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# Refractory SOC-Carbon Capture, Pectin, Silicon, Water and Lignin-Assessments

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**ABSTRACT**

These assessments are based on old texts. Humus, soil organic carbon (SOC), sustainability and its associations with Si have open questions. Humus is known to be formed from plant residues directly or indirectly. Degradation of rice fodder, grown with or without Si supplementation were studied in rumen. Si supplementation of fodder did not change degradability (digestibility) of its neutral detergent fibers (NDF): cellulose, hemicelluloses nor lignin, but effected on degradability of non-NDF (pectin's, proteins, sugars and lipids and ash). The short-term degradability of non-NDF was higher for straw with low (0.0 g/kg) Si content (77 %) than for straw with higher (9.8 g/kg) Si (58 %). Long term degradation of SOC and Si-carbon complexes are discussed. Conclusions: Carbon capture by Si seems to be realistic. Non-NDF proportion of plant dry matter, its pectin, pectin derivatives and Si, can have a role in formation of refractory SOC. Long term studies on pectin turnover (e.g., by 13C labeling) in soil are suggested.

**Keywords:** Refractory SOC; Pectin; Silicon; C/Si Ratio; Water; NDF; Lignin; Carbon Capture

**Abbreviations:** NDF: Neutral Detergent Fibers-Remnants After Neutral Solvents: Cellulose, Hemicellulose and Lignin; SOC: Soil Organic Carbon

## Some Observations on Soil Carbon Formation and Sustainability

Silicon is known to bind carbon. Soil humus has been represented to be associated with groundwater [1]. Klotzbuecher, et al. [2] have challenged the benefits of Si in carbon capture by observations, that density of rice carbon and lignin (lignin derived phenols) associated negatively with rice Si content. They referred even Talbot and Treseder [3], who wrote that Si promotes straw degradation, because high Si content was associated with lower lignin (or lignin indicator) content. Data in [2] included without interpretation an interesting association between Si and C: Their sum seemed to be constant. Zhang, et al. [4] observed that by 42 rice mutants from Huazhong Agricultural University, Wuhan, China, Si content (1.4 – 3.9 %) correlated positively with cellulose, hemicelluloses and lignin (r = +0.31 - +0.38, P < 0.05). Remarkable is that Si supplementation did not correlate negatively with lignin (genetic differences?). Three of the mutants were selected for hydroponic culture. By these mutants Si content varied between 1.8 – 2.5 %. Their contents of cellulose, hemicelluloses and lignin could be lower or higher to the wild type (with the moderately higher Si-content).

The selected mutants showed 16-67 % higher hexose release to the wild type, before hydroponic tests. In hydroponic culture (+ 100 ppm Si), Si enhanced plant height, stem strength (by 50-90 %), cellulose and hemicellulose contents, but did not increase lignin in two of the three mutants. Si substitution could increase or decrease saccharification (disintegration of polysaccharides to monosaccharides) depending on rice mutant. Si enhanced biomass production by 50 – 90 %. Si content of rice cultivars in hydroponic culture varied between 3.4-4.6 %, (in Huazhong 1.8-2.5 %, by these mutants). Bahri, et al. [5] have measured faster turnover kinetics for lignin than for bulk soil organic matter. They referred even Kiem and Kögel-Knaber [6]: "long-term stabilization of lignin in soil does not occur". The process of determining NDF (Neutral detergent fiber) [7] content involves a neutral detergent that dissolves plant. This process produces fibrous parts such as cellulose, lignin and hemicellulose.

## Studies of Agbagla-Dohnani, et al. [8]

Available were rice fodder with 98 g Si/kg (group H) and rice from hydroponic culture with Si 0.0 g Si/kg (group L). In ruminal de sacco degradation the proportion of degraded dry matter (DM) during the first 24 h was higher in low silicon (L) group to the high silicon group (H) (47.8, vs 41.7 %. S.E. 0.42, **), but proportions of degraded NDF did not differ (37.6, vs. 36.6, S.E. 1.1, NS), ii.e., the sum of cellulose, hemicellulose and lignin degraded independently on the Si content of the straw [8]. The calculated different degradability of non-NDF was higher for straw of L group (77 %) than for straw of H group (58 %) in the respective time period (24-96 h, time scale not precisely represented) [8]. "Pectin(s) are uronic acid polymers, galacturonic acid polymers, partially esterified with methyl alcohol" [9]. Often is used term "pectin", in singular.

## Discussion

Si content of pectin from citrus fruits can be unusually high 2.5 mg/g. (Schwarz K, 1974) [10]. Plant resistance against drought can be increased by Si fertilization. Si can increase water holding capacity and plant available water in soils. By experimental data has suggested that the primary role of silicon in resisting effects of drought is the regulation of soil water [11]. Soil water sustains photosynthesis, organic matter production and SOC. Pectin concentration of plants can be remarkable: e.g., in xylem tissues of alfalfa which constitutes 60 % of cell wall mass proportion of pectin was 4 %, in non-xylem wall 25 % [12]. Ruminal test represented the most remarkable effects of Si-fertilization: Degradation speed of NDF (sum of cellulose, hemicelluloses and lignin) was independent on Si content, but calculated degradation speed of other parts of the plant, non-NDF (including the rest: pectin, proteins, sugars lipids and obviously ash) in high Si group (58 %) was remarkably slower to low Si group (77 %).Moderate strong alkali or acid are needed to dissolve silicon-polysaccharide bond [10]. This suggests on its stability in soil, too. Pectin could be a silicon transporter by its moderate high Si content. Derivatives of Si could have beneficial effects, too.

Si can increase total carbon binding, by higher yields, although same time C/Si ratio could slightly decrease. Percentual increase in yield, 50-90 %, after Si supplementation can compensate the increase in C-replacements (ca 2 %) by Si [4]. The Vietnamese rice C-content was 11 % lower to the respective value in Philippines (34.7/38.8) (Table 1). The experiments in [4] suggest on (more than 11 %) higher rice yields and higher amounts of C-capture per hectare, respectively in Philippines, too. Table 1 suggests that remarkable part of Si could be part of organic molecules and have replaced carbon. This could occur via following soil substrates or their metabolites: acid Na-acetate-Si, H2O2-Si, NH2OH·HCl-Si, NaOH-Si. [13]. In a short-term study silicon did not remarkably affect on degradability of cellulose, hemicellulose, lignin or the sum of these fibers [8]. The long-term degradability of lignin is not the same as its reductive effect on SOC. After degradation of lignin, its phenolic derivatives [14] could possibly participate in formation of SOC (humic substances) [15,16]. Even this could be promoted by Si (Si-polymers), which could work as "matrix for formation of organic compounds" [10]. Pectin has been during past years an object of intensive study in agriculture: PubMed search (Oct 2022) gives 386 results on "pectin soil", e.g. [17].

**Table 1:** Rice straw carbon and Si contents in different geographic areas (Philippine & Vietnam) Citation from Klotzbuecher et al. [2]: Table 2.

| | C % | Si % | (C + Si) % |
|---|---|---|---|
| Philippine (volcanic) | 34.7 | 7.9 | 42.6 |
| Vietnamese (non-volcanic) | 38.8 | 3.7 | 42.5 |

## Conclusion

Carbon capture by Si seems to be realistic. Non-NDF proportion of plant dry matter, its pectin, pectin derivatives and Si, can have a role in formation of refractory SOC. Long term studies on pectin turnover (e.g., by 13C labeling) in soil are suggested.

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