Multiple nutrients constrain fine root functioning in a lowland tropical rainforest

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Initial responses from a large-scale nutrient manipulation experiment in Central Amazonia

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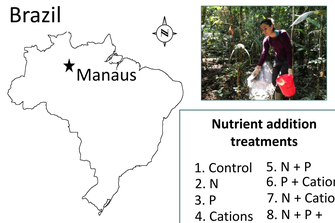
1. Introduction

- Phosphorus (P) is considered the main nutrient limiting productivity in tropical forests[1]
- 60% of Amazon forests grow in low-fertility soils[2]
- Root traits expression represents a trade-off between maximising the acquisition of resources and minimising root construction and maintenance costs[3]
- Plant investment in root biomass and nutrient uptake strategies should decrease with alleviation of nutrient limitation

How do fine root traits respond to nutrient addition in a slow-growing tropical forest in central Amazon?

2. Methods



Nutrient addition treatments

1. Control	5. N + P
2. N	6. P + Cations
3. P	7. N + Cations
4. Cations	8. N + P + Cations

Fig 1. Location of the study in Brazil and description of 8 treatments.

- **AFEX (Amazon Fertilisation Experiment),** located in low-fertility soils in a lowland *terra firme* forests near Manaus, Brazil
- 32 plots (50 x 50 m) where **N, P** and **cations** (Ca, Mg, K) were added
- Fine roots (<2mm diameter) sampled using **ingrowth cores** (IGC)[4] down to 30 cm (Fig 2a)
- Total **productivity** was calculated and subsamples were scanned for **morphological traits**[5] (Fig 2b)
- **Arbuscular mycorrhizal** (AM)[5] (Fig 2c) colonisation and **root phosphatase activity**[6] were also determined

a) 

b) 

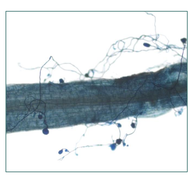
c) 

Fig 2. a) Details of the IGC in the field; b) image of roots scanned to determine morphological traits; c) root stained to account for AM colonisation.

3. Results

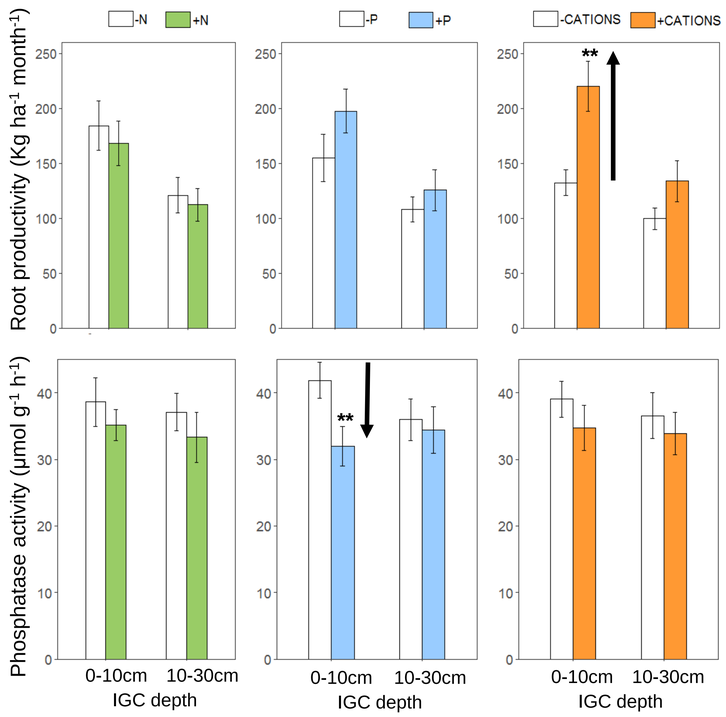


Fig 3. Responses of root productivity and root phosphatase activity after nutrient addition in two different soil depths. White bars are plots without the addition of an specific nutrient (n=16). Coloured bars are plots with the addition of nutrients (n=16).

- Root productivity increased **~52% with cations** addition only
- No effects of N and P addition
- Root phosphatase activity decreased **~23% with P addition (0-10 cm soil depth only)**
- No effects of N and cations

- Increased root diameter with **P addition (0-10cm) and cations addition (0-30cm)**
- No effects of nutrient addition on root specific length, area or tissue density

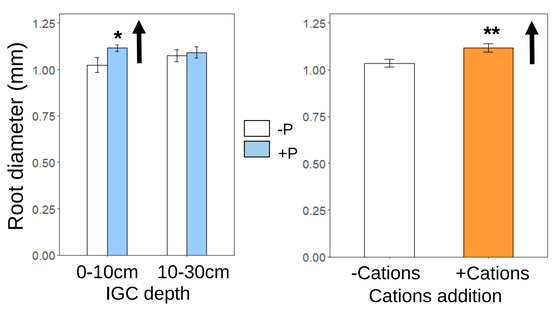


Fig 4. Responses of root diameter to P addition (blue bars; 0-10 and 10-30 cm) and cations addition (orange bars; mean 0-30cm) .

- Total root colonisation by AM increased **~53% with P addition** (although not significantly; n=4)

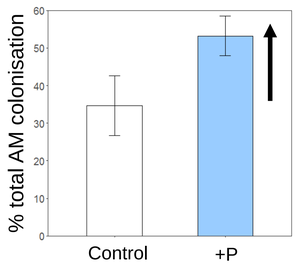
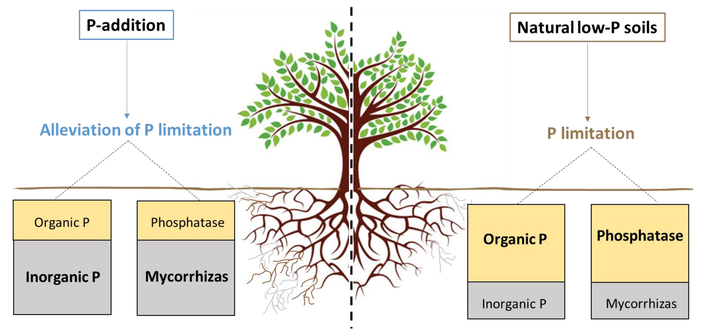


Fig 5. Responses of root AM colonisation to the addition of P (only control and +P plots in the 0-10 cm soil layer).

4. Discussion

- Higher **root productivity** with cations addition:
  - **Sign of root limitation by cations?**
  - Short-term response
- Increase, rather than decrease in **root diameter** with P and cations addition:
  - Increased mechanical protection against pathogens[7]
  - **Increased number of root cortical cells that could associate with mycorrhizas[8]**
- Decrease in phosphatase exudation & increase in mycorrhizal colonisation with P addition:
  - **Alleviation of P limitation**
  - **Shift from P-mining (phosphatase) to foraging strategies (mycorrhizas) with increased P availability[9]**



5. Conclusions

- **Root traits, even in slow-growing Amazon forests can respond very rapidly to changes in soil nutrient availability**
- **Multiple nutrients may limit belowground processes in central Amazon forests:**
  - Direct and clear evidence for **P limitation**
  - Direct or indirect **role of cations** limiting plants
  - No effect of N addition on fine roots
- **Shift in allocation between P-uptake strategies with alleviation of P limitation**

References: [1]Vitousek et al. 2010;[2]Quesada et al. 2011;[3]Aerts and Chapin 2000;[4]Metcalfe et al 2007; [5]Wurzburger and Wright 2015; [6]German et al 2011; [7]Laliberte et al. 2015;[8]Comas et al. 2014;[9]Nasto et al. 2017

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