Factorial Trials Evaluating the Separate and Combined Effects of SRI Practices

Robert Randriamiharisoa, University of Antananarivo, and Norman Uphoff, Cornell University

In 2000 and 2001, Jean de Dieu Rajaonarison and Andry Andriankaja, graduating students in the Faculty of Agriculture (ESSA) at the University of Antananarivo in Madagascar, conducted complex sets of trials evaluating six different factors that affect rice production. Their field research was supervised by the first author, at the time director of research for ESSA, with support from CIIFAD and a grant from the Rockefeller Foundation.

It was anticipated that carefully controlled trials might show that one or more of the SRI practices would not contribute much to higher yield so that the set of SRI practices could be simplified without much loss, making SRI easier to practice. In fact, however, the trials showed a high degree of ***synergy*** among practices. Although "young seedlings" were found to be the most important practice in both sets of trials, none could be discarded without some loss of yield. The trials also showed that the ***same pattern*** of increases in yield could be seen in two very different agroecosystems.

The first location was on the fields of the Centre de Baobab, an agricultural improvement center near Morondava on the west coast of Madagascar. The second was on farmers' fields in the village of Anjomakely, 18 km south of the capital Antananarivo, in the center of the country on its high plateau.

At Morondava, one of the factors evaluated was **rice variety**, comparing results from SRI vs. conventional practices using a high-yielding variety (2798) on half of the 288 trial plots and a common local variety, *riz rouge*, on the other half (see Table 1). All were planted on poor sandy soil near ***sea level*** in a ***tropical climate***. At Anjomakely, the effects of **soil quality** were evaluated, using *riz rouge* as the variety for all 240 trial plots. Half of the plots were better clay soil and the other half, poorer loam soil. The area is at ***1200 m elevation*** with a ***temperate climate*** (see Table 2).

The four SRI practices evaluated in both sets of trials were:

- Use of **young seedlings**, transplanted at 8 days of age, compared to 16 or 20 days (at Anjomakely with its higher elevation and colder temperatures, 20 days of seedling growth was equivalent to 16 days at Morondava with its higher more tropical climate).
- **Water management**, comparing practices that maintained soil moisture but avoided saturation (aerated soil, AS), with continuous flooding (saturated soil, SS).
- **Plant density**, with one seedling per hill vs. 3 seedlings per hill; and
- **Fertilization**, using compost, made from plant biomass, vs. NPK (16-11-22) in the recommended dosage vs. no fertilization as a control.

The variable of **spacing** was not really tested because both of the spacings used—25x25 cm vs. 30x30 cm—are within the SRI range, not conventional practice. There turned out to be no difference in average yields between the two sets of plots differentiated by spacing at Morondava (each N=144), and only 0.08 t/ha difference at Anjomakely (each N=120), with each set containing equal numbers of SRI and non-SRI practices with regard to seedling age, water management, density, etc. Since there was no real difference observed for this (narrow) range of spacings, the spacing trials were combined. Thus, instead of having three replications of each of 96 or 80 combinations in the experiment, all the averages reported below are based on ***at least six replications***. The factor of **weeding** was not evaluated as this would have required a doubling of trials, to 576 and 480, respectively, beyond the researchers' means.

All trial plots were 2.5x2.5m, laid out according to a modified Fisher bloc design. The main bloc at Morondava was divided by **water management** (AS vs. SS) because plots with these treatments could not be randomly irrigated (or not), given that water applied to an individual plot will permeate into adjoining plots. These main sub-blocks were divided into sub-blocs for **fertilization practice** to avoid any effects of sub-surface movement of nutrients. While this is not as serious a problem as sub-surface movement of water, it should be avoided as much as possible. Within these sub-sub-blocs, then, plots were randomized for different combinations of **plant age, plants per hill, spacing,** and **variety**.

For the Anjomakely trials, two nearby locations on farmers' fields were identified as having **better** or **poorer soil**. The first had more clay content, the latter was more loamy soil. These were close enough that there were no climatic differences. Within these two main blocs, there were sub-blocs for **water management** and within these, sub-sub-blocs for **fertilization**. Within these, randomized combinations of **plant age, plants per hill,** and **spacing** were established, all with the same variety (*riz rouge*).

