System of Rice Intensification (SRI) in southeastern lowlands of Amazonia – a viable alternative for smallholder irrigated rice production?

Christoph Gehring[1]; Emanoel Gomes de Moura[1] ; Robert Michael Boddey[2]

[1] M.Sc. Program of Agroecology – Maranhão State University, E-mail: christophgehring@yahoo.com.br
[2] Embrapa – National Agrobiology Research Center

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Introduction

Since land shortage limits territorial expansion of agricultural activities, intensification of land-use will need to be the main mechanism of boosting food production and meeting the increasing food demands worldwide. With yields of up to 10 tons of grains per hectare, irrigated rice figures among the most intense forms of agricultural land-use and, thus, a valuable option for such an undertaking. Conventional irrigated rice production is, however, very demanding in a wide range of resources other than land, namely water, fertilizers, pesticides and – ultimately – money. The strain involved in such great resource-use intensity is high and can result in conflicting interests in water consumption, contamination of aquifers in environmentally sensitive lowland or riverine areas, or socioeconomic exclusion of smallholder farmers unable to cope with the required high levels of technology and financial input. Consequently, demand is urgent for development efforts in the field of irrigated rice technology to go beyond a one-sided approach of increasing productivity and rather likewise include aspects of increased resource-use efficiency.

The System of Rice Intensification (SRI) could constitute such a technological improvement, supposedly uniting significant reductions in water-, fertilizer- and pesticide consumption and associated financial costs with similar or even increased grain yields as compared to conventional irrigated rice management (Mishra et al., 2006; Sato & Uphoff, 2007; Stoop et al., 2002). This is achieved based on a radically differing philosophy on the basic concepts of irrigated rice production:

(i) Though wetland rice is well adapted to flooding, it prefers aerobic (though continuously moist) conditions. Moist rather than flooded conditions will benefit the root system, increase rooting depth and thereby improve nutrient extraction from the soil;

(ii) Initial plant development is of key importance for further development of rice plants and therefore merits special care; and

(iii) Radically lower plant densities reduce competition and thereby increase plant vigour and yield. Strongly increased individual plant grain yield overcompensates the lower plant densities and results in increased overall (per hectare) yields (Mishra et al., 2006).

As a consequence, management of SRI likewise differs radically from conventional irrigated rice management (Table 1).

Table 1. Management features of SRI as compared to conventional irrigated rice

	SRI	Conventional
Water regime	Constantly moist but aerobic	Continuously flooded
Planting regime	Careful transplanting of young seedlings	Direct seeding
Plant density	Low (i.e. 25 transplants per m^{2-1})	High (i.e., >500 seedlings m^{2-1}

Next to the question if SRI can really live up to the high grain yields postulated by its advocates (Latif et al. 2005), the practicability of such profoundly altered management is a further decisive factor for the viability of SRI. The following two issues have been criticised in this respect: (i) increased labour demand required for careful transplanting (at a stage of general labour limitation) and for the maintenance of constantly moist but aerobic conditions (Moser & Barrett, 2003), and (ii) increased weed infestation (and resulting increased labour and/or pesticide demand) due to the absence of weed control via flooding.

Methods

a) Study area

Research was conducted at an Embrapa research station in Arari county, in the lowlands of the Mearim river, Maranhão State, southeastern periphery of Amazonia. This region is subject to a dynamic expansion of irrigated rice agriculture, due to the favourable hydric conditions and the comparatively fertile alluvial soils. Expansion of irrigated rice is both positive in terms of agricultural intensification and income generation, and problematic environmentally (danger of contamination of the aquifer) and socioeconomically (danger of marginalisation of smallholder agriculture due to the high investments involved). This constellation motivated efforts of searching for innovations capable of increasing the sustainability of irrigated rice production.

Irrigated rice production takes place during the dry season (August – November) when the absence of rain and the proximity to the Mearin river ensure complete control of the water regime. Soils are relatively fertile silty of alluvial origin.

b) Experimental layout and management

The experimental layout is bi-factorial, we compare SRI and conventional irrigated rice management at 2 levels of N-input (200 kg N as cow manure and cow manure + additional 100 kg N as urea). No other fertilizers were added, nor was there the nescessity of any pesticide application.

