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Evaluation of system of rice intensification in a high rainfall area of North-Western Himalayas

Pradeep K. Sharma* and S.S. Masand

Department of Soil Science, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur-176062 (HP), India

ABSTRACT

Field experiments were conducted during 2002-2004 to evaluate SRI in a high rainfall area of north-western Himalayas. Effects of age of seedlings (7-12-d old i.e. SRI vs 22-28-d old i.e. conventionally transplanted rice (CTR), plant-hill spacing (15x15 and 30x30 cm) and water regime (continuous, CF vs intermittent flooding, IF) on plant height, rice yield and yield parameters (tillers, grains panicle^{-1} and 1000-grain weight), and water use efficiency (WUE) in rice (cv. RP 2421) were investigated. Younger seedlings produced plants taller than older seedlings on average by 14.1 cm. Effective tillers hill^{-1} increased from 10 to 25 while effective tillers m^{-2} decreased significantly from 413 to 277 with the increase in plant-hill spacing. The 30x30 cm spacing produced higher grains panicle^{-1} (79) and 1000- grain weight (21.67 g) than the 15x15 cm spacing (70 grains panicle^{-1} and 20.42 g 1000-grain weight). Grain yield was statistically the same under all treatments (3.24-4.05 t ha^{-1}), except CTR-30 with significantly lowest grain yield of 2.84 t ha^{-1}. Numerically, SRI-15(CF) and SRI-30(CF) produced 20 and 13%, respectively, higher grain yield than CTR-15(CF) i.e. the farmers' practice. Total water use was higher by 80-634 mm in SRI than CTR. The WUE under CTR and SRI varied with the water regime; under CF, it was significantly higher with CTR-15 (1.87 kg ha^{-1} mm^{-1}) than SRI-15 (1.69 kg ha^{-1} mm^{-1}), and under IF, it was significantly higher at 15x15 cm (1.64-1.75 kg ha^{-1} mm^{-1}) than at 30x30 cm spacing (1.48-1.51 kg ha^{-1} mm^{-1}) under both SRI and CTR. SRI at 30x30 cm spacing required 222 man-days ha^{-1} compared to 833 man-days ha^{-1} with CTR-15; SRI required 19-11% more time for transplanting than CTR irrespective of hill-spacing. Compared with CTR-15, the SRI-30 showed advantage in terms of higher rice yield (13%), lower seed rate (1/10th of CTR) and lesser time and labour requirement during transplanting (1/4th of CTR).

Key words: *Age of seedlings, conventionally transplanted rice, plant-hill spacing, system of rice intensification, water regime, water use efficiency*

The system of rice intensification (SRI) is being practiced/evaluated in almost 22 countries, mostly Asian countries. The generation of database across different ecological situations has raised debate globally with regard to potential of SRI to raise rice productivity and economic returns to the farmers. The proponents of SRI have claimed substantial increases in rice yields, sometimes as high as 3-4 times, with the consequent increase in the productivity of land, labour, water and capital (Rabenandrasana, 1999; Uphoff, 2002; Uphoff and Randriamiharisoa, 2002: McHugh *et al.* 2002). According to Sinha and Talati (2007) SRI in West Bengal, India, increased rice yield over the conventional rice cultivation by 32% and net returns by 67%, while labour input decreased by 8%. Sato and Uphoff (2007), based on 12,133 trials covering an area of 9,429 ha in Indonesia, reported 78% (3.3 t ha^{-1}) increase in average rice yield with SRI, with reductions of 40% in water use, 50% in fertilizer use and 20% in cost of production as compared to conventional rice cultivation. Similar results have been published by several other workers from India (Kumar *et al.* 2006), Myanmar (Kabir and Uphoff, 2007), Bangladesh (Islam *et al.*, 2005; Rahman *et al.*, 2006) and China (Xu-FuXian et al. 2006). Reddy *et al.* (2005), based on data from 74 trials in Andhra Pradesh, India, concluded that SRI had no economic advantage over the conventional system of rice cultivation and that the prime gain from SRI was water saving rather than rice yield improvement. McDonald *et al.* (2006) analyzed data from 40 sites from different countries including Madagascar, Nepal, China, Thailand, Laos, India, Sri Lanka, Indonesia, Bangladesh and

Philippines, and concluded that 24 of 35 sites demonstrated inferior rice yields with SRI than with best management practices of rice cultivation. These results indicate the need for more systematic studies in SRI under different agro-ecological situations.

