Identification of the critical factors of System of Rice Intensification (SRI) for maximizing Boro rice yield in Bangladesh

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Abstract
Field experiments were conducted at the Bangladesh Rice Research Institute (BRRI) research farm, Gazipur, during 2007-2011 with a view to investigate the effects of the critical factors of SRI on the yield performance of irrigated *Boro* rice cv. BRRI dhan29. The highest grain yield in the first round of trials (7.80 tha^{-1}) was obtained when the crop was transplanted on 30 November using 12-day-old seedlings followed by 15 December (7.71 tha^{-1}) under SRI. Earlier and later transplanting gave lower yield with SRI methods. Grain yields of 7.82 tha^{-1} and 7.90 tha^{-1} were achieved in 2008 and 2009, respectively, under SRI irrigation regime combined with three times weeding/soil stirring at 20, 35 and 45 days after transplanting (DAT). Higher grain yields (8.44 tha^{-1} in 2008 and 8.52 tha^{-1} in 2009) were recorded from the application of 10 tha^{-1} of cow dung manure + 100% of the recommended inorganic fertilizer (RF) together with three times weeding/soil stirring. The wider-spacing treatments of 30cm × 25cm and 30cm × 30cm in 2008 were found to be essentially the same, with grain yields of 8.45 tha^{-1} and 8.40 tha^{-1}, respectively, when used with 12-day-old seedlings raised from a compost bed nursery. It was observed that the best performing SRI treatment was with wider spacing (30cm × 25cm), SRI irrigation schedule, younger seedlings (12 days old) raised in a compost bed, with 3 times weeding/soil stirring, and 10 tha^{-1} of cow dung manure + 100% RF. These produced the highest grain yield (10.17 tha^{-1}), which was 93% higher than the yield of 5.27 tha^{-1} obtained at the same time from the treatments that used BRRI recommended practices.

Key words
Soil stirring, SRI irrigation, Seedling age, Time of planting, Spacing, Manure.

Introduction

Rice is cultivated in 10.37 million hectares of land in Bangladesh, and the production is about 25.15 million tons, with an average yield of 4.4 tha^{-1} (BBS, 2006; IRRI, 2015). This yield level is well below that of many other rice-growing countries such as China, Japan, Korea and Egypt with yields of 6.8, 6.7, 7.5 and 10.10 tha^{-1}, respectively (IRRI, 2015).

The System of Rice Intensification - in French, called le Système de Riziculture Intensive; referred to as SRI in English and French and as SICA in Spanish -- is quite literally a "system" rather than a "technology" because it is not a fixed set of practices. The specific practices recommended for SRI should always be tested and verified according to local conditions rather than simply adopted (Uphoff et al, 2002).

The basic elements of SRI are transplanting younger seedlings quickly, carefully and shallow; wide spacing between plants so that roots and canopy have more room to grow; water management which keeps the soil moist but not continuously flooded; control of weeds by a mechanical weeder which aerates the soil as well as buries weeds in the soil as green manure; and increased applications of manure, compost or other organic matter to improve soil structure as well as functioning. These practices together promote larger, healthier and long-lived root systems and more abundant communities of beneefficial soil organisms.

This new approach for increasing rice yield was first developed in Madagascar by Fr. Henri de Laulanié, S.J., who worked with Malagasy farmers during 1961 and 1995 to explore the possibilities of enhanced rice production in that country (Laulanié, 1993). SRI is not a fixed package, but rather a set of principles translated into modifications of common practice for raising the productivity of all of the factors involved in rice production: land, labour, capital, seed, and water.

The System of Rice Intensification (SRI) methodology has been reported to have a high production potential in the *Boro* season in comparison with currently recommended practices, farmer practices, the seedling-throwing method, and use of a drum seeder in the light textured soils of Bangladesh (Sarker *et al.*, 2007). However, systematic evaluations need to be undertaken to gain an understanding of the principles underlying the higher productivity of SRI methods and how they under specified agro-ecological conditions. This has not been done previously in Bangladesh. So, the results of a detailed, multi-year study of the respective factors in their possible combinations at a given environmental site like that of the BRRI at Gazipur are worth examining.

