Introducing the System of Rice Intensification (SRI) to irrigated systems in Gao, Mopti, Timbuktu and to rainfed systems in Sikasso

2009/2010


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Consultancy Report
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List of Acronyms and Abbreviations

DAP	Di-Ammonium Phosphate (Inorganic Phosphorus Fertilizer)
DRA	*Direction Régionale d'Agriculture*, Government Regional Agriculture Service
IER	*Institut d'Economie Rurale du Mali*, National Agriculture Research Institution
n	Sample size
NGO	Non governmental organization
PIV	*Périmètre Irrigué Villagoise*, irrigated village perimeters
SAC	*Secteur de l'Agriculture du Cercle,* Government Agricultural Service of the Circle
SE	Standard error

Executive Summary

USAID's Integrated Initiatives for Economic Growth in Mali project (known as IICEM) works to stimulate economic growth by increasing agricultural productivity, improving linkages to markets, and facilitating rural finance. Among five selected value chains, IICEM works with rice in the northern regions of Mopti, Timbuktu and Gao in irrigated systems, and in the southern region of Sikasso in rainfed systems. Increased rice production has been put on top of the agenda for agricultural development by the Malian Government since 2008, given the steadily increase in rice consumption and the still high potential for Mali to increase its rice production given its extensive land and water resources.

Following up on the promising results obtained with the System of Rice Intensification, or SRI by Africare in the 2007/2008 and 2008/2009 cropping season in the Timbuktu region (Africare Mali, 2008; Styger, 2009), IICEM introduced SRI concept and practices to interested farmers into the regions of Gao and Mopti, to certain locations not already covered by Africare in Timbuktu, and tested adaptations of SRI principles to the rainfed rice cropping systems in the Sikasso region.

SRI is a methodology, developed in the 1980s in Madagascar, to increase the productivity of irrigated rice cultivation by changing the management of plants, soil, water and nutrients while reducing external inputs. It is based on six principles: i) transplanting young seedlings, ii) transplanting single seedlings, while iii) maintaining a wider spacing between the plants, iv) application of organic matter for fertilization (in preference to chemical fertilizer), v) frequent weeding with a simple mechanical weeder and vi) a reduction in application of irrigation water, keeping soils moist but not flooded.

Objectives for the 2009/2010 season were to i) introduce SRI into new zones where farmers were previously unfamiliar with SRI in the three northern regions of Mali, ii) evaluate rice crop performance under SRI practices in different agro-ecological conditions and compare it to the farmers' usual practices, and iii) test adapted SRI practices in the rainfed rice cropping systems in the southern region of Sikasso.

IICEM entered into agreements with the national agriculture research institution (IER) for the design, oversight and analysis of this SRI evaluation, and with the Regional Agriculture Service (DRA) and local NGOs, which implemented field activities as a team. 25 field technicians worked with 118 farmers in 21 villages across the four regions. Farmers participated as volunteers carrying out the technical recommendations for SRI on a test plot, which they compared side by side to a control plot.

For the irrigated systems, SRI yield performance was superior to the control plots and the yield average of the irrigation perimeters (PIV) by 40% to 68% in all three regions. A one-month delay in the onset of the rainy season across Mali had a negative impact on rice productivity, as rice yields decline rapidly when planting is delayed. Planting in the region of Gao was able to begin earliest (in June), followed by Mopti (July/August) and

Timbuktu (July-September). Average SRI yields for all farmers were 7.0 t/ha in Timbuktu and 7.84t/ha and 7.85t/ha in Gao and Mopti, respectively. Average yields on the PIVs were at the same time 4.19t/ha in Timbuktu, 4.78t/ha in Mopti, and 5.59t/ha in Gao. All yield parameters were superior for the SRI plots compared to the control plots.

Best yielding varieties were the longer cycle BG90-2, Kogoni, and Nerica L2, each producing between 8 and10t/ha of rice grain in all three regions. Farmers began to adopt certain SRI practices for their control plots, primarily application of organic matter, planting of younger seedlings, and planting a reduced number of seedlings per hill. Under SRI, farmers applied additional chemical fertilizer to the SRI plots only to correct observed nutrient deficiencies. Thus, farmers reduced fertilizer application by 50% in Gao, 63% in Mopti and 72% in Timbuktu. As regards to the control plots, it seemed that farmers there tried to compensate for the delay in planting by increased application of fertilizer in order to still obtain an acceptable yield.

Based on the evidence of SRI performance in irrigated systems across the many agro-ecological zones, it can be concluded that SRI practices present an economic and environmentally friendly alternative to current rice cultivation practices in northern Mali. This is confirmed by farmers' enthusiasm in all three regions regarding field performance of the rice crop when cultivated under SRI and about the associated economic and food security benefits for the farmers themselves.

In Sikasso, four rice-producing systems can be distinguished. An upland system-- purely rainfed, mostly planted with the Nercia 4 variety- and three lowland systems, located in large natural landscape depressions occupying different zones along the relief. The latter three are: lowland system – high zone (usually not flooded), lowland system – medium zone (flooded between 25-50cm), and lowland system low zone (flooded > 50 cm). SRI principles were adapted to these systems. The tests were run on two research stations and in three villages. Rice was direct seeded in hills at 2-3 grains/hill, and later thinned to 1 plant/hill. The distance between hills was 25cmx25cm, planted in lines. Organic matter was applied and the cono-weeder used if the soil conditions permitted. Water could not be controlled in these non-irrigated plots.

Adapted SRI plots showed consistently improved performance along the landscape gradient from the upland (lowest response) through the lowland high zone, lowland medium zone, to lowland low zone (highest response). This gradient response could not be detected in the control. SRI plots in the lowland low zone obtained yields of over 5 t/ha, in the uplands it was 3t/ha. The best-performing variety (unfortunately not identified) produced 6.6 t/ha with SRI, which is more than double the 3t/ha often cited as a high yield in the Sikasso region. Nerica 4 yields were 3.1 t/ha, for both SRI and the control. Because Nerica 4 is a low tillering variety, reduced SRI spacing from 25cm x25cm to 20cm x 20 should result in a yield increase.

Given these unexpected findings, the next step should be to test SRI techniques using a wide range of varieties in each of the four systems. This testing should include close collaboration with local farmers, including tests of their currently used local varieties. Because of constraints on their available time at the beginning of the season, women in the Sikasso region still sow by seed broadcasting, which results in low yields.

If adapted SRI practices are to be widely adopted in Sikasso, it will be essential to develop and make available a seeding machine that can seed rice in hills. Based on organic matter fertilization alone, SRI rice plants maintained deeply green-colored leaves until harvest time. Given the shortage of organic matter in the farming system, a range of techniques should be developed to produce organic matter specifically for the rice systems.

At that national level, extension efforts for SRI should be strengthened with effective technical oversight. Quality training for technicians and technical supervisors will be essential to establish a well-grounded common knowledge of SRI practices. Research organizations should take leadership in further developing innovations associated with SRI practices. A SRI exchange platform could be created for Mali, which would allow all interested stakeholders to have easy access to information and to share experiences.

Introduction

USAID's Integrated Initiatives for Economic Growth in Mali project (known as IICEM, or "*Initiatives Intégrées pour la Croissance Économique au Mali*" executed by Abt Associates, Inc.) works to stimulate economic growth by increasing agricultural productivity, improving linkages to markets, and facilitating rural finance. IICEM uses a value chain development approach to enable the various stakeholders, such as producers, processors, buyers and exporters, to satisfy market demands and thus accelerate economic growth. The five selected value chains are rice, potato, mango, shallot and tomato. For rice, IICEM works in the northern regions of Mopti, Timbuktu and Gao in irrigated production systems, and in the southern region of Sikasso in rainfed systems.

