Comparison of the system of rice intensification (SRI), recommended practices, and farmers' methods of rice (*Oryza sativa* L.) production in the humid tropics of Kerala, India

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Abstract

Field experiments were conducted to compare the System of Rice Intensification (SRI) with the best management recommendations and farmers' practices of rice (*Oryza sativa* L.) production. The experimental variables included combinations of seedling number and age (10 day-old single vs. 20 day-old two seedlings per hill), spacing (25 x 25 cm vs. 20 x 15 cm), irrigation (intermittent irrigation vs. continuous flooding), and weed control (cono-weeding vs. manual weeding) treatments, besides farmers' practice (control). The trial was laid out in completely randomized factorial design, replicated thrice. Highest grain yield (4467 kg ha^{-1}) and net returns (Rs 17745 ha^{-1}) were obtained for the suite of best management practices (planting two 20 days-old seedlings $hill^{-1}$ at 20 x15 cm + intermittent irrigation and cono-weeding). Yield under SRI management (planting 10 day-old single seedlings at 25 x 25 cm + intermittent irrigation and cono-weeding: 3326 kg ha^{-1}) was lower than that of recommended practices (20 day-old two seedlings at 20 x15cm+continuous irrigation and hand weeding: 4310 kg ha^{-1}) but was greater than that of farmers' practices (2643 kg ha^{-1}). Planting 10 day-old single seedlings at 25 x 25 cm spacing had little impact on yield under the experimental conditions. Although intermittent irrigation and continuous flooding were statistically at par, cono-weeding reduced the labour required for weeding by 35 man-days ha^{-1} and labour cost by Rs 3125 ha^{-1}. Farmers' participatory evaluation revealed that planting of one or two young seedlings $hill^{-1}$ at specified spacing and employing cono-weeding and intermittent irrigation are economically viable technologies.

Keywords: Farmers' practice, Recommended practices, Productivity, Profitability.

Introduction

The System of Rice Intensification (SRI) was conceptualized by Henri de Laulanie, a French missionary priest, in Madagascar during the early 1980s as a complementary suite of rice (*Oryza sativa* L.) management techniques. The main components of SRI include careful transplanting of single young seedlings at wider spacing, water management that keeps the soil moist but not continuously flooded, early and frequent (3 to 4 times) mechanical/manual weeding before canopy closure, and ensuring adequate nutrient supplies (Laulanie, 1993). SRI attracted attention because of its apparent success in increasing rice yields in experimental situations (Uphoff and Randriamiharisoa, 2002) and farmers' fields (Rafaralahy, 2002). Uphoff (2002) claimed that under SRI methods rice yields may go up to 15 to 20 Mg ha^{-1}. Stoop et al. (2002) reported that the synergies among these unconventional management practices unlock the physiological potential of rice, with results that challenge the prevailing notions of yield barriers in rice. However, these claims have been questioned (Dobermann, 2004; Sheehy et al., 2004). The SRI techniques also may have limited appli-

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cability (Moser and Barrett, 2003; Namara et al., 2003). Some authors, however, think that such limitations can be addressed if the agronomic value of the SRI approach to rice management is firmly established (McDonald et al., 2005).

Although rice is a predominant crop of Kerala, studies on systematic evaluation of the agronomic potential of SRI are meagre in the state. Some of the component practices of SRI such as intermittent irrigation (Mathew et al., 2003), cono-weeding (Suseela et al., 2002) were, however, evaluated in separate trials. Present management recommendations for rice in Kerala include planting two 20 to 25 day-old seedlings per hill at 20 x 15 cm spacing with hand weeding and continuous flooding (KAU, 2002). The primary question we sought to answer in this study is whether rice productivity under SRI is superior to that achieved under the recommended management practices. On-station and on-farm experiments were conducted to compare SRI techniques with the existing management recommendations (KAU, 2002) and farmers' practice. Attempts were also made to determine the economic viability of SRI and other crop management options for rice, besides assessing the acceptability of such practices by local farmers through farmers' field experimentation and surveys.