Materials and Methods

A total of nine field experiments were conducted at the BRRI experimental farm at Gazipur to find out what are the critical factors of System of Rice Intensification (SRI) and what are their values for maximizing Boro rice yield in Bangladesh. Experiments no. 1, 2, 3 and 4 were conducted during Boro 2007-08 (November through May) and these were repeated as experiments no. 5, 6, 7 and 8 during Boro 2008-09 to fulfill the objectives of the study. The location of the experimental site was between 23˚59'23.03'' N latitude and 90˚24'19.38'' E longitude, at a mean elevation of 49 ft above sea level. The site belongs to the agro-ecological region of Madhupur Tract. The mean annual precipitation is 2039 mm. The mean annual temperature is 25.7˚C, with a mean maximum temperature of 30.4˚C and a mean minimum temperature of 21.1˚C. The day length ranges from 10.7 to 13.7 hours.

Description of the Experiments: Expts. 1 & 5 were aimed to investigate the effects of crop establishment time and of seedling age on crop performance of *Boro* rice under SRI management. Six planting times along with four seedling ages were evaluated. Expts. 2 & 6 aimed to investigate the effects of irrigation water management and of soil stirring on the performance of *Boro* rice. Six water managements along with four stirring treatments were evaluated. Expts. 3 & 7 were conducted to find out the effects of organic and inorganic fertilizers along with soil stirring on crop performance of Boro rice under SRI practices. Eight fertilizer and manure treatments along with three soil stirrings were tested. Expts.4 & 8 were planned to investigate the effects of spacing and seedling-raising method on the crop performance of Boro rice along with other SRI management practices. Six spacing treatments together with four seedling-raising methods were evaluated. In Experiment 9, a final comparison was made in Boro season 2010-11 whereby the best-performing SRI factors that hads emerged out of the previous 8 trials were tested against the BRRI-recommended *Boro* rice production system.

A total of 32 treatments under five factors were evaluated. ***Factor A: Two irrigations (I),*** I_1= BRRI recommended water management, i.e., 5-7 cm depth irrigation followed by further irrigations at 3 days after disappearance of water from the soil; this irrigation was continued up to PI stage, after which 5- 7 cm standing water was kept up to the hard dough stage; and I_2= SRI water management, 2-3 cm depth of water added during irrigation time just for soaking the soils, with further irrigation added 3 days after disappearance of water from the soil; this irrigation was continued up to panicle initiation (PI) stage, when 5-7 cm standing water wre maintained up to hard dough stage; this was selected for expts. 2 & 6. ***Factor B: Two manure and fertilizer treatments (N),*** N_1= manure @10 tha^{-1} + 50% of the recommended inorganic fertilizers; and N_2= manure @10 tha^{-1} + 100% of the recommended inorganic fertilizers (100% inorganic recommended fertilizer was 250-80-100-10 kgha^{-1} of N-P_2O_5-K_2O-S, respectively). ***Factor C: Two spacings (S),*** S_1= recommended spacing as per BRRI (20 x 20 cm); and S_2= best-performing spacing in SRI (30 x 25 cm). ***Factor D: Two seedling ages (A),*** A1= 40-day-old seedlings; and A2= 12-day-old seedlings. ***Factor E: Two weedingss/soil stirringss (M),*** M_1= no stirrings; and M_2= three stirrings, at 15, 35 and 45 DAT. The experiments were laid out in a split-split plot design with three replications and all the treatments were kept weed free by manualy.

Results

From Expts. 1 & 5, the best-performing transplanting time was found to be either 30 November or 15 December with 12-day-old seedlings (Fig. 1). Earlier and later plantings performed less well. Selected best-performing treatment of Expts. 2 & 6 was SRI water management with three stirrings at 15, 30 and 45 DAT (Fig. 2). The best-performing SRI treatment from Expts. 3 & 7 was 10 tha^{-1} of manure + 100% of the recommended inorganic fertilizer treatment interacting with three stirrings at 15, 30 and 45 DAT (Fig. 3). From Expts. 4 & 8 the selected best-performing treatment was wider spacing of 30 × 25 cm when 12-day-old seedlings was raised from the compost-bed method (Fig. 4).

