Soil microbial communities influence plant carbon cost to acquire nutrients

J.A. Lankhorst, D. Behling, A. Odé, K.T. Rebel, H.J. de Boer

Utrecht University, the Netherlands, Copernicus Institute of Sustainable Development, Environmental Sciences.

UU website

j.a.lankhorst@uu.nl

Introduction

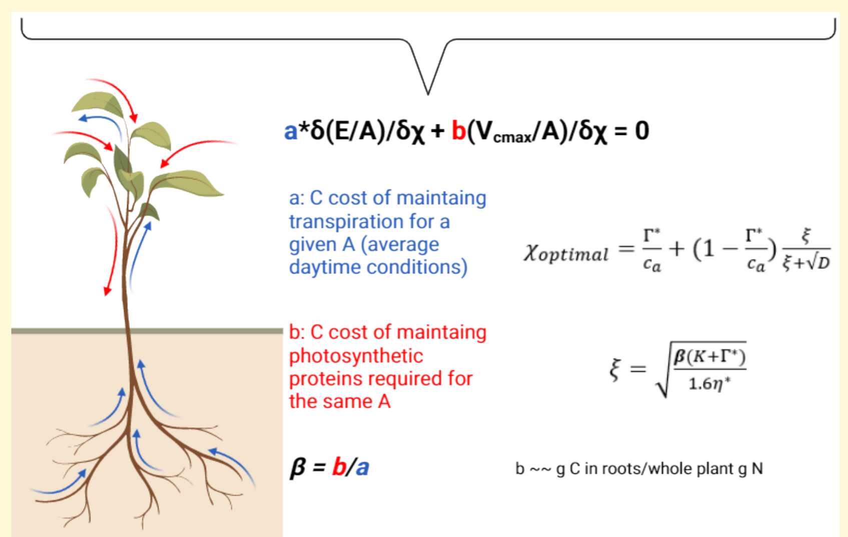
Next generation ecosystem models with a fundamental, physiological trait based approach are promising. At leaf level, Eco-Evolutionary Optimality (EEO) approaches are useful as a base for these kinds of models. A central theorem here is the optimization of resource use and allocation to different environments.

Optimization is defined as the minimization of the summed costs of maintaining transpiration (E) and carboxylation V_{cmax} for a given assimilation rate A:

Costs = a*E/A + b*V_{cmax}/A

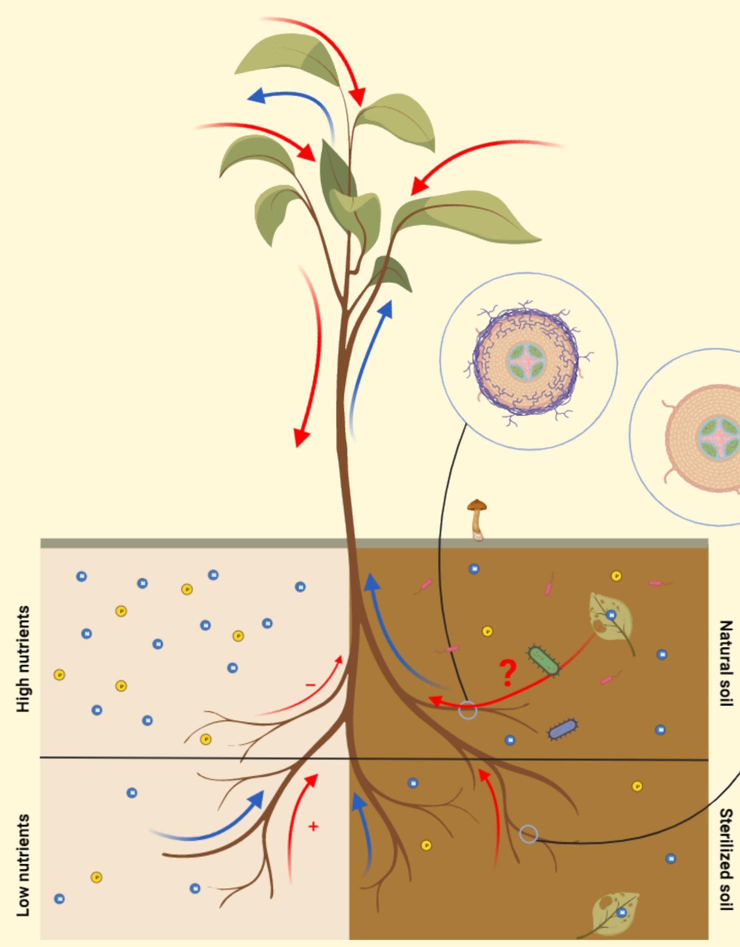
Within this framework, it has been found to be conceptually easier to predict the ratio of intercellular CO_2 (c_i) to environmental CO_2 (c_a), instead of stomatal conductance.