Mali is one of the four highest rice-producing countries in West Africa along with Nigeria, Guinea and Ivory Coast (Africa Rice Center, 2008). Mali has a high potential for increases in rice production given its extensive water and land resources. Given the steady increase in rice consumption in Mali and surrounding countries, increased rice production is essential to guarantee food security in Mali and the sub-region. As a response to the sharp increase in the price of basic foodstuffs that occurred in 2008, the Government of Mali launched the "Rice Initiative," putting increased rice production on top of the agenda for agricultural development.

For the 2008/2009 season, Mali's rice production reached 1.6 million tons, which covered about 85% of Mali's needs. Irrigated systems accounted for half of the rice production with over 800,000 tons, with a paddy yield average of 6t/ha. Rainfed systems in the south produced about 32,350 tons (or 2% of total rice productions), mostly based on the Nerica 4 variety cultivation. Average yield was 2.9t/ha. Rice production in the lowlands or landscape depressions reached 273,560 tons (or 17% of total production), with an average yield of 1.9t/ha. The rest of the rice production came from naturally flooded rice production systems (Ministère de l'Agriculture, 2009; DAI, 2009).

Based on the promising results obtained with the System of Rice Intensification, or SRI, by Africare in the 2007/2008 and 2008/2009 cropping season in the Timbuktu region (Africare Mali, 2008; Styger, 2009), IICEM decided to introduce SRI to interested farmers into the regions of Gao and Mopti, to certain locations not already covered by Africare in Timbuktu, and to test adaptations of SRI principles to the rainfed rice cropping systems in the Sikasso region.

SRI is a methodology, developed in the 1980s in Madagascar, to increase the productivity of irrigated rice cultivation by changing the management of plants, soil, water and nutrients while reducing external inputs. It is based on six principles: i) transplanting young seedlings, ii) transplanting single seedlings, while iii) maintaining a wider spacing between the plants, iv) application of organic matter for fertilization (in preference to chemical fertilizer), v) frequent weeding with a simple mechanical weeder and vi) a reduction in application of irrigation water, keeping soils moist but not flooded.

The objectives for the 2009/2010 season were to i) introduce SRI into new zones previously unfamiliar with SRI in the three northern regions of Mali, ii) evaluate rice crop performance under SRI practices in different agro-ecological conditions and compare it to the farmers' usual practices, and iii) test adapted SRI practices in the rainfed rice cropping systems in the southern region of Sikasso.

Methodology

Site description: *Irrigated systems*: The three Northern regions of Gao, Timbuktu and Mopti have a Sahelian and Sahelo-Saharian climate. Annual rainfall ranges from 150mm to 600mm, with Mopti receiving most (400-600mm). The Timbuktu region is the second region after Segou in irrigated rice production with over 20,000 hectares in 2009/2010 (DRA Tombouctou, 2010a), followed by Mopti with about 6,500 hectares and finally Gao, with less then 500 hectares (Ministère de l'Agriculture (2009). Irrigated rice is planted in village irrigation schemes or PIVs (*Périmètre Irrigués Villageois*), with an average size of between 10 and 40 hectares. A few larger-scale irrigation schemes exist in the Timbuktu region: Kabara, Koriome and Daye in the Timbuktu circle, Goubo in the Niafunke circle and Saoune and Ngorfouhondou in the Dire circle, each extending over a few hundred hectares.

In the PIVs, surface area per farmer is small with about 0.3 hectares whereas in larger schemes it is about 0.5 hectares (DRA Tombouctou, 2009). Most farmers use chemical fertilizers but at rates below the recommended doses. Farmers plant improved seeds but do not have easy access to certified seeds. One diesel motor pump irrigates one PIV, allowing full water control at the plot level. Average yield is between 4.5 and 5.5 t/ha.

Rainfed systems: The Sikasso region is part of the Sudano-Guinean and Guinean climate zone with annual rainfall of 750-1400 mm and a rainy season extending over a period of 6-7 months, from May to October. Agriculture is characterized by both upland and lowland cropping systems. Most important crops in the uplands are cotton, corn and millet. Upland rice has become more widespread over the past few years, as the Nerica 4 variety became available and as cotton planting has declined due to lower prices. The lowlands are characterized by large landscape depressions, sometimes several hundred hectares in size. They are cultivated with rice during the rainy season by women, and with vegetables during the off-season by men.

Site identification: Potential SRI villages were identified based on a history of good collaboration with IICEM during the previous year, villagers' openness to innovations, and accessibility of the village during the rainy season. Each identified village received a preliminary visit, during which IICEM staff explained the principles of SRI, shared results previously obtained in Timbuktu, and assessed villagers' interest in participating in an evaluation of SRI practices, using five volunteer farmers per village. All of the 22 villages - except one - quickly agreed to participate in this evaluation. The name of the villages, number of farmers and number of field technicians are presented in Table 1.

Table 1: Villages, number of farmers and field agents participating in the SRI evaluation in the Gao, Timbuktu, Mopti and Sikasso region

		Farmers	NGO field agents	DRA field agents
Region	**Villages**	Number	Number	Number
Gao				
	Bourem	10	1	1
	Tondibi	10	1	1
	Djeflani	5		1
	Tonditiho	5	1	
	Tobon	5		1
Timbuktu				
	Kabara	5	1	
	Koriome	5	1	
	Day	5		1
	Beregoungou	5	1	
	Bourem Inaly	5		1
	Sibo	5	1	
	Sibonet	5	1	
	Goubou	5		1
Mopti				
	Touara	6	1	
	Kouin	5		1
	Kamaka	5	1	
	Kouana	5		1
	Korientze	12	1	1
Sikasso				
	Mpengneso	2	(IER supervision)	
	Lountana	4	1	1
	Finkolo-Ganad.	4	1	1
Total		**118**	**13**	**12**

Meeting 22 villages in four regions, where SRI was explained to village communities and interest assessed if farmers like to participate in evaluating SRI performance. All but one village decided to participate

Kamaka, Mopti — Bourem, Gao — Lountana, Sikasso

<u>Farmer selection:</u> Each village selected five volunteer farmers. IICEM provided technical support through collaboration agreements with DRA, local NGOs, and IER. IICEM also supplied one cono-weeder (a tool not previously known) to each farmer. Farmers provided land, seeds, other inputs, and labor.

<u>Plot selection:</u> Farmers were advised to choose easily accessible plots that could be independently irrigated and centrally located, so that they can have a good demonstration effect. This was often obtained with plots close to the principal irrigation canal.

Treatments and plot size: An SRI plot and a control plot, which should represent farmers' usual practices, were installed side by side. The recommended plot size was 100 m^2, 200 m^2, or 250 m^2. The final decision about plot size remained with the farmer.

Seeds: Farmers were free to choose varieties. The same seed was used for both the control and the SRI plot. Nurseries for both the SRI and control plots were to be started on the same day.

Technical SRI recommendations: Farmers were asked to apply 10-15t/ha of organic matter. Technicians measured the weight of dried organic matter filled in bags in order to know the amount applied to each plot. It was recommended to complement the base fertilization of organic matter with additional fertilization only when deficiencies were observed, using either organic or inorganic fertilizers as the farmer preferred. Organic matter was tilled under, and plots were leveled under dry soil conditions (with hoes), and again once water was introduced to the plot and the soil was wet (using a wooden board).