More detailed information on soil characteristics and the design and trials themselves is available in the theses (*memoires de fin d'etudes*) written by Rajaonarison and Andriankaja, including tests of statistical significance. These theses, in French, are available in electronic form from CIIFAD. The summary presentation below is concerned with any **patterns of difference in yield** according to the different combinations of practices, SRI or non-SRI, and the different extents to which SRI practice were used (zero SRI, 25% SRI, 50% SRI, 75% SRI, or 100% SRI—see Tables 3, 4, 5 and 6).

For both sets of trials, data were gathered also on the number of tillers, number of panicles, panicle length, root length, and root density (the latter measured by a pull test of root system resistance to uprooting). The patterns for these measurements of yield components and plant characteristics mirrored those reported below for yield. Statistical analysis shown in Tables 2 and 3 shows the differences to be quite significant. The differences in Tables 5 and 6 are even larger, but significance tests have not been calculated for those yet.

With growing conditions controlled, using all SRI practices—young seedlings, one per hill, aerated soil, with compost added—gave yield increases of 140% to 245%, compared to plots where only non-SRI practices—more mature seedlings, three per hill, saturated soil, with NPK fertilizer applied—were used. In both sets of trials, the increments to average yield generally increased as a larger ***proportion*** of SRI practices was used, with the largest increase in both sets of trials coming when the combinations went from 75% SRI to 100% SRI. This added almost 2 t/ha to yield in these trials. (The factor of weeding might have added even more to yield, but this was not tested in these experiments.)

Absolute and relative yields will vary, possibly considerably, across different sets of factorial trials as differences in soil, climate and variety will affect the outcomes from any particular set of practices. However, that these two sets of trials, under very different soil and climatic conditions, showed such a **consistent pattern** of results, based on averages for 6 rather than just 3 test plots, suggests that the relationships reported here are reasonably robust.

This analysis should be seen, however, not so much as a set of conclusions as an invitation for others to undertake similar sets of factorial trials to assess the effects of SRI practices both separately, other things being equal, and collectively, in different combinations.

Table 1. Factorial trial results comparing high-yielding and traditional variety responses with SRI methods vs. non-SRI methods, Morondava, 2000

Yield figures below in tons/ha are all averages from 6 replicated trial plots. Conventional results are *italicized* and SRI results are **bold faced**. Two different varieties were used in these trials; the soil type for all was *sable roux* (rough sand).

	CONTINUOUS FLOODING				SRI WATER MANAGEMENT			
	16-day plants		8-day plants		16-day plants		8-day plants	
	3 per hill	1 per hill	3 per hill	1 per hill	3 per hill	1 per hill	3 per hill	1 per hill
MODERN VARIETY (2798)—RIZ BLANC								
No Fertilizer	1.68	1.90	2.28	2.31	1.69	1.92	2.61	3.47
NPK	*2.84*	2.79	4.08	4.50	4.04	4.10	5.75	6.62
Compost	2.69	2.73	3.35	3.85	4.18	3.82	4.42	**6.83**
TRADITIONAL VARIETY—RIZ ROUGE								
No Fertilizer	1.49	1.77	2.01	2.46	1.91	1.95	2.46	3.14
NPK	*2.11*	2.28	3.09	3.65	2.64	2.89	3.34	4.29
Compost	2.67	2.47	4.50	5.18	3.10	2.88	4.78	**5.96**

Table 2. Factorial trial results comparing yield responses on clay and loamy soils with SRI methods vs. non-SRI methods, Anjomakely, 2001

Yield figures below in tons/ha are all averages from 6 replicated trial plots Conventional results are *italicized* and SRI results are **bold faced**. A traditional variety (*riz rouge*) was used for all trials, with soil type as a variable.

