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Performance of rice (*Oryza sativa*) varieties at different spacing under system of rice intensification (SRI) in mid hill acid soils of Sikkim Himalayas

R.K. AVASTHE[1], S. VERMA[2], ASHOK KUMAR[3] AND H. RAHMAN[4]

ICAR Research Complex for NEH Region, Sikkim Centre, Tadong, Gangtok, Sikkim 737 102

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ABSTRACT

Field experiments were conducted at the ICAR Sikkim Research Farm, Tadong located at an altitude of 1450 m amsl in the per-humid mid hill acidic soils during *kharif* (rainy season) of 2008 and 2009 to evaluate the performance of four rice (*Oryza sativa* L.) varieties *viz*., 'RCPL 1-87-8' (medium-duration, 125 days), 'Pusa Sugandh-2' (medium-duration, 130 days), 'RC Maniphou-7' (long-duration, 150 days) and one local cultivar '*Thulo Attey*' (long-duration, 155 days) under different spacing in system of rice intensification (SRI) compared with conventional rice cultivation. 'RC Maniphou-7' recorded the highest grain yield (6.73 t/ha), N uptake (124.8 kg/ha), P uptake (40.5 kg/ha), K uptake (84.3 kg/ha), water use efficiency (2.879 kg/ha-mm), net return (Rs. 72,750) and benefit: cost (2.09) at 20 cm × 20 cm spacing under SRI. Total N, P and K uptake was the highest in SRI with a spacing of 20 cm × 20 cm in 'RCLP 1-87-8', 'RC Maniphou-7' and local cv '*Thulo Attey*' over conventional rice cultivation. The optimum spacing under system of rice intensification for 'RCPL 1-87-8', 'RC Maniphou-7' and local cv '*Thulo Attey*' was 20 cm × 20 cm. 'Pusa Sugandh-2' recorded a 2.0% yield decrease at 20 cm × 20 cm and 23.0% yield decrease at SRI 10 cm × 10 cm, as compared to conventional rice cultivation and did not respond to SRI.

Key words: Acid soils, Long duration rice, Manure, Mid-hills, Mountain regions, Medium duration rice, Nutrient uptake, Water use efficiency

Rice (*Oryza sativa* L.), the staple food grain of Sikkim is cultivated in 13,000 ha with a total production of 22,230 tonnes and a productivity 1.71 t/ha (DFSAD 2009). This production is no sufficient for the mountainous region with 5.5 lakhs residents and an annual floating tourist population of three lakhs. The requirement of rice in 2010 is projected to be 1,33,000 tonnes/annum as per on-going National Census, 2011. Thus, there will be an estimated deficit of 1,11,000 tonnes/annum for this small state. Acreage under rice decreased in Sikkim from 15,210 ha in 2000-01 to 13,000 ha in 2008-09, whereas production increased marginally from 21,350 to 22,230 t/annum (DFSAD, 2009).

The productivity of rice in the state can be increased by following the appropriate cultural practices along with high yielding rice varieties. Thakur *et al.* (2009) suggested that the system of rice intensification (SRI) holds a great promise in increasing the rice productivity. The basic principles of SRI are: planting young seedlings (<14 days) singly in a square pattern (Stoop *et al*., 2002). The soil is just kept saturated with water and flooding is not allowed till reproductive stage, after which a thin layer of water (1-2 cm) is kept in the field. Weeds are primarily controlled by mechanical weeding (Cono weeder) which also helps in incorporation of weed biomass and maintains proper aeration in soil (Satyanarayana *et al*., 2007).

Various planting densities have been evaluated in plains (Latif *et al*., 2005, Thakur *et al*., 2009) for SRI with the general recommendation being 25 cm × 25 cm. No information is, however, available on this for the mountains. In this study we evaluated the effect of various spacing in SRI on yield and yield attributing characters, water use efficiency and nutrient uptake in three high yielding rice varieties and one local cultivar in the acid soils of mid hills of Sikkim Himalayas.