In the village of Kouin in Mopti all fields are plowed by oxen

Field leveling starts with hoes under dry soil conditions

After water is introduced into the plot, this 300 m^2 SRI plot gets leveled with a wooden board

A SRI nursery was established according to guidelines from the technical manual by Africare Mali and SAC Goundam (2009). Young seedlings at the 2-leaf stage were transplanted at 1 plant/hill, with a distance of 25cm x 25cm between the plant, planted in lines. Irrigation was to be done according to alternate wetting and drying principles during the vegetative period. The mechanical cono-weeder was recommended to be used the first time 20 days after transplanting, with subsequent use of every 7-10 days, ideally after each irrigation event, up to four times or until the crop rows were closing in.

SRI nurseries in the foreground, traditional nurseries in the back ground in the village of Kouin, Mopti

Transplanting seedlings at the 2-leaf stage in the village a Kouin, Mopti

<u>Implementation arrangement</u>: IICEM collaborated with local NGOs and the Government Regional Agriculture Service (DRA) for the field implementation of the SRI evaluation. The names of the participating NGOs were CONFIGES in Gao, PEENAL in Mopti, RCGOP in Timbuktu and GREFA in Sikasso. NGO and DRA field technicians worked together as a team, with each technician being responsible for one or more villages. Field technicians collected data according to a technical protocol established by IICEM and IER.

In each of the regions, DRA appointed a SRI supervisor, who was able to oversee the field implementation. IER researchers from each of the regions established test methodology, supervised field implementation, and analyzed the data at the end of the season. An overview of the number of field agents involved is presented in Table 1. A theoretical and practical five-day training was organized by IICEM in Timbuktu in May 2009, at the beginning of the cropping season, for participating NGO, DRA, and IER staff.

Five-day SRI training for 50 technicians associated with this project from 4 regions in Timbuktu, May 2009

Visit to SRI fields and discussions with SRI farmers

Technicians implemented all technical steps for themselves: here at plot leveling

Group photo of all participants

Data collection and analysis: For all participating SRI farmers, data was collected on establishment and management of both the SRI and control plots. Measurement of yields was carried out at harvest in all SRI and control plots as follows: In each plot, five 1m^2 squares, or sub-plots, were placed at random in the plot. Grain was harvested separately for each of the five sub-plots, threshed on location and weighed with a precision PESOLA™ scale. At the same time, the moisture content of the harvested grain was measured using a FARMEX MT-PRO™ moisture meter. The number of hills per square meter was counted to determine planting density. Ten plants were selected at random from each plot in order to count the number of tillers and panicles, and to measure both the height of the plants and the length of the roots. In addition, five panicles were selected at random from each plot to measure panicle length, and to count the number of both filled and empty grains per panicle. Data were analyzed by DRA supervisors and IER researchers and presented in a number of season reports (Traore, 2009; CRRA-Gao, 2010; CRRA-Sikasso, 2010; DRA Tombouctou, 2010b; Odiaba et al, 2010).

Timeline: This project began in March 2009 and ended in April 2010. Cropping season extended from June to January across the different regions.

Dissemination of results: In each of the regions, one or more field days were organized, inviting farmers of the area, technical partners and local authorities. IICEM organized a national workshop in Bamako on February 16-17, 2010. SRI season results were presented from all the IICEM sites by: 1) involved IER scientists, 2) Africare Mali working in Timbuktu with funding from USAID and the Better U Foundation, and 3) IER in Niono and Mopti who worked on SRI with funding from the Syngenta Foundation. IICEM produced a SRI video, SRI leaflets, and posters explaining the irrigated and the rainfed SRI systems.

Results

1. Introducing SRI practices to irrigated rice systems in Gao, Mopti and Timbuktu

1.1. Rice grain yields in Gao, Mopti and Timbuktu

The rice grain yield from the three regions is shown in Table 2. SRI yield performance in the three regions was superior to farmers' control plots and the surrounding fields in the same PIVs. In Gao and Mopti average yields for all farmers were almost the same, at 7.84 t/ha and 7.85 t/ha. In Timbuktu, average yield was a bit lower at 7.0t/ha. This was mostly due to the delay in the onset of the rainy season that impacted this region more seriously than the others (see also section 3.6. below).

Table 2: Rice grain yields (t/ha) for SRI and control plots and PIV

Regions	SRI t/ha	SE (n)	Control t/ha	SE (n)	PIV* t/ha	SE (n)	Increase of SRI (%) over control	Increase of SRI (%) over control
Gao	**7.84**	0.27 (38)	**5.72**	0.31 (35)	**5.59**	0.42 (8)	37	40
Mopti	**7.85**	0.27 (28)	**7.15**	0.33 (28)	**4.78**	0.36 (5)	10	64
Timbuktu	**7.00**	0.44 (36)	**5.90**	0.42 (39)	**4.19**	0.43 (7)	19	68
All regions	**7.56**		**6.26**		**4.85**		21	56

* PIV: Average yields in PIVs of SRI test; Results provided by DRA Gao, Mopti and Timbuktu

The control plot yields were 5.72 t/ha in Gao, 7.15 t/ha in Mopti, and 5.9 t/ha in Timbuktu. Control plots should represent farmers' usual practice, but many of the control plots received improved crop management compared to the surrounding fields, and farmers even started to copy some of the SRI practices (see sections 3.4, 3.5 and 3.6). In each region, the DRA evaluates the yields in the PIVs they are working with by randomly selecting and harvesting 10% of the farmers plots (see also Tables 2, 5, 7 and 9 for PIV averages). Thus, for an evaluation of SRI in comparison to farmers' practices, the PIV averages are more representative than those of the control plots. They are added in the yield tables.

Yield increases of SRI plots compared to farmers' practices are 40 % more for Gao, 64% more for Mopti and 68% more for Timbuktu. These results are very similar to Africare findings from the last 3 seasons. These results show that increases in yields using SRI techniques are significant throughout within the various ecological environments northern Mali.

1.2. Yield parameters

In all three regions, yield parameters performed better in the SRI plots compared to the control plots (Table 3). Unfortunately, we do not have the yield parameters from DRA's PIV evaluations. It can be expected that the differences between PIV yield parameters and SRI plots will be higher than between control and SRI plots. In the SRI plots, the hills had more tillers and panicles than in the control. The percentage of fertile tillers was slightly higher in SRI plots in Gao and Timbuktu and the same in Mopti. Also plant height and root depthh were remarkably longer under SRI than in the control plots. The number of tillers and panicles per square meter was higher under SRI in Gao, but lower in Mopti and Timbuktu, due to higher planting densities in the control plots in the latter two regions compared to Gao. Panicle lengths were between 1.1 and 1.6 cm longer under SRI, and SRI plants had between 25 and 31 more grains /panicle compared to the control plots. Also, SRI plants had a lower percentage of empty grains (between 17 and 24%) compared to the control (between 23 and 28%). This last finding indicates an overall better seed quality for SRI plants.

