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Innovative design of smart farming systems: Some insights from the enhancement of native mycorrhizae in Martinique

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1 Introduction

The consensus in support of agroecological principles gained more and more currency with the exacerbation of global changes (Tomich *et al.*, 2011). The natural capacity of ecological systems to adapt to shocks is being exceeded (IPCC, 2014). It reaffirms the importance of human intervention to promote their viability through innovative methods that activate ecological processes. Mobilizing biodiversity offers new lines of action (Doré *et al.,* 2011) and is likely to lead to *smart agriculture* (FAO, 2010). Unexplored potential of soil biodiversity may enhance crop health and productivity, reducing the use of chemicals. For instance, mycorrhizae (symbioses between more than 80% of plants and some soil fungi) provide multiple input services (provisioning, regulating, supporting) and are of growing interest for the ecologization of agriculture. Valorizing mycorrhizae requires to promote a holistic farming system approach and to develop agroecological engineering strategies based on knowledge-intensive sharing process (Angeon & Chave, 2014). An innovative design strategy based on the KCP® (**Knowledge Concepts Propositions**) methodology (Hatchuel *et al.,* 2009) was experienced with horticulture producers in Martinique.

2 Materials and Methods

A partnership gathered researchers (4), technical advisers (4) and farmers (19) to build and take part in a new thinking area on the valorization of mycorrhizae. Three stages were implemented:

1. A collaborative workshop for sharing **Knowledge** and exploring the mycorrhization **Concept**.

Knowledge available in scientific literature shows deficient information on mycorrhizal networks mobilization in agriculture. From a scientific review two paradoxes were identified: i) Although mycorrhizal fungi are present in most of the soils worldwide, the inoculation of standard propagules (mycorrhized roots fragments or spores) is the most spread technology. In soil, these industrialized products are in competition with native mycorrhizae. ii) Few information on agricultural practices necessary for an efficient development of mycorrhizal networks is provided.

Hence, the partners were involved in exploring the concept of mycorrhizal networks mobilization. Three steps aimed at sharing knowledge on « How to enhance and benefit from mycorrhizal networks?» : i) an experimental design based on native mycorrhizal networks mobilization through chive (*Allium fistulosum*) and tomato (*Lycopersicon esculentum*) intercropping, ii) a pedagogical model -representing soil interactions- to understand how to mobilize latent mycorrhizae, iii) a card game to co-construct mycorrhizal networks friendly practices (limiting tillage, reducing chemical inputs etc.).

2. Surveys to assess **Knowledge** and **Concepts** appropriation

Surveys were conducted on farm to situate each of the 19 farmers in learning loops (Argyris & Schön, 1996). The interviews were run on two items: i) mycorrhizae nature and functions, ii) agricultural practices and farming system design. Farmers' answers were assessed in four levels of learning: 0. no learning; 1. simple knowledge acquisition (which does not result in any action); 2. incremental acquisition of knowledge resulting in action; 3. radical acquisition of knowledge (change of values that allows for redesigning farming systems).

3. A collaborative workshop to combine emerging **Propositions** in a design strategy

Two steps were proposed: i) the results of the experimental design and the survey were debated with farmers. ii) a concept-projector for mycorrhizae mobilization was introduced to orient collective creativity for the future. It consisted of the presentation of a virtual start-up producing local selected mycorrhizae strains.

3 Discussion

The farmers' learning processes were analyzed. Among the 19 farmers, two cohorts significantly differed (Student test $\alpha<0{,}05$ p-value $< 0{,}0003$) regarding learning levels. 7 "best learners" (up to level 2) and 12 "in progress learners" (below level 2) were distinguished.

Experience and agronomic brakes were major constraints identified by both cohorts of learners (Fig. 1A). The agronomic practices and the organizational arrangements (Propositions) suggested by both cohorts of farmers to valorize mycorrhizae were capitalized (Fig. 1B).