	CONTINUOUS FLOODING				SRI WATER MANAGEMENT			
	20-day plants		8-day plants		20-day plants		8-day plants	
	3 per hill	1 per hill	3 per hill	1 per hill	3 per hill	1 per hill	3 per hill	1 per hill
CLAY (BETTER) SOIL								
No Fertilizer	2.26	2.78	3.09	3.75	4.82	5.42	5.65	6.25
NPK	*3.00*	5.04	5.08	6.07	7.16	8.13	8.15	8.77
Compost	3.71	4.50	6.72	7.45	6.86	7.70	9.32	**10.35**
LOAM (POORER) SOIL								
NPK	*2.04*	2.78	2.60	3.15	3.89	4.36	4.44	5.00
Compost	2.03	2.44	3.41	4.10	3.61	4.07	5.17	**6.39**

Table 3. Factorial trial results, yield in tons/ha, evaluating effects of using greater numbers of SRI methods, Morondava, 2000

N of trials in parentheses; SRI practices shown in **bold face**

	Variety		
	HYV	Traditional	Average
Conventional			
SS/16/3/NPK	2.84 (6)	2.11 (6)	2.48 (12)
1 SRI Practice			
SS/ 16 / 3 / **C**	2.69 (6)	2.67 (6)	
SS/16/**1**/NPK	2.74 (6)	2.28 (6)	
SS/ **8** /3/NPK	4.08 (6)	3.09 (6)	
AS/16/3/NPK	4.04 (6)	2.64 (6)	
	3.34 (24)	2.67 (24)	3.01 (48)
	[+0.50 t]	*[+0.56t]*	*[+ 0.53 t]*
	(p=.021)	(p=.007)	
2 SRI Practices			
SS/16/ **1** / **C**	2.73 (6)	2.47 (6)	
SS / **8** / 3 / **C**	3.35 (6)	4.33 (6)	
AS/16/**1**/NPK	4.10 (6)	2.89 (6)	
AS/16/ 3 / **C**	4.18 (6)	3.10 (6)	
SS/ **8** /**1**/NPK	5.00 (6)	3.65 (6)	
AS/ **8** /3/NPK	5.75 (6)	3.34 (6)	
	4.28 (36)	3.24 (36)	3.78 (72)
	[+0.94 t]	*[+0.62 t]*	*[+0.78 t]*
	(p=.000)	(p=.000)	
3 SRI Practices			
SS/ **8** / **1** / **C**	3.85 (6)	5.18 (6)	
AS/16/ **1** / **C**	3.82 (6)	2.87 (6)	
AS/ **8** / 3 / **C**	4.49 (6)	4.78 (6)	
AS/ **8** /**1**/NPK	6.62 (6)	4.29 (6)	
	4.69 (24)	4.28 (24)	4.48 (48)
	[+0.41 t]	*[+ 0.99 t]*	*[+0.70 t]*
	(p=.000)	(p=.000)	
All SRI Practices			
AS / 8 / 1 / C	6.83 (6)	5.96 (6)	6.40 (12)
	[+2.14 t]	*[+1.68 t]*	*[+1.92 t]*
	(p=.000)	(p=.000)	

Table 4. Factorial trial results, yield in tons/ha, evaluating effects of SRI methods used without any fertilization, Morondava, 2000

N of trials in parentheses; SRI practices shown in **bold face**

	Variety		
	HYV	Traditional	Average
Conventional			
SS / 16 / 3	1.51 (6)	1.49 (6)	1.50 (12)
1 SRI Practice			
SS / 16 / **1**	1.90 (6)	1.77 (6)	
SS / **8** / 3	2.36 (6)	2.01 (6)	
AS / 16 / 3	1.69 (6)	1.91 (6)	
	1.93 (18)	1.89 (18)	1.91 (36)
	[+0.42 t]	*[+0.40 t]*	*[+ 0.41 t]*
	(p=.0036)	(p=.007)	
2 SRI Practices			
SS / **8** / **1**	2.31 (6)	2.46 (6)	
AS /16/ **1**	1.92 (6)	1.95 (6)	
AS / **8** / 3	2.61 (6)	2.46 (6)	
	2.28 (18)	2.28 (18)	2.28 (36)
	[+0.35 t]	*[+ 0.39 t]*	*[+0.37 t]*
	(p=.0003)	(p=.0003)	
All SRI Practices			
AS / 8 / 1	3.47 (6)	3.14 (6)	3.30 (12)
	[+1.19 t]	*[+0.86 t]*	*[+1.02 t]*
	(p=.000)	(p=.000)	