Materials and Methods

The station trials were conducted at Mannuthy, Thrissur, Kerala (10°31'N, 76°13'E; altitude 40.3 m) during the rainy seasons (June to October) of 2006, 2007, and 2008. The site experiences a typical humid tropical climate. The soils are classified as Ultisol and are acidic, deep, well drained kaolinitic and ustic sandy loam (NBSS & LUP, 1996). Pre-treatment soil nutrient status was determined following standard procedures (Hesse, 1971). It showed that the soil is medium in available N (131.9 mg kg^{-1}) and available P_2O_5 (19.6 mg kg^{-1}), and low in available K_2O (45.2 mg kg^{-1}) status. The experiments were laid out in completely randomized factorial design, replicated thrice. The treatments consisted of two levels each of four crop management practices viz., crop establishment (planting 10 day-old single and 20 day-old two seedlings hill^{-1}), spacing (25 x 25 cm and 20 x 15 cm), irrigation (intermittent irrigation and continuous flooding), and weed control (cono-weeding and manual weeding). Farmers' practice (planting 28 day-old 6 to 10 seedlings hill^{-1} irregularly with continuous flooding and hand weeding) served as control. Among the 16 treatment combinations, planting 10 day-old single seedlings at 25 x 25 cm+ intermittent irrigation and cono-weeding represents SRI management and planting 20 day-old two seedlings at 20 x 15 cm + continuous irrigation and hand weeding constitutes the recommended practice (KAU, 2002). The remaining 14 treatments were combinations of SRI and recommended practices (KAU, 2002). Medium duration rice variety 'Aiswarya' was used as the test variety. Farmyard manure (5 Mg ha^{-1}) and 90:45:45 kg N: P_2O_5, and K_2O ha^{-1}) were applied uniformly in all treatments. One-third N, full P, and half K were applied basally, $^1/_3$ N applied at maximum tillering, and the remaining $^1/_3$ N and ½ K applied at panicle initiation.

Ten day-old seedlings raised in a modified mat nursery (soil, sand, and cow dung mixed in equal proportions and spread uniformly on a plastic sheet; 1 to 2 cm thickness) were used. Twenty and 28 day-old seedlings were raised in standard wet nurseries. Weeding in the cono-weeded treatments started 10 days after planting and was repeated at 10 days interval. In the manually weeded plots, one hand weeding was given at 30 days after planting. Intermittent irrigation treatments consisted of providing light irrigations to keep the soil moist. After panicle initiation, a thin layer (1 to 2 cm) of water was maintained in this treatment and the field was completely drained 10 to 15 days before harvest. In the continuously flooded treatment, 3 to 5 cm water was kept throughout the growing period. Data on weed incidence and weed dry matter were collected from 0.25 cm^2 random quadrats in each plot. Leaf area was measured using a portable leaf area meter (Model CI-202). Growth and yield attributes on 10 randomly selected hills were noted. At harvest, grain yields from the net plots (5 x 4.5 m) were recorded after sun-drying (13% moisture), cleaning, and winnowing and the straw yield was determined on oven-dry weight basis. Labour charges, cost of inputs, and the additional cost of incorporating the treatments were worked out to compute the gross expenditure. Gross returns were calculated based on local market prices of paddy and straw and net returns by subtracting the total cost of cultivation from gross returns, treatment-wise. Benefit: cost ratio was computed by dividing gross returns with gross expenditure. Data were analyzed statistically using ANOVA and the significance was tested by Fisher's least significant difference (p=0.05).

