Critiquing SRI criticism: beyond scepticism with empiricism

Amod K. Thakur

The system of rice intensification (SRI), developed in Madagascar, is based on a set of practices to manage plants, soil, water and nutrients that reduce seed requirement, save irrigation water, lower the costs of production, while enhancing crop yield. This makes irrigated rice cultivation more productive, profitable and sustainable. SRI has faced the criticism of a number of sceptics, despite growing popularity among farmers all over the world. In this article, various aspects of the published criticisms of SRI are reviewed and critically discussed to understand the disparity between scientific and farmer perspectives.

Keywords: Best management practices, criticism, debate, system of rice intensification.

DURING the last decade, the system of rice intensification (SRI) as an alternative method of rice cultivation has received considerable attention both in print as well as from farming communities. SRI consists of a set of management practices that were mainly developed through participatory on-farm experiments in the central highland of Madagascar in the 1980s. The management practices include: (i) transplanting young (8–15 days old) seedlings, (ii) widely spaced transplanting with one seedling per hill in a square pattern, (iii) application of compost or other organic amendments, (iv) intermittent irrigation before panicle initiation (PI) and shallow water management from PI to maturity, and (v) mechanical weed control starting 10 days after transplanting and continuing until the canopy closes[1]. SRI advocates have claimed that this approach would permit resource-poor farmers to attain high yields, even with infertile soil, without mineral fertilizer input and with reduced irrigation water and fewer seeds[1].

SRI controversy

In the literature available on SRI, on one side there are reports of rapid acceptance and significant benefits among farmers, while on the other side there is controversy among rice scientists regarding its reported superiority over standard rice cultivation practices. Dismissals of this innovation have prompted curiosity and criticism. An article in *Nature*[2] presented views of both proponents and detractors of SRI, acknowledging its growing popularity with the pointed question: who will eradicate hunger and poverty – SRI of Madagascar or modern agronomy laboratory?

SRI has been characterized as 'voodoo science,' said to be based on unconfirmed field observations (UFOs)[3], with the high yields reported being described as a 'consequence of measurement error'[4]. On the other hand, significantly large contributions to the literature have documented enhanced rice productivity[5–10], water saving[11] and higher returns with SRI management[12]. There has been enough farmer satisfaction with SRI that it has emerged as an alternative rice production system, showing benefits now in 39 countries around the world (http://ciifad.cornell.edu/sri).

Origins of the SRI controversy

Possibly some objections are raised against the origins of SRI emerging from farmers' fields in Madagascar, rather than from experimental stations, where measurements and documentation would have been more precise and framed in terms familiar to agronomists. That SRI was developed inductively, with no clear links to existing agricultural research has been an impediment, and sometimes it appears that this innovation is regarded as 'alien'. Initial criticisms of SRI came from many rice scientists[3,13,14] and they rejected the validity of reported yield increases, arguing that the energy requirements for achieving such high yields with SRI management are beyond the thermodynamic capabilities of plant photosynthesis and the crop's use of solar energy. They suggested that the reports of remarkable SRI performance reflected some misunderstanding of the processes of plant growth and yield.

Amod K. Thakur is in the Directorate of Water Management (ICAR), Chandrasekharpur, Bhubaneswar 751 023, India.
e-mail: amod_wtcer@yahoo.com

Shortcomings in comparisons between SRI and other rice production systems

A negative commentary on SRI[14] points out that it uses very low plant densities necessarily leading to poor light interception and that high plant density is needed for maximum light interception, plant growth and crop yield. This explanation makes certain assumptions about the relationship between plant density, light interception and grain yield that are amenable to empirical evaluation, however. Our study[9] has found that, in fact, higher plant density may not achieve greater light interception and therefore does not necessarily translate into higher grain yield. It does create higher competition below and above ground, for nutrients, space and light, especially in the later stages of growth. This contributes to reductions in leaf size, panicle size, grain number and grain weight. Resulting grain yield is accordingly reduced, as in direct-seeding or broadcast methods of crop establishment.