In Experiment 9 in the 2010-11 *Boro* season, higher grain yield increase was observed when SRI practices relating to irrigation, weeding/soil stirring, spacing, and seedling age interacted, in comparison with the presently recommended practices (Table 1). It was observed that wider spacing (S_2), SRI irrigation method (I_2), younger seedling age (A_2), three soil stirrings (M_2), and 10 t ha^{-1} compost with recommended inorganic fertilizers (N_2) resulted in higher grain yield than the present recommendations for spacing (S_1), irrigation method (I_2), older seedlings (A_1), and no stirring (M_1).

The highest grain yield (10.17 t ha^{-1}) was obtained from the treatment $S_2A_2M_2I_2N_2$ where all selected best SRI principles were collectively interacting, followed by the treatment $S_2A_2M_2I_1N_2$ (9.43 t ha^{-1}) where also all the selected best SRI practices were performed together but irrigation management was different. Also it was better than the treatment $S_2A_1M_2I_2N_2$ (7.97 t ha^{-1}), where also all SRI practices except seedling age were performed together. It is also observed that nutrient management N_1, that is applying manure @ 10 t/ha + 50% of the recommended inorganic fertilizer treatment had always a significantly negative affect compared to nutrient management N_2, that is manure @ 10 t/ha + 100% of the recommended inorganic fertilizer management treatment in respect of all the other tested factors combinations. This occurred due to less amount of nutrient which did not fulfill the plants' requirements and it also may have affected the soil's fertility status in terms of supportive biological activity.

Grain yield results showed that nutriment management had a highly significant interaction with spacing and seedling age. Higher grain yield was recorded when N_2 nutrient management treatment interacted with more of of the SRI factor treatments. It is observed that grain yield of BRRI dhan29 was significantly affected by nutrient management interactions with irrigation and stirring treatments. In all aspects of irrigation and stirring treatments, N_2 nutrient management produced higher grain yield than N_1 nutrient management.

Conclusions

Based on the study, it may be concluded that integration of the best-performing SRI cultural factors may be recommended for maximization of *Boro* rice yield for a long-duration variety like BRRI Dhan29 in Bangladesh. The following best-performing SRI cultural factors are to be considered: 1. Transplanting should be done during the period from 30 November to 15 December. 2. Younger seedlings of 12-days age, preferably raised in compost bed, should be used for transplanting. 3. Transplanting may be done with wider spacing of 30cm × 25 cm than at present. 4. SRI irrigation management should be followed. 5. Soil stirrings at 15, 30 and 45 DAT may enhance the productivity irrigated rice. 6. Only BRRI-recommended fertilizer applications are not enough for maximizing grain yield with SRI techniques. Integrated use of fertilizer and manure at 10 t ha^{-1} manure along with recommended rate of inorganic fertilizers would enhance the productivity.

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Table 1: Effect of selected factors of System of Rice Intensification (SRI) techniques in comparison with existing recommended practices on grain yield (tha^{-1}) of BRRI dhan29 in *Boro* season.

Sub Plot (Spacing × Seedling Age)	**Main Plot** (Irrigation × Stirring)	**Sub-sub plot (**Nutrient management**)**		
		N_1	**N_2**	**Differences**
	$A_1 = M_1I_1$			
$B_1 = S_1A_1$	M_1I_1	5.27 c	5.85 b	-0.58 *
$B_2 = S_1A_2$	M_1I_1	5.62 b	6.72 b	-0.81 *
$B_3 = S_2A_1$	M_1I_1	6.04 ab	6.74 b	-0.70 *
$B_4 = S_2A_2$	M_1I_1	6.65 a	7.39 a	-0.74 *
	$A_2 = M_1I_2$			
$B_1 = S_1A_1$	M_1I_2	6.00 b	6.57 c	-0.57 *
$B_2 = S_1A_2$	M_1I_2	6.28 b	6.93 bc	-0.65 *
$B_3 = S_2A_1$	M_1I_2	6.82 a	7.65 ab	-0. 83 *
$B_4 = S_2A_2$	M_1I_2	7.08 a	7.79 a	-0.71 *
	$A_3 = M_2I_1$			
$B_1 = S_1A_1$	M_2I_1	5.54 c	6.26 c	-0.72 *
$B_2 = S_1A_2$	M_2I_1	6.39 b	7.48 b	-1.08 **
$B_3 = S_2A_1$	M_2I_1	6.25 bc	7.83 b	-1.58 **
$B_4 = S_2A_2$	M_2I_1	7.72 a	9.43 a	-1.71 **
	$A_4 = M_2I_2$			
$B_1 = S_1A_1$	M_2I_2	5.87 c	6.62 c	-0. 75 *
$B_2 = S_1A_2$	M_2I_2	7.03 b	7.84 b	-0.81 *
$B_3 = S_2A_1$	M_2I_2	6.63 b	7.97 b	-1.35 **
$B_4 = S_2A_2$	M_2I_2	7.87 a	10.17 a	-2.30 **

