Final narrative report
ACTEA Small Grant Facility
SOFUNRICE Project

Enhancing Soil functional diversity of Rice fields

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CANSEA component

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Partnership

IRD-IPME, France; VNUA, Vietnam; ITC, Cambodia; GDA/DALRM, CASC; Cambodia; CIRAD-AIDA and CIRAD, CSIA, France; LMI Rice, Vietnam.

THE FUNDED INITIATIVE: Enhancing Soil functional diversity of Rice fields

Main Field of involvement:

Soil management, climate change adaptation and mitigation

Summary of the initiative

In South-East Asia, rice small-scale farming represents 200 million households and 144 million ha, and this on less than 1 ha farms. Rice production is increasingly constrained by water scarcity, soil fertility depletion and climatic events (floods, drought, and sea level rise in the deltas). Climate change has a direct incidence on the prevalence of diseases and pests, more particularly plant-parasitic nematodes (PPNs). The phytosanitary treatments against these parasites are expensive and strongly regulated; they are prohibited due to their harmful impact on human health and on the environment. Alternative rice cropping systems are essential to reduce the environmental burden associated with rice cultivation without jeopardizing production, commoditization and global food security. To address this issue, an experiment was conducted in the irrigation scheme of Stung Chinit assessing the impacts of contrasted soil and crop management on PPNs, soil nematofauna, soil microbial communities' diversity and abundance. Two main rice cropping systems were compared with conventional plough-based management (CT) and direct seeding mulch-based cropping (DMC) systems. Our results demonstrated that:

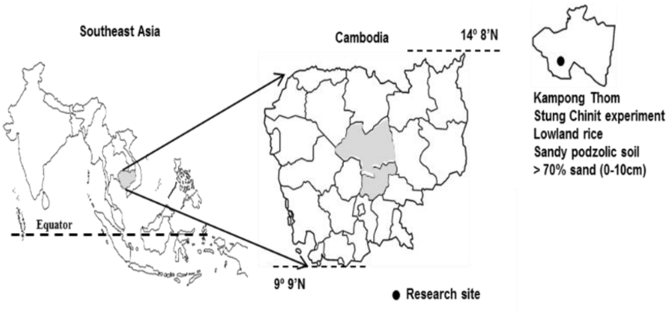
(i) After a long term of DMC practice (six years) the PPN prevalence was reduced from 52 to 72% in comparison to the CT practice. This was confirmed for four different evaluated rice genotypes (two *oryza sativa indica* and two *oryza sativa japonica*);

(ii) the nematofauna composition and diversity found under DMC practice showed a much more complex soil food web that could not be found under CT conditions;

(iii) Cultural practices induced a modification of the bacterial community structures found in rice roots.

Location:

Experimental lowland fields established in 2011 in the Stung Chinit irrigation scheme were sampled (Santuk district, Kampong Thom province, Cambodia (12°32'55"N and 105°08'47"E)). Contrasted crop management was used to assess the changes in nematode communities and more specifically on PPNs prevalence, soil nematofauna, soil texture, SOC dynamics and microbial diversity. Four pair-wise comparisons of CT and DMC systems were used on a sandy podzolic soil (Suong et *al*., forthcoming and Leng et *al*., forthcoming).



Backgroud of the intervention:

Plant Parasitic Nematodes (PPN) cause extensive damage and substantial yield losses in lowland and upland paddy fields in Asia. In terms of occurrence and plant damage in Asia, *Meloidogyne graminicola* is the most prevalent PPN infecting rice in all agro-ecosystems (Win 2013), more specifically in upland conditions and shallow intermittently flooded lands where they cause significant yield losses (De Waele and Elsen 2007). To date, no rice lines resistant to PPN infection are available for farmers. As a result, the only alternative to the use of hazardous chemicals, banished in most countries (M.B.T.O Committee 2010), is to manage the infection by controlling a permanent irrigation of the rice field. Indeed, under flooded conditions, water constitutes a physical barrier that protects plants from *Meloidogyne* spp. infection, thus limiting its impact (Prot and Matias, 1995). However, due to the global warming and to the regulation of water flow by the actual construction of series of dams on the Mekong River to produce electricity, brutal consequences on the water access could be predicted (Ziv et *al*., 2012). **Thus, rice farming is facing a dual challenge of delivering sufficient and nutritious food to meet the projected demands of population growth and markets, and overcoming issues such as climate change (CC), soil fertility depletion, pests and diseases management, and water scarcity**. **The design of climate-smart rice cropping systems require a close match between the water needs of rice during its cycle, an enhancement of soil health to adapt rice farming to CC, an integrated management of pests and diseases to reduce the use of external inputs**. The enhancement of biodiversity (i.e., plant and soil communities) is receiving increasing attention as it is associated with pest and diseases suppression, bioremediation of xenobiotics, reduction of chemical inputs, efficient nutrient cycling, and it will contribute effectively to mitigate and to **adapt farming systems to climate change**. Maintaining soil biodiversity and soil functions are essential for improving both productivity and food stability while preserving the quality and quantity of ecosystem services in a sustainable way (Tilman et *al*., 2002).