For any system of rice cultivation to achieve higher grain yield, the relationship among plant density, tiller number, leaf area index, leaf angle and light interception need to be optimized. SRI practices through optimum spacing attempt to minimize competition among rice plants for the various growth factors. They are as a consequence associated with higher leaf area index at flowering, more favourable canopy architecture, and achievement of greater light interception, even with a reduced number of plants per sq. metre.

Critics of SRI have also maintained that the standard practice of continuous flooding of paddy fields results in high yields[14]. Flooded paddy field certainly ensures water availability and helps in reducing weed emergence, but this by itself does not maximize rice yields. However, many reports have indicated that, compared to the flooding of fields with conventional methods, reduced water applications through saturated soil culture treatment or alternate wetting and drying (AWD) have little or no adverse impact on grain yield[15–18]. Indeed, some researchers have reported yield increases using AWD method[6].

It is well documented that moist field conditions and AWD improves root development[19,20], reduce crop lodging, and provide better soil aeration[15]. Replacing conventional flooding of paddy fields with maintenance of moist soil conditions or irrigating by AWD methods under SRI practice can enhance rice yield due to the aforesaid advantages in addition to saving water. Precise control on irrigation water is always required for best results from SRI method. Thus, risk associated with water-saving irrigation, such as uncertainty about the timing and amount of water release for irrigation sometimes may affect SRI adoption adversely[7].

In a previous assessment, synergistic effects of SRI practices with AWD were not observed[21], and rice yield under SRI management in their trials were reduced. However, these trials were conducted on salt-affected soils, and it is well known that reduction in irrigation water (AWD) in saline soils creates unfavourable conditions for plant growth through increased salt concentrations[22]. So these negative results are to be expected and do not invalidate SRI methods for the majority of soils.

One of the experimental reports[4], characterized as 'classical research' by some rice scientists[3,14], has been presented as sufficient evidence to discard the claim that there can be any yield advantage from SRI management. This experiment was conducted on three small plots in different locations in China to evaluate the efficacy of SRI and found no significant yield advantage in SRI over 'best management practices' (BMPs). However, average SRI yield from the three locations was a bit higher than that from BMPs, even though the protocol followed deviated in evident ways from that specified by SRI proponents[23].

In these trials[4], they used excessive applications of mineral fertilizers (180–240 kg N ha^{-1}). Such excessive applications of synthetic fertilizer negate the SRI objective of maximizing the contributions of soil biota to crop productivity. Recent findings have shown that optimizing fertilizer N application rates under SRI is important to increase yield and highest N application (240 kg ha^{-1}) was associated with decrease in grain yield[10]. Also, there was no active soil aeration with a rotating hoe or cono-weeder as recommended in SRI practice. Herbicides were used instead. The yield from SRI methods should have been considerably higher if one of the three SRI plots had not partially lodged because of the over-application of N fertilizer. So the results of these three small plots provide no reliable empirical basis for concluding that SRI methods can have 'no major role in improving rice production generally'.

SRI versus BMP

Recently, the focus of the SRI debate has been redirected toward comparative assessment of SRI performance with available BMPs[24,25]. It has been argued that significant yield advantages for SRI over BMPs are yet to be documented experimentally[24], except for certain Madagascar trials reported earlier[26]. This raises the question whether the data sets being compared are indeed representative of the alternative management systems. It has been pointed out that there is not enough information on the respective trials to know whether they met the respective criteria for SRI and BMP, citing a number of instances where the data used in the analysis clearly did not meet the authors' own criteria[25].

