:
    - Moldboard Plow (MP)
    - Sweep (SW)
  - N rate:
    - 45 kg N ha^{-1}
    - 180 kg N ha^{-1}
- Soil cores (2-cm increments) were used to measure coarse organic matter (COM), fine organic matter (FOM), pH, bulk density (ρ_b), water-soluble C (C_{ws}), and water-soluble Si (Si_{ws}).

Results and Discussions:

- Sweep system had higher COM and lower ρ_b in the top 10-cm depth than moldboard system (Fig.3).
- N fertilizer decreased pH and Si_{ws} decreased by 17% compared to treatment without N application (Fig. 3 & 4).
- The FOM fraction for the sweep system was 14% higher than the moldboard system for the 180 kg N ha^{-1} (Fig. 4).
- Manure application increased Si_{ws} by 10%. The Si solubilization and movement in response to reduced pH was greater in the absence of organic amendments (Fig. 5 & 6).

Fig. 3

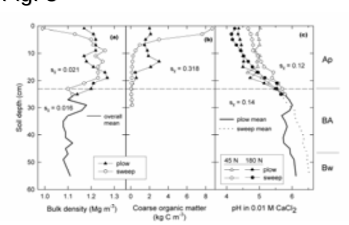


Fig. 4

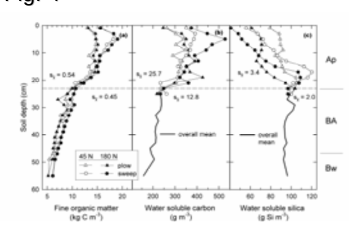


Fig. 5

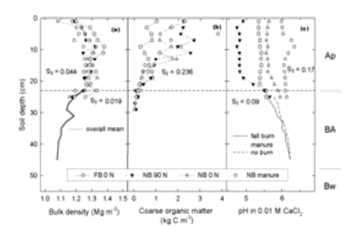
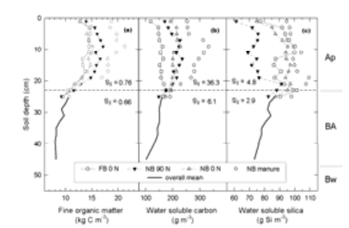


Fig. 6



Conclusion:

High SOC, particularly FOM, reduced Si dissolution, illuviation and deposition at the base of the Ap horizon. Although the form of this Si_{ws} and SOC association was not determined, it is likely the occluded SOC in phytoliths reduced the siliceous surface available for dissolution. The role of organic C occluded within phytoliths in soil carbon sequestration should be examined because this passive C pool component of SOC is highly resistant to oxidation compared to other OC components in the soil.

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