MATERIALS AND METHODS

A field experiment was conducted with rice at the ICAR Sikkim Centre, Tadong located at an altitude of 1450 m amsl in the per-humid mid hill acidic soils during rainy (*kharif*) seasons of 2008 and 2009. The clay loam soils had pH 5.3, organic carbon 1.76%, available N (*al-*

[1]**Corresponding author Email:** ravisikkim@yahoo.co.in

[1]Head, Divsion of HRD, Central Soil and Water Conservation Research & Training Institute, Dehradun, Uttarakhand 248 195; [2]Senior Technical Officer; [3]Scientist (Senior Scale); [4]Joint Director, ICAR Sikkim Centre, Tadong

kaline $KMnO_4$) 207.5 kg/ha, available (Brays' P) P 25.2 kg/ha, available K (NH_4OAc extractable) 183.6 kg/ha and CEC 15.5 cmol(p^+)/kg. Three rice varieties of different durations '*RCPL 1-87-8*' (medium-duration, 125 days), '*Pusa Sugandh-2*' (medium-duration, 130 days), '*RC Maniphou-7*' (long-duration, 150 days) and one local cultivar '*Thulo Attey*' (long-duration, 155 days) were planted with four different spacing (25 cm × 25 cm; 20 cm × 20 cm; 15 cm × 15 cm and 10 cm × 10 cm) in SRI and their performance was compared with the conventional rice (CR) cultivation with a spacing of 20 cm × 15 cm.

In SRI plots, 12-days old single seedling/hill and in conventional rice, 25-days old seedlings (2/hill) were planted. SRI plots were kept moist throughout the vegetative stage with required irrigation when the gap in the rains was long. However, in conventional rice (CR) all the plots were flooded with 5–10 cm standing water until the flowering stage. Weeding was done by Cono-weeder in the SRI plots and by hand in CR plots thrice [15, 30 and 45 days after transplanting (DAT)]. The experiment was conducted in a randomized complete block design with four replications of 10 m^2 plots. N, P and K were applied at the rate of 80, 60 and 40 kg/ha, through FYM (in terms of organic equivalents) in the SRI plots, whereas in CR urea, single super phosphate and muriate of potash were applied with full P and K as basal dose. N was applied in three splits i.e., 25% 10 DAT, 25% at maximum tillering and 50% at panicle initiation. FYM was applied basally three days before transplanting in SRI plots. Well-rotten FYM contained 0.50% N, 0.85% P, 0.40% K, 0.35% OC, and C:N ratio- 15.3:1.

One m^2 area of each plot was harvested for the determination of crop yield. Observations were recorded for yield attributes *viz*., tiller numbers, panicle number, panicle length and number of grains/panicle for each replication. Grain yield was reported at 14% moisture content. Plant N was determined by Kjeldhal method, while P and K contents were estimated in di-acid digests using vanadomolybdophosphoric yellow colour method and flame photometer, respectively (Jackson, 1973). Statistical analyses were done by Duncan's multiple range tests (DMRT) at $P \leq 0.05$ level of significance (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Growth, yield attributes and yield

Plant population increased significantly as the SRI spacing decreased from 25 cm × 25 cm to 10 cm × 10 cm whereas the plant height decreased with a decrease in spacing in all the varieties. 'RCPL 1-87-8', 'RC Maniphou-7' and local cv *Thulo Attey* the tillers and panicles/hill increased significantly with every increase in spacing between plants and rows whereas Pusa Sugandh-2 did not respond similarly as compared to conventional rice (Table 1). The lowest number of tillers and panicles/hill was recorded at 10 cm × 10 cm spacing of SRI. At 25 cm × 25 cm spacing the number of tillers and panicles in each hill reached up to 28-29 and 25-26, respectively. The length of panicle was also significantly higher under SRI with higher spacing (20 cm × 20 cm and 25 cm × 25 cm). In SRI, RCPL 1-87-8, RC Maniphou-7 and local cv *Thulo Attey* number of tillers and panicles per unit area decreased with the increase in spacing.

In the medium-duration variety RCPL 1-87-8, SRI increased grain yield by 20.7 and 9.7 per cent, respectively over the conventional rice at the higher spacing of 20 cm x 20 cm and 25 cm x 25 cm. However, grain yield was not statistically different with SRI 15 cm x15 cm spacing as compared to the conventional rice growing method (CR) (Table 2). The yield reduction for 10x10 cm and 15x15 cm was 7.2 and 4.7 per cent, respectively as compared to conventional rice.