The broader issue is whether it is justified to compare two systems which are based on different philosophies and agronomic management principles with different target groups of farmers simply in terms of yield[25]. Considerations such as productivity of irrigation water (kg of rice produced m^{-3}) and water saving, labour requirements and labour saving, profitability, and impact on soil and water quality are also relevant. Further, before comparing SRI with BMPs – rather than with farmers' prevalent practices of rice cultivation – one should consider why so many millions of farmers in Asian countries have not adopted or are not following the scientists' recommended BMPs. What constitute BMPs will vary from site-to-site in any case, influenced by factors like local soil fertility status, variety used, socio-economic status of the farmers, and much more. The cost and availability of 'improved' inputs often constitutes a barrier to adoption even if the recommended technology is appropriate for local conditions. So it is most relevant to evaluate and compare SRI vis-à-vis current farmers' practice.

Scientific relevance of the critiques on SRI versus BMP

The conclusion of a few rice scientists[4,27] that BMP outperformed SRI practices in the reported trials is not really supported by their data. In one of the experiments[4], the SRI plants spaced at 30×30 cm (11 hills m^{-2}) surpassed the yield levels of conventional system (25 hills m^{-2}) in one out of the three cases. The range of SRI yields was 6.70–9.86 t ha^{-1} versus 7.22–9.08 t ha^{-1} for conventional practice. Although this difference was not significant statistically, it showed that less than half the number of plants under SRI management could produce grain yield equal to conventionally transplanted rice. Another report[27] showed that grain yield using practices recommended by the Bangladesh Rice Research Institute (BRRI) (7.64 t ha^{-1}) surpassed yield from SRI practices (7.11 t ha^{-1}) in on-station experiments. However, these comparisons were again between 11 hills m^{-2} with SRI and 26 hills per sq. metre with BMP. Both the trials confirmed that SRI practices improved the productivity of individual hills (plants), but yield per unit area with SRI methods in these trials was not superior, given fewer plants per sq. metre. The benefits from the other SRI components (younger seedlings, aerobic soil conditions, active soil aeration) was masked by using wider spacing (i.e. 30×30 cm) than normally recommended under SRI management[1]. When farmers are introduced to SRI, unless their soil is evidently very fertile, they are advised to start with 25×25 cm spacing and to experiment with wider (e.g. 30×30 cm) and narrower (e.g. 20×20 cm) spacing to determine whether – for their soil, climatic and other conditions – sparser or denser spacing will improve upon the initial spacing used. Perhaps even 20×20 cm could be the optimal inter-plant spacing for the soils/variety on which the trials were done. Many reports on SRI has shown highest grain yield with spacing of 20×20 cm for their soil and variety[6,7,9]. Thus, in any case, arbitrarily using a single spacing to evaluate the merits of the whole set of practices is not valid.

Evidence used for criticism

One of the recent critical papers on SRI published in Field Crops Research (FCR) cited 'other evidence' as supporting its conclusion that SRI does not increase yield[24]. However, these claims, as seen here, warrant close scrutiny.

The commentary in this paper on results from an experiment conducted at Nepal[28] incorrectly states that 'SRI at wider spacing (30×30 cm) had lower grain yield (5.0 t ha^{-1}) than the conventional system with manual weeding, which had mean grain yield of 6.6 t ha^{-1}'. In fact, in the latter trial, SRI with 30×30 cm spacing and manual weeding produced the highest grain yield (6.8 t ha^{-1}), while conventional practice at spacing of 20×20 cm gave 5.1 t ha^{-1} although it was reported[24] as 6.6 t ha^{-1}. Moreover, this experiment[28] also reported that the highest grain yield under SRI – at spacing of 20×20 cm combined with manual weed control (8.8 t ha^{-1}) – was obtained on a nearby farmer's field. Admittedly, the experimental results at Nepal had certain weaknesses like being single-season data, and the distinct effects of mode of weeding on grain yield remained unexplained. Several papers on SRI have clearly emphasized the role of mechanical weeding in enhancing soil aeration which leads to increased grain yield[11]. Under the present scenario of costly manual labour and its limited availability, there is a need to develop low-cost weeders, which can be used by readily available women's labour; and to make it easily available for carrying out weed management in SRI fields.

