Management of hotspots for sustainable crop production: hotter, deeper, or simply more?

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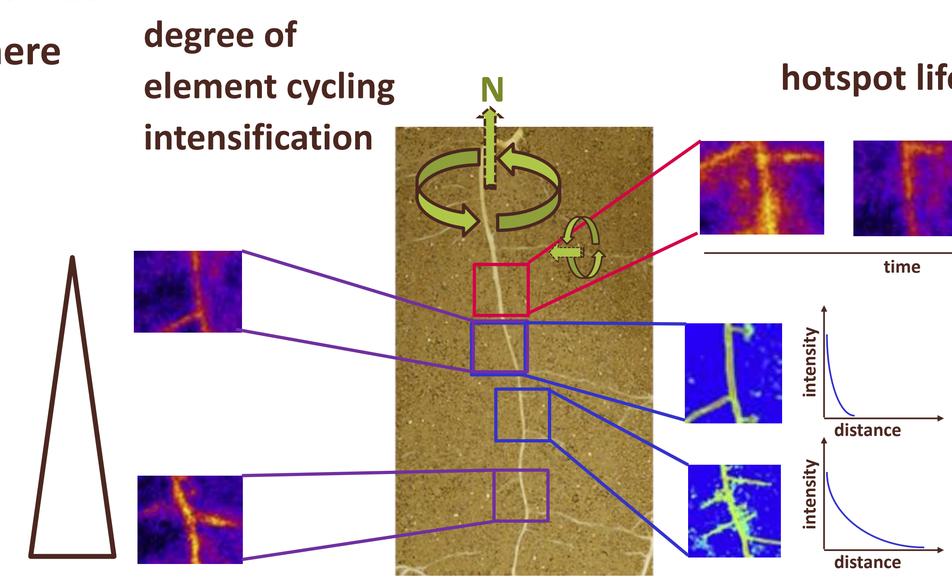
Conceptual View on Hotspots

Key hotspot properties:

example rhizosphere



Ma et al. 2019

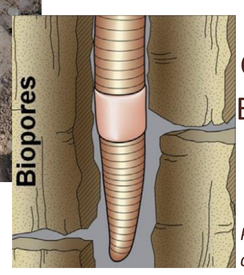
Further important agricultural hotspots:

Thanks to Peter Gernandt for providing photo

detritusphere

Example: corn field post harvest

Thanks to Marcel Lüsebrink for providing photo



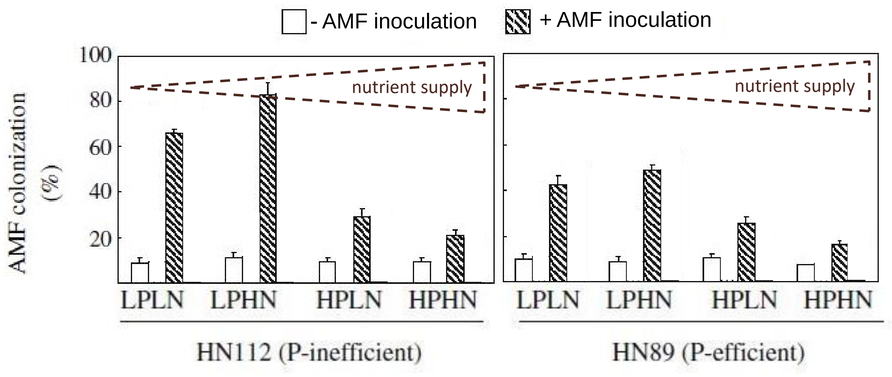
drilosphere

Example: earthworm pore

Photos taken from Kuzyakov and Blagodatskaya 2015

Hotspots in arable soils: state of the art

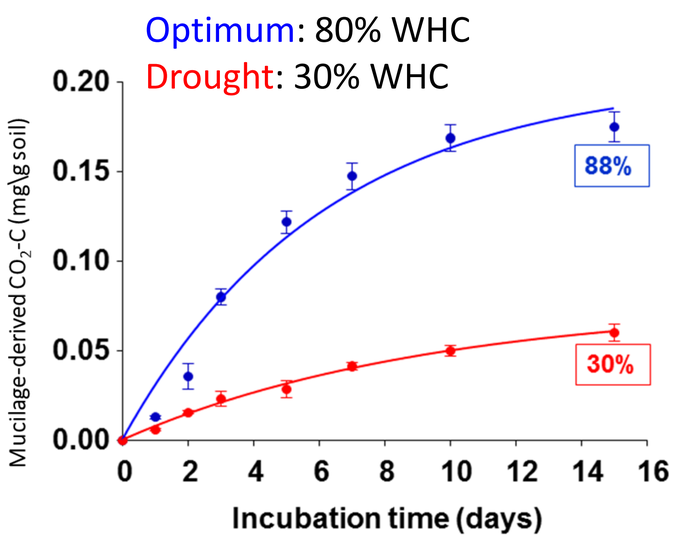
1. Hotspot intensity by nutrient mining



AMF colonization with and without AMF inoculation under different N and P conditions (HP & LP is high and low P, respectively and HN & LP is high and low N respectively) (Figure modified from Wang et al. 2011)

Nutrient deficiency increases mycorrhization → Intensity of nutrient-exploitation around root increases most likely by intensified rhizo-hyphosphere microbiome activity

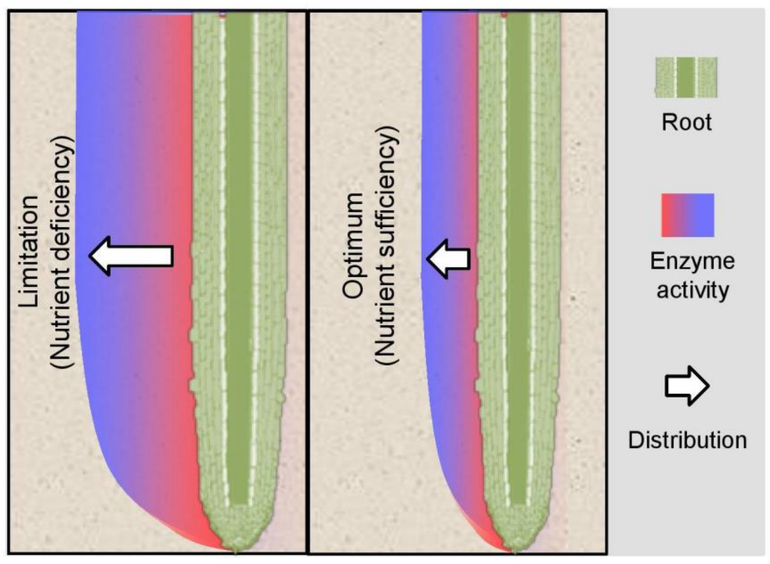
2. Hotspot lifetime and abiotic constraints



Mucilage decomposition during 16 days incubation with soils of two water contents (Ahmed et al. 2018)

Root exudates decompose more slowly under water limitation → Droughts increase the hotspot lifetime in agricultural soils

3. Hotspot spatial extent and soil fertility

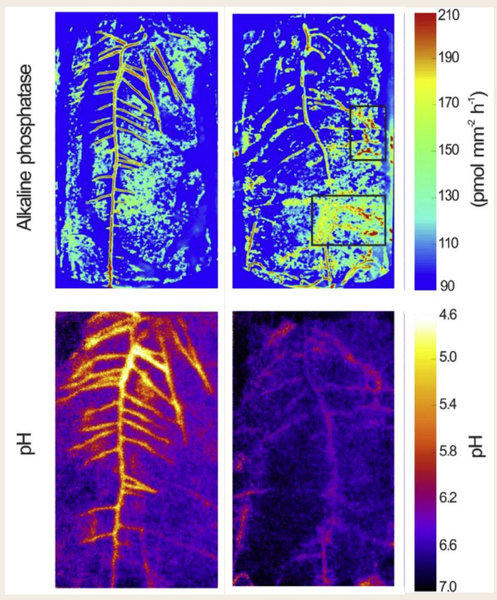


Conceptual figure on spatial extent of exoenzymatic-driven nutrient mobilization depending on nutrient deficiency (thanks to Bahar Razavi for provision modified from Razavi et al. 2016)

