Effects of soil structure complexity on root growth of plants with contrasting root architecture

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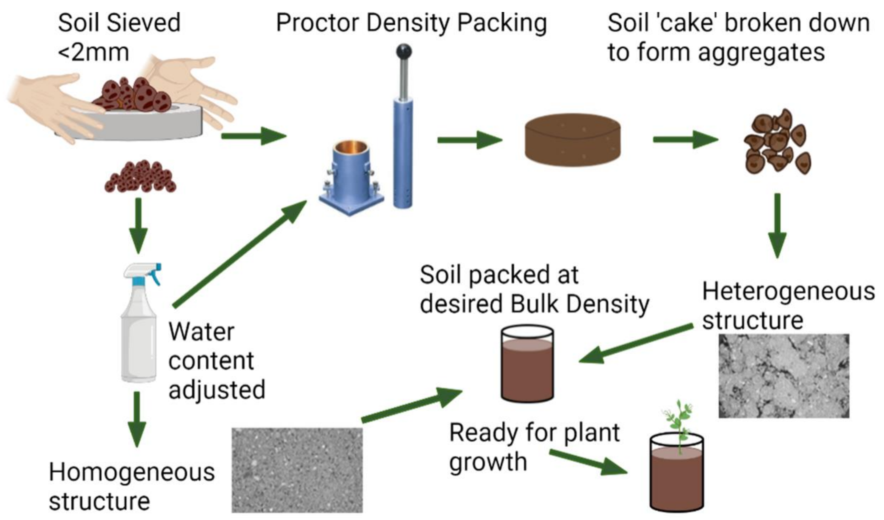
Background and aims

Typically, when investigating physical constraints to root growth, a homogeneous soil is used. The aim of this study was to compare root and shoot growth under controlled unstructured and structured soil conditions.

Methods

- *H. vulgare*, *P. sativum L.*, and *A. thaliana* were grown in three levels of compaction (1.25 g cm^{-3}, 1.40 g cm^{-3}, 1.55 g cm^{-3}) in 'unstructured' and 'structured' soil for 10 days.



- Soil structure was quantified from water retention characteristics and X-ray Computed Tomography (CT).
- Below-ground measurements: total root length, root volume, tip number, root weight, and average diameter.
- Above-ground measurements: height, weight, chlorophyll, nitrogen, and flavonoid content.

Results

- At the same bulk density 'structured' soil had 50% more macropores at 1.55 g cm^{-3} than 'unstructured' soils, despite total porosity remaining the same **(Table 1)**.
- Pore size distribution between 'structured' and 'unstructured' soils at the same bulk densities showed significant differences between treatments **(Figure 1 and 2)**.
- Pore structure complexity in the 'structured' soil was found to be beneficial for root growth of *P. sativum* and *H. vulgare* but not *A. thaliana* **(Figure 3 and 4).**
- Shoot biomass of *P. sativum* grown in 'structured' soil at 1.55 g cm^{-3} increased by 65% when compared to 'unstructured' soil, whereas *H. vulgare* and *A. thaliana* shoot biomass did not differ significantly between any treatments.

Conclusions

Despite soil bulk density remaining the same, soil structural heterogeneity influenced many root properties and above-ground biomass, with impacts found to be species-dependent.

Property	Unstructured Soil			Structured Soil		
Bulk Density (g cm^{-3})	1.25	1.40	1.55	1.25	1.40	1.55
Penetrometer Resistance (MPa)	0.40(0.114)	0.67(0.208)	1.08(0.160)	0.46(0.287)	0.87(0.384)	1.25(0.500)
Total Porosity (m^{3}m^{-3})	0.53(0.002)	0.47(0.002)	0.41(0.002)	0.50(0.007)	0.47(0.002)	0.41(0.002)
Air Filled Porosity at -5 kPa (m^{3}m^{-3})	0.26(0.013)	0.18(0.009)	0.08(0.010)	0.22(0.016)	0.16(0.010)	0.08(0.005)
Macroporosity (m^{3}m^{-3})	0.23(0.01)	0.14(0.008)	0.04(0.016)	0.19(0.015)	0.13(0.019)	0.06(0.022)
Macroporosity (CT Scan m^{3}m^{-3})	0.21(0.012)	0.11(0.008)	0.04(0.001)	0.22(0.003)	0.14(0.012)	0.06(0.003)