"Best learners" identified less brakes than "in progress learners". They were able to overwhelm agronomic brakes and moved more easily from the knowledge-sharing phase (K) to the proposition of levers (P). They stressed the importance of collective arrangements to implement agroecological farming systems.

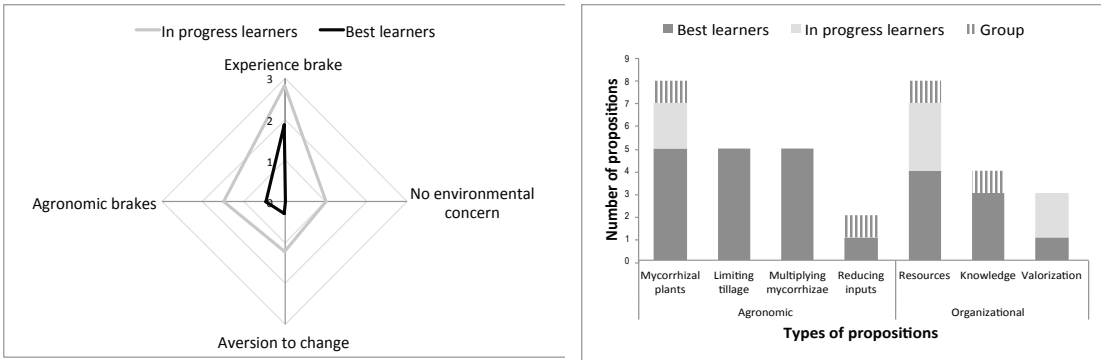

Fig. 1. Brakes (A) and levers (B) identified by farmers exploring the concept of mycorrhizae valorization.
"Best" and "In progress" learners significantly differed regarding learning levels (Student test α <0,05 p-value < 0,0003)

All the partners' propositions were synthetized in a concept tree (Fig. 2) starting from an initial concept "C0: mycorrhizae valorization" which is progressively divided in sub-concepts. Most of the farmers' propositions rely on the concept of mycorrhizal networks mobilization (C1) rather than on the use of propagules. All the farmers rejected the inoculation of standard and local selected strains.
On farm native mycorrhizae amplification (C2) was appropriated. The farmers suggested experimenting native strains production through mycorrhizal crops cultivation in given pedoclimatic areas (C3). Hence, farmers proposed to implement collective arrangements to define the convenient technology. Indeed, on farm native mycorrhizae production is labor-intensive and uncertain (Douds *et al.*, 2005), and the work organization is cost-consuming. It necessitates cooperation between farmers and technical advisers to be developed efficiently.

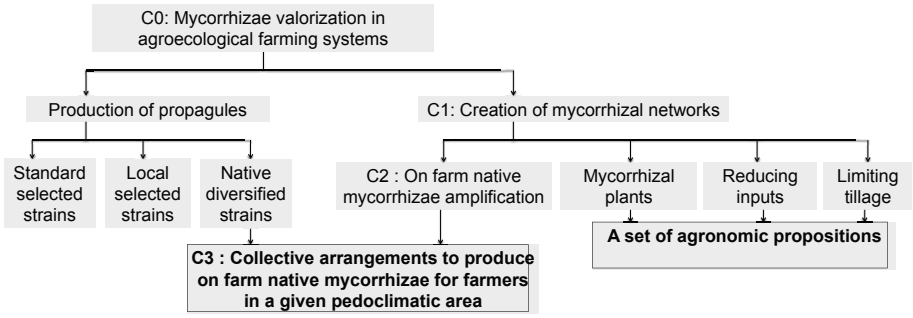

Fig. 2. Concepts tree from C0 to C3. Partners explore the concept of mycorrhizae valorization.
Bold letters indicate farmers' proposals.

The whole KCP® approach resulted in a common research-action project to help farmers to implement C3.

4 Conclusions

The innovative design of smart farming systems based on native mycorrhizae led in Martinique illustrates the pattern of a strong ecologization of agriculture. Further experiences in other contexts will help understand how the mycorrhizae valorization case study supports different agroecological transition pathways.

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