Farmers' participatory evaluation of the best management practices was made in 10 selected farmer's field sites in the major rice growing areas of the state: Kuttoor and Venpala in Pathanamthitta district, Pulimath and Koduvazhanoor in Thiruvananthapuram district, Sulthan Batheri in Wayanad district, Mala, Puthukkadu, and Kolazhy in Thrissur district, and Peringottukurussi and Marutharoad in Palakkad district of Kerala state. The trials were conducted during the period from September 2007 to December 2008, depending on the rice growing seasons of the selected locations. As part of these trials, the selected farmers were trained on the merits and demerits of various management techniques pertaining to nursery preparation, seedling age, planting one or two seedlings per hill, spacing, weed management using cono-weeder, water management techniques followed under SRI management practices and the recommended practices (KAU, 2002). From among these management options, the farmers were asked to choose the best techniques they wanted to test in their fields. The plot size was variable depending on the availability of land and at nine locations (except Kuttoor) it ranged from 0.2 to 0.8 ha. At Kuttoor, the trial was conducted in a 25 ha *padasekharam* (aggregation of paddy fields), of which 10 ha was planted as per the best management practices.

Farmer used rice varieties were chosen and the seedlings were raised in a modified mat nursery. One or two 15 to 20 day-old seedlings hill^{-1} were planted at 20 x 15 cm spacing. The crop was cono-weeded with intermittent irrigation. This was compared with the local farmers' practice (planting 30 to 40 day-old 6 to 10 seedlings hill^{-1} irregularly with continuous flooding and hand weeding). Perception of the farmers about various aspects of rice cultivation was collected and the constraints experienced by farmers while adopting these management techniques were also elucidated from 15 farmers who practiced SRI cultivation. The yield data were analysed using ANOVA for randomized block design.

Results and Discussion

On-station evaluation

Planting two 20 day-old seedlings significantly increased the grain (14%) and straw yield (17%) compared to planting 10 day-old single seedlings (Table 1). Thiyagarajan et al. (2002) also reported that use of younger seedlings do not necessary result in high yields, even under SRI management. Twenty day-old seedlings had consistently higher leaf area index and tiller number than 10 day-old seedlings (Table 2). Growth parameters such as plant height, tiller production, and dry matter production during early growth period also followed a similar pattern.

As can be seen from Table 1, closer spacing (20 x 15 cm) gave higher grain yield than wider spacing (25 x 25 cm). This may be due to the higher number of panicles m^{-2} in the closer spacing treatment. Although productive tillers and weight of panicles were higher in the 25 x 25 cm spacing, number of panicles was significantly more in the 20 x 15 cm spacing. While the rice plant adapts well to decreased plant density by increasing yield per plant due to plastic responses, this was apparently not enough to compensate for the 50% reduction in plant density, as reported by Sheehy et al. (2004) and Latif et al. (2005).

Irrigation treatments did not substantially alter the growth and yield parameters of rice (Tables 1 and 2). Mathew et al. (2003) also reported that intermittent irrigation was as good as continuous submergence, but may save about 50% of irrigation water use. Weed count and weed dry matter, however, were significantly more (Table 3) in the intermittent irrigation treatment owing to the generally favourable conditions for weed growth prevailing under that treatment, compared to continuous flooding (Latif et al., 2005).

Table 1. Effect of management techniques on the yield parameters, yield, and economics of rice (pooled data) in the Ultisols of Kerala, India.

Treatment	Panicle m^{-2}	Panicle weight (g)	1000 grain wt. (g)	Filled grain %	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Gross return (Rs. ha^{-1})	Net return (Rs. ha^{-1})	B: C ratio
Seedling $hill^{-1}$ and age									
Single seedling, 10 day-old	297^a	26.6^a	30.0^a	68.1^b	3542^b	3717^b	30196^b	8810^b	1.46^b
Two seedlings, 20 day-old	301^a	24.1^b	29.6^b	73.5^a	4112^a	4492^a	35146^a	13299^a	1.66^a
Spacing (cm)									
25 x 25	195^b	27.9^a	29.8^a	$70.\ 8^a$	3644^b	3983^b	31150^b	10035^b	1.52^b
20 x 15	403^a	22.7^b	29.9^a	70.8^a	4010^a	4226^a	34192^a	12074^a	1.60^a
Irrigation									
Intermittent irrigation	300^a	$24.\ 9^a$	30.1^a	71.3^a	3846^a	4035^a	32789^a	11323^a	1.58^a
Continuous flooding[1]	298^a	25.8^a	29.6^b	70.3^a	3808^a	4174^a	32553^a	10789^a	1.54^a
Weeding									
Cono weeding	301^a	25.1^a	30.0^a	70.8^a	3802^a	4084^a	32462^a	12408^a	1.66^a
Manual weeding	297^a	25.6^a	29.6^b	70.8^a	3852^a	4125^a	32880^a	9701^a	1.46^a
Farmers practice[2]	176*	17.7*	25.3*	57.3*	2643*	3008*	23710*	–505*	0.975*

