A multi-criteria approach in comparing conventional and conservation agriculture in rice-maize cropping systems in the degradable and *Striga*-infested soils of Central Madagascar

Meva Tahiry Randrianjafizanaka[1]; Roger Michellon[2]; Alain Paul Andrianaivo[3]; Jonne Rodenburg[4]; Philippe Letourmy[2]; Patrice Autfray[2]
[1]Université de Tuléar; [2]CIRAD; [3]FOFIFA; [4]Africa Rice Center
rmtahiry@yahoo.fr

1. Introduction

Arable upland soils in Central Madagascar are characterized by an inherent low soil fertility, a high vulnerability to soil erosion and a high pressure of the hemi-parasitic weed *Striga asiatica* on cereals i.e. rice and maize. *Striga asiatica* is an important weed to rice in southern parts of East Africa, causing high yield losses (Rodenburg et al., 2010). In the Mid-West of Vakinankaratra this crop pest jeopardizes the extension of upland rice (Husson et al., 2008) and obliges farmers to introduce fallow periods after a short-term cropping period (Sorèze, 2010). Conservation Agriculture based cropping systems show to be a promising set of solutions to counteract negative externalities of conventional agriculture and to allow permanent cultivation (Scopel et al., 2013) and was successfully tested in Central Madagascar. The aim of this paper is to present a 3-year agronomic experiment with a multi-criteria approach conducted in the Mid-West of Vakinankaratra (800 to 1200 m altitude) on upland rice based cropping systems.

2. Material and methods

This experiment was carried-out at Ivory (930m a.s.l.) on a 1.3ha field, previously abandoned due to high *S. asiatica* pressure. From 2011 to 2014 the conventional cropping system (CONV), i.e. rice-maize rotation practice involving seasonal tillage and crop residue removal was compared with conservation agriculture (CA) cropping systems with 3 different maize-legume intercrops i.e. a mix of cowpea (*Vigna unguiculata*) and mucuna (*Mucuna pruriens*), hereafter indicated as CA CM, rice bean (*Vigna umbellata*), indicated as CA RB, and stylo (*Stylosanthes guianensis*) indicated as CA ST. The experimental design was a split-plot level (with a sub-plot size of 90m²). Rice varieties included in this experiment were: B22, locally popular but *Striga*-susceptible, and NERICA 4 (N4) and NERICA 9 (N9), both *S. asiatica*-resistant. Each year all the rice and maize systems received organic fertilizer (farmyard manure) at an average dose of 5t ha^{-1}, comparable to local farmers' practice. We recorded: (i) rice and maize yields; (ii) cumulated above-ground biomass per cropping systems; (iii) bulk density, total nitrogen, and available phosphorus (0-10cm) and; (iv) above-ground *S. asiatica* plant numbers.

3. Results

3.1 Crop yields

3.1.1 Rice

From the year 1 to year 3 rice yields increased for all the treatments. The first year's rice yields were not different among the systems (Figure 1) as all cropping systems started with the same soil tillage and coverage. The only exception was CA ST, where the rice was intercropped with *Stylosanthes*.
Significant rice grain yield differences were recorded between the cropping systems in the 2nd and the 3rd year. In both years the CA CM treatment yielded more the CONV treatment. In CA ST the 2nd year rice yields were low due to competition of *S. guianensis* as the legume was managed as a live-mulch. This constraint was solved during the 3rd year, where legume sprouts were cutted. Here, rice yields were at the same level as CA CM, and significantly higher than with the conventional rice –maize rotation system.

3.1.2 Maize
Maize grain yields remained low during the 3 years for all systems, ranging from 0 to 1.27 t ha^{-1}; probably soil fertility replenishment was not sufficient to meet maize production requirements (Figure 2). The 2nd year maize yields were highest with the CONV treatment, while the 3rd year maize yields were highest with CA RB.
Compared with the 2nd year maize yields were reduced during the 3rd year in the CONV treatment while they increased in CA CM and CA RB. The 2nd and the 3rd year in CA ST maize yields were around zero due to a strong competition with the legume.