The medium-duration variety 'Pusa Sugandh-2' did not respond to SRI and gave significantly lower grain yield than CR at three spacing (10 cm × 10 cm, 15 cm × 15 cm and 25 cm × 25 cm); only at 20 cm × 20 cm it gave an yield, which was statistically at par with CR. Yield reduction in SRI ranged from 2.0% in 20 cm × 20 cm spacing to 23.0% in 10 cm × 10 cm spacing as compared to CR. The long-duration variety 'RC Maniphou-7' was found similar to 'RCPL 1-87-8' and responded negatively to lower spacing of SRI, while the yield increased by 4.17 and 47.59 at 25 cm × 25 cm and 20 cm × 20 cm spacing, respectively, as compared to CR. 'RC Maniphou-7' recorded lower SRI grain yield (9.7 and 7.0) at 10 cm × 10 cm and 15 cm × 15 cm, respectively, when compared with CR. All the three improved rice varieties gave highest yield at 20 cm × 20 cm spacing in SRI. The local cultivar '*Thulo Attey*' revealed the highest response in terms of grain yield increase. In '*Thulo Attey*' the yield increase in SRI was 40.71% in 25 cm × 25 cm spacing and 81.42% in 20 cm × 20 cm spacing; the yield increase being much less in narrower spacing.

With an increase in spacing in SRI the panicles/m^2 decreased while the panicle length increased in all the varieties evaluated (Table 1). In all the varieties except, 'Pusa Sugandh-2', the highest grain yield was observed for the 20 cm × 20 cm spacing. All the four varieties were subject to yield reduction due to decline in panicle length and/or lower number of grains when transplanted at a spacing narrower than 20 cm × 20 cm due to lesser panicles/unit area. The low yield at 25 cm × 25 cm spacing was mainly due to lower number of effective tillers due to lesser hills/

unit area. This finding is similar to Latif *et al*. (2005) and Thakur *et al*. (2009) on acid soils. Higher effective tillers recorded at 15 cm × 15 cm and 10 cm × 10 cm spacing in SRI resulted in yield drop in 'RCPL 1-87-8' (4.72 and 7.19 %), 'Pusa Sugandh-2' (21.01 and 23.04%) and 'RC Maniphou-7' (7.02 and 9.65%) than CR due to thinner tillers, shorter panicles, and fewer grains/panicle. This might be due to higher competition for nutrients, space and air between the plants at narrow spacing. It is well known that increased tillering in rice is accompanied by decreased grains/panicle (Yoshida and Parao, 1972). Only local cv. '*Thulo Attey*' recorded 52.65 and 47.79% yield increase at 15 cm × 15 cm and 10 cm × 10 cm spacing, respectively over CR, which may be related to the significantly higher tillers/hill and panicles/m^2. Normally a low yielder under conventional system of cultivation (CR) local cultivar '*Thulo Attey*' responded positively to SRI. Wider spacing in SRI creates conditions conducive for uninhibited root growth that ensures better access to light and air thereby creating 'the border effect' (Satyanarayana *et al*., 2007) that generates higher grain yield.

Nutrient uptake

NPK uptake by rice was very much influenced by the grain yield of rice obtained in different treatments. In 'RCPL 1-87-8' and 'RC-Maniphou-7' the NPK uptake was highest with 20 cm × 20 cm spacing in SRI, significantly higher than other spacing and CR. The next in order was 25 cm × 25 cm spacing in SRI, which was superior to 15 cm × 15 cm and 10 cm × 10 cm spacing in SRI as well as to CR. As a contrast 15 cm × 15 cm and 10 cm × 10 cm spacing in SRI recorded significantly lesser NPK uptake than the CR.

In '*Pusa Sugandh*' which did not respond to SRI, NPK uptake was the highest in CR significantly higher than all the spacing studies in SRI. As regards different spacing studied in SRI, NPK uptake was the highest with 20 cm × 20 cm, significantly higher than 25 cm × 25 cm spacing, which in turn was significantly superior to 15 cm × 15 cm and 10 cm × 10 cm spacing; the later two were at par.