[1] Standing water column of 3-5 cm maintained throughout the growing period; [2]Planting of 28 days old 6 to10 seedlings $hill^{-1}$ irregularly with continuous flooding + hand weeding; *Farmers' practice vs. the rest statistically significant (p=0.05); Values with the same superscript do not differ significantly.

Table 2. Effect of management techniques on the growth parameters of rice at different growth stages (pooled data) in the Ultisols of Kerala, India.

Treatment	Plant height (cm)			Tillers $hill^{-1}$			Leaf area index			Dry matter production (kg ha^{-1})		
	AT	PI	H	AT	PI	H	AT	PI	H	AT	PI	H
Seedling $hill^{-1}$ and age												
Single seedling, 10 day-old	61.3^b	81.1^b	111.0^a	9.6^b	12.0^a	11.9^a	2.0^b	3.7^b	2.3^b	819^b	2811^b	4927^a
Two seedlings, 20 day-old	64.3^a	$87.^a$	112.9^a	11.6^a	12.4^a	12.0^a	2.7^a	4.0^a	3.2^a	1332^a	3523^a	4320^b
Spacing (cm)												
25 x 25	62.0^b	83.1^b	111.9^a	11.8^a	13.8^a	12.7^a	$1.\ 7^b$	3.2^b	2.1^b	1093^a	3490^a	5204^a
20 x 15	63.3^a	85.1^a	111.9^a	9.3^b	10.7^b	11.3^a	3.1^a	4.6^a	3.5^a	1058^a	2846^b	4046^b
Irrigation												
Intermittent irrigation	62.5^a	83.2^b	110.2^b	10.6^a	12.4^a	12.2^a	2.3^a	3.8^a	2.8^a	1040^a	3224^a	4424^a
Continuous flooding[1]	62.9	84.9^a	113.7^a	10.6^a	12.1^a	11.8^a	2.5^a	3.9^a	2.9^a	1110^a	3110^a	4823^a
Weeding												
Cono-weeding	62.3^a	84.0^a	112.0^a	10.8^a	12.2^a	12.0^a	2.3^a	3.9^a	2.8^a	1035^a	3045^a	4716^a
Manual weeding	63.1^a	84.1^a	111.9^a	10.5^a	12.3^a	11.9^a	2.4^a	3.9^a	2.8^a	1105^a	3266^a	4534^a
Farmers practice[2]	64.4*	82.9*	104.1*	11.1*	11.2*	10.2*	2.2*	2.5*	2.2*	1234*	2048*	3696*

AT – Active tillering; PI – Panicle initiation; H – Harvest; [1] Standing water column of 3-5 cm maintained throughout the growing period; [2]Planting of 28 days old 6 to 10 seedlings $hill^{-1}$ irregularly with continuous flooding + hand weeding; *Farmers' practice vs. rest statistically significant (p=0.05). Values with the same superscript do not differ significantly.

Table 3. Effect of management techniques on the growth of weeds at 50 days after planting (pooled data) in the Ultisols of Kerala, India.

