A multidisciplinary research strategy for legume contributions in the biogeochemical cycles of N, P and C in agricultural and forestry systems under Mediterranean and Tropical climates

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Since 2008, the Eco&Sols mixed research unit has been coordinating the PerfCom, Intens&Fix and Fabatropimed projects with Agropolis Fondation, ANR Systerra and EU Averoes supports, for studying and promoting the association or rotation of N_2-fixing legumes in a diversity of agricultural and foresty systems (fig 1) .

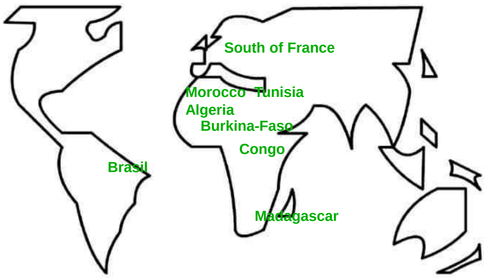

Figure 1. Network of reference agrosystems with legumes.

Agronomic & environmental diagnosis, and sustainability assessment

The field activities (WP1 and WP5 in fig 2) includes agronomic experiments and participatory research in reference agroecosystems with a wide range of agroclimatical and socioecological situations (e.g. fig 3 and 4).

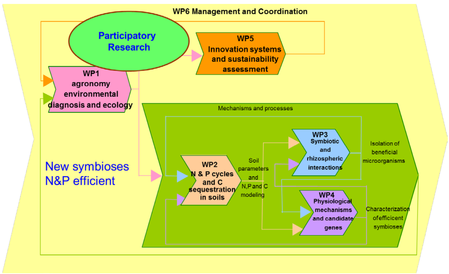

Figure 2. The interdisciplinary strategy for Fabatropimed.

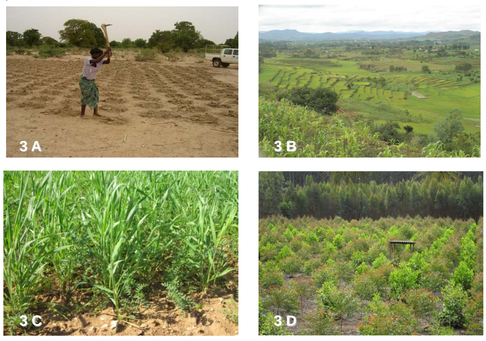

Figure 3. A, Zaï cultivation for cowpea associated to sorghum in Burkina Faso; B, Common-bean associated to maize in rotation with rainfed rice in Madagascar ; C, Wheat associated with chickpea or faba bean (not shown) in South of France ; D, Acacia-hevea in Brazil.

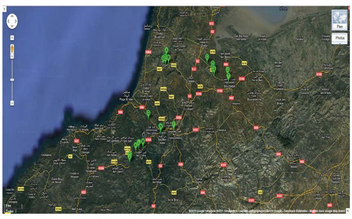

Figure 4. Localisation of field sites for nodular diagnosis on Common bean in the agro-ecosystem of Aïn Temouchent in Algeria (from C. Benadis).

N & P biogeochimical cycles and C sequestration in soils

The exchange of N, P and C between soils, legumes and atmosphere are conceptualized as biogeochemical models and provide working hypotheses (fig 5). These are tested in the field or in controlled conditions (pots, rhizotrons). The results obtained (e.g. fig 6) allow comparisons of the hypotheses with the facts and help to identify efficient farming practices.

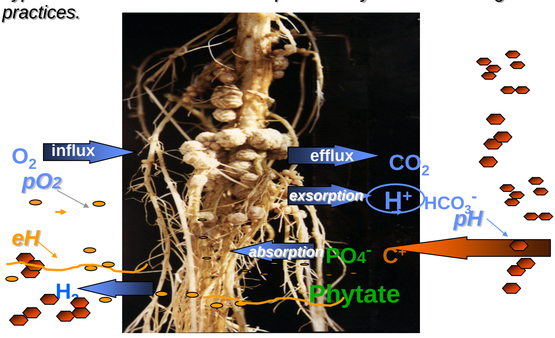

Figure 5. Increasing N_2 dependent growth of legume in a low-P soil would generate physico-chemical and biotic mechanismes to enhance P bioavailability in the nodulated-root rhizosphere, and generate a virtual cycle of N&P fertility.