With: $c_i : c_a = \chi$

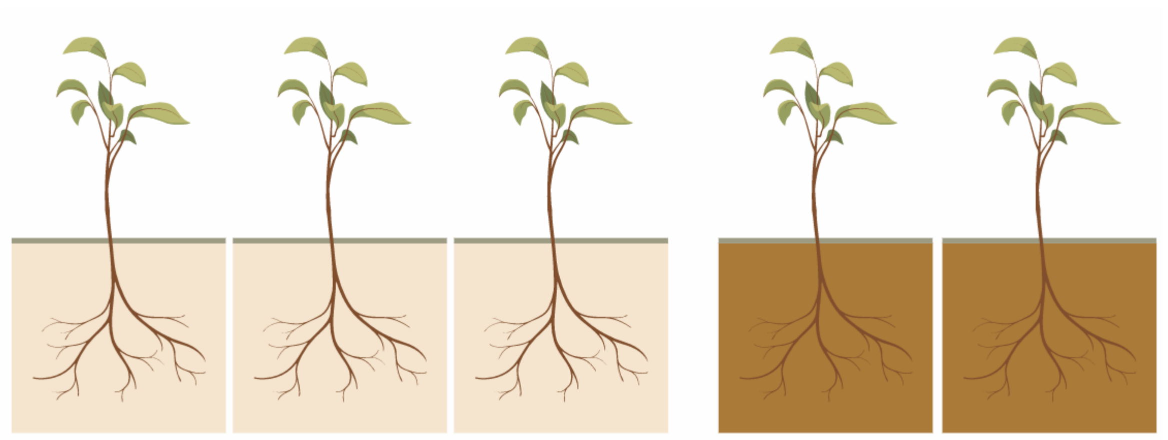


How does the carbon cost to acquire nutrients change between sterilized and natural soils compared to an increase in nutrients and how does that impact photosynthetic capacity?

An active microbiome can potentially alleviate nutrient or water stress by mutualistic symbiosis. Conversely, parasitic or pathogenic relations decrease a plant's overall fitness. How do these relations change optimality from a plant's perspective?



Methods



Substrate	Treatment
Sand	Low N+P
	Medium N+P
	High N+P
Soil	Sterilized
	Natural

Low: 26mg N + 1.75mg P
Medium: 36mg N + 2.40mg P
High: 78mg N + 5.25mg P

Both soils: 36mg N + 2.04mg P (readily available)

Two species native to the Netherlands were chosen: *Holcus lanatus* (C3, grass) and *Solanum dulcamara* (C3, forb). Per treatment combination 10 individual plants per species were planted (total n = 100).

Plants were measured for photosynthetic capacity after 7 weeks and destructively harvested after 8 weeks of treatment.

Physiological results

Maximum, RuBisCo limited, photosynthetic capacity, V_{cmax}, increases with nutrient addition, with an significantly negative effect of soil sterilization compared with natural soils.

Structural carbon cost for nutrient acquisition shows and inverse effect to V_{cmax}, lowering in the higher nutrient treatments and in the natural soil.