Treatments	Weed count (# per 0.25 m^2)				Weed dry matter (g per 0.25 m^2)			
	Grasses	Broad leaved	Sedges	Total	Grasses	Broad leaved	Sedges	Total
Seedlings $hill^{-1}$ and age								
Single seedling, 10 day-old	4.12^a	8.37^a	6.12^a	18.62^a	0.61^a	1.24^a	0.48^a	2.33^a
Two seedlings, 20 day-old	4.20^a	9.95^a	5.25^a	19.41^a	0.69^a	1.27^a	0.46^a	2.43^a
Spacing (cm)								
25 x 25	4.66^a	8.79^a	6.04^a	19.50^a	0.66^a	1.24^a	0.51^a	2.41^a
20 x 15	3.66^a	9.54^a	5.33^a	18.54^a	0.64^a	1.27^a	0.44^a	2.35^a
Irrigation								
Intermittent irrigation	4.79^a	15.5^a	7.92^a	27.58^a	0.72^a	1.59^a	0.63^a	2.93^a
Continuous flooding	3.54^a	2.83^b	4.08^b	10.45^b	0.59^a	0.91^b	0.32^b	1.83^b
Weeding								
Cono weeding	4.83^a	9.54^a	5.79^a	20.16^a	0.73^a	1.43^a	0.50^a	2.67^a
Manual weeding	3.5^a	8.79^a	5.58^a	17.87^a	0.57^a	1.07^a	0.45^a	2.09^a

Values with the same superscript do not differ significantly.

Cono-weeding and manual weeding also did not differ significantly in terms of rice growth and yield (Tables 1 and 2). However, net return and B:C ratios were significantly more when cono-weeder was used. This was mainly because of the reduced labour requirement in cono-weeded plots compared to manually weeded treatments (Thakur, 2010). Indeed, cono-weeding reduced the labour requirement for weeding by 35 man-days ha^{-1} and labour cost by Rs. 3125 ha^{-1}.

Rice yield under farmers' practice was significantly lower than other management practices (Table 1), implying that planting 6 to 10 older seedlings (28 day-old) irregular spacing may lead to poor rice growth and yield. Grain yield reduction following planting of older seedlings (Menete et al., 2008) at high density (San-oh et al. 2004) was reported earlier too. Indeed, plant population density in the farmers' field was lower than that of other treatments and planting more seedlings per hill probably led to poor tillering. This was also reflected in the returns and B:C ratio and yield attributes such as number of panicles $hill^{-1}$, panicles m^{-2}, panicle weight, 1000 grain weight and filled grain percentage (Tables 1 and 2).

Overall, the highest grain yield (4467 kg ha^{-1}) and net returns (Rs 17745 ha^{-1}) were obtained when a combination of recommended crop management practices (planting two 20 day-old seedlings $hill^{-1}$ at 20 x15 cm spacing: KAU, 2002) and SRI techniques (intermittent irrigation and cono-weeding) were adopted (Table 4). Furthermore, grain yield under recommended practices (4310 kg ha^{-1}) was significantly higher than that under SRI management (3326 kg ha^{-1}), which in turn, was greater than that obtained in the farmers' practice (2643 kg ha^{-1}). Labour requirement for weeding was less in the cono-weeded plots denoting lower cost cultivation in SRI compared to other crop management systems. SRI, recommended practices and their combinations resulted in increased productivity and profitability of rice compared to farmers' practice.

On-farm evaluation

At all farmers' field sites, planting one or two 15 to 20 day-old seedling $hill^{-1}$ at 20 x 15 cm spacing and employing cono-weeding and intermittent irrigation increased rice productivity compared to conventional practice, i.e., planting six to ten 30 to 40 day-old seedlings $hill^{-1}$, adopting an irregular pattern with continuous flooding and hand weeding (Table 5).

An analysis of the general perception of the sampled

Table 4. Comparison of different management techniques of rice in the Ultisols of Kerala, India.