SRI holds promise in hilly areas, as in the state of Himachal Pradesh, where land holdings are relatively small and rice is cultivated in terraced fields, and mostly family labour is employed for the job. More than 7% of the cultivated area in Himachal Pradesh, that is about 4,000 km^2, falls in high rainfall (mean annual rainfall >1500 mm) zone where, due to continuous rains, it is difficult to provide intermittent drying in rice fields, an essential requirement of SRI. Field studies, therefore, were undertaken in a humid temperature region of Himachal Pradesh representing the high rainfall area of the state to evaluate SRI in comparison to the traditional system of rice cultivation by varying the age of seedlings, plant-hill spacing and water management practice. Traditionally, rice in this region is grown as a transplanted crop in well puddled fields, which remain flooded for almost the entire cropping season.

MATERIALS AND METHODS

Field experiments, comparing SRI and conventionally transplanted rice (CTR), were conducted during wet seasons of 2002, 2003 and 2004 at the experimental farm of CSK Himachal Pradesh Agricultural University, Palampur, India (32°6' N, 76°3' E, 1300 m above msl) located in the north-western Himalayan region. The experimental site represents high rainfall area of the state, with average (1974-2007) annual rainfall of 2446 mm. The climate of the area is humid temperate. The mean monthly temperature varied between 7.9°C in January (coldest month) and 28.4°C in June (hottest month), and mean relative humidity between 45% in May and 85% in July/August.

The experimental soil (acid alfisol) was a silty clay loam (35.6% clay, 41.2% silt and 23.2% sand) in texture (ISSS), and had 5.5 pH (1:2.5 soil, water), 12.0 c mol (p^+) kg^{-1} CEC, 10.4 g kg^{-1} organic carbon (by dichromate-oxidation method), 271 kg ha^{-1} available N (by $KMNO_4$ method), 23.5 kg ha^{-1} Olsen's P, and 271 kg ha^{-1} of 1 N neutral Ammonium-acetate-extractable K (by emission spectrophotometry). The soil retained 49.0% moisture at saturation, 26.7% at -33 kPa and 16.7% at -1500 kPa matric potential (by pressure plate apparatus).

The experiment compared three factors in eight treatment combinations, replicated thrice in a randomized complete block design. The three factors were: age of rice seedlings (two), plant-hill spacing (two) and water regime (two). The number of irrigation applied in SRI plots was 26,11,21 and 15,22,23 in CTR plots during 2002, 2003 and 2004, respectively. Henceforth, for convenience, transplanting of younger rice seedlings will be referred as SRI and transplanting of older seedlings as CTR. The average length of seedlings at transplanting in SRI was about 11-13 cm (at about 2 leaf stage) and of seedlings in CTR was about 33-36 cm (at 3-4 leaf stage). The rice cultivar was RP 2421. The plot size was 9 m^2.

The plots were dug manually with spades to about 15 cm depth, submerged with water and puddled with a power tiller. About 80 mm irrigation water was consumed during puddling. Each plot received single super phosphate and muriate of potash at the rates of 17P and 33 kg ha^{-1}, along with 5 t ha^{-1} farm yard manure (FYM) on dry-weight basis, at the time of puddling. Nitrogen (urea) was applied in different splits of 30 kg ha^{-1} each. The first N-split was broadcasted at 10 days after transplanting while subsequent N applications were based on leaf colour chart (LCC). The LCC values were determined at every 7-d interval in ten randomly selected plants diagonally across each plot, and 30 kg ha^{-1} N was applied at average LCC of 4 during 2002 and 3 during 2003 and 2004. Total amount of N applied was 120 kg ha^{-1} during 2002 and 90 kg ha^{-1} each during 2003 and 2004.

