The System of Rice Intensification (SRI) in Bhutan: A feasibility study of a new rice farming system with special reference to location specific trials and yield performance of different varieties

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1. Introduction

Rice is one of the most important staple food crops for the people of Bhutan. Different varieties of rice, both local and introduced, are cultivated in a wide range of elevations, from subtropical lowlands (150 m) in the south up to elevations as high as 2600 masl in the north (Table 1). The present productivity of rice, less than 3 t/ha, cultivated on 46,585 acres out of the 69,414 acres of irrigated land has not been able to attain food sufficiency level in the country (MoA, 2004).

The constant land degradation plus expansion of development activities taking place on the extremely limited area of arable land for agriculture (7.8% of the total land area of 39,911 km^2) has detracted from cultivable land for rice, and productivity is constrained by a lack of farmer education on rice planting and rice ecosystems, further complicating achievement of the country's goal of food security for all. As a result, a huge amount of rice is imported from India to meet the increasing food demand in the country, with population growth still increasing by 3.1% per annum (http://www.fao.org/ag/agl/aglw/aquastat/countries/bhutan/print1.stm).

The prevalence of small-scale and marginal farms, with an average rice cultivation of 1.5 acres or less, made it appropriate to evaluate through systematic trials the feasibility of using the System of Rice Intensification (SRI) in Bhutan. This method is known to have advantages for small and marginal farmers in terms of economic and environmental benefits as compared to conventional methods of rice cultivation.

SRI as understood internationally to mean "Growing rice in a new way." It involves changing certain management practices for rice plants soil, water and nutrients, so as to produce better growing conditions, particularly in the root zone, for rice plants than those of plants that are grown under traditional practices (Uphoff, 2001). Early transplanting, planting single seedlings, wider spacing, careful transplanting, moist but unflooded soil conditions, and encouraging extensive root development are the most important principles of SRI.

Since this was the first evaluation of SRI methods in Bhutan, the full set of recommended practices was not assessed: only (a) seedling age, (b) spacing (plant density per hill and per sq. meter), and (c) water control. The practices of (d) active soil aeration through use of a rotary weeder and (e) organic fertilization were not introduced and evaluated. The results reported here are thus for a partial application of the SRI methodology. However, even with just these three methods altered from conventional practice, the impact on rice plant productivity was clear.

SRI has been successfully tested in many rice-growing countries such as China, India, Indonesia, Philippines, Sri Lanka, Bangladesh and Nepal. A recent article, "Nepal farmers reap bumper harvest" on BBC News (Sept. 2, 2005) (http://news.bbc.co.uk/2/hi/south_asia/4200688.stm) was a testimony of SRI success next door to our country, Bhutan. Besides increasing rice crop productivity, other benefits of SRI experienced by farmers include earlier crop maturity, higher grain and straw yields, and reduced cost of production from requiring less input of seeds, water, manure, fertilizers and pesticides (Uphoff, 2005).

Given this context, an initial evaluation of SRI methods was undertaken in Bhutan from a base at Sherubtse College of the Royal University of Bhutan during 2006 with the following objectives in mind:

2. Objectives

- To evaluate and assess the different rice varieties (cultivars) grown in the country for their respective responsiveness to SRI practices as compared to conventional methods.
- To carry out and promote SRI experiments with different cultivars with the involvement of farmers and extension workers for demonstration purposes.

Table 1. The four rice agroecological zones of Bhutan

Rice zones	Altitude (m)	Rainfall (mm)
Warm temperate	1800 - 2500 (high)	650 - 850
Dry subtropical	1200 - 1800 (mid)	850 - 1200
Humid subtropical	600 - 1200 (mid)	1200 - 2500
Wet subtropical	150 - 600 (low)	2500 - 550

Source: Chettri et al. (2000).

