Management of *Striga asiatica* in the vulnerable uplands of Central Madagascar: combining zero-tillage rice–maize cover-crop rotations with resistant varieties

Jonne Rodenburg[1], Roger Michellon[2], Alain Paul Andrianaivo[3], Meva Tahiry Randrianjafizanaka[4], Naliharilala Miora Rakotoarivelo Njaramanana[2], Patrice Autfray[2]
[1]Africa Rice Center; [2]CIRAD; [3]FOFIFA; [4]Université de Tuléar
j.rodenburg@cgiar.org

Introduction

Striga asiatica (L.) Kuntze is one of the most important parasitic weeds in sub-Saharan Africa (Rodenburg, *et al.*, 2010). In the mid-west of the Vakinankaratra region in Madagascar, characterized by degradable soils, *Striga asiatica* is a frequently observed problem particularly at medium altitudes (800–1100 m a.s.l.) where maize is increasingly being rotated with rainfed upland rice. In both crops the parasitic weed causes serious yield losses in this area (e.g. Rakotoarisoa, 1999). While complete eradication is nearly impossible, through the consistent and long-term deployment of an integrated management strategy, *Striga* spp. can be controlled to acceptable low infestation levels (Schulz, *et al.*, 2003). Suitable component technologies of such an integrated approach include the use of resistant cultivars (e.g. Cissoko, *et al.*, 2011) and crop rotations or intercropping with non-host or trap crops (e.g. Riches, *et al.*, 2005). For the purpose of soil conservation, crop management practices that avoid soil tillage and that keep a vegetative soil cover throughout the year are preferred (Dusserre, *et al.*, 2012). A combination of *Striga* control and soil conservation technologies has been tested in a multi-factorial cropping systems experiment in central Madagascar to check the hypothesis that combining zero-tillage with intercropping of legumes and resistant rice varieties will reduce the *Striga* infestation rates in both rice and maize.

Material & Methods

The study was conducted in Ivory (1000 m above sea level, about 87 km north west of Antsirabe) on a lateritic red soil type (Ferralsol) with high silt-clay content, representative of the mid-west of the Vakinankaratra region, Madagascar. We tested four main treatments: (1) rice rotated with maize using conventional tillage and crop residue removal (farmer practice), (2) rice rotated with maize intercropped with cowpea (*Vigna unguiculata*) and mucuna (*Mucuna pruriens*; sown in January after the cowpea harvest) using zero-tillage and crop residue mulching, (3) rice rotated with maize intercropped with rice bean (*Vigna umbellata*) using zero-tillage and crop residue mulching and (4) rice intercropped with the perennial cover crop *Stylo* (*Stylosanthes guianensis*) and rotated with maize sown in *Stylo* cover crop (second year) followed by rice sown in the residues of slashed *Stylo* (third season) using zero-tillage. For rice a sub-treatment was included, consisting of three different rice varieties: (1) B22 (a locally popular but *Striga* susceptible variety), (2) NERICA-9 (a newly released variety) and (3) NERICA-4 (an already adopted variety with resistance against *Striga*).

The experiment was laid out following a split-plot design with systems on the plot level, and rice varieties on the sub-plot level, in six replicates. Prior to crop establishment in the first season, all systems were plowed. Plowing of the 'farmer practice' plots is done manually before and after each season. In the zero-tillage systems, the remaining biomass is slashed prior to each new season to prepare for sowing. The monocrop rice and maize is weeded using a hand hoe, the first two weeks after sowing and by hand (all weeds but *Striga*) in later crop stages to avoid disturbance of *Striga* growth. All zero-tillage treatments are hand weeded regularly (all weeds but *Striga*).

Aboveground numbers of *Striga* are counted (in rice and maize) in 40 m^2 central areas within each plot. Data (maximum aboveground *Striga* numbers) are subjected to ANOVA, using the statistical software Genstat (16^{th} Edition), followed by a comparison of means test (LSD) at the 95% confidence level. To meet the assumptions underlying ANOVA, logarithmic transformations were applied (Log [X + c], with X is the maximum *Striga* number of an individual sub-plot and c=1.0). The means presented in this paper represent back-transformed values.

Results

Striga infection levels vary strongly between years (Table 1). NERICA-4 consistently showed significant lower *Striga* infection levels than the most susceptible variety, B22, as well as the intermediate resistant variety, NERICA-9. In season 1, the maximum *Striga* number in the rice monocrop was not significantly different from that in rice intercropped with *Stylo*. In season 2, in rice grown in plots preceded by maize and *Stylo* the maximum *Striga* number was on average 4.5 times lower than in rice plots preceded by maize and rice bean, 8.25 times lower than in rice following maize intercropped by cowpea and mucuna and 10.5 times lower than in rice following maize monocrop. In season 3, *Striga* infection levels in the rice – rice bean intercrop and the rice – *Stylo* intercrop were significantly lower than in the rice monocrop (5.5 and 12.8 fold reductions respectively). In season 2, significant system by rice variety interactions were observed, with the highest *Striga* numbers following the farmer practice of rice monocropping preceded by maize monocropping using rice variety B22, and the lowest *Striga* numbers in the rice – *Stylo* intercrop and any other system using the resistant NERICA-4. In this season, no *Striga* was observed with the rice – *Stylo* intercrop plots using rice variety NERICA-4. Following the *Striga* reductions under resistant rice varieties NERICA-9 and NERICA-4 in season 1 and 2, a spectacular carry-over effect of this resistance was observed in season 2 and 3 in maize; irrespective of the cropping system, where maize followed rice variety B22 the maximum *Striga* density in season 2 was four times higher than in maize following *Striga* resistant NERICA-4 (Table 2). In the rice and maize monocrop rotation plots this carry-over effect of resistance was even more pronounced. In season 3, with lower overall infection levels in maize, this carry-over effect was less strong, albeit still significant. As with rice, the highest *Striga* numbers in maize were recorded in the farmer practice of monocropping maize rotated with monocropping rice using rice variety B22. No aboveground *Striga* was observed in the maize-*Stylo* intercrop in any season.