** = significant at 1% level, * = significant at 5% level, ns = not significant

In a column under each A, means followed by a common letters are not significantly different at the 5% level by DMRT.

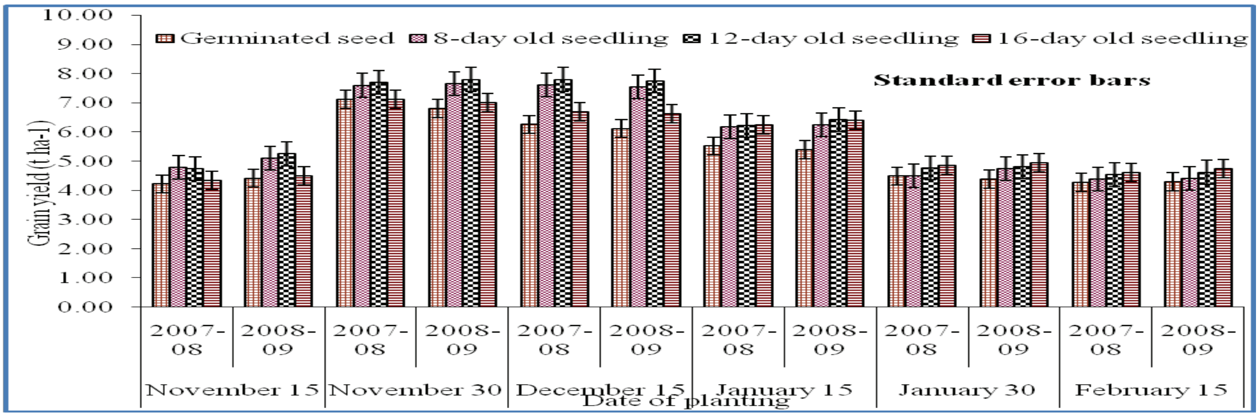

Fig. 1 Effect of date of planting and seedling ages on grain yield (t ha^{-1}) in expts. 1 & . 5 in *Boro* seasons under SRI techniques.