3. Materials and Methods

3.1 Ground Work

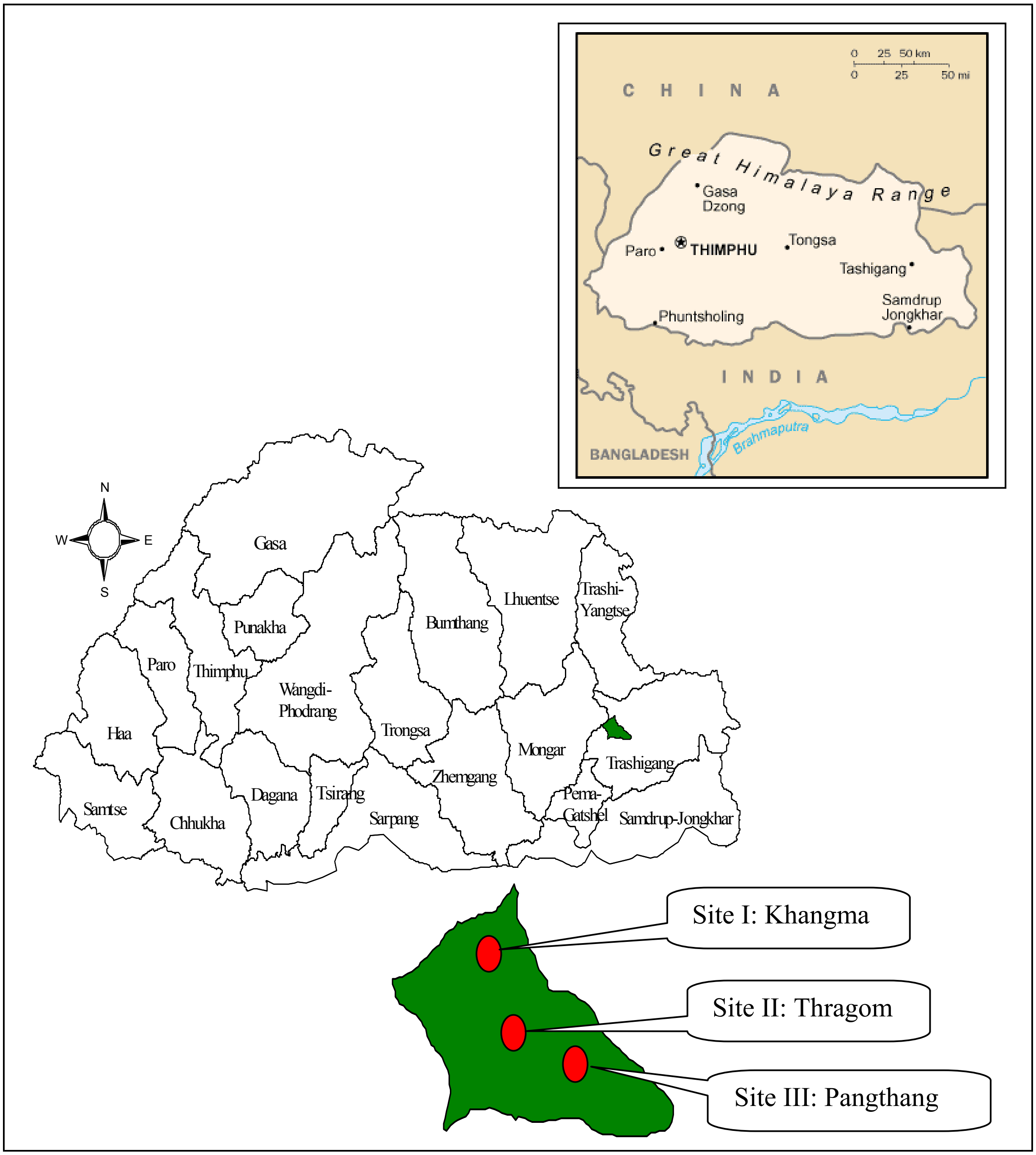
The project work commenced after getting approval from the Council for Renewable Natural Resources Research Centre (RNR-RC), Ministry of Agriculture (MoA), Royal Government of Bhutan,Thimphu. The planned survey was conducted in nearby villages to identify convenient sites approachable by road. The identification of sites was not difficult, but to meet the rightful landowner who could allow the use of his land for the trial work was a time-consuming task. However, information on the types of rice grown, yield and methodology practiced could also be gathered from the farmers during such visits. (What I have gathered was that most of the farmers at Kanglung, practice transplanting of a single or double seedlings in a hill but they are using mature seedlings that are above 45 days old. The reason I surmised was that transplanting single or double seedlings in a hill saves lots of seed used in the nursery. However, nursery is planted by broadcasting seeds on a cleared field; after transplanting of seedling,s fields are kept irrigated until the reproductive stage has past).