Table 3: Rice yield parameters of SRI and control plots in the three regions of Gao, Mopti and Timbuktu, 2009/2010

	Yield t/ha	SE	Tillers/hill Number	SE	Panicles/hill Number	SE	Fertile tillers %	Plant height cm	SE	Root length cm	SE
Gao											
SRI	**7.84**	0.27 (38)	**32.6**	1.52	**25.6**	0.78	**79**	**99.9**	1.65	**24.0**	0.67
Control	**5.72**	0.31 (35)	**20.0**	1.21	**15.4**	0.55	**77**	**93.9**	2.64	**19.1**	0.61
Mopti											
SRI	**7.85**	0.27 (28)	**25.3**	1.03	**21.4**	0.69	**85**	**102.4**	1.60	**23.8**	0.80
Control	**7.15**	0.33 (28)	**17.2**	0.91	**14.7**	0.76	**85**	**98.5**	1.61	**20.2**	0.66
Timbuktu											
SRI	**7.00**	0.44 (36)	**26.9**	0.93	**25.0**	0.76	**93**	**91.6**	2.65	**26.3**	0.98
Control	**5.9**	0.42 (39)	**21.3**	2.36	**18.4**	1.55	**86**	**83.3**	2.48	**22.3**	0.81

	Plants/m2 Number	SE	Tillers/m2 Number	Panicles/m2 Number	Panicle length cm	SE	Grains/panicle Number	SE	Empty grains* %
Gao									
SRI	**15.874**	0.03	**517**	**407**	**25.0**	0.39	**120.6**	3.65	**24**
Control	**23.251**	0.98	**465**	**357**	**23.6**	0.41	**95.5**	3.44	**27**
Mopti									
SRI	**15.846**	0.05	**400**	**339**	**25.4**	0.44	**129.2**	3.98	**17**
Control	**30.383**	1.51	**524**	**446**	**24.3**	0.45	**99.2**	3.49	**23**
Timbuktu									
SRI	**15.357**	0.21	**414**	**384**	**22.7**	0.38	**117.2**	6.14	**24**
Control	**31.092**	1.20	**664**	**572**	**21.1**	0.44	**86.4**	3.56	**28**

* Empty grains: not properly filled grains, float on water, whereas filled grains sink

1.3. Rice grain yield by variety

Yield results from all the varieties and regions are shown in Table 4 and Figure 1. Varietal performance across the three regions shows that under SRI, BG90-2, Kogoni, and Nercia L2 produced between 8-10 t/ha. Less consistent were the results for Nionoka, Wassa and Adny 11. This may be partly due to different climatic and environmental conditions that influenced the cropping season.

Table 4: Rice grain yields (t/ha) for tested varieties in Gao, Mopti and Timbuktu

		SRI t/ha	SE (n)	Control t/ha	SE (n)	Increase of SRI over control %
Gao						
	BG90-2	**10.00**	0.624 (4)	**8.14**	0.378 (4)	23
	Kogoni 91-1	**9.05**	0.213 (6)	**6.28**	0.302 (6)	44
	Nerica L2	**8.08**	0.468 (5)	**6.81**	0.77 (5)	19
	Nionoka	**7.30**	0.362 (17)	**4.89**	0.445 (16)	49
	Adny 11	**6.54**	0.655 (6)	**4.43**	0.439 (4)	48
Mopti						
	Nerica L2	**8.63**	0.37 (9)	**7.97**	0.52 (9)	8
	BG90-2	**8.38**	0.21 (7)	**6.93**	0.75 (7)	21
	Kogoni 91.1	**7.64**	0.62 (6)	**7.32**	0.42 (6)	4
	Wassa	**6.71**	0.51 (3)	**5.98**	1.70 (3)	12
Timbuktu						
	Kogoni	**10.15**	0.34 (2)	**9.78**	0.06 (2)	4
	Adny 11	**9.45**	0.35 (3)	**8.77**	0.26 (3)	8
	BG	**8.57**	0.36 (16)	**7.12**	0.53 (16)	20
	Nionoka	**5.17**	0.31 (7)	**4.29**	0.37 (5)	20
	Wassa	**4.13**	0.82 (3)	**3.47**	0.54 (3)	19

(SE: standard error, n: sample size)

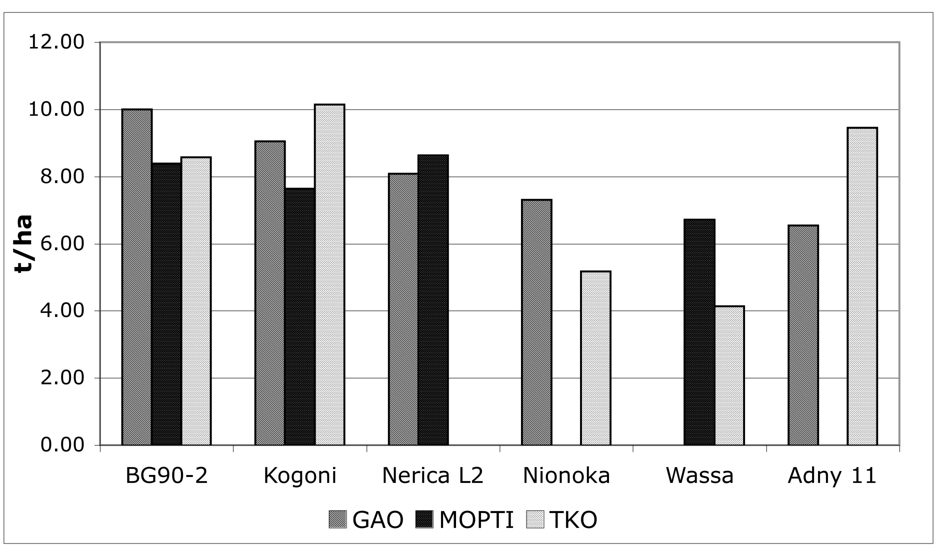

Figure 1: SRI rice grain yield (t/ha) for 6 varieties in 3 regions of Mali

1.4. Yield evaluation for Gao

The yield performance for SRI, control and PIV plots for the eight sites is reported in Table 5.

Table 5: Rice grain yield (t/ha) for SRI, control and PIV for 8 sites in Gao

	SRI t/ha	**Control** t/ha	**Village PIV** t/ha
Mozanga	10.00	8.14	6.50
Djeflani	9.05	6.27	6.90
Bourem PNIR	*8.37*	*4.04*	*4.25*
Adourourou	8.17	6.36	5.90
Ucutoha	8.08	6.81	5.90
Tobon	7.47	6.29	6.40
Bourem Bankass	6.54	4.26	5.50
Tonditiho	*5.80*	*3.12*	*3.40*
All villages	**7.93**	**5.66**	**5.59**
SRI increase %		40	42

In six out of eight PIVs, seeding and transplanting was done in June, which is the best month to assure a high production. In the two PIVs, Tonditiho and Bourem PNIR (in italics in the table), rice was transplanted in early to mid-August. Given the delay of almost 2 months, yields in these two sites were also considerably lower in the control plots, PIV plots and Tonditiho SRI. In contrast, Bourem PNIR SRI yields were high with 8.37 t/ha.

Yields in control plots and the PIVs were very similar. We unfortunately do not know the technical characteristics of the PIV plots, but we know the common crop establishment and management practices in each of the PIVs (Table 6). SRI farmers copied some of the SRI principles for their control plots, such as the application of organic matter (45% of farmers), which is usually not done on the PIVs. Furthermore, 60-75% of farmers reduced the number of plants in the control plots to 2.2 and transplanted them at 21 days of age, compared to the common practices of 3 plants/hill transplanted at 28.5 days. SRI seedlings were transplanted at 1 plant/hill at 10 days of age.