Another study conducted at West African Rice Development Association (WARDA) centre in West Africa[29] comparing SRI with BMPs was also cited in this paper[24] as support for their conclusion that SRI does not enhance rice yield, was also prematurely interpreted. The conventional system in comparisons reported[29] out-yielded SRI by 48% and 21% in the first two seasons only because of lack of proper control of water regime and the top dressing with nitrogen fertilizer of the SRI treatments. Subsequently, with improved control over water management and with standardized fertilizer applications, the yield advantage in BMPs was reduced to 8% in 2001 dry season and 2.5% in wet season, neither difference being significant. It was concluded in the African experiment that moist but aerated soil conditions with SRI management created favourable pre-conditions for increased grain yields because of extended vegetative phase of crop growth, and this low-external-input, environmental-friendly technology could help farmers to make gains in factor productivity and grain yield. By reporting only the 48% deficit in SRI yields when its methods had not been properly used, and by overlooking the non-significant 2.5% difference when SRI methods were more correctly used (and not considering the resource savings that these methods permitted), the authors[24] defended their dismissal of SRI potential to help farmers achieve substantial and cost-effective yield improvements in rice production through better use of SRI practices for water and nutrient management.

A study conducted in West Bengal compared SRI with farmer practices[12], where some of the SRI methods were not properly followed by the farmers, like precise water control (these farmers practised a rainfed version of SRI), application of organic manure (some farmers applied only mineral fertilizers), and adopting mechanical weeding. These points were used as evidence against the value of SRI concepts and practices. Yet, despite these deviations from best SRI practice, average yield benefits of 32% was achieved with SRI compared to farmers' present practices (and this was in one of the two village areas surveyed experiencing severe drought, which was better resisted by SRI-grown plants). Thus, the merits of the study[12] conducted under the auspices of the International Water Management Institute's India programme, which highlighted the potential benefits of SRI methods for resource-limited, mostly tribal farmers were buried under the stilted argument. Achieving benefits by using many if not all of the SRI-recommended practices should not be considered as a disqualification for the full set of recommendations. It is not always possible to implement all the SRI components at the same time in the fields.

This article ascribed the superior grain yields reported in the experiments conducted by Tamil Nadu Agricultural University (TNAU) researchers[11] as due to a combination of younger seedlings with conventional irrigation, and not to SRI water management. However, in these experiments, SRI planting methods as a whole produced higher grain yield under both irrigation methods (flooding as well as SRI irrigation) compared to conventional planting method. This indicated superiority of SRI over conventional techniques irrespective of irrigation methods, not inferior performance. However, the impact of SRI irrigation management in these TNAU experiments was below the level expected because some previous literature had suggested that reduced-irrigation methods are better for root development[30] and save water [30,31] compared to conventional continuous flooding method. Further, TNAU evaluations showed advantages from both using younger seedlings and SRI water management.

Thus, the experimental evidence referred in this recent publication in FCR[24] to support their conclusion – that SRI does not offer any advantage in terms of grain yield of rice and has little to offer beyond what is already known by rice scientists – has misinterpreted the evidence cited to dismiss the advantages of SRI practice.

Scientific basis for some of the SRI practices

Recommendation of transplanting single, young seedlings at wide spacing has many advantages, as a recent publication confirms that hills containing single plants had a greater number of crown roots compared to hills produced from three plants[32]. Well-developed root systems of hills from single plants enhance the synthesis of cytokinins[32,33] and also maintain higher cytokinin fluxes from roots to shoot during the ripening stage, which helps to maintain higher levels of Rubisco in the leaves and a greater photosynthesis rate compared with three plants in each hill[34].

The highly efficient photosynthetic performance of super high-yielding rice in China is largely due to the increased cytokinin content in their roots, contributing to higher grain yield[35]. The use of single seedlings with optimally wide spacing in SRI practice can produce greater root growth[11], which in turn is associated with enhanced cytokinin flux and delayed senescence of the lower leaves. This helps to maintain the photosynthetic efficiency of the plant at later growth stages compared to conventional practice[36]. Such physiological changes in SRI plants could be one of the reasons for the better grain filling and higher grain yield seen with SRI methods.