This provided a basis and an encouragement to initiate my research in the hope of changing the farmers' current management practices. Furthermore, the interest and the willingness shown by farmers towards this research reinforced the plan. Approval of Site I and Site IV was easily arranged as these sites belong, respectively, to the Agriculture Research Centre (ARC) Khangma (Site I) and the college where I work as a faculty member (Site IV). The ARC was already aware of SRI technique and wanted to experiment with its possibilities in the climatic conditions of eastern Bhutan. After site identification, necessary equipment was arranged, and follow-up activities were carried out.

3.2 Experimental site

The evaluation trials were carried out at four sites at Kanglung sub-district (1800 masl) during the rice-growing season in 2006 (Figure 1). Each site was far apart – about 6 km distance, with 10 km being the maximum distance (between Site I and Site III). Kanglung is one of the 16 sub-districts of Trashigang district (total 20 districts in the country), and it falls within the mid and high altitude rice-growing zones. It has a total of 588.5 acres under paddy cultivation, and the total production for the sub-district is recorded at 408.28 MT (equal to 3.66 MT/ha), which is higher than the average yield in the country (MoA, 2004).

Figure 1. Map showing the experimental sites at Kanglung sub-district.



Results from Site IV are not reflected in this report because the paddy there failed to bear fertile panicles at the time of harvest. That site was selected for utilizing the left-over seedlings, and it was prepared after clearing a field that left fallow for about 10 years seeing that the soil analysis showed high nutrient content (Table 3). Transplanting (12^{th} and 14^{th} July for 2- and 3-leaf stages, respectively) was late by about 3 weeks, however. Early plant growth and tillering were profuse, but unfortunately the plants failed to produce fertile panicles within the growing season.

3.3 Experimental Design

The experimental design was a simple randomized complete block design (RCBD) with 3 replications and five treatments. The treatments are:

1. 20 x 20 cm spacing, 3-leaf stage seedling age
2. 20 x 20 cm spacing, 4-leaf stage seedling age
3. 30 x 30 cm spacing, 3-leaf stage seedling age
4. 30 x 30 cm spacing, 4-leaf stage seedling age
5. Control (farmers' normal practice, > 7 leaf stage)

Farmers' practice was represented by transplanting of older seedlings, singly or bunched at close distance, with application of pre-emergence selective herbicide (Butachlor), chemical fertilizers (Urea), flooded conditions, and irregular weeding.

Plot size was 5 x 4 m^2, and there were a total of 15 plots in each site. Solarized bed technique was used to raise the nursery. Seeds were soaked in water for 48 hrs before sowing. For control plots, 45-50 day old seedlings were planted (Site II and Site III), except for Site I (32-day seedlings).

3.4 Rice Variety

Each site was planted with a different variety of rice: Paropa and Verna (two local varieties) at Sites II and III, respectively, while an improved variety (Khangma maap) was used at Site I. Selection of variety for this study was based testing a popular cultivar grown at each.

3.5 Site Characteristics (altitude, soil, pH)

Soil samples (composite) were collected after preparing the beds and were completely oven-dried to measure the soil moisture. The samples were then sent to the Soil and Plant Analytical Laboratory (SPAL), Semtokha, Thimphu, for further required analysis (Table 2 and Table 3).

