Implication of conservation agriculture cropping systems for upland rice breeding in Madagascar: lessons from genotype x cropping systems interactions

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Introduction

Conservation agriculture (CA) offers new opportunities to improve the sustainability of rainfed crops. CA is based on minimal soil disturbance, permanent soil cover with crop residues or growing plants, and crop rotations. Changing from conventional to conservation agriculture cropping systems creates new environmental conditions to which improved varieties have to be adapted (Trethowan et al., 2012). Thus, the true importance of genotype x cropping system interaction needs to be evaluated in order to determine whether or not, plant breeding need to be performed in a particular CA-based cropping system rather than in a conventional one.

Experimental designs (Table 1)

New varieties are evaluated under different cropping systems at different selection stages in our breeding station in the middle west of Madagascar (S19 33 16.8, E46 25 29.3, 900 m asl).
The first variety trial design, initiated in 2007-2008, compares two distinct conservation agriculture cropping systems with no tillage: (1) a rotation of upland rice following maize intercropped with rice bean (*Vigna umbellata*) that was replaced in 2011-2012 by *Dolichos lablab* and (2) a rotation of upland rice following *Stylosanthes guianensis*. It is a split plot design that compares cropping systems on main plots and eight upland rice varieties on subplots. In both cropping systems crop residues were maintained to cover soil surface. Only grains from the maize and rice were harvested. In this experiment, upland rice variety trials have been conducted in 2008-2009, 2010-2011 and 2012-2013.
The second variety trial design, initiated in 2008-2009, compares a cropping system with conventional tillage (CT) to a CA cropping system with no tillage. It is a split plot design that compares cropping systems on main plots and eight upland rice varieties on subplots. The CT system is based on a rotation of upland rice following maize intercropped with rice bean that was replaced in 2010-2011 by *Dolichos lablab*. The CA system is a rotation of upland rice following stylosanthes. In both cropping systems the crop residues were conserved either to be incorporated in the soil after ploughing in the CT system or to cover soil surface in the CA system. Only grains from the maize and rice crops were harvested. In this experiment, upland rice variety trials have been conducted in 2009-2010, 2011-2012 and 2013-2014.
In the course of our breeding program, we also compare every year a higher number of upland rice varieties (around fifty) on different cropping systems (CT versus CA) in what will be referred to as preliminary variety trials. These evaluations are conducted in separate fields

therefore yield under CT cannot be compared directly to yield under CA but we analyzed the correlations between varieties yield under CT and under CA in 2012-2013 and 2013-2014.

In all these trials, 5 tons of cattle manure + 500 kilos Dolomite + 80 kilos urea (split in two applications) were applied per hectare on the rice crop. Mineral fertilizer (NPK 11-22-16) was applied at the rate indicated in Table 1.

An analysis of variance has been performed in variety trials 1 and 2 so as to test the significance of the variety x cropping system interactions and of the yield differences between cropping systems. Pearson phenotypic correlation coefficients between yields obtained in the compared cropping systems were calculated on the basis of the means of the varieties over replicates.

Table 1: Description of the cropping systems. Comparison of yields obtained under different cropping systems. Correlation for grain yield of each variety under the two compared cropping systems. Statistical significance of the variety x cropping system interaction.