The use of younger seedlings with SRI contributes to better root and shoots characteristics with greater uptake of nitrogen and manganese than is found with older seedlings[37]. This provides specific evidence to explain some of the benefits of this element of SRI practice. Other reports have also showed higher grain yields obtained with the use of younger seedlings than from older ones[21,38]. The overall advantage of SRI practices on phenotype and physiology of rice plants, in terms of root growth, canopy development, rapid tillering, light interception and its utilization for photosynthesis and grain yield, has clearly been shown compared with conventional scientific practices[39].

But clearly the body of scientific knowledge necessary to evaluate and refine SRI methods is not yet sufficient or complete. The insights and principles for attaining higher yield gathered under the rubric of SRI methodology deserve more and continuing attention by researchers to fill in fundamental knowledge gaps and to address the synergies of individual SRI components for diverse rice ecologies and production systems[40]. It is quite convincing that there are no shortcuts to achieving increased, sustainable crop yield. Hence comprehending the complexity of plant growth and yield under SRI management needs further critical appraisal through detailed research[14].

Concluding remarks

At this juncture of SRI research and its dissemination to farmers' fields, the benefits of higher grain yield and greater productivity of inputs with SRI practice are well-documented. The rice research establishments in India, China, Indonesia and Vietnam, where about two-thirds of the world's rice is produced, have done their own evaluations of SRI and have found merit in them. Some critiques[41] have explicitly accepted that SRI prastices have substantial advantages over farmers' prastices in rice production, but then deflected the discussion by invoking vaguely-defined BMPs as a standard of comparison that has little relevance to the majority of the world's rice farmers.

The anticipation that SRI will slip into obscurity[13] is proving false as there are around 1–1.5 million farmers who have adopted SRI. It is time for rice researchers around the globe to direct their intelligence and knowledge toward refinement of this innovation through critical research that can bring in a greener green revolution, addressing the question raised by Surridge[2], whether or to what extent SRI methods and insights can substantially reduce hunger and poverty.