Table 2. Soil types, pH and altitude at three sites

Site	Altitude (m)	Soil Texture by hand	pH (H_2O)
I (Khangma)	2000	Loam	4.40
II (Thragom)	1850	Loamy to sandy clay	4.47
III (Pangthang)	1600	Sandy loam to sandy clay loam	5.99
IV (Campus)	1750	Loam	5.54

3.6 Nutrient Status

Table 3. Nutrient status of soil at the sites

Site	Average											
	%		mg/kg		Ex. bases¶ (mg/100g)				Micronutrients (mg/kg)			
	C	N	Av. P	Av. K	Ca	Mg	K	Na	Cu	Zn	Fe	Mn
I	2.40	0.20	105.0	39.6	5.05	0.55	0.13	0.02	2.0	3.6	407.0	156.0
II	1.40	0.12	45.0	49.6	2.80	0.53	0.29	0.12	2.2	1.5	325.6	72.9
III	0.40	0.10	54.6	58.7	3.90	0.37	0.41	0.19	1.9	3.7	224.5	104.1
IV	4.80	0.28	17.86	103.5	12.1	2.01	0.77	0.20	32.3	46.9	357.4	140.9

¶ = Exchangeable bases
Av =Available   C = Carbon   N = Nitrogen   P = Phosphorus
K = Potassium   Ca = Calcium   Mg = Magnesium   Na = Sodium
Cu = Copper   Zn =Zinc   Fe = Iron   Mn = Manganese

3.7 Fertilizer Application

No compost was applied, but a small quantity of urea (46:0:0) at the rate of 173.8 gm per plot, equivalent to 40 kg/ha, was applied at 55 days after transplantation due to yellowing of the tips of leaves. Normally, SRI practice involves provision of organic sources of soil fertilization.

3.8 Water Management

After the transplantation of seedlings at shallow depth slightly in a slanting position in well-puddled soil, following a square pattern, moist soil condition was maintained for about 2 weeks in all the experimental plots except the control, which was flooded. Then, a cycle of alternate wetting (up to 2 cm water level) and drying (about to crack) was executed during the vegetative phase. Initially, the duration of wetting was kept about 2- 3 days more than that of drying, due to high summer heat. About 5-7 cm water level was maintained during the entire reproductive phase, and the water was removed about 20 days before the harvest.

3.9 Weeding

A total of three weedings were done by hand, aided by small tools. The first weeding was carried out at about 3 weeks after transplantation, and the subsequent weedings at an interval of 2 weeks in between. There was no active soil aeration with rotary hoe, as usually recommended with SRI.

4. Results and Discussion

Data from the observations were statistically analyzed and evaluated with computer assistance, using ANOVA to test the effectiveness of the result. The main results of the evaluation trials on SRI are summarized in Table 4. The age-of-seedling and spacing effects most productive were consistent with SRI theory and expectations as 3-leaf stage seedlings spaced at 30 x 30 cm gave best results for all measurements. These results are bold-faced in Table 4 to make comparisons of results easier, especially with the data from the control (farmers' practice) plots.

Table 4. Yield and yield-contributing parameters of trials at three different sites

Sl.No	Parameters	Site I (Khangma)	Site II (Thragom)	Site III (Pangthang)
1	Rice variety	Khangma maap	Paropa	Verna
2	Date of SRI seed sowing	9th May 2006	14th May	20th May
2.1	Date of control seed sowing	9th May 2006	12th May	10th May
3	Date of transplanting			
3.1	3-leaf stage (seedling age)	24th May	29th May	4th June
3.2	4-leaf stage (seedling age)	2nd June	7th June	14th June
3.3	Control	8th June	23rd June	24th June
4	Planting spacing (cm)	20 x 20 30 x 30 Control (random)	20 x 20 30 x 30 Control (random)	20 x 20 30 x30 Control (random)
5	Average tiller number			
5.1	20x20 3-leaf stage	25	27	21
5.2	20x20 4-leaf stage	21	22	18
5.3	**30x30 3-leaf stage**	**34**	**32**	**30**
5.4	30x30 4-leaf stage	29	27	26
5.5	Control	16	15	14
6	Average fertile tiller/hill			
6.1	20x20 3-leaf stage	17	18	17
6.2	20x20 4-leaf stage	14	16	14
6.3	**30x30 3-leaf stage**	**25**	**26**	**25**
6.4	30x30 4-leaf stage	22	23	22
6.5	Control	08	10	09
7	Plant height (cm)			
7.1	20x20 3-leaf stage	142	134	142
7.2	20x20 4-leaf stage	141	138	141
7.3	**30x30 3-leaf stage**	**144**	**146**	**144**
7.4	30x30 4-leaf stage	143	135	143
7.5	Control	136	121	133
8	Average filled grains/panicle			
8.1	20x20 3-leaf stage	163	160	163
8.2	20x20 4-leaf stage	170	170	170
8.3	**30x30 3-leaf stage**	**174**	**176**	**174**
8.4	30x30 4-leaf stage	155	165	155
8.5	Control	135	111	124
9	Number of weedings	3	3	3
10	Date of crop cutting	28th October	27th October	29th October
11	Number of hills/6m^2			
11.1	20x20 3-leaf stage	132	144	136
11.2	20x20 4-leaf stage	137	146	144