Season	nb of varieties	plot surface	nb of repetitions	NPK (11/22/16) (kg ha^{-1})	Treatment 1 (T1) preceding crop/tillage	Treatment 2 (T2) preceding crop/tillage	T1 Yield (Kg/ha)	T2 Yield (Kg/ha)	T1 yield - T2 yield	correlation T1/T2	interaction variety x cropping system
comparisons CA/CA											
2008-2009	8	16	4	300	stylosanthes/ NT	Maïs+rice bean/ NT	5406 a	5036 a	370	0,90**	No
2010-2011	8	16	4	150	stylosanthes/ NT	Maïs+rice bean/ NT	**5985 a**	**4570 b**	1415	0,91**	No
2012-2013	8	16	4	150	stylosanthes/ NT	Maïs+dolichos/ NT	4902 a	4889 a	13	0,86*	No
comparisons CA/CT											
2009-2010	8	18	4	300	stylosanthes/ NT	Maïs+rice bean/ CT	5014 a	5226 a	-213	0,83*	No
2011-2012	8	18	4	150	stylosanthes/ NT	Maïs+dolichos/ CT	4776 a	4001 a	776	0,64ns	No
2013-2014	8	18	4	150	stylosanthes/ NT	Maïs+dolichos/ CT	**6435 a**	**5286 b**	1148	-0,25ns	**P=0,0017**
2012-2013	44	6	2	150 NT; 300 CT	Dolichos/NT	Arachis/CT	-	-	-	0,61****	-
2013-2014	52	6	2	150 NT; 300 CT	Mucuna/NT	Arachis/CT	-	-	-	0,59****	-

NT: no tillage; CA: conservation agriculture;CT: conventional tillage

Results

In variety trial 1 comparing two no-till CA systems, the correlations between the rice yields obtained with a mulch of stylosanthes and the rice yields obtained with a mulch of maize+ricebean (2008-2009 and 2010-2011) or maize+dolichos (2012-2013) were significantly high (Figure 1 and Table 1). No significant variety x cropping system interaction was observed in any of the cropping seasons. Rice yield was significantly better under the CA system with a mulch of stylosanthes than under the CA system with a mulch of maize+rice bean in 2010-2011 (Table 1).

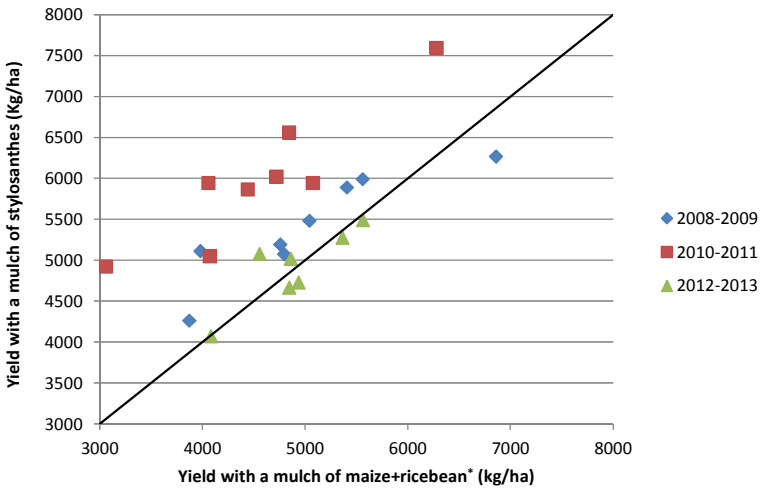

Figure 1: Relationship for upland rice grain yield under two CA systems (one with a mulch of maize+ rice bean and the other one with a mulch of stylosanthes). The solid line indicates the 1:1 ratio. Average yields per variety measured in each cropping system are plotted against each other for three rice rotations of variety trial 1. Varieties are different between years.