3.2 Cumulated above-ground biomass
Cumulated above-ground biomass in the CA cropping systems were reported on Table 1. The 3-year cumulative mean of above-ground biomass produced in CA ST was more than 28 t ha^{-1} while those of CA CM and CA RB were on average 7.20 and 8.58 t ha^{-1} respectively.

3.3 Soil
3.3.1 Porosity
The soil bulk density after 3 years showed to be slightly reduced on CA ST compared with CONV, CA CM and CA ST (Figure 3).

3.3.2 Total nitrogen and available phosphorus
Total soil N increased significantly between year 1 and year 3 for all cropping systems (Figure 4) while available soil phosphorus significantly reduced in the same period (Figure 5). A cropping system effect was only showed for N during year 3. In CA ST the N content in the soil (2.312) was significantly higher than in CONV (2.067). No significant differences were observed with CONV, CA CM and CA RB.

3.4 *S. asiatica* pressure on rice crop
In both the 2nd and 3rd year a negative relationship between the number of *S. asiatica* plants and rice's yields were observed with the susceptible variety B22 only (Figure 6). Compared to the 1st and 2nd year, the *S. asiatica* pressure increased the 3rd year.
The highest *S. asiatica* pressure was found on rice variety B22 in the CONV treatment. The *Striga* pressure was lowest in CA ST, even for B22 (Figure 7).

4. Discussion and conclusion

Rice yields with CA based maize intercropping with the legumes *Vigna unguiculata* and *Mucuna pruriens* were increased the 2nd and the 3rd years. A soil fertility increase was observed in a relative short period (3 years) with the introduction of *Stylosanthes guianensis*, i.e. a significant increase of total N and a slight increase of porosity at the top-soil. This legume cover crop produced a high amount of biomass. *S. asiatica* infestation levels in rice were highly reduced with *Stylosanthes* intercropping even with B22, the most susceptible rice variety. Available soil P showed to be decreased and this may have caused a strong limiting factor for maize production in all systems. This requires additional soil fertility management practices. The use of legumes as cover crops, in particular *Stylosanthes guianensis* and *Vigna unguiculata* combined with

5. References

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6. Figures and tables

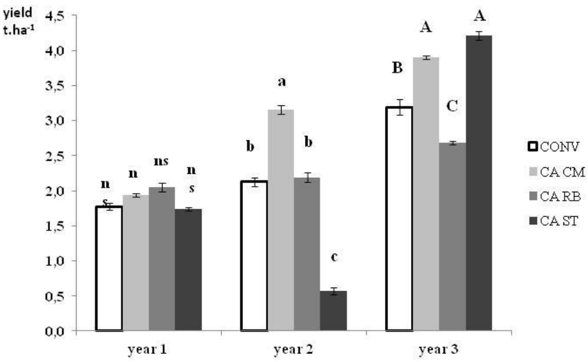

Figure 1: Paddy rice yields during the 3 years

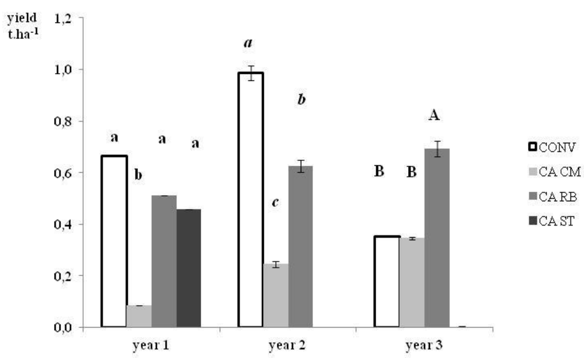

Figure 2. Grain maize yields during the 3 years.

Table 1. Cumulated rice, maize and legume residues for the 3 year.

Cropping systems	CA CM	CA RB	CA ST

Biomass (t.ha^{-1})	7,20 B	8,58 B	28,38 A
Standard-error	0,06	0,21	0,21

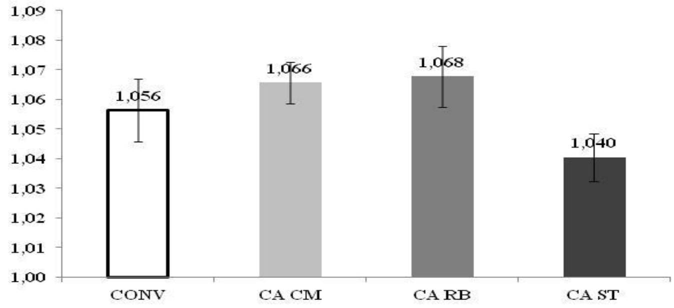

Figure 3. Soil bulk density at 0-10 cm the 3rd year.