11.3	**30x30 3-leaf stage**	**65**	**66**	**66**
11.4	30x30 4-leaf stage	65	66	66
11.5	Control	285	199	237
12	Yield (kg/plot/Mt/ha)*			
12.1	20x20 3-leaf stage	(3.90) 5.7	(2.63) 3.9	(2.57) 3.8
12.2	20x20 4-leaf stage	(3.47) 5.2	(2.57) 3.8	(2.20) 3.3
12.3	**30x30 3-leaf stage**	**(4.03) 6.0**	**(2.83) 4.2**	**(2.83) 4.2**
12.4	30x30 4-leaf stage	(3.53) 5.3	(2.53) 3.8	(2.43) 3.6
12.5	Control	(3.50) 5.2	(2.45) 3.6	(2.45) 3.6

* At 14% moisture content

4.1 Yield-contributing Parameters

All the SRI plots had healthy and non-lodging rice plants as compared to control plots. Also the total numbers of productive tillers (panicles), length of panicle, and number of filled grains per panicle were found more in SRI plots than with conventional methods (Figure 1). The result confirms that maintaining wider spacing one plant per hill and transplanting younger seedling induces more robust root growth, profuse tillering, longer panicles and consequently more grains per panicle than closer spacing and transplanting older seedlings. The SRI methods used in these trials were not the complete set, so there is likely to be further productivity gains that can be made from this methodology.

The highest numbers of productive tillers ranged from 25 to 26, observed with the treatment employing 30x30 cm spacing and transplanting at the 3-leaf stage. The maximum number of filled grains per panicle (174-176) as well as the maximum average plant height (144-146 cm) were observed for this treatment. The control plots with a maximum of 10 productive tillers as well as a total of 111-135 filled grains per panicle were far behind the other treatments (Table 4). The prevalence of diseases was negligible; however, a few insect pests (stem borers) were observed in all plots.

4.2 Yield

In all the three sites, SRI plots on average showed better yield performances as compared to conventional method. This finding is in line with the evaluation conducted by Anthofer (2004) that SRI method had better yield performance than conventional methods in Cambodia. Among these sites, better yield performance was observed at Site I as compared to Site II and III for both SRI as well as control plots. This may be attributed to the type of variety planted (Wang, 2002), soil types (SRI Report, 2002) or differences in nutrient status (Amiri, 2006; BIND, 2003) found among the three sites (Table 3).

The highest yield recorded was 6.0 t/ha at site I and 4.2 t/ha at the other two sites. The increase in yield achieved across the three sites for this partial use of SRI methods was 16.2%, as these three component methods (young seedlings, wider spacing, and no flooding) produced on average 0.67 t/ha more with 30x30 spacing and 3-leaf seedlings. The average yield of this partial use of SRI practices in three locations, 4.8 t/ha, was almost 2 t/ha more than the nation's average yield of 2.88 t/ha.

As seen from Table 4, among the treatments, 30x30 cm spacing x 3-leaf stage seedling age obtained the highest yield of 6.0 t/ha with 65 hills (plants) per $6m^2$ (crop cut plot size) followed closely by 20x20 cm spacing x 3 leaf stage seedling age with 5.7 t/ha, having 132 hills per $6m^2$. Least grain yield of 3.3 t/ha was observed for a treatment at site III with 65 hills per $6m^2$, having older seedlings and closer spacing. For the control plots, with 285 and 237 hills per $6m^2$, respectively, the yields were 5.2 t/ha and 3.6 t/ha,.