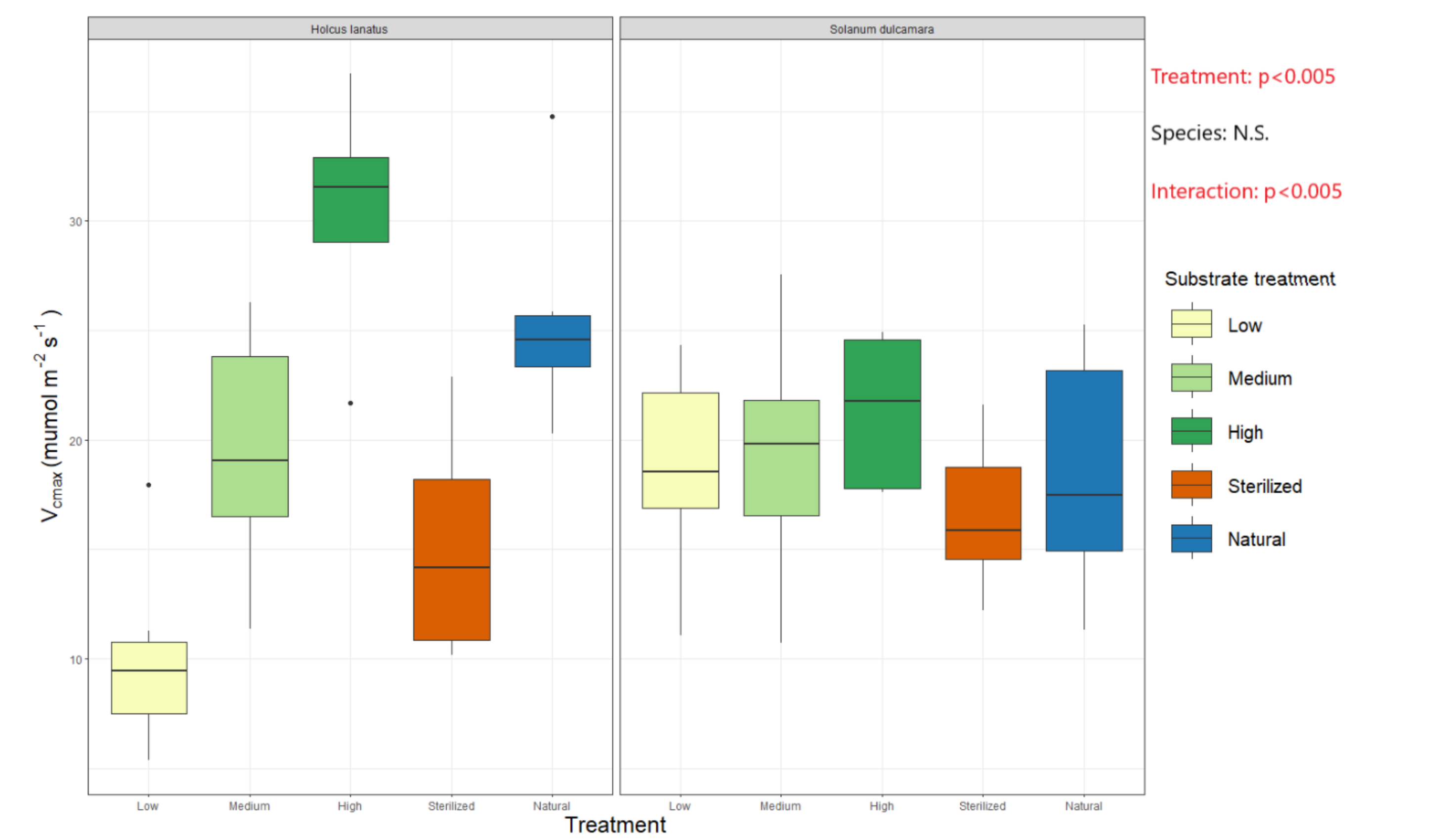


Fig. 1. Maximum rate of carboxylation (V_{cmax}, μmol CO_2 m^{-2} s^{-1}) measured 7 weeks after treatment start. n = 50 Statistical analysis: Two-way ANOVA