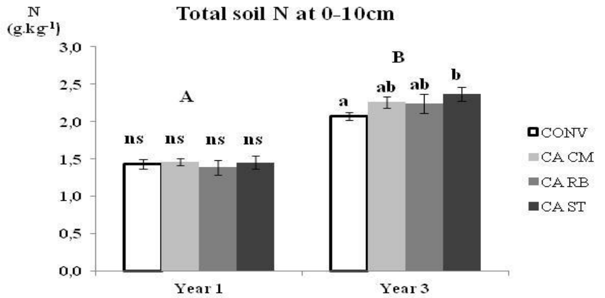

Figure 4. Total nitrogen at 0-10 cm the 3rd year.

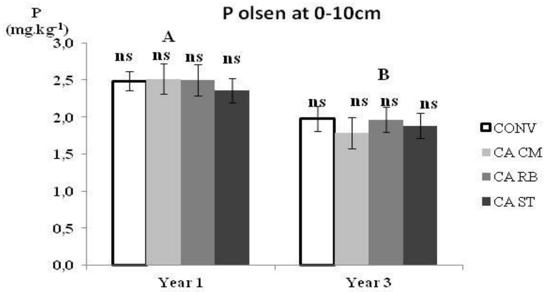

Figure 5. Available phosphorus at 0-10 cm the 3rd year.

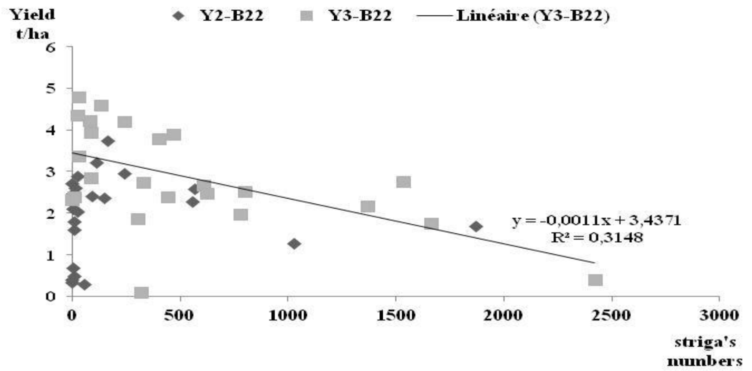

Figure 6. Relation between the number of *S. asiatica* plants (37.8m²) and rice yields the 3rd year with B22 at 110 days after sowing.

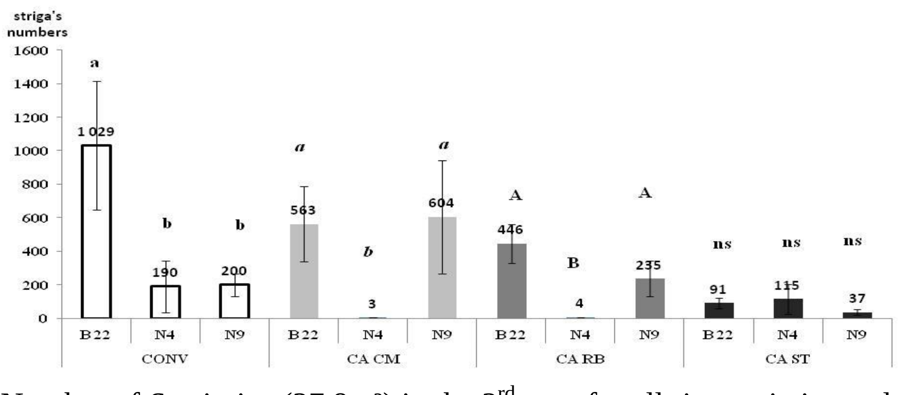

Figure 7. Number of *S.asiatica* (37.8m²) in the 3rd year for all rice varieties and treatments.