Our objective was thus triple:
(i) Describe the consequences of the change of cultural practices on the microfauna and the nematofauna; **(ii)** Look for signatures of these changes in soil biodiversity and relate it to the level of soil infestation and plant infection; **(iii)** Involve farmers and young researchers in these soil biodiversity analyzes to give them explicit notions of what biodiversity is and how it is essential to control parasitism.

References and previous works

Poor sandy rice fields highly infested by parasitic nematodes are largely represented in Cambodia. Suong et al. (2017) observed that 90% of the surveyed lowland rice fields throughout the country were infected by *Meloidogyne* spp. Thus, there is a need to rethink rice farming systems that ensure that enough nutritious food is produced to meet with local demands and market strategies in a context of plant parasitism.

Under Conservation Agriculture (CA) and direct seeding mulch-based cropping (DMC) systems the primary goal is to build a permanent flow of carbon from above and belowground biomass to improve all compartments of the soil's fertility. Based on the diversity and quantity of biomass-C inputs DMC systems increase soil organic C and N pools depleted by previous plow-based tillage (Hok et *al*., 2015), nutrient and water-use efficiency as well as enhance soil biodiversity and functions (Lienhard et *al*., 2013), while improving net primary production and crop productivity (Sá et al. 2015). Both high levels of plant diversity and increases of net primary production under DMC modify the basal resources, thus drastically modifying the nature of the food web. Nematodes occupy key positions as primary and intermediate consumers in soil food webs. Therefore, evaluation and interpretation of the abundance and function of their community assemblages (they belong to different trophic group: some are plant parasitic, others feed on fungi or bacteria; others are carnivores or omnivores) offers an in situ assessment of soil quality (Bongers and Ferris, 1999). Because they are present in 4 of the 5 existing trophic groups, nematode faunal composition has emerged as a useful monitor of environmental conditions and ecosystem function in the soil.

It is suggested that an increase of organic matter leads to plant-parasitic nematode (PPN) suppression (Min and Toyota, 2013). However the mechanisms of this pest suppression remains poorly understood even if the contribution of macrofauna and microbial activities is strongly suggested (Oka, 2010; Min and Toyota, 2013).

For several years and especially thanks to the thesis work of Malyna Suong (University of Montpellier, IRD 2017), we have seen that the lowland rice fields in Cambodia and particularly in the Stung Chinit region are very infested by the *Meloidogyne* species. During this study it appeared that the degree of infection between DMC or traditional type systems are very different but that the cause of these differences remained unexplained.

At the same time, work on the same experimental site of Vira Leng and Florent Tivet showed that in a DMC system, the soil enrich in nutrient, have a better structure and offers better rice yields. Without being able to describe it precisely, the microfauna also seemed to be enriched in the DMC system. As a result, promising cropping systems are being developed in the region, but there is still little knowledge of nematode populations (parasitic and living plant nematodes) and microbial communities. In addition, if DMC had an impact on PPN infection, this would suggest that microfauna diversity and activity are key players in this biological control. This document aims to better understand the role of microfauna and nematofauna in biocontrol.

Historical presence in the area of the proposed project, and potential knowledge of local stakeholders in agriculture

We came to this region by an academic path. Following the establishment of the SUNRISE Network (South East Asia Rice Health Surveillance Network) in 2012, agronomists and plant pathologists brought together international and regional partners in Southeast Asia. We participate in the training of Master students in Vietnam and Cambodia. Science students from the Hanoi University of Science and Technology (USTH), the Vietnam National University of Agriculture (VNUA) and the Cambodian Institute of Technology (ITC) participated in activities related to field, soil sampling, and laboratory and data analysis. After having done her PhD work within the Nefonev team at LMI-Rice (Hanoi, Vietnam) and IRD (UMR IPME, Montpellier, France), on "the effects of the conservation agriculture on root-parasitic nematodes of rice and study of the diversity of *Meloidogyne graminicola*.

Recognizing the need to bring farmers directly closer to biodiversity awareness and biocontrol approaches, we have co-built a network of colleagues from GDA / DALRM, CASC, and from the Universities of UBB, RUA and ITC at the service of agroecology. In 2018 and to form this network, we were a young girl associated with the IRD (JEAI). In 2018 and to form this network, we applied as a « Jeunes Équipes Associées à l'IRD » (JEAI). This JEAI "HealthyRice" is an IRD-funded program designed to promote and strengthen new research teams in developing countries through partnership with IRD research units (and other patners). Three main objectives will be expected in this JEAI: **(i)** to identify parameters in diversified agricultural rice systems allowing an increase in soil & plant health, and a decrease in pesticide use and their occurrence as residues in consumption products; **(ii)** A multidisciplinary approach to identify best agricultural practices fitting with pesticides regulations and markets that will be promoted to farmers for a more sustainable production of rice; **(iii)** To structure and build interactions between multiple actors in rice agroecology in Cambodia where local stakeholders will play a central role.