	SRI	Best combination[1]	POP	Farmers' practice
Grain yield (kg ha^{-1})	3326	4467	4310	2644
Straw yield (kg ha^{-1})	3605	4847	4638	3008
Labour ha^{-1}requirement for treatments	55	67	104	104
Cost of cultivation (Rs ha^{-1})	19325	20415	24215	24215
Gross Return (Rs ha^{-1})	28413	38160	36805	23710
Net Return (Rs ha^{-1})	9088	17745	12590	–505
BC Ratio	1.51	1.92	1.56	0.975

SRI= System of Rice Intensification; [1]Planting 20 day-old two seedlings at 20 x 15 cm with intermittent irrigation + cono-weeding; POP= Package of Practice recommendations of Kerala Agricultural University. Rs= Indian Rupee (exchange rate: Rs 44.2 per US dollar as on 12 April 2011).

Table 5. Yield performance of rice under farmers' participatory trials comparing the suite of best management practices with farmers' techniques in Kerala, India.

Location	District	Grain yield (kg ha^{-1})		% increase over farmers' practice
		Best combination[1]	Farmers' practice[2]	
Venpala	Pathanamthitta	5120	4200	21.90
Kuttoor	Pathanamthitta	6200	5000	24.00
Sulthan Batheri	Wayanad	4000	3600	11.11
Pulimath	Thiruvananthapuram	2500	2000	25.00
Koduvazhanoor	Thiruvananthapuram	2700	2400	12.50
Marutharoad	Palakkad	4500	3450	30.43
Peringottukurussi	Palakkad	4700	4000	17.50
Kolazhy	Thrissur	5000	3800	31.57
Mala	Thrissur	6100	5000	22.00
Puthukkadu	Thrissur	4000	3800	5.26
Mean		4482^a	3725^b	20.3

[1]Planting 15 to 20 day-old one or two seedlings at 20 x 15 cm with intermittent irrigation and cono-weeding; [2]Planting of 30 to 40 day-old 6 to 10 seedlings $hill^{-1}$ irregularly with continuous flooding + hand weeding. Values with the same superscript do not differ significantly.

farmers indicate that reduced seed cost owing to lower seed rates following planting one or two seedlings $hill^{-1}$ at 20 x 15 cm spacing is the foremost advantage (100% respondents), compared to the farmers' practice of planting 6 to 10 seedling $hill^{-1}$ adopting an irregular pattern. Varghese et al. (2005) also reported similar observations. Increased production of tillers and panicles (92% farmers), higher grain yield (68% farmers), cost effectiveness of cono-weeding (68% farmers) and water saving by intermittent irrigation (60% farmers) are other positive aspects of the best management practice. Conversely, difficulties in transplanting one or two young seedling $hill^{-1}$ at specified spacing which requires skill (98% farmers), drudgery and difficulty of using cono-weeders (60% farmers), and increased weed growth in non-flooded fields (80% farmers) are disadvantages of the best management practices. Farmers also find it difficult to maintain the field saturated due to uncertainty in receipt of rain and/or irrigation. Among the sampled farmers, only 30% adopted the recommended practice of planting 15 to 20 day-old one or two seedling $hill^{-1}$ at 20 x 15 cm spacing and employing cono-weeding and intermittent irrigation.

Conclusions

The on-station experiments showed that SRI did not increase rice yields compared to the recommended practices. The key management principles stated in

SRI such as age of seedling (10 day-old) and wider spacing (25 x 25 cm) had negligible effects on rice productivity. Intermittent irrigation, however, was equally effective as continuous flooding. By employing cono-weeding, the labour required for weeding could be reduced by 35 man-days ha^{-1} and labour cost by Rs. 3125 ha^{-1}. This study did not support the notion that the multiple SRI component practices act synergistically under humid tropics, implying that the yield benefits of SRI practices was inferior to that of the recommended management practices. SRI practices, however, gave better yield than the farmers' practices. On farm experiments revealed that planting one or two 15 to 20 day-old seedlings hill^{-1} at 20 x 15 cm spacing and employing cono-weeding and intermittent irrigation are economically feasible technologies. In general, the recommended practices outperformed SRI in the farmers' field trials, implying the need for sustained extension support for ensuring adoption of improved technologies.

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