Table 6: Crop management for SRI plots, control plots and PIV in the Gao region

	SRI	Control	Farmer Practice (FP)
Plants/hill (numbers)	1	2.21	3
Age of tranplanted plants (days)	9.8	21.1	28.5
Urea used (kg/ha)	105	167	200 recom
DAP used (kg/ha)	0	47	100 recom
Hand weeding (numbers)	1	2	2
Cono-weeding (numbers)	3.1	-	-
Irrigation	AWD*	Flooded	Flooded

* AWD: Alternative Wetting and Drying

The agriculture technical service recommends using 200 kg/ha of urea and 100 kg/ha of DAP as fertilizer. We do not know how much fertilizer the farmers used on the PIV. An average of 167 kg/ha of urea and 47kg/ha of DAP were used on the control plots, for a total of 214 kg/ha of inorganic fertilizer application. For the SRI plots, farmers used an average of 105 kg/ha of urea, and did not use DAP, thus reducing fertilizer application by half. SRI plots were weeded 3.1 times by the cono-weeder and once by hand at the beginning of the cropping season. Control plots were weeded twice by hand, which corresponds with farmer practice. Control and PIV plots were flooded, whereas for SRI alternate wetting and drying irrigation was used.

1.5. Yield evaluation for Mopti

In the Mopti region, SRI yields averaged 7.72 t/ha, 10% higher than the control plots (7.01 t/ha) and 61% higher than the PIV average with 4.78t/ha (Table 7). Many of the farmers adopted some of the SRI practices in their controls.

Table 7: Rice grain yields (t/ha) for SRI plots, control plots and PIV for 5 villages in the Mopti region

	SRI t/ha	**Control** t/ha	**Village PIV** t/ha
Korientzé	8.92	8.34	6.00
Kouin	8.24	7.01	4.19
Kouana	8.00	7.72	4.78
Touara	7.51	6.28	3.93
Kamaka	5.90	5.68	5.00
All villages	**7.72**	**7.01**	**4.78**
SRI increase %		10	61

Contrary to Gao and Timbuktu, farmers' practice in Mopti usually includes some application of organic matter to rice plots. It can be estimated that under current practices about half the farmers use organic matter at a light dose of about 5t/ha or less.

Compost is dug out of the pit in village of Korientze, Mopti..

.. and prepared to be transported to the field,…

.. where it is at first distributed in heaps, before spread out and plowed under

In the control plots, 43% of the farmers applied an average 13.9t/ha of organic matter. This represents an important increase over what is usually done and is only a bit lower compared to the SRI average of 17 t/ha (Table 8). More than 85% of the farmers used seedlings younger than 21 days. Some farmers even used the residual seedlings from the SRI nurseries. Also 20% of the control plots were planted in lines, and farmers used the cono-weeder at least once in those plots.

Table 8: Crop management for SRI plots, control plots and PIV in the Mopti region

	SRI	Control	Farmer Practice (FP)
Plants/hill (numbers)	1	3	3.5
Age of tranplanted plants (days)	9.7	15	25
Organic matter (t/ha)	17.1	3.5*	2.5
Urea used (kg/ha)	54	143	200 recom
DAP used (kg/ha)	6	21	100 recom
Additional organic matter (t/ha)	3.97	3.88	-
Hand weeding (numbers)	1	2	2
Cono-weeding (numbers)	2.86	-	
Irrigation	AWD**/flooded	Flooded	Flooded

* 3.5 t/ha is the means for all farmers, which is same as 13.9t/ha for 43% of farmers
** AWD: Alternative Wetting and Drying

In addition to organic matter, farmers also applied much higher amounts of chemical fertilizers to their control plots with an average total of 164 kg/ha (143 kg/ha of urea, and 21 kg of DAP), compared to SRI plots with a total of 60 kg (54 kg/ha of urea, and 6 kg of DAP). Fertilizer reduction under SRI was therefore 63%. As in the other regions, farmers did not achieve the recommended fertilizer application of 100 kg/ha of DAP and 200 kg/ha of urea. The adoptions of certain SRI practices with the relatively high chemical fertilizers applications explain the relatively higher yields in the control plots compared to the PIV average.

One important constraint in the Mopti region for the SRI practices is the flooding of the PIVs due to rainfall. This is not the case in Gao and Timbuktu where usually low rainfall contributes to irrigation with amounts comparable to a normal irrigation event. Also, rainfall events are more spread-out in time, so that plots have the time to dry out in-between the events. In Mopti, on the other hand, rainfall is higher and more frequent, resulting in longer flooding periods of the PIVs. This has made it difficult and sometimes impossible to adhere to the principle of alternate wetting and drying irrigation.

Furthermore, because the PIVs in Mopti were not designed with drainage canals, it is often not possible to evacuate the water from a plot. Under the flooded irrigation method, stagnant water within the PIV was perceived to be desirable. It also meant that farmers did not have to pay for pumping irrigation water. With the SRI system, which requires more accurate control of irrigation water, the design and management of PIVs will need to be modified.

1.6. Yield evaluation for Timbuktu

The yields from nine sites in the Timbuktu region are given in the following table.

Table 9: Rice grain yields (t/ha) for SRI plots, control plots and PIV for 9 sites in the Timbuktu region

Growing calendar Villages	**SRI** t/ha	**Control** t/ha	**Village PIV** t/ha
Transplanted July-mid August			
Sibonet	9.72	9.39	5.6
Sibo	9.73	9.17	5.2
Goubou	8.44	6.51	4.94
Daye	7.50	6.22	3.54
Iloa	8.18	4.79	-
	8.71	***7.22***	***4.82***
Transplanted end August-Mid-September			
Koriome	4.43	3.73	2.35
Kabara	5.39	4.07	4.17
Bourem Inaly	2.88	3.29	3.5
Beregoungou	-	-	-
	4.23	***3.70***	***3.34***
All villages	**7.03**	**5.90**	**4.19**
SRI increase %		20	68

Seeding and transplanting were done at very different times for the nine Timbuktu sites. This was due to both the delay of the rainy season by more than a month, compared to the previous year, and because planting at a number of PIVs --Goubou, Kabara, Bourem Inaly and Beregoungou-could not start in time because rehabilitation work was not finished at the beginning of the season. This had a major impact on productivity. We can distinguish two groups: one which transplanted from early July to mid-August, and the other which transplanted from end of August to mid-September.

I) In the Niafunke circle, transplanting at Sibonet and Sibo started in mid to late July, for Goubou it was early August. These sites had the highest yields with an average of 9.3 t/ha compared to farmers' practice of 5.25 t/ha. The control plots also yielded high with 8.36 t/ha. At the perimeter of Daye, plots were transplanted between the end of July and early August. SRI yields were 7.5 t/ha, control plots were 6.22 t/ha and the PIV average was 3.54 t/ha. Farmers in Iloa, a PIV of 40 ha, transplanted in early to mid-August achieved high yields of 8.18 t/ha under SRI compared to 4.79 t/ha in the control plots. Average SRI yield for these five sites was 8.71 t/ha, for the control plots it was 7.22, and for the PIV fields 4.82 t/ha.

II) Transplanting at the sites of Koriome, Kabara, Bourem Inaly and Beregoungou was delayed until the end of August to mid-September. Transplanting at the Kabara and Koriome fields took place at the end of August and in early September. In Kabara, SRI yields were 5.4 t/ha and in Koriome they reached only 4.43. In the control plots, yields were 4.07t/ha and 3.73t/ha, and on the PIV 4.17 t/ha and 2.35 t/ha, respectively. In Bourem Inaly, where transplanting took place only in early September, harvests were greatly reduced as the cold season impeded flowering and grain filling, and not all rice plants achieved maturity. SRI yields were very low with 2.88t/ha, control yields 3.29t/ha and PIV yields 3.5 t/ha. In the village of Beregoungou, where rice was transplanted in mid-September, farmers had to forego the rice harvest entirely, as the crop could not mature. These results show that if transplanting is done later than mid-August the risk for production loss increases rapidly. Transplanting in September entails a very high risk, as a 100% crop failure is highly probable.