The statistical analysis of the five treatments using ANOVA revealed that among the five treatments, better yield performance was observed for wider spacing, 30 x 30 cm x 3-leaf stage seedling age in all three sites. The computation difference was found to be highly significant at 1% level of significance (Table 5). A comparison between mean yields of the control and four treatments using LSD test further supported that the treatment (30x30 cm x 3-leaf stage) is highly significant (Table 6). This corresponds to the findings reported elsewhere which have shown that with SRI, optimally wider spacing gives better yield.

Additionally, almost all the SRI plots had a large number of secondary tillers (more than the control plots) with filled but immature grains, which could have matured provided the growth period was longer, which was not available under the prevailing climatic conditions at this location. Therefore, it is recommended to perform different location trials at lower altitudes to assess the possibilities for proper growth of secondary tillers up to maturity.

Table 5. Analysis of variance (RCB) of grain yield data in Table 4[a]

Sources of variation	Degree of freedom	Sum of squares	Mean squares	Computed F[b]	Tabular F	
					5%	1%
Replication	8	35.05	4.38	4.54**	2.67	3.97
Treatment	4	3.11	0.78			
Experimental error	32	5.48	0.17			
Total	44	43.64	5.33			

[a] *cv* = 9.5%
[b] ** = Significant at 1% level of significance

Table 6. Comparison between mean yields for the control and each of the four treatments, using LSD test

Treatment	Mean yield,[a] t/ha	Difference from control[b] t/ha	
20X20 3-leaf stage	4.45	0.29	*ns*
20X20 4-leaf stage	4.09	-0.07	*ns*
30X30 3-leaf stage	4.81	0.65	**
30X30 4-leaf stage	4.24	0.08	*ns*
Control	4.16		

[a] = average of nine replications
[b]** = significant at 1% level
ns = not significant

5. Observed Advantages of SRI Methodology

1. A significant reduction in the use of seeds for nursery raising was observed. About 2 kg seed has been found sufficient to cultivate an acre of rice field (or 5 kg/ha).
2. Besides substantial increase in grain yield, it was observed that almost all the SRI plots had large number of secondary tillers, more than the control plots, with filled but immature grains which had the potential to mature provided a longer growth period was available.
3. Profuse tillering of the plants created sensation to the farmers and onlookers.
4. Use of herbicides, pesticides and chemical fertilizers is not so important, so they can be reduced, thereby cutting down the cost of production.
5. Removing young seedlings in big clump along with the soil from the nursery also saves time and keeps roots undamaged as against uprooting single or bunches of mature seedlings together from nursery as practiced in the traditional method.
6. Transplantation using wider space between seedlings and between rows allows the free movement of weeders around the plot without trampling the seedlings.
7. Water management technique helps to save excessive use of water for irrigation.
8. Mortality rate for the transplanted seedlings was very low as compared to the conventional method. This could because of the aerobic soil conditions with SRI practice.

6. Constraints with SRI Methodology

1. Leveling of well-puddled fields is difficult, due to the foot marks left while transplanting where water gets accumulated later.
2. Replacing the dislodged transplanted seedlings in the central part of the plot was difficult because of reason no.1.
3. Water management at times is very difficult without separate irrigation and drainage channels supplying water to the field, which is normally not feasible in hilly areas.
4. Manual weeding is time-consuming and often cumbersome. Access to rotary weeders would make SRI practice quicker and more effective (because of the soil-aeration effect).

7. Conclusion

The first yield results of SRI trials and the yield-contributing parameters showed a positive effect from the SRI methods evaluated in this study, as has been observed also in many other countries. An increase of doubled yield as compared to the nation's average yield is a successful endeavor for this first set of evaluation trials. There is a potential to eventually capitalize on higher yield with this technique once skills are improved and mastered through more experimentation, and as more of the recommended SRI practices are taken up. These first-year trials have already sparked some interest amonbg farmers as well as researchers and extensionists. It is worth mentioning that SRI techniques are not entirely different from conventional methods. It would be appropriate to keep farmers' interest growing through further studies and demonstrations, which would help build the trust and confidence among farmers to adopt this technique**.** Further trials in the coming season at different locations are required using other factors to strengthen the validity of this technique as far as possible.

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