1. Stoop, W. A., Uphoff, N. and Kassam, A., A review of agricultural research issue raised by the system of rice intensification (SRI) from Madagascar: opportunities for improving system for resource poor farmers. *Agric. Syst*., 2002, **71**, 249–274.
2. Surridge, C., Feast or famine? *Nature*, 2004, **428**, 360–361.
3. Sinclair, T. R. and Cassman, K. G., Agronomic UFOs. *Field Crops Res*., 2004, **88**, 9–10.
4. Sheehy, J. E. *et al.*, Fantastic yields in the system of rice intensification: fact or fallacy? *Field Crops Res.*, 2004, **88**, 1–8.
5. Uphoff, N., Higher yields with fewer external inputs? The system of rice intensification and potential contributions to agricultural sustainability. *Int. J. Agric. Sustain*., 2003, **1**, 38–50.
6. Ceesay, M., Reid, W. S., Fernandes, E. C. M. and Uphoff, N., The effects of repeated soil wetting and drying on lowland rice yield with system of rice intensification (SRI) methods. *Int. J. Agric. Sustain.*, 2006, **4**, 5–14.
7. Senthilkumar, K., Bindraban, P. S., Thiyagarajan, T. M., Ridder, N. and Giller, K. E., Modified rice cultivation in Tamil Nadu, India: yield gains and farmers' (lack of) acceptance. *Agric. Syst.*, 2008, **98**, 82–94.
8. Namara, R., Bossio, D., Weligamage, P. and Herath, I., The practice and effects of the system of rice intensification (SRI) in Sri Lanka. *Quart. J. Int. Agric*., 2008, **47**, 5–23.
9. Thakur, A. K., Choudhari, S. K., Singh, R. and Kumar, A., Performance of rice varieties at different spacing grown by the system of rice intensification in eastern India. *Indian J. Agr. Sci*., 2009, **79**, 443–447.
10. Zhao, L., Wu, L., Li, Y. S., Lu, X. H., Zhu, D. F. and Uphoff, N., Influence of the system of rice intensification on rice yield and nitrogen and water use efficiency with different application rates. *Expl. Agric*., 2009, **45**, 275–286.
11. Satyanarayana, A., Thiyagarajan, T. M. and Uphoff, N., Opportunities for water saving with higher yield from the system of rice intensification. *Irrig. Sci*., 2007, **25**, 99–115.
12. Sinha, S. K. and Talati, J., Productivity impacts of the system of rice intensification (SRI): a case study in West Bengal, India. *Agric. Water Manage*., 2007, **87**, 55–60.
13. Sheehy, J. E., Sinclair, T. R. and Cassman, K. G., Curiosities, nonsense, non-science and SRI. *Field Crops Res*., 2005, **91**, 355–356.
14. Sinclair, T. R., Agronomic UFOs waste valuable scientific resources. *Rice Today*, 2004, **3**, 43.
15. Bouman, B. A. M. and Tuong, T. P., Field water management to save water and increase its productivity in irrigated rice. *Agric. Water Manage*., 2001, **49**, 11–30.
16. Tabbal, D. F., Bouman, B. A. M., Bhuiyan, S. I., Sibayan, E. B. and Sattar, M. A., On-farm strategies for reducing water input in irrigated rice: case studies in the Philippines. *Agric. Water Manage*., 2002, **56**, 93–112.
17. Belder, P. *et al*., Effect of water and nitrogen management on water use and yield of irrigated rice. *Agric. Water Manage*., 2004, **65**, 193–210.
18. Cabangon, R. J. *et al*., Effect of irrigation method and N-fertilizer management on rice yield, water productivity and nutrient-use efficiencies in typical lowland rice conditions in China. *Rice Field Water Environ*., 2004, **2**, 195–206.
19. Zhang, H., Xue, Y., Wang, Z., Yang, J. and Zhang, J., An alternate wetting and moderate soil drying regime improves root and shoot growth in rice. *Crop Sci*., 2009, **49**, 2246–2260.
20. Yang, C., Yang, L., Yang, Y. and Ouyang, Z., Rice root growth and nutrient uptake as influenced by organic manure in continuously and alternately flooded paddy soils. *Agric. Water Manage.*, 2004, **70**, 67–81.
21. Menete, M. Z. L., van Es, H. M., Brito, R. M. L., DeGloria, S. D. and Famba, S., Evaluation of system of rice intensification (SRI) component practices and their synergies on salt-affected soils. *Field Crops Res*., 2008, **109**, 34–44.
22. Scardaci, S. C., Shannon, M. C., Grattan, S. R., Eke, A., Roberts, S. R., Goldman-Smith, S. and Hill, J., Water management practices can affect salinity in rice fields. *Calif. Agric*., 2002, **56**, 184–188.
23. Stoop, W. A. and Kassam, A., The SRI controversy: a response. *Field Crops Res*., 2005, **91**, 357–360.
24. McDonald, A. J., Hobbs, P. R. and Riha, S. J., Stubborn facts: still no evidence that the system of rice intensification out-yields best management practices (BMPs) beyond Madagascar. *Field Crops Res*., 2008, **108**, 188–191.
25. Uphoff, N., Kassam, A. and Stoop, W., A critical assessment of a desk study comparing crop production systems: the example of the 'system of rice intensification' versus 'best management practice'. *Field Crops Res*., 2008, **108**, 109–114.
26. Uphoff, N., Agroecological implications of the system of rice intensification (SRI) in Madagascar. *Environ. Develop. Sustain*., 1999, **1**, 297–313.
27. Latif, M. A., Islam, M. R., Ali, M. Y. and Saleque, M. A., Validation of the system of rice intensification (SRI) in Bangladesh. *Field Crops Res*., 2005, **93**, 281–292.
28. Neupane, R. B., System of rice intensification (SRI) – a new method of rice cultivation. National Wheat Research Programme, Bhairawa, Nepal, 2003; http://ciifad.cornell.edu/sri/countries/nepal/nepbhrep.pdf
29. Stoop, W. A., The system of rice intensification (SRI): results from exploratory field research in Ivory Coast – research needs and prospects for adaptation to diverse production systems of resource-poor farmers. West African Rice Development Association, WARDA, Ivory Coast, 2005, p. 27; http://ciifad.cornell.edu/sri/Stoopwarda05.pdf
30. Bouman, B. A. M., Lampayan, R. M. and Tuong, T. P., *Water Management in Irrigated Rice: Coping with Water Scarcity*, International Rice Research Institute, Los Baños, Philippines, 2007, pp. 54.
31. Guerra, L. C., Bhuiyan, S. I., Thuong, T. P. and Barker, R., Producing more rice with less water in irrigated systems, SWIM Paper No. 5, International Water Management Institute, Colombo, 1989.
32. San-oh, Y., Mano, Y., Ookawa, T. and Hirasawa, T., Comparison of dry matter production and associated characteristics between direct-sown and transplanted rice plants in a submerged paddy field and relationships to planting patterns. *Field Crops Res*., 2004, **87**, 43–58.
33. Soejima, H., Sugiyama, T. and Ishihara, K., Changes in the chlorophyll contents of leaves and in levels of cytokinins in root exudates during ripening of rice cultivars Nipponbare and Akenohoshi. *Plant Cell Physiol*., 1995, **36**, 1105–1114.