As in other regions, a number of farmers adopted some the SRI practices for their control plots. This concerned in particular application of organic matter in combination with relatively high fertilizer application, and the use of younger seedlings, especially in the sites where the cropping season was started before mid-August.

In many sites, the age of seedlings for control plots was older than what farmers usually practice, again due to the delay of the cropping season. Farmers started nurseries before water was available for their fields, and with the delay of the season, age of seedlings in the nurseries was older than farmers' usual practice. Also the number of plants/hill was slightly higher than usual. This indicates that farmers wanted to compensate for the loss of tillering abilities of older seedlings.

The amount of fertilizers used in the control treatment is higher compared to the other regions; for DAP it was even higher than the recommended dose. In total 285 kg/ha of chemical fertilizers were applied compared to 79 kg/ha in the SRI plots. This represents a reduction for SRI of 72%. Again, the farmers may have tried to compensate for the season delay by applying a higher dose of fertilizer in the hope to secure a normal yield. Farmers used the cono-weeders 3.5 times, and weeded once by hand, whereas in the control plots farmers weeded 2.3 times by hand, which again is slightly higher compared to the usual farmers' practice. (Table 10)

Table 10: Crop management for SRI plots, control plots and PIV in the Timbuktu region

	SRI	Control	Farmer Practice (FP)
Plants/hill (numbers)	1	3.75	3
Age of tranplanted plants (days)	10.9	35.8	28
Organic matter (t/ha)	19.8	2.7	-
Urea used (kg/ha)	79	153	200 recom
DAP used (kg/ha)	0	132	100 recom
Additional organic matter (t/ha)	0	0	0
Hand weeding (numbers)	1	2.32	2
Cono-weeding (numbers)	3.45	-	-
Irrigation	AWD*	Flooded	Flooded

* AWD: Alternative Wetting and Drying

2. Adapting SRI principals to rainfed rice systems of Sikasso

2.1. Description of the rainfed rice cropping systems

In the Sikasso region, rice is produced in four distinct rice production systems: one upland system and three lowland systems.

1. Upland rice system is a purely rainfed system, where the crop is grown exclusively with rainwater. There is no groundwater influence. Drought can be a major constraint, often accompanied by termite attack and damage to the rice crop. The Nerica 4 variety is adapted to this system, and its use is spreading quickly throughout the region.

The lowland systems are located in natural landscape depressions that can be several hundred hectares in size. They are characterized according to the different zones along the relief of these depressions. We distinguish three systems:

2. Lowland system – high zone: In the high location zone of the lowlands water is rarely stagnating during the season, and plants can benefit from a high water table. Capillary water is available to the crop in times of drought and in times when the rains are not regular and plants are in need of water. If rice is flooded, the levels are below 25cm.

3. Lowland system – medium zone: In the medium location of a depression, water will accumulate during the second part of the cropping season, and height of the flooding level is between 25 and 50 cm.

4. Lowland system – low zone: During the rainy season, water, which has not been absorbed by the soils, is collected in the low locations. Rice is flooded throughout the second part of the cropping season at heights superior to 50 cm. Flooding can happen very rapidly depending on the intensity and frequency of the rainfalls.

In each system different varieties are grown as adapted to the respective flooding levels. Infrastructures to regulate water are still rare in Sikasso, but have a potential to contribute to a better water distribution across the systems and during the length of the season. The systems are diverse as regards crop establishment and management. Across the systems, seed is either broadcast, planted in hills and in lines using a string (5-6 seeds/hill), planted in lines with a seeding machine, or more rarely using the corn-seeding machine dropping rice seeds in hills at a rather high number of seeds/hill (up to 15). Distances between hills range from 10cm x 10cm to 20cm x 20cm.

More than 90% of the rainfed rice in Sikasso is cultivated by women. For women, rice is their only crop, and rice productivity determines much of their food security and income. Yields are low with an average of 1.5 t/ha. There are many production constraints. Women have very little time at the beginning of the rainy season to establish their fields, as they also assist their husbands in the upland cultivation activities. They do not have access to seeding machines as men use them or the upland crops. They often lack the time to do a proper line planting, and thus use the simpler, but less productive, method of seed broadcasting instead.

Typical lowland system in Lountana Sikasso during soil preparation, cultivated exclusively by women

Women prepare their land by hand with small hoes. Working in teams is important in tackling these large surfaces

Nevertheless, women have understood the great advantage of seeding in lines, as weeding is less time-consuming than working in a densely sown field. Weed pressure is a major constraint in lowland rice cropping systems, and women weed their fields by hand or with small hoes (*dabas*) up to 4 times during a cropping season.

Fertilization with organic matter is usually not used for lowland rice, as the available organic matter produced each year-- based on animal manure and crop residues--is used on the upland fields and in the vegetable gardens, both planted by men.

Lowlands during mid-season in the village of Lountana, Sikasso

Lowlands at harvest time in the village of Lountana, Sikasso

2.2. Technical guidelines for rainfed SRI testing

This test was designed to obtain a preliminary indication of how an adapted form of SRI will perform in these different systems, and how farmers will perceive it. Tests were conducted in two IER research stations for the three of the four systems (upland, high zone and medium zone of the lowlands). Two IER farmer collaborators installed a test plot in their upland systems. In the two villages Lountana and Finkolo-Ganadougou, the women's associations selected women farmers to conduct the tests in all four systems. See details in Table 11.

Table 11: Set up of SRI test for the four rainfed rice cropping systems in Sikasso

Sites	Setting	System	Farmers
Longorola	Research station	LO H, M	-
Farako	Research station	UP	-
Mpengnesso	Farmers IER	UP	2
Loutana	Farmers	All	4
Finkolo	Farmers	All	4

LO= Lowland, H=High, M=Medium, L= Low, UP= Upland

The six SRI principles were adapted to the four systems in a collaborative effort between IICEM, IER, DRA and the NGO GREFA. The following guidelines were produced as shown in Table 12 and are further discussed below.

Table 12: Guidelines for testing adapted SRI practices in the four rainfed rice cropping systems of Sikasso.

System	Establishment	1 plant/hill	Transplanting young seedlings	Increased Spacing	Planting in lignes	Water control	Cono-weeder	Organic Matter
1. Upland	Direct seeding	2-3 pl, to 1plant	-	yes	yes	No	to be tested	yes
		No	-	yes	yes	No	to be tested	yes
2. Lowland high zone	Direct seeding	2-3 pl, to 1plant	-	yes	yes	some	with water layer	yes
		No	-	yes	yes	some	with water layer	yes
3. Lowland medium zone	Direct seeding	2-3 pl, to 1plant	-	yes	yes	some	with water layer	yes
	Transplanting	Yes	Yes/not sure	yes	yes	some	with water layer	yes
4. Lowland low zone	Direct seeding	2-3 pl, to 1plant	-	yes	yes	No	with water layer	yes
		No	-	yes	yes	No	with water layer	yes

Plant establishment: Farmers do not use nurseries for plant establishment. There are three main reasons: i) to use nurseries translates into more work, whereas women's time availability for plant establishment is already very limited; ii) the uncertainty of rainfall is high. To estimate the timing correctly in order to transplant young seedlings becomes difficult, and iii) in the lowland zone, where transplanting of seedlings may seem well suited, transplanting would need to occur later in the season than seeding, to assure good water availability for the plants. At that stage, these locations are already prone to flooding. Thus it is safer for the farmers to do a direct seeding with the first rains, and let rice plants get established even with little available water. Despite these constraints, we integrated one comparison of direct seeding with transplanting in the lowland medium zone, which seems to be the most suitable zone for a successful transplanting.