Transplanting was done at 15x15 and 30x30 cm plant-hill spacing, with one seedling $hill^{-1}$ in SRI and 3 seedlings per hill in CTR. The time required for transplanting was recorded and converted in to man-days ha^{-1} (8 hours = one man-day).

In continuous submergence (CS) treatment, the rice plots were kept submerged under ± 3 cm water layer for first 15 days and ± 5 cm water layer during rest of the cropping season. In intermittent flooding (IF) treatment, irrigation was withheld for 10 days, twice each at 15 and 45 days after transplanting (DT) and draining of rainwater was arranged to avoid water stagnation in rice plots.

Plant height (from the ground level to the tip of the flag leaf) was recorded at flowering stage based on randomly selected ten plants. The 5 m^2 area in the middle of each plot was harvested for recording grain and straw yield. Five rice hills, immediately outside the harvested area, were selected and harvested separately for recording yield parameters, viz. total tillers, effected tillers, grains panicle^{-1} and 1000-grain weight.

RESULTS AND DISCUSSION

The plant height was significantly affected by the age of seedlings at the time of transplanting, but not by plant-hill spacing and water regime. Transplanting of younger seedlings produced significantly taller plants than transplanting of older seedlings by 14.1 cm (Table 1). Vijayakumar *et al.* (2006) also reported taller plants with SRI (14-d old seedlings) than with conventional system of transplanting (21-d old seedlings). Younger seedlings developed better root growth which in turn supported vigorous and taller plants (Uphoff, 2002).

Tillering was significantly affected by plant-hill spacing; the effects of the age of seedlings and water regimes were non-significant (Table 1). While the effective tillers hill^{-1} were higher at 30x30 cm (25) than at 15x15 cm hill spacing (10) by about 2.5 times, the effective tillers m^{-2} were higher at 15x15 cm (413) than at 30x30 cm hill spacing (277) by about 1.5 times. Kumar *et al.* (2006) also reported similar results: effective tillers hill^{-1} at 40x40 cm spacing were 46.6 as against 12.2 tillers hill^{-1} at 15x10 cm spacing; effective tillers m^{-2}, on the other hand, were highest (353) at 15x10 cm spacing and lowest at 40x40 cm spacing (208). Rice plants develop relatively more tillers at wider spacing because of advantage of space, nutrition and sunlight in comparison to narrow spacing. But increase in tillers hill^{-1} due to wider spacing is offset by decrease in the number of hills per unit area; the 30x30 cm spacing accommodated 11.1 hills m^{-2} as compared to 44.4 hills m^{-2} at 15x15 cm spacing. The increase in tillering was not in proportion to decrease in the number of hills m^{-2}. Hence, although effective tillers hill^{-1} increased, the effective tillers m^{-2} decreased with increase in plant-hill spacing.

Number of grains panicle^{-1} and 1000-grain weight were significantly affected by plant-hill spacing and not by the age of seedlings and water management treatments (Table 2). Data pooled over three years and two water regimes indicated about 13% higher grains panicle^{-1} (79) at 30x30 cm spacing than at 15x15 cm spacing (70). Similarly, 1000-grain weight was higher at 30x30 cm (21.67 g) than at 15x15 cm spacing (20.42 g). Kumar *et al.* (2006) also reported higher grains panicle^{-1} and higher 1000-grain weight at 40x40 cm than at 15x10 cm spacing. According to Chen ShuiXiao (2006) also grains panicle^{-1} increased significantly as the planting density decreased from 18,000/667 m^2 through 15,000, 12000 to 9,000/667 m^2; 1000-grain

Table 1. Effect of age of seedlings, plant-hill spacing and water regime on plant height and effective tillers of rice