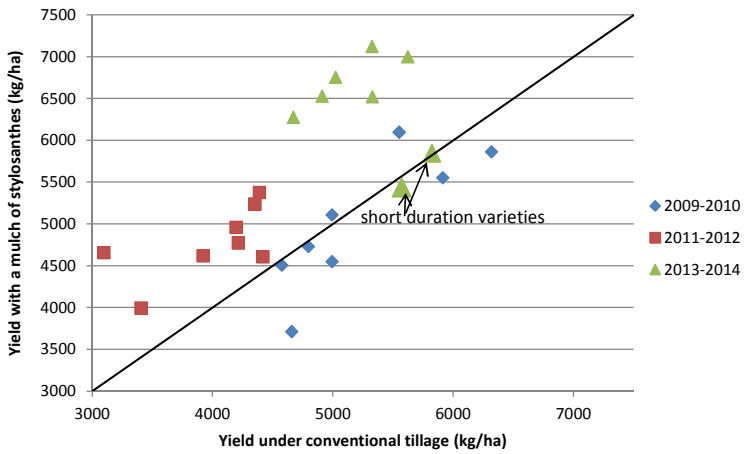

Figure 2: Relationship for upland rice grain yield under CA system (using a mulch of stylosanthes) and a conventional tillage system. The solid line indicates the 1:1 ratio. Average yields per variety measured in each cropping system are plotted against each other for three rice rotations of variety trial 2. Varieties are different between years.

In variety trial 2 comparing CA and CT systems, a significant variety x cropping system interaction has been observed only in the 2013-2014 cropping season. Two short duration varieties (number of days to 50% flowering=76 and 80 days compared to 88 days on average for the other six varieties) appeared to perform less under CA system than other varieties. Except for these two varieties, the relationship between yield under CA and CT is positive and roughly linear although the correlation was significant only in 2009-2010 (Table1, Figure 2). Rice yield was significantly better under the CA system with a mulch of stylosanthes than under the CT system in 2013-2014. The difference between CA and CT systems seems to increase overtime in favor of the CA system (Table 1).

In preliminary variety trials, there was a highly positive and significant correlation for grain yield of the varieties under CT and under CA both in 2012-2013 and in 2013-2014 trials (Table 1, Figure 3). This indicates that varieties that are high yielding under CT are also high yielding under CA.

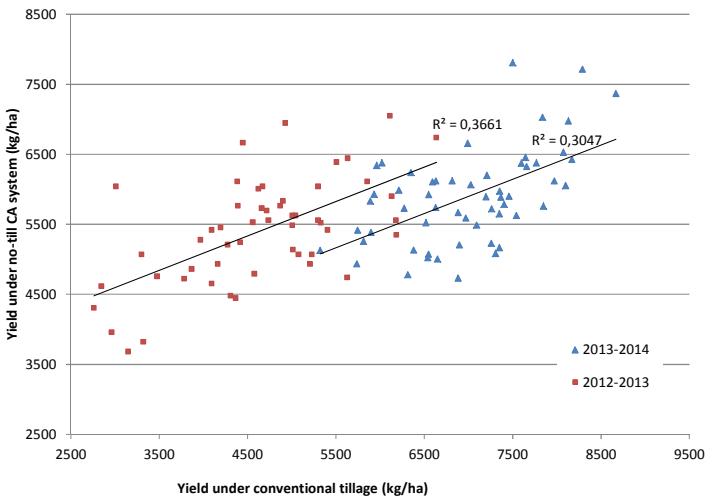

Figure 3: Relationship for upland rice grain yield under CA system (using a mulch of stylosanthes) and a conventional tillage system in preliminary variety trials in 2012-2013 and 2013-2014. The regression lines are indicated for each of the studied cropping seasons. Varieties are different between years.

Discussion

There was little cropping system × cultivar interactions observed in our variety trials which overall involved more than 100 distinct genotypes. In wheat and maize also, in most studies, little tillage x genotype interaction is observed (Herrera et al., 2013). Therefore, we conclude, at this stage and in the conditions of the Middle West of Madagascar, that the selection of upland rice varieties can be conducted under either CA or conventional systems without penalizing too much expected genetic gains whatever the cropping system. However, two short duration varieties seemed to have performed less under CA than the others. In this particular case, the observed interaction may have resulted from an interaction with the date of nitrogen application. Keeping the residues may lead to soil N immobilization during the early stages of their decomposition thus putting at a disadvantage short-duration varieties because of N deficiency.

Selection under CA systems will continue to be considered in our breeding program at least in the variety trials. Moreover, further investigations of cropping system x genotype interactions that take into account contrasted level of fertilizer input are also needed.

References

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