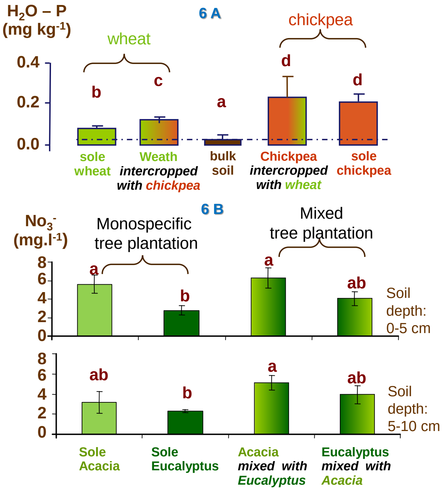

Figure 6. A, In the rhizosphere, water-extractable P was higher for chickpea than for durum wheat in a P-poor luvisol of France, and intercropping increased water-extractable P for wheat (Betencourt et al. 2012 – *Soil Biol. Biochem.*); B, Acacia introduction in Eucalyptus plantations decreased phosphorus availability (not shown) but increased nitrate availability in Congo.

Soil biota, symbiotic and rhizospheric microorganisms

In the laboratory, the projects include the study of the role in the cycles of C, N and P of microorganisms (bacteria like rhizobia, mycorrhiza ..) that are present in the symbiotic nitrogen-fixing nodules (e.g. fig 7A) and in the rhizosphere of legumes (e.g. fig 7 B and C)

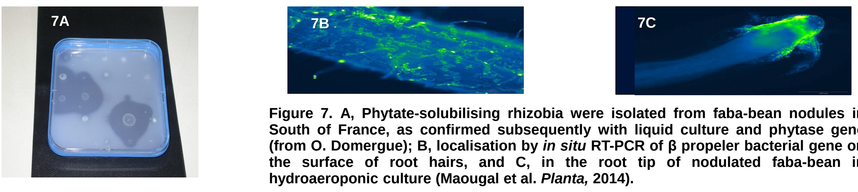

Figure 7. A, Phytate-solubilising rhizobia were isolated from faba-bean nodules in South of France, as confirmed subsequently with liquid culture and phytase gene (from O. Domergue); B, localisation by *in situ* RT-PCR of β propeler bacterial gene on the surface of root hairs, and C, in the root tip of nodulated faba-bean in hydroaeroponic culture (Maougal et al. *Planta,* 2014).

N & P utilisation efficiency in plants, and candidate genes

For a given legume, some genotypes are more tolerant than others to low P conditions (eg. Fig 8a). The study of these genotypes and their symbiotic nodules (eg. Fig 8B) indicates genes that might promote such tolerance.

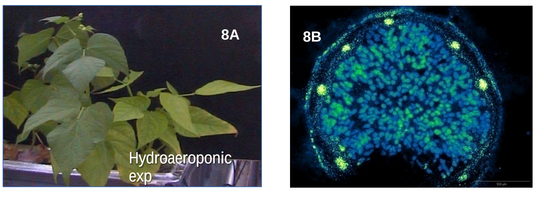

Figure 8. A, Recombinant inbred lines of common-bean contrasting in phosphorus use efficiency for symbiotic nitrogen fixation ; B, Localisation by *in situ* RT-PCR in common-bean nodules of plant gene of phospho enol P phosphatase (Bargaz et al., *J Exp Bot*, 2013), and (not shown) Fructose biP phosphatase, phytase (Lazali et al. *Planta,* 2014)

Institutes involved in the research projects :

Algeria : ENSAA Algiers, Universities of Constantine & Oran; **Brazil :** Embrapa, University of Sao Paulo ; **Burkina-Faso :** INERA, University of Ouagadougou ; **Congo :** CRDPI ; **France :** CIRAD, INRA, IRD, Montpellier SupAgro, ESA-Angers, AFAF, Arvalis, BioCivam11 ; **Madagascar :** FOFIFA, GSDM, University of Madagascar, TAFA; **Morroco :** IAV Rabat, University of Marrakesh; **Tunisia :** INRAT, University of Tunis.

http://intens-fix.cirad.fr & http://www6.inra.fr/fabatropimed & http://www6.montpellier.inra.fr/systerra-perfcom_eng/