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Could hydrogels improve soil pore network? Preliminary results on three different soils

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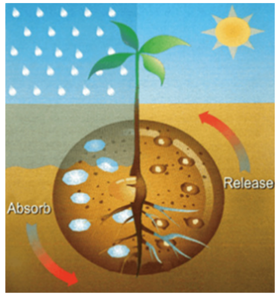
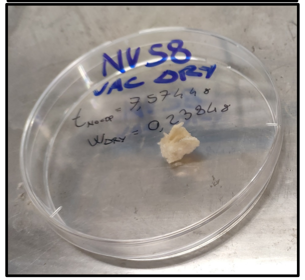


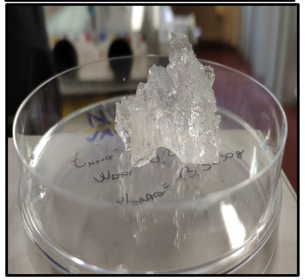
Introduction

Hydrogels (HGs) are defined as natural or synthetic polymeric 3D networks that can absorb and retain large amounts of water. The unique swelling ability of HGs makes them an ideal platform for water and nutrient delivery. This study aimed to evaluate the effect of two HGs on the porosity, pore size distribution, and swelling of soils at soil water saturation.

Dry hydrogel



Swollen hydrogel



Materials and Methods

- Three treatments: two hydrogels (polyacrylate- “CI” and cellulose-based “H30”) applied at 4% w/w compared with control “CTRL” (no HG)
- Three soil types: Sand (S), Sandy Loam (SL), and Clay (C)
- Three replicates
- Three techniques to study soil porosity: gas adsorption “BET” (0.4-57 nm range), mercury intrusion porosimetry “MIP” (0.0074–138 µm range), and X-ray computed microtomography (µCT) (55-2151 µm range)
- Pore architectural and morphological indices (mean pore diameter “MD”, fractal dimension “FD”, degree of anisotropy “DA” and tortuosity) were derived from MIP and X-ray
- One-way ANOVA was applied to consider the treatment effect on all i-th pore characteristics.

Results

- BET porosity: ca. 11% of total porosity and varied in the 2.10-4.58, 13.57-15.98, and 67.91-75.86 mm^3g^{-1} ranges for S, SL, and C soils, respectively
- MIP-derived porosity: 74% of total porosity, not affected by treatment in either S or C soil, SL soil contracted by H30 (224.01 vs 249.64 mm^3g^{-1})
- X-ray µCT porosity: 18% of total porosity, unaffected by treatment in S soil, CI significantly increased porosity in SL soil by 84.67 mm^3g^{-1} with respect to CTRL, H30 significantly increased porosity in C soil by 49.72 mm^3g^{-1}

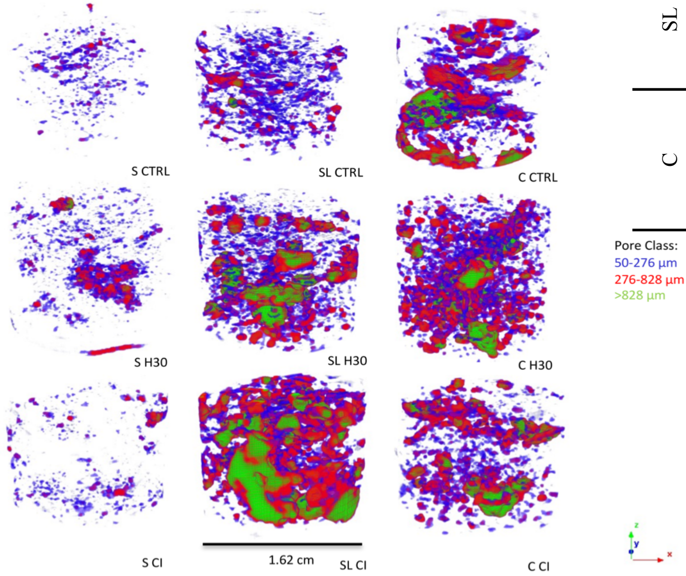


Figure 2. 3-D representation of X-ray µCT-derived soil porosity for each soil (S, SL, and C) and treatment (CTRL, H30, and CI).

Table 1. Pore size distribution (mm^3g^{-1}) and total porosity (TP) were measured by BET, MIP, and X-ray µCT. Different letters indicate a significant difference according to Tukey’s test at p<0.05.

		BET	MIP	µCT	TP
		0.4-57 nm	0.0074-138 µm	(>55µm)	>0.4 nm
S	CTRL	2.84	116.27 ns	5.80 ns	123.37 ns
	CI	4.58	127.65 ns	4.07 ns	132.46 ns
	H30	2.10	131.70 ns	7.40 ns	138.08 ns
SL	CTRL	15.98	249.64 a	23.70 b	273.62 b
	CI	14.98	235.03 ab	108.37 a	348.74 a
	H30	13.57	224.01 b	76.10 ab	299.96 ab
C	CTRL	75.86	181.69 ns	34.32 ns	271.56 ns
	CI	74.16	158.66 ns	45.54 ns	258.78 ns
	H30	67.91	175.81 ns	84.04 ns	305.03 ns

- MD significantly increased by HGs for SL soil, from 247 to 731 µm
- FD decreased by HG application on coarse soils, with S being similarly affected by both HGs (-0.11, on average) and SL affected by CI (-0.07)
- DA significantly decreased with both HGs by 0.14 (S) and 0.21 (C). In SL soil, only CI showed a significant decrease from 0.66 to 0.35.
- Tortuosity increased significantly only with H30 in SL soil (1.82 vs 1.77)

Conclusions

- Improved soil pore network found in SL soil after HG application regarding macroporosity
- Strengthened soil structure and higher water holding capacity might be expected after HG addition, irrespective of original building blocks (e.g., natural or synthetic)
- Development of natural-derived HG is strongly encouraged

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