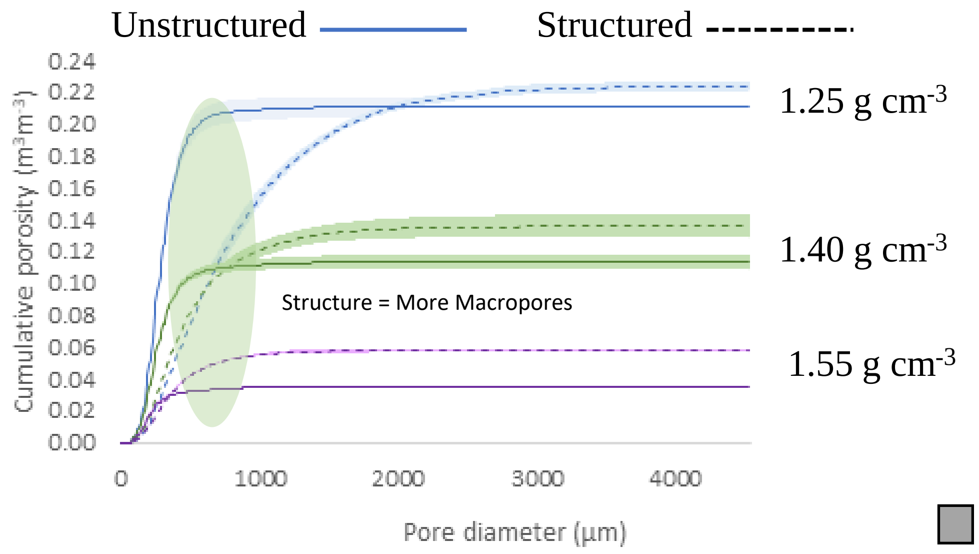


Figure 1: Cumulative porosity (<50 µm) after harvest from X-Ray CT. Shaded area is the standard error of mean.

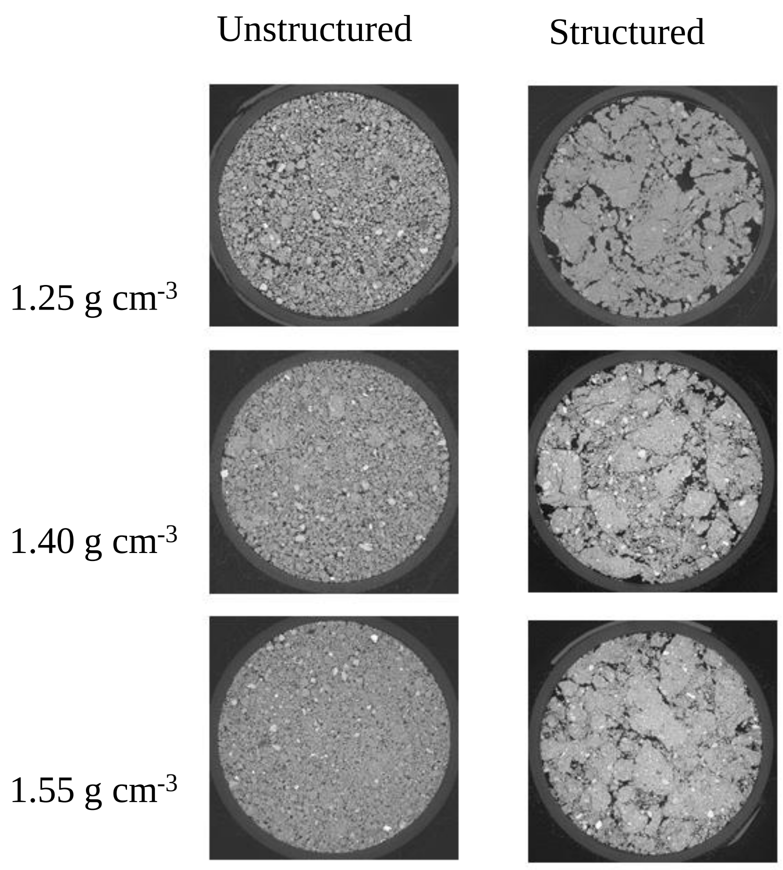


Figure 2: Cross-section of cores at harvest from X-Ray CT. Diameter is 5 cm.