Treatments	Plant height (cm)				Effective tillers (No. hill^{-1})				Effective tillers (No. m^{-2})			
	2002	2003	2004	Pooled	2002	2003	2004	Pooled	2002	2003	2004	Pooled
With continuous flooding (CF)												
SRI-15	141.3	103.2	101.0	116.6	10	11	7	10	445	478	326	421
CTR-15	110.8	95.8	93.8	100.4	9	10	7	9	398	443	299	385
SRI-30	138.5	102.2	105.3	116.5	28	28	20	26	311	306	220	282
CTR-30	118.1	92.0	99.8	103.9	26	25	19	24	292	276	214	263
With intermittent flooding (IF)												
SRI-15	138.3	102.3	101.1	115.2	11	10	7	10	486	456	319	427
CTR-15	119.0	93.7	92.0	102.3	10	11	8	10	444	490	301	419
SRI-30	142.3	102.3	104.4	117.8	29	29	20	26	322	323	218	292
CTR-30	116.0	93.9	97.8	103.0	28	25	19	24	309	281	210	270
LSD (5%)	16.6	6.3	6.3	10.9	3	5	2	4	18	46	43	38
LSD (1%)	23.0	8.7	8.7	15.1	4	7	3	5	25	64	60	53

CTR= Conventionally transplanted rice; SRI= System of rice intensification; Numerals 15 and 30 refer to plant-hill spacing (cm) weight showed a slight difference at different planting densities. Wider spacing favoured number of grains panicle^{-1} and grain weight probably through advantage of space, nutrition and sunlight.

Grain and straw yield differences due to different treatments were generally non-significant, except that grain and straw yields were significantly higher with SRI-15 than with CTR-30 treatment, irrespective of water regime (Table 3) However, the farmers generally do not transplant seedlings at 30x30 cm spacing. These data show that reduction in effective tillers m^{-2} at 30x30 cm spacing was compensated by increase in number of grains panicle^{-1} and grain weight, resulting into statistically similar grain yields at 15x15 and 30x30 cm spacing, except in one case of CTR-30. Compared to farmers' practice of CTR-15(CF), rice grain yield with SRI-15(CF) and SRI-30(CF) was higher by about 20 and 13%, respectively.

The water regimes (CF vs IF) did not show significant effect on rice yield because, being a high rainfall area, continuous rains kept the SRI plots almost saturated with water inspite of mid-season drainage. Thus, the requirement of SRI with respect to water management was not precisely met. Further, the advantage of mid-season drainage or intermittent irrigation may be expected in excessively reduced Fe-rich or OM-rich soils. In normal soils, especially under lowland–upland cropping sequence (eg. rice-wheat system), as in the present case, IF treatment may not increase rice yields; it may rather decrease rice yields, if soil moisture stress exceeds -10 kPa matric potential (Sharma, 1989). Rice yields in the present case were relatively higher with CF than IF treatment, although differences were statistically non-significant. The yield advantage due to intermittent irrigation, as reported by some workers (Uphoff, 2002), therefore, appears site specific and needs careful investigation under different soil conditions.

Total water use irrigation contrary to several published reports, was higher in SRI than in CTR system by 559, 634 and 380 mm during 2002, 2003 and 2004, respectively. It resulted from the fact that younger seedlings were transplanted about two-three weeks earlier than in CTR in the month of June before the onset of monsoons. Delay in transplanting of SRI in this part of the state is not suitable as the reproductive phase coincides with low temperature, resulting in increased sterility and low yield. The atmospheric evaporati on during this period in this region is at its peak. Consequently, the SRI plots had to be irrigated almost daily to keep them water saturated. The SRI received about 440, 440 and 80 mm additional water before CTR was transplanted during 2002, 2003 and 2004, respectively. After the monsoons set in, the rains were almost continuous during the period of study and irrigation was required very occasionally to keep rice fields flooded. In parts of the state where low temperature is not a problem, transplanting of SRI with

Table 2. Effect of age of seedlings, plant-hill spacing and water regime on number of grains per panicle and 1000-grain weight of rice