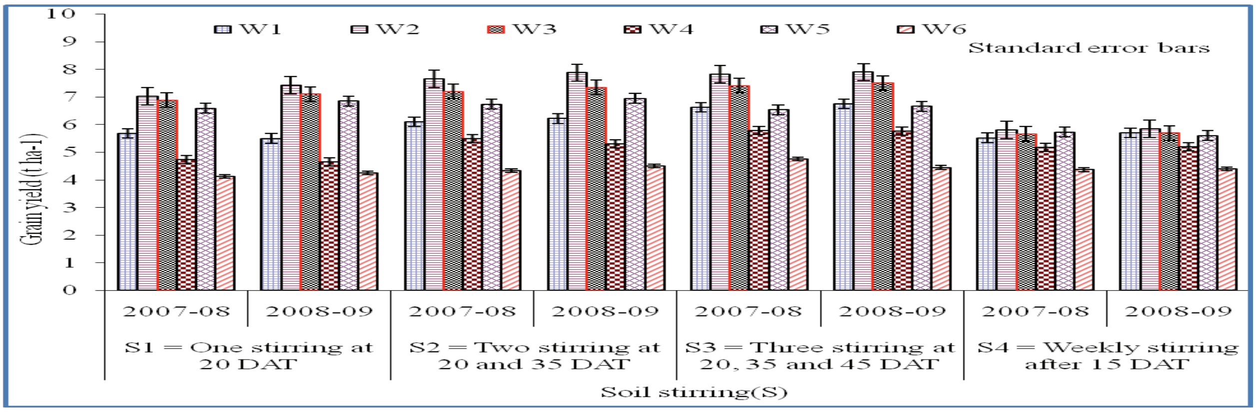

Fig. 2 Effect of SRI water management technique and soil stirring on the grain yield (t ha^{-1}) of BRRI Dhan29 in expts. 2 & 6 under SRI techniques.

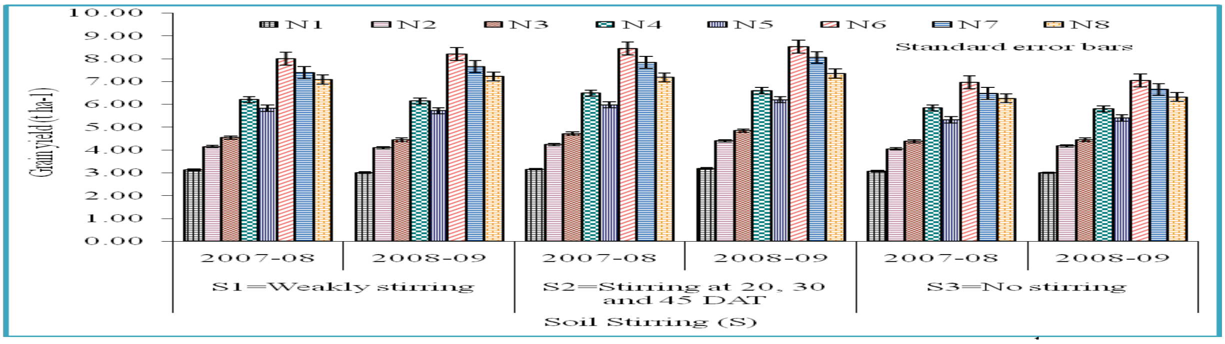

Fig. 3. Effect of integrated use of fertilizers and manures and soil stirring on the grain yield (tha^{-1}) of BRRI Dhan29 in Expt. 3 & Expt. 7 under SRI

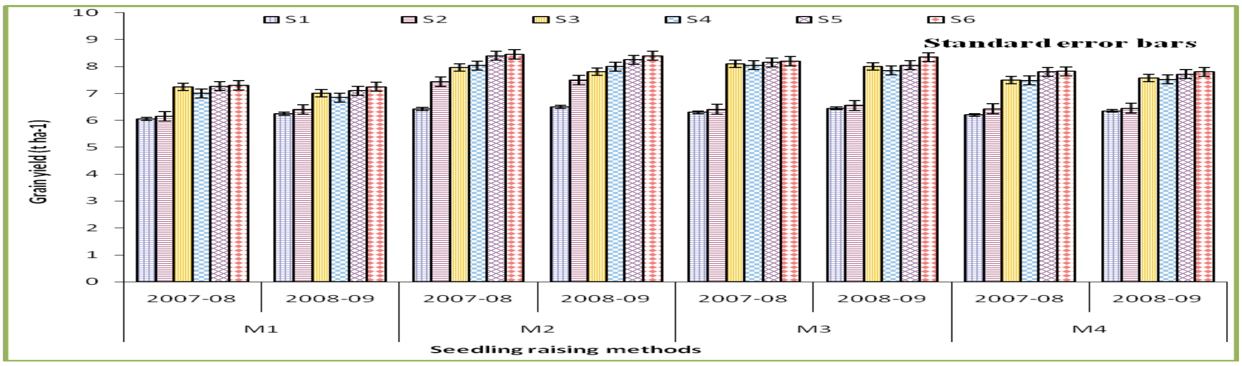

Fig. 4. Effect of spacing and seedling raising methods on the grain yield (t ha^{-1}) of BRRI Dhan29 in Expt. 4 & Expt. 8 under SRI