The experiment was conducted in a completely randomized block design with 4 treatments and 4 replications, plot size was 52 m^2. Plots were separated from one another by approximately 2m wide drainage channels, thereby allowing for the maintenance of contrasting water-regimes in neighbouring plots.

c) Statistics

Data were analysed with Statistica 6.0 (Statsoft Inc.). All variables followed normal distribution (Kolmogorov-Smirnov and Lilliefor’s tests). We subsequently applied bi-factorial ANOVA (at the 5% level). Since fertilizer level had significant effects on all variables, we show significance levels of ANOVA for between system comparisons only.

Results and Discussion

Table 2 compares the key rice plant development parameters between SRI and Conventional Rice management at two levels of N-fertilization. Since N-fertilizer level had significant effects on all parameters, we only show the effects of rice management systems. Interactions between rice management system and N-fertilizer level were non-significant for al variables (data not shown).

Table 2. Comparison of key plant development parameters between SRI and Conventional Rice management at 2 levels of N-application (means ±SE)

	SRI		Conventional		System Significance[1)]
	Cow manure	Manure & urea	Cow manure	Manure & urea	
Aboveground biomass (t/ha)	3.63 (±0.4)	5.20 (±0.9)	6.33 (±0.5)	8.56 (±0.8)	***
Root biomass (t/ha)	0.90 (±0.1)	1.84 (±0.4)	1.29 (±0.1)	1.56 (±0.2)	n.s.
Plant height (m)	0.81 (±0.01)	0.91 (±0.01)	0.71 (±0.02)	0.86 (±0.03)	**
Stems / m^2	189 (±32)	266 (±26)	343 (±21)	400 (±38)	***
Stems / plant	11.8 (±2.0)	16.6 (±1.6)	0.8 (±0.1)	0.9 (±0.1)	***

1) significance levels of between system comparison within a bi-factorial ANOVA (system * fertilizer level): ***: $p<0.001$, **: $p<0.01$, n.s.: not significant.

Rice production was slightly, though significantly higher in conventional than in SRI treatments (4.4 vs 3.7 t / ha grains with manure and 6.2 vs 5.7 t / ha grains with manure + urea application). Plant biomass and 1000 grain weight were likewise higher in conventional than in SRI treatments. On the other hand, SRI did demonstrate its potential as management alternative, with a more vigorous root system and larger root biomass, with larger panicles, and with the lower plant density nearly compensated by the strong increase of the number of shoots per plant.

Table 3. Comparison of rice grain production parameters between SRI and Conventional Rice management at 2 levels of N-application (means ±SE)

	SRI		Conventional		System Significance[1)]
	Cow manure	Manure & urea	Cow manure	Manure & urea	
Grain yield (t/ha)	3.66 (±0.3)	5,72 (±0.4)	4.42 (±0.3)	6.24 (±0.1)	*
1000 grain weight (g)	21.2 (±0.3)	21.5 (±0.4)	23.0 (±0.2)	23.8 (±0.5)	***
Panicle size (cm)	24.3 (±0.3)	26.0 (±0.5)	21.0 (±0.7)	23.6 (±0.5)	***
Grains / panicle	166 (±5)	181 (±9)	108 (±11)	151 (±7)	***

1) significance levels of between system comparison within a bi-factorial ANOVA (system * fertilizer level): ***: $p<0.001$, **: $p<0.01$, *: $p<0.05$, n.s.: not significant.

Weed pressure was a serious problem associated with the lack of flooding in SRI, calling for the development of mechanical devices for weeding in SRI fields. In summary, the merely slightly lower productivity of SRI confirms its potential as a promising management alternative. Future R&D is needed and under way to investigate (i) altered nutrient dynamics under SRI conditions, (ii) the potential of SRI in other soils, (iii) the danger of greenhouse gas emissions associated with SRI, and (iv) better adapt SRI management to the local context.

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