Conclusion

For subsistence farmers in central Madagascar, that have to deal with soils that are both highly infested by *Striga asiatica* and highly vulnerable to degradation, a crop rotation system of rice and maize with the legume *Stylosanthes guianensis* as intercrop, without tillage and crop residue removal, is likely to represent an attractive alternative to the current practice of rice – maize rotations following conventional tillage. Such rotation systems would benefit from the introduction of *Striga* resistant rice varieties as they further reduce parasite densities in both the rice and the following crop.

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References

Cissoko, M, Boisnard, A, Rodenburg, J, Press, MC and Scholes, JD, 2011. New Rice for Africa (NERICA) cultivars exhibit different levels of post-attachment resistance against the parasitic weeds Striga hermonthica and Striga asiatica. *New Phytologist* 192 (4): 952-963.

Dusserre, J, Chopart, JL, Douzet, JM, Rakotoarisoa, J and Scopel, E, 2012. Upland rice production under conservation agriculture cropping systems in cold conditions of tropical highlands. *Field Crops Research* 138: 33-41.

Rakotoarisoa, J, 1999. From organic matter management to rainfed cropping systems including cover crops in midwestern Madagascar, In: F. Rasolo and M. Raunet (Eds.), *Agrobiological Management of Soils and Cropping Systems*, pp. 265-270.

Riches, CR, Mbwaga, AM, Mbapila, J and Ahmed, GJU, 2005. Improved weed management delivers increased productivity and farm incomes from rice in Bangladesh and Tanzania. *Aspects of Applied Biology* 75: 127-138.

Rodenburg, J, Riches, CR and Kayeke, JM, 2010. Addressing current and future problems of parasitic weeds in rice. *Crop Protection* 29 (3): 210-221.

Schulz, S, Hussaini, MA, Kling, JG, Berner, DK and Ikie, FO, 2003. Evaluation of integrated Striga hermonthica control technologies under farmer management. *Experimental Agriculture* 39 (1): 99-108.

Table 1. Mean maximum above-ground *Striga* numbers (m^{-2}) in rice, following different cropping systems and rice varieties

Season	System		Rice variety							
			B22		NERICA-9		NERICA-4		Mean	
2011/2012[1]	S1: Rice//maize		1.02		0.22		0.01		0.17	
	S2: Rice//maize cowpea + mucuna		0.26		0.05		0.04		0.08	
	S3: Rice//maize rice bean		0.17		0.07		0.03		0.07	
	S4: Rice + *Stylo*//maize + *Stylo*		0.24		0.05		0.03		0.08	
		Mean	0.33	A[2]	0.08	B	0.02	C		
2012/2013[3]	S1: Rice//maize		3.07	a[4]	0.58	bc	0.02	ef	0.42	x[5]
	S2: Rice//maize cowpea + mucuna		0.94	ab	0.58	bc	0.05	def	0.33	x
	S3: Rice//maize rice bean		0.24	bcd	0.72	ab	0.02	ef	0.18	xy
	S4: Rice + *Stylo*//maize + *Stylo*		0.14	cde	0.04	def	0.00	f	0.04	y
		Mean	0.57	A	0.34	A	0.02	C		
2013/2014	S1: Rice//maize		29.25		9.36		0.79		6.05	x
	S2: Rice//maize cowpea + mucuna		19.05		4.45		0.11		2.26	xy
	S3: Rice//maize rice bean		10.98		1.34		0.07		1.09	yz
	S4: Rice + *Stylo*//maize + *Stylo*		1.89		0.35		0.15		0.47	z
		Mean	10.38	A	2.13	B	0.18	C		

[1] In the 2011/2012 season all systems, except that including *Stylo*, are rice-only; [2] Values in the same row followed by different letters (A-C) are significantly different (P<0.05); [3] Results on rice in season 2012-2013 are derived from plots that were preceded by maize or maize and cover crops in the 2011-2012 season; [4] Values followed by different letters (a-f) are significantly different (P<0.05); [5] Values in one column followed by different letters (x-z) are significantly different (P<0.05).

Table 2. Maximum above-ground *Striga* numbers (m^{-2}) in maize in season 2 and 3, following different cropping systems and with different rice varieties in the preceding season.

Season	System		Rice variety in preceding season							
			B22		NERICA-9		NERICA-4		Mean	
2012/2013	S1: Rice//maize		30.17	a[1]	9.52	ab	1.29	c	7.22	x[2]
	S2: Rice//maize cowpea + mucuna		0.79	cd	0.62	cd	1.02	cd	0.79	y
	S3: Rice//maize rice bean		1.82	bc	1.39	bc	0.15	de	0.75	y
	S4: Rice + *Stylo*//maize + *Stylo*		0	e	0	e	0	e	0	z
		Mean	1.01	A[3]	0.66	A	0.25	B		
2013/2014	S1: Rice//maize		1.47		0.41		0.48		0.66	x
	S2: Rice//maize cowpea + mucuna		1.93		0.65		0.43		0.82	x
	S3: Rice//maize rice bean		0.79		2.08		0.23		0.73	x
	S4: Rice + *Stylo*//maize + *Stylo*		0		0		0		0	y
		Mean	0.47	A	0.33	AB	0.17	B		

[1] Values followed by different letters (a-e) are significantly different (P<0.05); [2] Values in 'Mean' column followed by different letters (x-z) are significantly different (P<0.05).
[3] Values in the 'Mean' row followed by different letters (A-B) are significantly different (P<0.05).