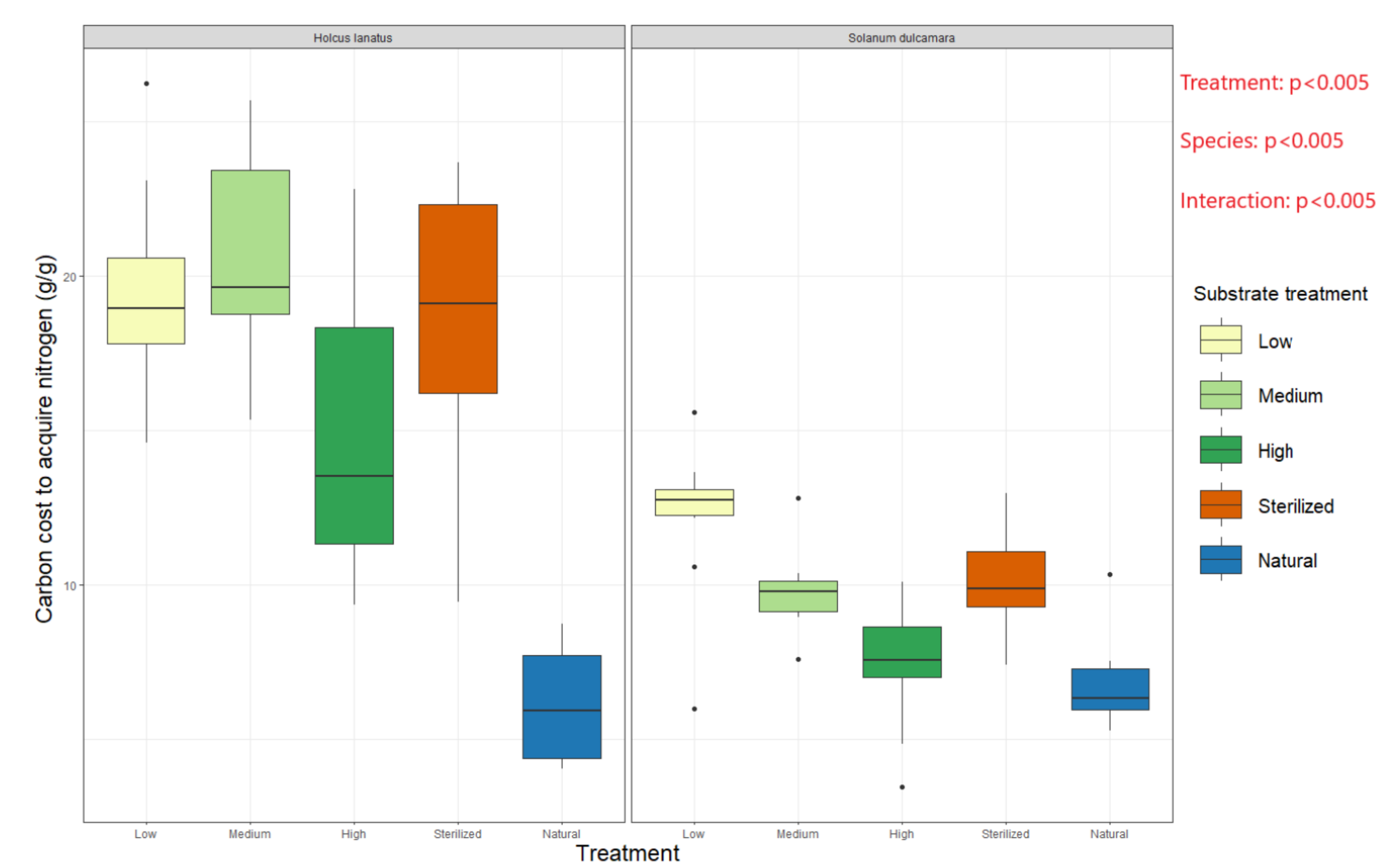


Fig 2. Carbon cost to acquire nutrients, defined as the structural carbon in roots divided by whole plant nitrogen (g/g). n = 96 Statistical analysis: Two-way ANOVA

Plant growth

Dry weight increases with nutrient addition, with a strong positive effect of soil sterilization compared with natural soil.

Plants grown in natural soils underperformed compared to plants grown in sand with similar available nutrients.

Plants grown in sterilized soils overperformed compared to the same, sand grown, plants.