34. San-oh, Y., Sugiyama, T., Yoshita, D., Ookawa, T. and Hirasawa, T., The effect of planting pattern on the rate of photosynthesis and related processes during ripening in rice plants. *Field Crops Res.*, 2006, **96**, 113–124.
35. Shu-Qing, C., Rong-Xian, Z., Wei, L., Zhi-Rui, D. and Qi-Ming, Z., The involvement of cytokinin and abscisic acid levels in roots in the regulation of photosynthesis function in flag leaves during grain filling in super high-yielding rice (*Oryza sativa*). *J. Agron. Crop Sci*., 2004, **190**, 73–80.
36. Mishra, A., Whitten, M., Ketelaar, J. W. and Salokhe, V. M., The system of rice intensification (SRI): a challenge for science, and an opportunity for farmers empowerment towards sustainable agriculture. *Int. J. Agric. Sustain*., 2006, **4**, 193–212.
37. Mishra, A. and Salokhe, V. M., Seedling characteristics and early growth of transplanted rice under different water regimes. *Expl. Agric*., 2008, **44**, 1–19.
38. Pasuquin, E., Lafarge, T. and Tubana, B., Transplanting young seedlings in irrigated rice fields: early and high tiller production enhanced grain yield. *Field Crops Res*., 2008, **105**, 141–155.
39. Thakur, A. K., Uphoff, N. and Antony, E., An assessment of physiological effects of system of rice intensification (SRI) practices compared with recommended rice cultivation practices in India. *Expl. Agric*., 2010, **46**, 77–98.
40. Dobermann, A., A critical assessment of the system of rice intensification (SRI). *Agric. Syst*., 2004, **79**, 261–281.
41. McDonald, A. J., Hobbs, P. R. and Riha, S. J., Does the system of rice intensification outperform conventional best management? A synopsis of the empirical record. *Field Crops Res*., 2006, **96**, 31–36.

ACKNOWLEDGEMENTS. I thank Prof. Norman Uphoff, Cornell International Institute for Food, Agriculture and Development, Ithaca, USA and Dr Willem A. Stoop, former staff member and consultant for West African Rice Development Association (WARDA), for reviewing the draft of this manuscript and offering useful comments.

Received 11 September 2009; revised accepted 15 April 2010