Number of plants per hill: two to three seeds were sown by hand, and thinned later to one plant per hill.

SRI plots seeded with several plants/hill. The hills were thinned to one plant after the next rain had softened the soil (Lountana)

Seed broadcast rice field in lowland system in village of Finkolo-Ganadougou. Notice the high plant density and irregular initial plant development

Transplanting of young seedlings: as described above, the right timing is very difficult. With the delay of the rainy season in 2009/2010 the plants in the first nurseries grew beyond the recommended size for transplanting , and a second nursery had to be established. Thus, transplanting young seedlings in a rainfed system is more difficult to plan than in an irrigated system.

Increased spacing: Current spacing is between 10cm and 20cm, we tested the spacing of 25cm x 25cm.

Planting in lines: was possible

Water control: water can be only partially controlled in the lowlands if an infrastructure is present that allows some control of water levels in the fields, although this is not common. Some water control may be possible in the lowland high and medium zone, by creating bunds (earth embankments) around the fields that can retain the run-off surface water for a longer period of time. We recommended this to the farmers, but none of them followed through, which indicates that they may not agree with the beneficial effects these bunds were supposed to have or they did not want or could take on the extra work of making the bunds.

Cono-weeder: The cono-weeder developed for the irrigated systems was tested. It worked well when soil did not stick to the weeder drums, either under drier soil conditions (in the uplands) or when a thin water layer was covering the soil (lowlands). To choose the right timing for weeder use was therefore critical. Some adaptations of these weeders should be designed to better respond to the specific soil conditions of the rainfed systems.

Organic matter: As discussed above, there is much competition for organic matter in the Sikasso agriculture systems, and most often women do not have access to it. We nevertheless asked to include it in the test, in order to get an insight of how the rice crop would respond to it.

Based on these guidelines, we developed a test protocol for the research station and for the farmers (Table 13) .The adapted SRI system was compared with the recommended practices by IER on the research station, and with the farmers' practices in the farmers' fields.

Table 13: Implementation of adapted SRI practices and control practices for the research station and the farmers' fields.

	Research Station		**Farmers**	
	SRI	Control	SRI	Control
Soaking of seeds (24h)	yes	no	yes	no
Direct seeding				
Spacing	25x25	20x20	25x25	10x10 to 20x20, or broadcast
Plants/hill seeding	2 to 3	5 to 10	3 to 5	3 to 6
Thinning	yes	yes	yes	no
Plants/hill after thinning(numbers)	1	5	1	3 to 6
Transplanting				
Spacing	25x25	20x20	25 x25	missing info
Age of transplanting (days)	10	10	16.5	missing info
Plants/hill	1	3	1	missing info
Fertilization				
Organic matter (t/ha)	10t/ha	0	10-15t/ha	0
Urea used (kg/ha)	0	120	0	100
Cotton complex NPK (kg/ha)	0	120	0	100-200
Weeding				
Cono-weeder use	yes	no	yes	no

2.3. Rice grain yields in the four systems

This yield analysis for the four systems combines both research and on-farm testing. For an analysis per site see IER report from Sikasso (CRRA-Sikasso, 2010). The following table shows the yields obtained in the four systems.

Table 14: Rice grain yields (t/ha) for SRI and control plots in four cropping systems in Sikasso.

System	**SRI Yield** t/ha	SE (n)	**Control Yield** t/ha	SE (n)	% SRI Increase over control
Upland	**3.10**	0.50 (5)	**3.09**	0.37 (5)	1
Lowland High	**4.08**	0.82 (4)	**2.86**	0.35 (4)	43
Lowland Medium	**4.54**	0.87 (5)	**3.13**	0.58 (5)	45
Lowland Low	**5.06**	1.97 (2)	**2.94**	0.17 (2)	72
All systems	4.20	(16)	3.00	(16)	40

Highest yields were obtained with SRI in the lowland low system with 5.06 t/ha, followed by the lowland medium (4.54 t/ha) and lowland high system (4.08t/ha). The upland system had the lowest yields with 3.1 t/ha, being about two metric tons lower than the lowland low system. This landscape gradient is not obvious in the control plots, and yields vary only slightly between the systems: from 2.86 t/ha to 3.13 t/ha, which is only a 0,27 t/ha difference. Comparing SRI performance with control plots in the uplands did not show any difference. On the other hand, the difference increases for the lowland high, medium and low systems by 43%, 45% and 72% respectively.

SRI upland plot with Nerica 4 on the IER research station Faraka-Finkolo, Sikasso

2.4. Yield parameters for the four systems

Analysis of the yield parameters show that SRI compared to the control have a much higher tiller and panicle formation in the lowland systems than in the upland system (Table 15). In the upland system, Nerica 4 was grown exclusively (see discussion under the variety section), which seems to have a restricted tillering ability. Plant heights and root depths were all longer under SRI than in the control. In the lowland high zone, SRI roots reached double the length of the control plants. As discussed above, there is a water table influence in this zone and plants with long roots are more likely to tap the water table in times when dry spells occur. It is clear from the data that SRI plants have an advantage for this. In addition, SRI plants have longer panicles, more grains per panicle and fewer empty grains than the control plots in all 4 systems.

Table 15: Yield parameters for SRI and control plots in four rice systems in Sikasso

		Yield t/ha	SE	Tillers/hill Number	SE	Panicles/hill Number	SE	Fertile tillers %	Plant height cm	SE
Upland (n=5)										
	SRI	**3104**	501	**7.7**	1.0	**6.3**	0.8	**82**	**118**	5.7
	Control	**3088**	367	**8.2**	1.3	**6.3**	0.9	**76**	**114**	3.4
Lowland (n=4)										
High Zone	SRI	**4084**	820.0	**12.2**	2.8	**11.0**	2.6	**90**	**120**	11.3
	Control	**2862**	349	**7.3**	1.8	**5.9**	1.1	**80**	**102**	4.0
Lowland (n=5)										
Medium Zone	SRI	**4543**	874	**9.9**	1.7	**9.0**	1.4	**91**	**130**	11.9
	Control	**3126**	577	**6.3**	1.6	**6.2**	1.1	**98**	**120**	9.5
Lowland (n=2)										
Low zone	SRI	**5064**	1966	**13.7**	6.1	**13.4**	6.2	**98**	**146**	3.6
	Control	**2941**	171	**3.6**	0.6	**3.6**	1.0	**99**	**141**	13.6

		Root length cm	SE	Panicle length cm	SE	Grains/panicle Number	SE	Empty grains* %
Upland (n=5)								
	SRI	**15.5**	2.0	**24.2**	0.6	**386**	133	10
	Control	**11.9**	1.1	**20.4**	1.2	**258**	94	22
Lowland (n=4)								
High Zone	SRI	**20.7**	6.6	**24.6**	0.9	**543**	152	12
	Control	**10.8**	1.0	**21.2**	0.8	**453**	127	21
Lowland (n=5)								
Medium Zone	SRI	**15.9**	1.9	**21.5**	0.6	**489**	143	14
	Control	**12.2**	1.4	**19.8**	0.3	**447**	138	11
Lowland (n=2)								
Low zone	SRI	**24.6**	5.6	**24.2**	4.6	**832**	42	9
	Control	**18.7**	4.7	**20.5**	2.5	**586**	11	18

* Empty grains: not properly filled grains, float on water, whereas filled grains sink

2.5. Rice grain yields for six varieties

A yield analysis for the six used varieties is presented in Table 16

Table 16: Rice grain yield (t/ha) for 6 rainfed rice varieties for SRI and control plots in Sikasso

Variety	System*	SRI Yield t/ha	SE (n)	Control Yield t/ha	SE (n)	% SRI Increase over control
Local	M, L	**6.61**	0.28 (3)	**3.63**	0.26 (3)	82
Sik 131	H	**6.33**	(1)	**3.83**	(1)	65
Shwetasoke	H	**4.29**	(1)	**2.57**	(1)	67
Sik350 A150	M	**4.00**	0.63 (2)	**3.43**	0.63 (2)	17
Nerica 4	Up, H	**3.06**	0.41 (6)	**3.05**	0.30 (6)	0
Bw348	M, L	**2.64**	0.36 (3)	**1.99**	0.52 (3)	33
All Varieties		4.49		3.08		46

Highest yields were obtained with a local variety, the name of which was not determined by IER. The yields were high under SRI with 6.61t/ha compared to 3.63 t/ha in the control. This variety was planted in the low and medium zones of the lowland system.