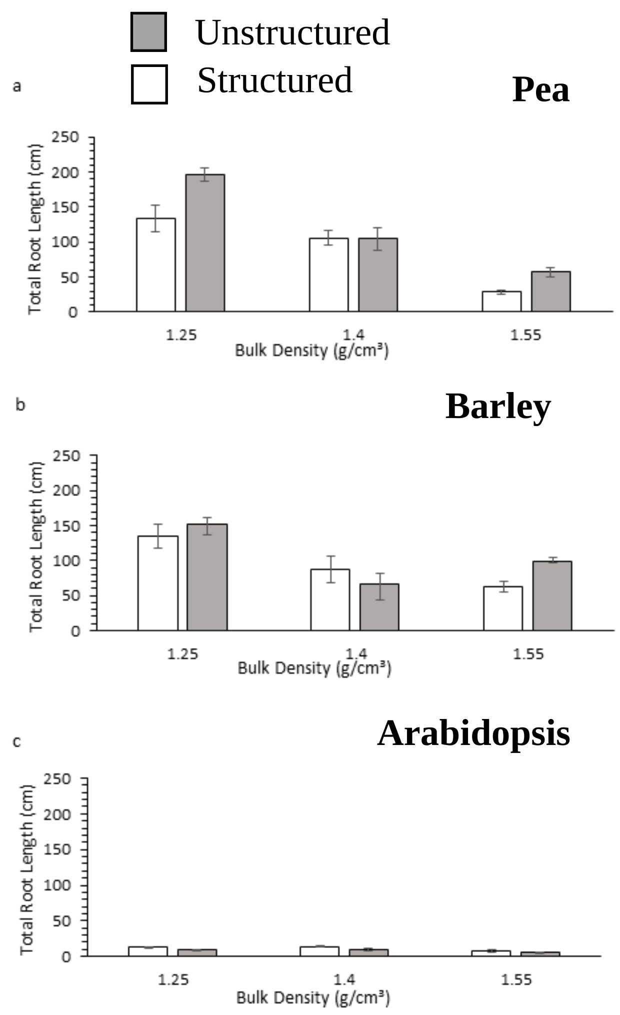


Figure 3: Total root length of the different species at harvest. Standard error is shown.

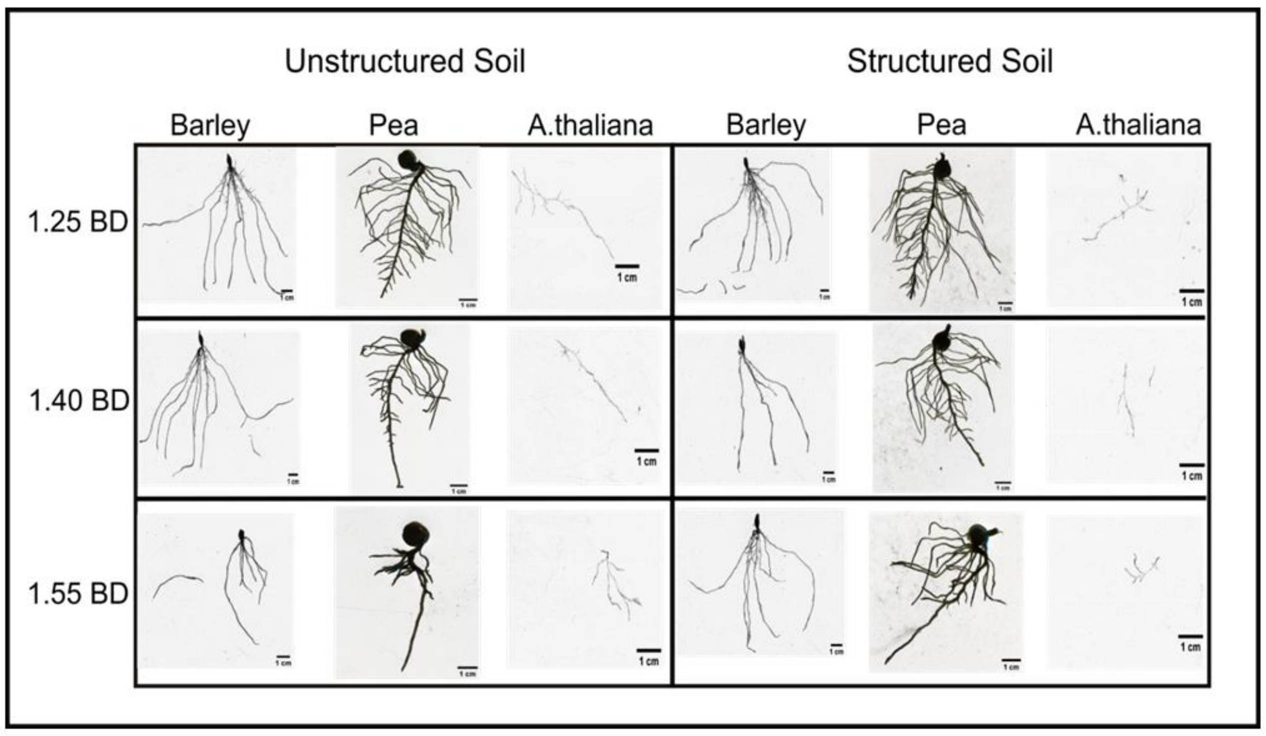


Figure 4: 2D root images of the different plants, structures and bulk densities.