Treatments	Grains (No. panicle^{-1})				1000-grain weight (g)			
	2002	2003	2004	Pooled	2002	2003	2004	Pooled
With continuous flooding (CF)								
SRI-15	68	61	90	74	20.00	19.91	22.11	20.70
CTR-15	64	58	83	69	20.10	19.98	21.08	20.39
SRI-30	83	77	91	84	22.04	21.98	22.85	22.29
CTR-30	72	71	86	77	21.07	21.19	20.83	21.03
With intermittent flooding (IF)								
SRI-15	61	59	87	70	19.57	19.87	21.97	20.50
CTR-15	61	57	82	68	19.72	19.69	20.78	20.07
SRI-30	76	75	90	81	22.03	21.92	22.63	22.20
CTR-30	71	67	83	74	21.24	21.39	20.81	21.15
LSD (5%)	6	13	ns	10	0.98	0.63	ns	0.82
LSD (1%)	8	18	ns	14	1.36	0.87	ns	1.14

CTR=Conventionally transplanted rice; SRI= System of rice intensification; Numerals 15and 30 refer to plant-hill spacing (cm)

Table 3. Effect of age of seedlings, plant-hill spacing and water regime on rice yield

Treatments	Rice grains (t ha^{-1})				Rice straw (t ha^{-1})			
	2002	2003	2004	Pooled	2002	2003	2004	Pooled
With continuous flooding (CF)								
SRI-15	4.13	5.08	2.54	4.05	6.63	6.71	4.59	6.06
CTR-15	3.47	4.02	2.43	3.37	6.26	6.12	4.61	5.71
SRI-30	3.99	4.51	2.67	3.80	5.87	5.94	4.25	5.41
CTR-30	2.33	3.79	2.09	2.84	5.54	5.45	3.81	5.00
With intermittent flooding (IF)								
SRI-15	4.12	4.92	2.50	3.98	6.61	6.33	4.50	5.89
CTR-15	3.04	4.06	2.42	3.24	6.40	6.32	4.58	5.83
SRI-30	3.52	4.42	2.60	3.59	5.98	5.84	4.14	5.38
CTR-30	2.54	3.68	2.02	2.83	5.44	5.51	3.80	4.98
LSD (5%)	1.18	1.01	0.34	0.92	1.16	1.02	0.43	0.93
LSD (1%)	1.64	1.40	0.47	1.27	1.61	1.42	0.60	1.29

CTR=Conventionally transplanted rice; SRI= System of rice intensification; Numerals 15and 30 refer to plant-hill spacing (cm)

the onset of rains may decrease total water use in rice.

Less time was required for transplanting rice seedlings at 30x30 than at 15x15 cm spacing, which was obvious as the number of hills m^{-2} in the former was 1/4th (11.1) of that in later case (44.4). It lowered the man-day requirement for transplanting rice seedlings at 30x30 cm spacing than at 15x15 cm spacing. The SRI at 30x30 cm spacing required about 1/4th man-days ha^{-1} (222 man days ha^{-1}) as compared to CTR-15 (833 man days ha^{-1}) - the farmers' practice. Transplanting of younger seedlings required careful handling, and thus consumed 9-11% more time than transplanting of older seedlings.

Transplanting one seedling $hill^{-1}$ at 30x30 cm spacing in SRI significantly lowered seed requirement compared to transplanting 3 seedlings $hill^{-1}$ at 15x15 cm spacing as in CTR (Farmers' practice). Based on the number of seedlings $area^{-1}$ and considering 100% seed germination, the seed requirement in SRI would be about 1/10th of that in CTR. Hence, even in the absence of yield advantage, SRI is superior to CTR in terms of seed and labour and time required during transplanting.

The plant-hill spacing showed more effect on rice yield and yield attributes as compared to age of seedlings at transplanting and water regimes under high rainfall conditions. The SRI (7-12-d old seedlings, one seedling $hill^{-1}$) at 15x15 and 30x30 cm spacing yielded 20 and 13%, respectively, more rice grains than conventional system of rice cultivation (22-28-d old seedlings, 2-3 seedlings $hill^{-1}$ at 15x15 cm spacing). Although these yield differences were statistically non-significant, the SRI had additional advantage over CTR in terms of lower seed rate (about 1/10th of CTR), and time and labour requirement during transplanting (about 1/4th of CTR). The highest rice gain yield was obtained with SRI-15(CF). SRI in a high rainfall area showed benefit in terms of water use efficiency under IF water regime only.

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