→ Nutrient mining is more spatially-extended around roots in infertile soils

Potential Strategies for Hotspot Management

Ex. 1: Select root & rhizosphere traits matching the local resource availability

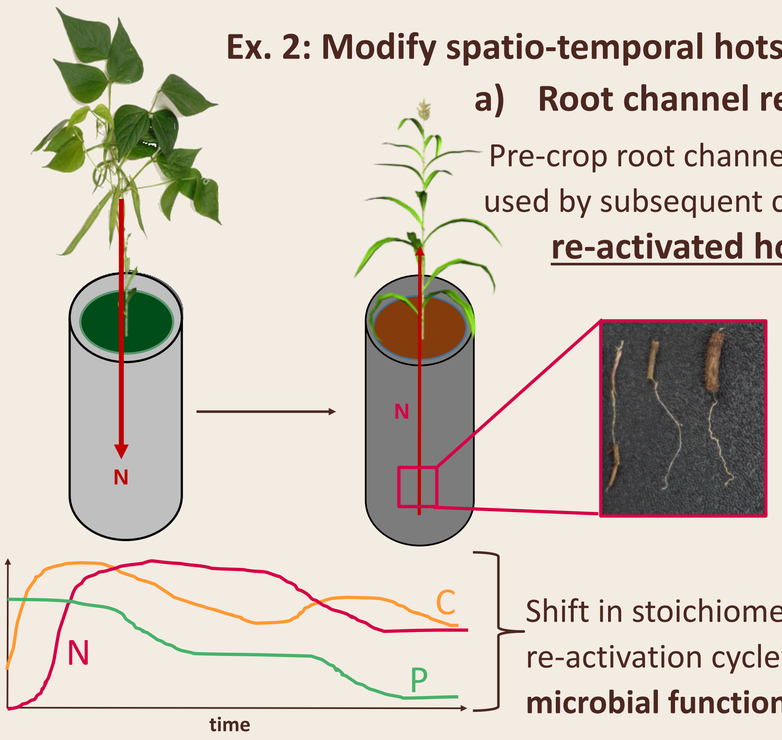


Images taken from Ma et al., SBB, 2019: pay attention: images are out of context and just examples for potential adaptation strategies of different genotypes, which were not aim of that study!

Left: Root system with moderate phosphatase activity in the rhizosphere – but strong rhizosphere acidification → specialized for soils with inorganic P reservoirs of moderate availability (mobilizable by H^+)

Right: Root system with low rhizosphere acidification but hotspot areas (here cluster roots) with spatially extended mining for organic phosphorus → specialized for soils with relatively high organic P reservoirs

Ex. 2: Modify spatio-temporal hotspot management



a) Root channel re-use:

Pre-crop root channel can be re-used by subsequent crops' roots:

re-activated hotspot

b) Spatial distribution

Deep-rooting pre-crops can reach subsoil with strongly altered resource availability:

subsoil hotspot

Shift in stoichiometry during a "root channel re-activation cycle" → stoichiometry controls **microbial functions** in agricultural hotspots

Conclusions

Agricultural hotspots host a vast majority of microbial functions which are a) the "motors" of agroecosystem element cycling and b) essential for agricultural production on low-fertile soils or under non-optimal conditions (low-input agriculture). **Smart hotspot management strategies** may substantially increase the resource use efficiency of crops even in strongly water and nutrient limited production systems.

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