Targeted beneficiaries of the intervention and targeted audience

The main objective was to study whether conservation agriculture could provide the means to improve soil biodiversity for the benefit of soil and plant health. Concrete indicators of good health have been sought to provide farmers with indicators and encourage them to continue their transition to conservation agriculture. We then target the country's students for analytical approaches and rural actors to make them aware of the tremendous potential of bio-control.

Main objectives of the funded initiative

Our objective was triple:
(i) Describe the consequences of the change of cultural practices on the microfauna and the nematofauna.
(ii) Look for signatures of these changes in soil biodiversity and relate it to the level of soil infestation and plant infection.
(iii) Involve farmers and young researchers in these soil biodiversity analyzes to give them explicit notions of what biodiversity is and how it is essential to control parasitism.

Approach & methodology

In order to realize this project and taking in account that the budget was limited, we were connected to the network already posted on the site at Stung Chinit by F. Tivet (CIRAD) and Vira Leng (GDA/DALRM, CASC). They have in fact made available experimental plots and a network of actors including local actors. Moreover, it is essential that students are involved in this study. Indeed, students and their supervisors make it possible to involve the whole of the local actors which will be able to support in the short and medium terms these changes of cultural practices by communicating their results with the political actors (ministries) and pedagogical (university).
Our activities have been divided into three stages:
1. Implementation of the experimental protocol involving all partners and explaining the expected objectives
2. Field activity consisting mainly of preparing the experiment and sampling while involving farmers and students
3. Laboratory work in Cambodia and France where researchers and students had to reveal soil biodiversity.

A fourth step is now under way and it consists of returning to the field to communicate the results.

Main activities implemented

- Establishment of plant nurseries
- Establishment of field trials
- Sampling on the plots
- Nematode and root microbiome extraction workshop at ITC
- Formalization of the creation of a network on agroecological practices associating Cambodian researchers and farmworkers

How the project has contributed to promoting agroecology transition ?

Thanks to this support, we have been able to highlight that conservation agriculture makes it possible on the one hand to increase soil biodiversity and on the other hand that the consequences of this increase seem to be the reduction of parasitism (plant parasitic nematodes). Nevertheless and looking at the history of these plots we realize that the establishment of a conservation agriculture, if it has the simple objective of reducing parasitism, must be seen in the long term.
Indeed, the first years after the establishment of such a system of contrary effects can be observed (Malyna Suong, PhD 2017), which suggests that biodiversity and the notion of biological control should not be considered as simple acts resulting in quick answers.
Our analyzes should make it possible to offer reliable indicators that can help farmers and actors of the Ministry of Agriculture that their efforts are going in the right direction and should lead to the establishment of a stabilized system or the impact of pests can be naturally controlled

Communication & dissemination activities

We first communicated in the field with our partners and during the establishment of the JEAI on the importance of agroecological practices and their impact on parasitism. Laboratory training took place twice at ITC (April and June 2018) to transfer our knowledge to a panel of Master's students.

Following this project, two theses have just begun, one in Vietnam (Hue Nguyen, PhD USTH/VNUA) and the other in France (AS Masson, PhD Montpellier University) on this theme and which will aim to decrypt the impact of these changes in cultural practices on root microbiome and plant health.

Lessons learnt from the project

We have been able to highlight that biodiversity at both the microbiome and the nematofauna level increases with so-called conservation farming practices. Among the bacteria identified in the soil, a number of them could play a determining role in soil health. Our main objective will be to see if these enrichments take place on all the rice genotypes tested (analysis in progress, These of H. Nguyen) and to confirm if these bacteria play indeed a role in bio-control (These of A.S. Masson). We plan to conduct field trials in 2019 where the soil will be pre-inoculated with these Cambodia isolated bacteria to confirm their role in bio control strategies. If the results are confirmed, these selected subset of bacteria will be able to serve as markers of good soil health (follow the evolution of the transition of a soil in conservation agriculture) and also be directly inoculated on the seeds before sowing (project JEAI).

Main outputs of the projects

The two main conclusions of this project are:

1. Conservation agriculture can be a way to control pests such as plant parasitic nematodes.
2. The transition to conservation agriculture can be accompanied by increased soil biodiversity and activity.

It remains now to identify precisely the micro-organisms naturally present in the soil and whose conservation agriculture seems to have favored development in favor of the health of the plant. This will be the subject of future studies that we wish to develop in Cambodia through two doctoral studies and research activities that will be developed in partnership with local actors and national and international research centers in the JEAI project " HealthyRice”

AFD

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