As regards local cultivar '*Thulo Attey*' the trend was different for the nutrients *viz.*, NPK. The highest NPK uptake was recorded with 20 cm × 20 cm spacing in SRI and

Table 1. Effect of plant spacing on growth and yield attributing characters under system of rice intensification (SRI) and conventional rice (CR) in different varieties (Data pooled over two years)

Methods	Plant population (hills/m^2)	Plant height (cm)	Tillers/ hill	Tillers/m^2 at harvest	Panicles/ hill	Panicles/ m^2	Panicle length (cm)
RCPL 1-87-8 (*medium duration rice)*							
SRI: 25cm×25cm	14.8f	108.3i	27.5a	228.3d	26.4a	194.5e	22.3a
SRI: 20cm×20cm	23.7e	107.5j	25.2b	289.5c	24.7a	271.5c	21.4a
SRI: 15cm×15cm	34.6c	102.3k	14.6e	335.6b	15.3c	302.4b	17.5b
SRI: 10cm×10cm	95.0ab	101.6l	7.5g	363.8a	10.2d	322.5a	15.5c
Conventional	28.2d	108.8i	11.3f	343.4b	11.5d	298.3b	17.8b
Pusa Sugandh-2 (*medium duration ri*ce)							
SRI: 25cm×25cm	14.5f	99.4n	17.5d	214.2d	21.3b	179.1f	20.1b
SRI: 20cm×20cm	22.8e	98.8n	15.8de	258.4d	19.8b	208.6e	19.2b
SRI: 15cm×15cm	33.5c	95.4o	10.8f	291.5c	9.4d	233.5d	16.8c
SRI: 10cm×10cm	93.2b	93.2p	6.5g	308.3c	7.8d	262.2c	15.7c
Conventional	27.4d	100.1m	14.8e	294.7c	14.8c	249.7cd	19.8b
RC Maniphou-7 (*long duration rice*)							
SRI: 25cm×25cm	15.4f	124.4e	29.3a	233.1d	24.5a	192.3e	23.4a
SRI: 20cm×20cm	24.1e	123.8f	27.2a	293.4c	23.8a	277.6c	22.8a
SRI: 15cm×15cm	35.2c	122.3g	20.5c	330.7b	15.8c	314.4b	18.4b
SRI: 10cm×10cm	96.1a	120.2h	9.4f	375.3a	10.6d	356.2a	16.5c
Conventional	28.8d	122.5g	12.8e	338.6b	13.4c	308.7b	18.7b
Local cultivar Attey (*long duration rice*)							
SRI: 25cm×25cm	14.7 f	161.4a	20.4c	218.6e	22.5b	168.5f	21.2a
SRI: 20cm×20cm	23.5e	160.6b	18.5cd	248.2d	20.8b	224.5d	20.4b
SRI: 15cm×15cm	34.8c	158.2c	14.6e	273.4c	8.2d	258.4c	17.1c
SRI: 10cm×10cm	94.5ab	156.2d	7.6g	313.4c	7.8d	296.5b	14.8c
Conventional	28.0d	158.0c	10.5f	178.3e	10.2d	154.5f	16.6c
SEm±	0.8	0.2	0.7	4.2	0.9	11.2	0.8
CD (P=0.05)	2.4	0.6	2.1	12.7	2.6	33.7	2.3

Figures in a column followed by same letter(s) are not significantly different by DMRT at 5% level of significance (n=5) the lowest with CR. In the case of N, 15 cm × 15 cm and 10 cm × 10 cm spacing in SRI were at par and significantly superior to 25 cm × 25 cm. In the case of P, 25 cm × 25 cm, 15 cm × 15 cm and 10 cm × 10 cm were at par, while in the case of K, 15 cm × 15 cm and 10 cm × 10 cm were at par but gave significantly higher K uptake than 25 cm × 25 cm spacing.

The present study thus shows that local cultivar interacted with spacing as far as NPK uptake is concerned. These findings are in agreement with Hussain *et al.* (2009)

Water use efficiency (WUE)

WUE was relatively higher in SRI over conventional rice for all four varieties (Table 2). