Relationship between phosphorus availability and symbiotic n2 fixation rate in terrestrial ecosystems

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Phosphorus availability in terrestrial ecosystems does not constrain symbiotic N_2 fixation rate

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Introduction and Objective

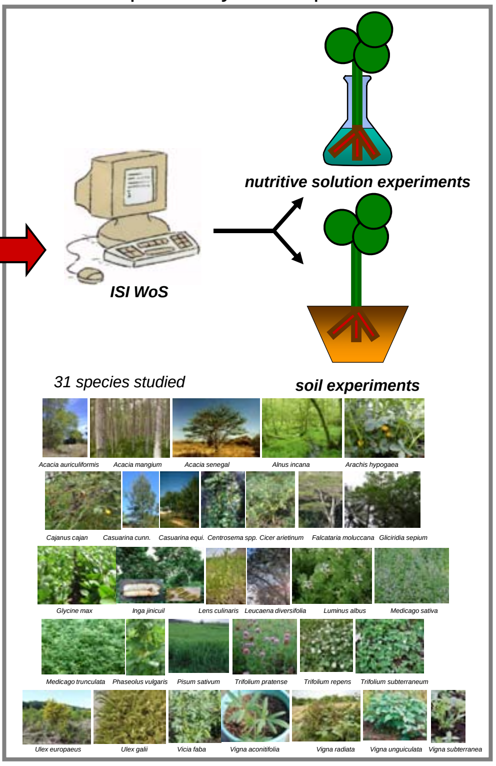
Symbiotic N_2 fixation (SNF) is a major input flux in terrestrial ecosystems. The process has been extensively studied and the factors controlling it, like phosphorus (P), are well identified. Phosphorus is also limiting plant growth in many parts of Earth and is thus of great importance for carbon sequestration in the current context of global change. Although the interactions between P and SNF have been identified as one of the few important research areas on N_2 fixation, the way P controls SNF is still a source of controversy and remains unclear. Considering the importance of SNF for ecosystems, our aim was to elucidate the dependency of this process on P availability in soils of the world.

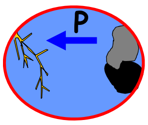
Material and Methods

We compiled published studies which measured the SNF of plants under different levels of P supply. The results of this compilation were put into a global perspective by comparing them with an extensive analysis of soil phosphorus status throughout the world.

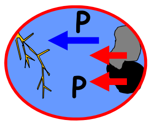
• ***Compilation of SNF studies under different levels of P supply***
We used the ISI Web Of Science database to find published literature on the effect of P supply on SNF of plants grown in natural soils (in the field or in pots) or artificial irrigated substrates (e.g. perlite or hydroponics).

• ***Worldwide data on P in soils***
We used the ISI Web Of Science database to find published literature characterizing water–P (PO_4 soluble in soil water) or labile–P (water soluble PO_4 + soil P fractions available for plants; Hedley fractionation method) in the top layer of the mineral soil or in the forest floor. Data were collected throughout the world. Each continent (North America+West Indies+Central America; South America; Europe; Africa; Asia; Oceania+Pacific) represented 9–33% of our dataset. All biomes, climates (continental to tropical), land uses (croplands, forests, grasslands and savannas) and soil types were represented.



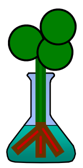


Water-P
(water soluble PO_4)
508 values



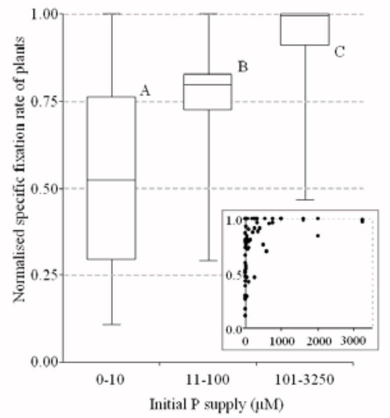
Labile-P
(bioavailable P)
631 values

Results and Discussion

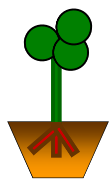


nutritive solution experiments

SNF rate under direct P control

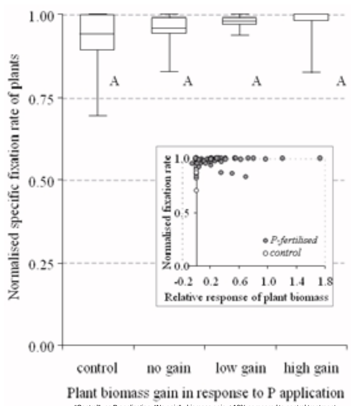


In nutritive solutions, the symbiotic fixation rate of plants ($N_{\text{fixed}}/g_{\text{plant}}$) was clearly affected by the P availability (mainly at [P] < approx. 10 µM)



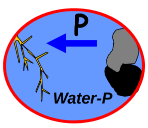
soil experiments

SNF rate under indirect P control



"Control"=no P application; "No gain"= biomass gain ≤ 10% compared to control treatment; "Low gain"= biomass gain between 10% and 30%; "high gain"= biomass gain > 30%

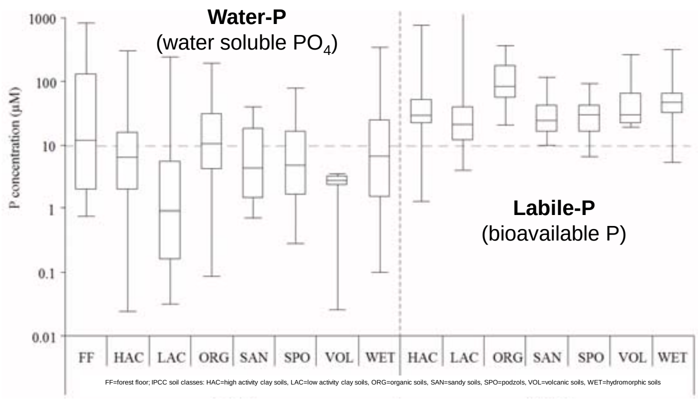
Plants growing in soils did not significantly modify their symbiotic fixation rate but may have increased their SNF flux through enhanced biomass production



not enough water soluble PO_4 in soils to always enable an efficient SNF rate

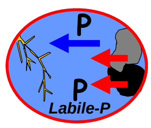
In soil solutions, the [PO_4] could be extremely low and sometimes far below 10 µM

Water-P
(water soluble PO_4)



Labile-P
(bioavailable P)

FF=forest floor; IPCC soil classes: HAC=high activity clay soils, LAC=low activity clay soils, ORG=organic soils, SAN=sandy soils, SPO=podzols, VOL=volcanic soils, WET=hydromorphic soils



plants can mine enough P at levels enabling an efficient SNF rate

Plants can develop mining strategies (mycorrhizal symbioses, phosphatases…) giving them better access to P. Labile-P is most of the time higher than 10 µM. This suggests that SNF rate is not *in situ* constrained by P supply, like in soil experiments.