SS = saturated soil
AS = aerated soil (SRI)
16 = 16-day seedlings
8 = 8-day seedlings (SRI)
3 = 3-day seedlings
1 = 1 seedling per hill (SRI)
NPK = chemical fertiizer
C = compost (SRI)

Table 5. Analysis of factorial trial results, with soil differences, Anjomakely, 2001

N of trials in parentheses; SRI practices shown in **bold face**

	Clay	Loam	Average
Conventional			
SS/20/3/NPK	*3.00* (6)	*2.04* (6)	*2.52* (12)
1 SRI Practice			
SS/ 20 / 3 / **C**	3.71 (6)	2.03 (6)	
SS/20/**1**/NPK	5.04 (6)	2.78 (6)	
SS/ **8** /3/NPK	7.16 (6)	3.89 (6)	
AS/20/3/NPK	5.08 (6)	2.60 (6)	
	5.25 (24)	**2.83** (24)	**4.04** (48)
	[+2.25 t]	[+0.79t]	[+1.52 t]
2 SRI Practices			
SS/20/ **1** / **C**	4.50 (6)	2.44 (6)	
SS / **8** / 3 / **C**	6.86 (6)	3.61 (6)	
AS/20/**1**/NPK	6.07 (6)	3.15 (6)	
AS/20/ 3 / **C**	6.72 (6)	3.41 (6)	
SS/ **8** /**1**/NPK	8.13 (6)	4.36 (6)	
AS/ **8** /3/NPK	8.15 (6)	4.44 (6)	
	6.74 (36)	**3.57** (36)	**5.16** (72)
	[+1.49 t]	[+0.74 t]	[+1.12 t]
3 SRI Practices			
SS/ **8** / **1** / **C**	7.70 (6)	4.07 (6)	
AS/20/ **1** / **C**	7.45 (6)	4.10 (6)	
AS/ **8** / 3 / **C**	9.32 (6)	5.17 (6)	
AS/ **8** /**1**/NPK	8.77 (6)	5.00 (6)	
	8.31 (24)	**4.59** (24)	**6.45** (48)
	[+1.57 t]	[+1.02 t]	[+1.29 t]
All SRI Practices			
AS / 8 / 1 / C	**10.35** (6)	**6.39** (6)	**8.37** (12)
	[+2.04 t]	[+1.80 t]	[+1.92 t]

Table 6. Analysis of factorial trial results on clay soils with no fertilizer or compost applied, Anjomakely, 2001

N of trials in parentheses; SRI practices shown in **bold face**

	Clay (Better) Soil	
Conventional		
SS / 20 / 3	*2.26* (6)	
1 SRI Practice		
SS / 20 / **1**	2.78 (6)	
SS / **8** / 3	4.82 (6)	
AS / 20 / 3	3.09 (6)	
	3.56 (18)	[+ 1.30 t]
2 SRI Practices		
SS / **8** / **1**	5.42 (6)	
AS /20/ **1**	3.75 (6)	
AS / **8** / 3	5.65 (6)	
	4.94 (18)	[+1.38 t]
All SRI Practices		
AS / 8 / 1	**6.25** (6)	[+1.31 t]

Trials without any fertilizer or compost were not conducted on the poorer loam soils at Anjomakely as this did not appear to the researcher worth the effort to manage an additional 48 plots on top of the 240 plots laid out in the design.

The effect of "young seedlings" was very pronounced on this better clay soil when neither fertilizer nor compost was added.