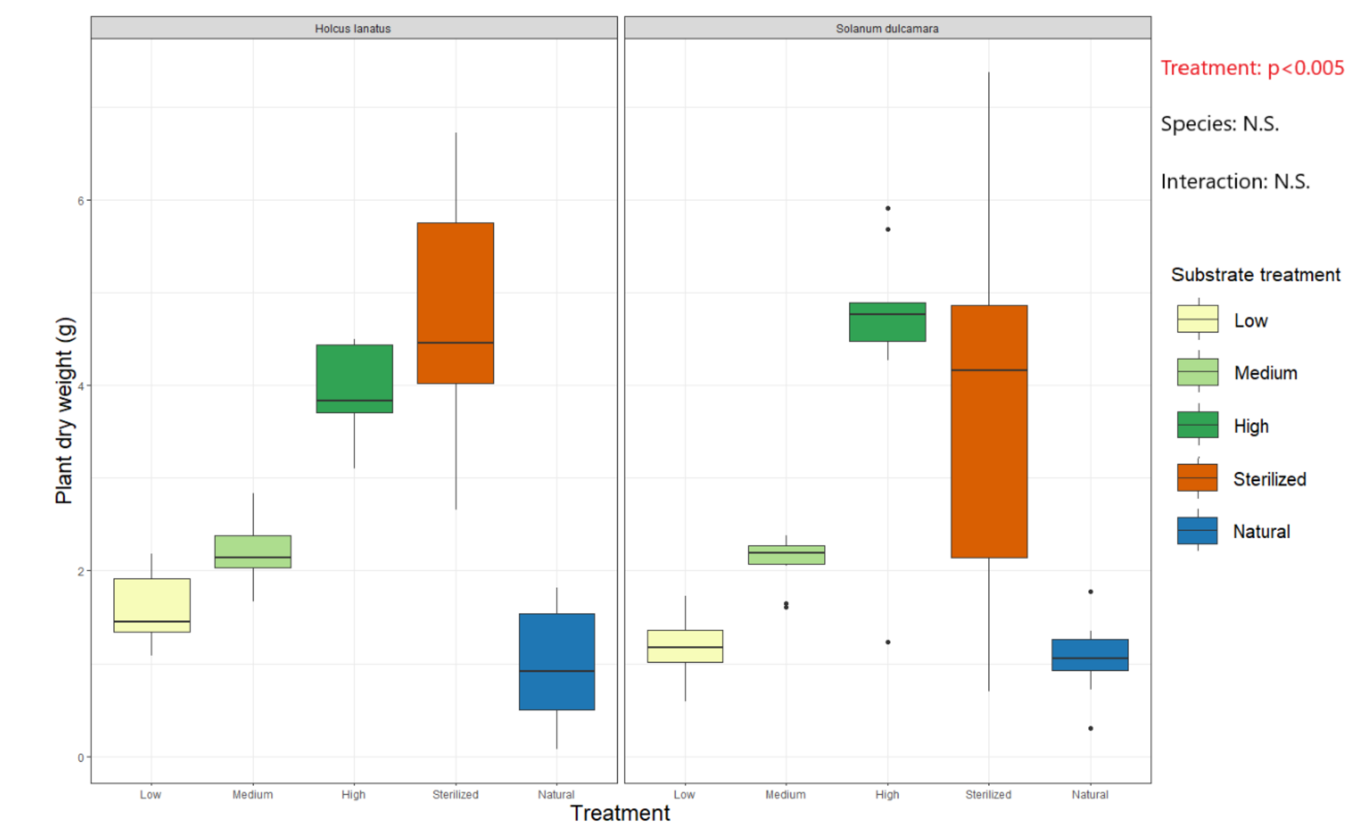


Fig. 3. Plant dry weight 8 weeks after treatments start. n = 98. Statistical analysis: Two-way ANOVA

Conclusion & discussion

In this particular setup, natural soils provided a rather costly environment for the plants compared to the same, sterilized, soil. This is however only visible in biomass production. Total biomass was significantly higher for plants in sterilized soils compared to natural soils, but the structural carbon cost to acquire nutrients was also higher.

There are rather remarkable inverted relations between photosynthetic capacity, carbon cost to acquire nutrients, and dry weight when comparing plants grown in pure sand to plants grown in natural soils, sterilized or not.

- The presence/absence of a rich microbiome does not compare, in combined physical and physiological terms, to sterilized sand with added nutrients.
  - In nutrients in sand we see an increase in dry weight correlated with an increase in V_{cmax}, and a decrease in carbon cost to acquire nutrients.
  - In sterilized and natural soils we see an increase in dry weight correlated with a decrease in V_{cmax}, and an increase in carbon cost to acquire nutrients.

- Further analyses on isotope inferred χ (ci : ca ratio) will enable us to test the optimality framework, and the effect the microbiome has on the modelled optimization of V_{cmax} and χ to the environment.

Literature

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Acknowledgements

Experiment was designed by JL, HdB, DB, KR. It was performed by JL, DB, and AO.
Special thanks to Corné Pieterse and Melissa Uribe Acosta for their help providing materials and methods