The other high yielding variety was SIK131 with a SRI yield of 6.33 t/ha and a control yield of 3.83 t/ha planted in the lowland high zone. The two other varieties-- Shwetasoke and Sik350 A150-- produced over 4 t/ha with SRI and between 2.6 and 3.4 t/ha in the control.

Nerica 4 did not show any difference between SRI and the control plots, producing a yield of 3.06 t/ha. Only Bw348 had a lower yield than Nerica 4. Given the low tillering of Nerica 4, a closer SRI spacing of 20cm x 20cm should be tested with a likely yield increase compared to the spacing of 25cm x 25cm applied this season. These results suggest that under SRI practices many varieties express a high yield increase, but not all varieties respond in the same way.

2.6. Comparison of direct seeding with transplanting in the lowland medium system

In two locations – one on-farm and one on the research station – direct seeding was compared to transplanting young seedlings in the lowland medium zone. The findings are shown in the following table.

Table 17: Yield of transplanted and direct seeded rice (t/ha) for SRI and control plots in the lowland medium zone rice cropping system of Sikasso

Variety	Site	Setting	**SRI Yield** t/ha	**Control Yield** t/ha
Transplanting				
Local	Lountana	Farmer's field	6.70	3.89
Sik350 A150	Longorola	Research station	4.63	4.06
Average			**5.67**	**3.97**
Direct Seeding				
Local	Lountant	Farmer's field	6.09	3.89
Sik350 A150	Longorola	Research station	3.37	2.80
Average			**4.73**	**3.34**
Percentage increase of transplanting over direct seeding			20%	19%

Transplanting rice showed an increase of 20% over direct seeding both in the SRI plots and in the control plots. As discussed above, there are many constraints as regards transplanting. Improving direct seeding methods would most likely be more acceptable to farmers. Nevertheless, transplanting may be an option for specific situations, and should be further evaluated in situations where it fits well with cropping system practices.

2.7. Fertilization

As seen in Table 13, SRI plots received only organic matter fertilization in all locations, no chemical fertilizer was applied. Control plots did not receive organic matter amendments but were fertilized with the standard NPK cotton complex as a start up fertilizer, complemented by one or two application of urea later in the season. Although it was left up to SRI farmers to decide whether to complement organic matter application with chemical fertilizer if needed, none of the farmers used it. SRI plants remained dark green up to harvest, whereas the control plots, despite NPK and urea application, were remarkably paler at harvest time. This was an unexpected result and impressed the farmers, who usually do not use organic matter with the rice crop.

3. Conclusions and recommendations

3.1. Adapted SRI in the rainfed systems of Sikasso

SRI practices showed consistently improved performance along the landscape gradient from the upland (lowest response) through the lowland high zone, lowland medium zone, to lowland low zone (highest response). SRI plots in the lowland low zone obtained yields of over 5 t/ha. The results obtained in this first test indicate a higher level of productivity than what is usually thought possible. Discussions about high yields in the Sikasso region refer often to 3 t/ha using the Nerica 4 variety. Although Nercia 4 is an important variety for the upland system, its yields ranked 5th out of 6 tested varieties. The best-performing variety (unfortunately not identified) was grown by the women in the village of Lountana. It can be recommended that SRI testing should be done with a range of varieties in the four systems. Close collaboration with local population is to be developed including the work with their currently locally used varieties.

A main constraint in the rice farming systems of Sikasso is the non-availability of improved crop establishment techniques. Faced with labor constraints, women still use seed broadcasting, which results in low yields. Women do not have access to seeding machines because they are owned and used by the men. Also, available seeding machines only seed in continuous lines. In Mali, there are no seeding machines yet commercially available that can seed rice in hills. The IER mechanization program in Niono has started working on this issue, and is currently testing a few prototypes. This should be reinforced. A seeding machine that can seed rice in hills will be essential if adapted SRI is to be widely adopted in Sikasso.

Rainfed rice clearly responded to additions of organic matter. No inorganic fertilizer was needed to maintain deeply green-colored leaves until harvest time. Because there is a shortage of organic matter within the farming system and farmers use available manure/compost in their upland and vegetable fields, organic matter production should be specifically developed for the rice systems. In the lowland areas, the options for growing green manures should be explored as an alternative to more labor-intensive composting systems. There is much potential to develop a range of techniques for organic matter production that can be offered to farmers.

3.2. SRI in irrigated systems of Gao, Mopti and Timbuktu

SRI yields in the three northern regions of Mali showed an average increase of 56% for 101 farmers who obtained 7.56t/ha, significantly higher than the current farmer practice at 4.85 t/ha. This confirms results obtained by Africare in the Timbuktu region over the past three years (Africare Mali, 2008; Styger, 2009, Styger 2010).

Given the evidence established across the many agro-ecological zones, it can be concluded that SRI practices present an economic and environmentally friendly alternative to current rice cultivation practices in northern Mali. This is confirmed by farmers' enthusiasm in all three regions regarding field performance of the rice crop when cultivated under SRI and about the associated economic and food security benefits for the farmers themselves.

Extension efforts for SRI should be strengthened with good technical oversight to reach farming communities in the sometimes remote areas in the North. Good training of technicians and technical supervisors will be essential to establish a well-grounded common knowledge of SRI practices within both governmental and non-governmental technical support services. Research organizations should lead in further developing innovations associated with SRI practices, seeking further improvements in rice productivity and reducing production costs.

SRI extension efforts will be much stronger if accompanied by ongoing technical improvements. These are critical for soil preparation: there is much scope for improvement through appropriate mechanization using hand tractors for better tilling, puddling and field leveling. Production of organic matter for compost and green manure should be associated with SRI extension efforts. Various methods can be developed that are well-adapted to their specific agro-ecological environments. The goal should be that irrigation perimeters will be able to produce the amounts and quality of organic matter needed to sustainably maintain healthy soil systems.

Different rice varieties can be evaluated in the various zones in order to determine the each one's potential to improve productivity in local rice cropping systems. Innovation by farmers should be encouraged, and PIV management will also need to innovate to deal with new demands on their organizational practices, such as distribution of irrigation water according to rice cropping systems. For example, irrigation associations could be encouraged to adjust payments for water pumping according to the rice cropping system used.

SRI practices have shown their potential in five of Mali's eight regions. A SRI exchange platform could be created for Mali, which would allow all interested stakeholders to have easy access to information and to share experiences. Participants in this platform could assist each other to plan, implement and evaluate their work with SRI. It is important that knowledge gained not be lost or hidden away, but widely shared and useful for all.

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