SS = saturated soil
AS = aerated soil (SRI)
20 = 20-day seedlings
8 = 8-day seedlings (SRI)
3 = 3-day seedlings
1 = 1 seedling per hill (SRI)
NPK = chemical fertiizer
C = compost (SRI)

Table 7. Comparisons of factor effects, Morondava

The yield differences reported here are with all other factors being equal; averages were calculated with an equal number of SRI and non-SRI practices for each of the other factors [N = 144 for each average reported, except for fertilization, for which each N = 96].

Young seedling effect		*+1.40 t/ha*		
8 days old	3.96 t/ha	vs.	16 days old	2.56 t/ha
Water management effect		*+0.85 t/ha*		
Water control	3.71 t/ha	vs	. Flooding	2.86 t/ha
Fertilization effect (average for clay/loam soils)		*+.027 t/ha*		
Compost	3.96 t/ha	vs	NPK fertilizer	3.69 t/ha
Plants per hill effect		*+ 0.46 t/ha*		
1 plant/hill	3.51 t/ha	vs.	3 plants/hill	3.05 t/ha
Spacing effect (note: both distances are within SRI range)		*+0.00t/ha*		
30 x 30 cm	3.28 t/ha	vs.	25 x 25 cm	3.28 t/ha

Table 8. Comparisons of factor effects, Anjomakely

The yield differences reported here are with all other factors being equal; averages were calculated with an equal number of SRI and non-SRI practices for each of the other factors [N = 120 for each average reported, except for fertilization, for which each N = 96].

Young seedling effect		*+2.48 t/ha*		
8 days old	6.28 t/ha	vs.	20 days old	3.80 t/ha
Water management effect		*+1.41 t/ha*		
Water control	5.75 t/ha	vs	Flooding	4.34 t/ha
Fertilization effect (average for clay/loam soils)		*+1.01 t/ha* [1, 2]		
Compost	5.49 t/ha	vs	NPK fertilizer	4.48 t/ha
Plants per hill effect		*+ 0.78 t/ha*		
1 plant/hill	5.43 t/ha	vs.	3 plants/hill	4.65 t/ha
Spacing effect (note: both distances are within SRI range)		*+0.08 t/ha*		
30 x 30 cm	5.08 t/ha	vs.	25 x 25 cm	5.00 t/ha
Soil effect (averaged for equal number of trials with compost and NPK fertilization)[2]				
Clay (better) soil	6.75 t/ha	vs.	Loam (poorer) soil	3.72 t/ha

[1]*These results are for a traditional variety, which is expected to be less responsive to the application of NPK and conversely, relatively more responsive to compost.*

[2]*Average yield on clay (better) soil without either compost or NPK amendments was 4.25 t/ha*

Table 9. Summary comparisons of factorial trials, Morondava, 2000, and Anjomakely, 2001

	Standard Practices (t/ha)	SRI Practices (t/ha)	Increase (%)
	16- or 20-day seedlings 3 plants per hill Standing water Fertilizer (NPK)	8-day seedlings 1 plant per hill Water control Compost	
Morondava#			
HYV (2798) (N=144)	2.84	6.83	140%
Traditional (riz rouge) (N=144)	2.11	5.96	182%
Anjomakely*			
Good (clay) soils (N=120)	3.00	10.35	245%
Poor (loam) soils (N=120)	2.04	6.39	213%
Seedling Age	16/20 days	8 days	
Morandava	2.61	3.96	+1.35 t/ha#
Anjomakely	3.80	6.28	+2.48 t/ha
Water Management	Flooding	Water control	
Morandava	2.86	3.71	+0.85 t/ha#
Anjomakely	4.34	5.75	+1.41 t/ha
Plants per Hill	3 seedlings	1 seedling	
Morandava	3.05	3.51	+0.46 t/ha#
Anjomakely	4.65	5.43	+0.78 t/ha
Fertilization	NPK	Compost	
Morandava	3.69	3.96	+0.27 t/ha#
Anjomakely	4.48	5.49	+1.01 t/ha*

**All Anjomakely trials were done with traditional variety (*riz rouge*) whereas Morandava trials were half with traditional variety, half with improved, high-yielding variety (2798).*

#*All Morondava trials were carried out on poorer sandy soils (*sable roux*) than on the soils available at Anjomakely.*