Nutrient acquisition in intercropping: Insights from a rhizobox study and a field experiment

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Introduction

Intercropping = growing (at least) two crop species simultaneously

→ can contribute to increased plant nutrient uptake (P: phosphorus; N: nitrogen) resulting in higher yields and improved grain nutritional quality

Potential mechanisms of nutrient acquisition in intercropping include:

- Increased phosphatase activities and changed concentrations of protons and/ or organic anions in the rhizosphere of companion plants that increase P mobilization and P availability also for main crop
- N input to soil by legumes can increase phosphatase activity and N transfer from the legume to the main crop can increase N availability

The aim of this study was to test these potential mechanisms of nutrient acquisition in two intercropping experiments (greenhouse and field).

METHODS

Rhizobox study:

- Maize (*Zea mays*) intercropped with either blue lupin (*Lupinus angustifolius*), faba bean (*Vicia faba*) or white mustard (*Sinapis alba*) in comparison to maize monoculture (control)
- Rhizoboxes (30 x 50 x 3 cm / inclined by 50°) → five replicates
- Soil: loamy sand from field experiment → pH(H_2O) = 6.9; P(H_2O) = 244 mg kg^{-1} soil; TN = 2.2 g kg^{-1} soil
- Soil zymography[1] to study the spatial distribution of phosphatase activities in the rhizosphere
- pH imaging[2] to investigate pH changes in the rhizosphere

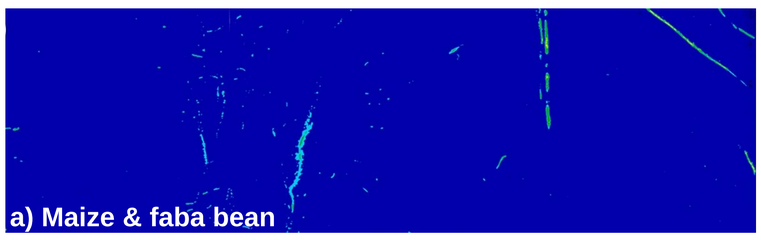
Field experiment:

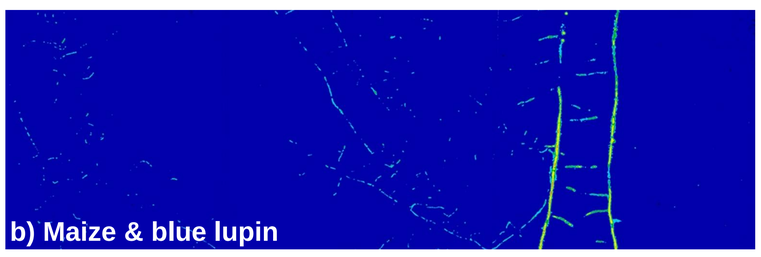
- Maize intercropped with either blue lupin, faba bean, white mustard or soy (*Gylcine max*) and in monoculture (control)
- Plots (1.7 x 2.5 m) with row intercropping (eight rows with twelve plants each) → five replicates
- Row intercropping: 20 cm row and plant distance
- Harvest of 10 plants per species & plot → analysis of biomass production (dry mass), nutrient contents (P, N) and isotopic N signature (decreased $\delta^{15}N$ signature as indicator for N transfer)

RESULTS

Rhizobox study:

- Phosphatase activity was highest in the rhizosphere of legumes
- pH changes: faba bean decreased pH and white mustard increased pH; maize and blue lupin showed inconsistent changes





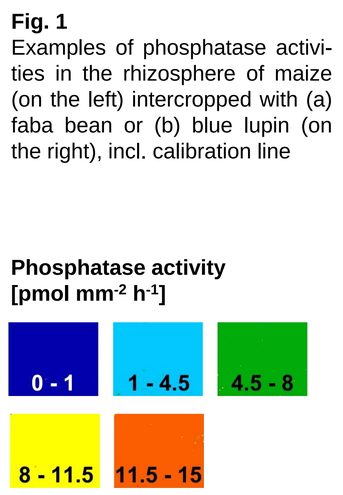


Fig. 1
Examples of phosphatase activities in the rhizosphere of maize (on the left) intercropped with (a) faba bean or (b) blue lupin (on the right), incl. calibration line

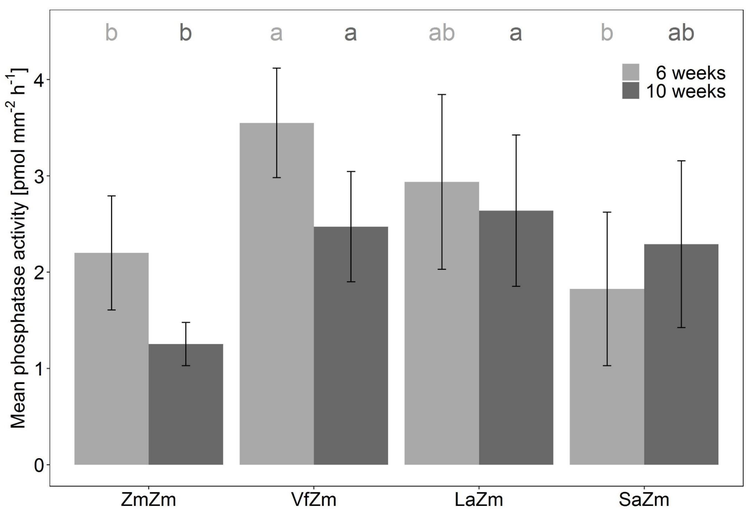
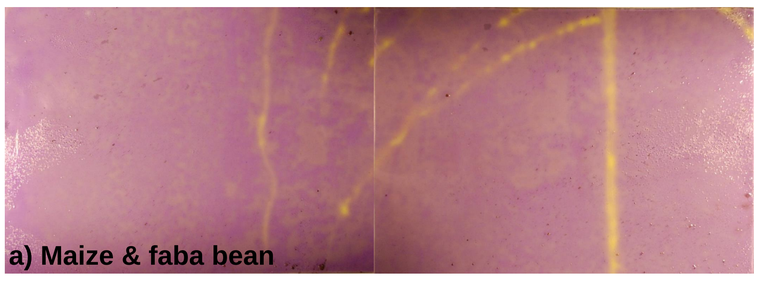
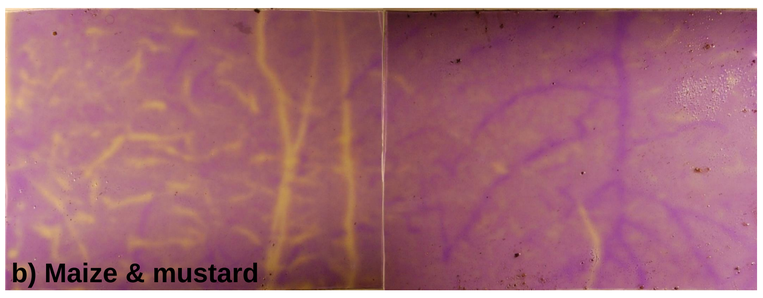


Fig. 2
Mean phosphatase activities in the rhizosphere of the companion crops (Zm: maize; Vf: faba bean; La: blue lupin; Sa: white mustard) six and ten weeks after sowing. Columns show means ± standard deviations (SD; n = 5). Lowercase letters indicate significant differences ($p < 0.05$) between intercropped species, tested separately for the two analysis.





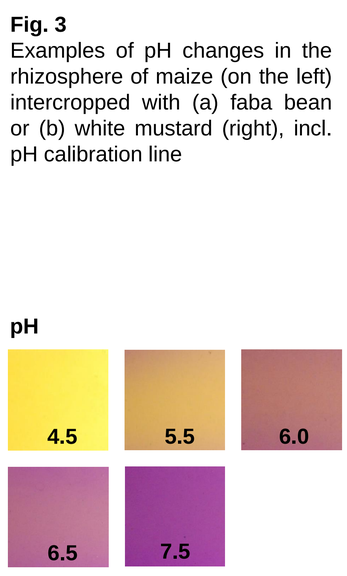


Fig. 3
Examples of pH changes in the rhizosphere of maize (on the left) intercropped with (a) faba bean or (b) white mustard (right), incl. pH calibration line

Field experiment:

- Biomass, yield and nutrient uptake of maize intercropped with blue lupin, soy, or white mustard were significantly higher as in monoculture

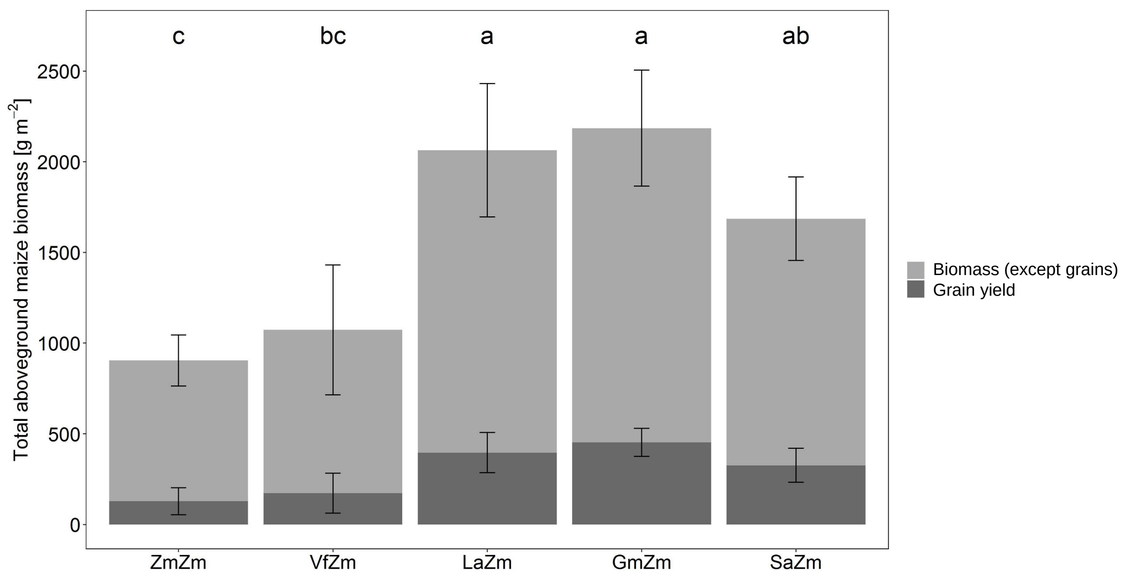


Fig. 4
Grain yield and additional aboveground biomass of maize in monoculture (ZmZm) or intercropped with faba bean (VfZm), blue lupin (LaZm), soy (GmZm) or white mustard (SaZm). Columns show means ± SD (n = 5). Lowercase letters indicate significant differences ($p < 0.05$) between treatments, tested separately for biomass and yield.

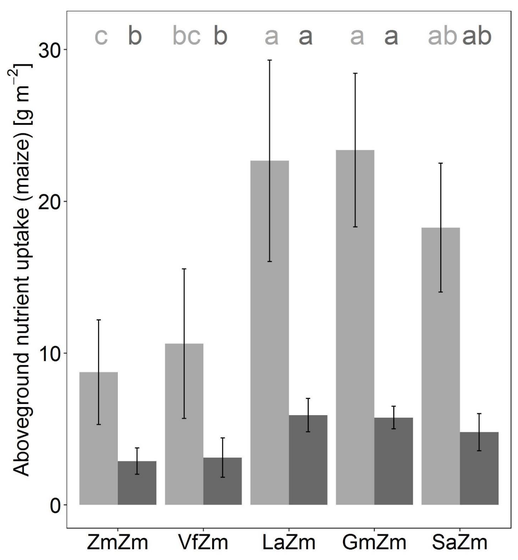


Fig. 5
N and P uptake of aboveground maize biomass (grouping and statistics as before, cf. Fig. 4; tested separately for N and P)

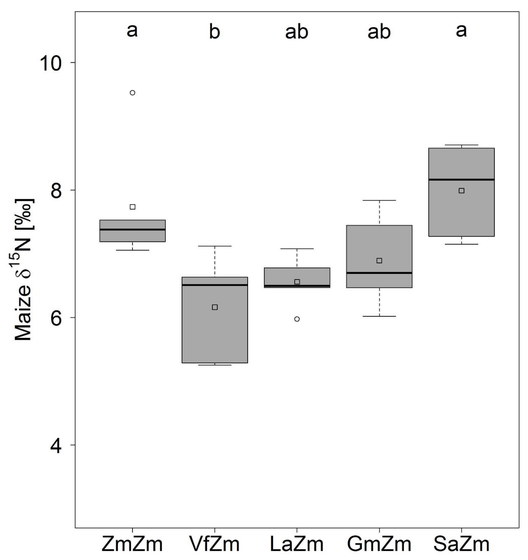


Fig. 6
$\delta^{15}N$ signatures of aboveground maize biomass (grouping and statistics as before, cf. Fig. 4)

Conclusion:

- Companion crops affect rhizosphere properties by changing phosphatase activities and/ or soil pH that can increase P mobilization
- Legumes additionally transfer N to maize plants

→ Intercropping can facilitate maize nutrient uptake and maize grain yields

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[1] Spohn M, Carminati A, Kuzyakov Y (2013): Soil zymography – A novel *in situ* method for mapping distribution of enzyme activity in soil. Soil Biology & Biochemistry 58: 275–280.

[2] Marschner H, Römheld V, Ossenberg-Neuhaus H (1982): Rapid Method for Measuring Changes in pH and Reducing Processes Along Roots of Intact Plants. Zeitschrift für Pflanzenphysiologie 105: 407–416.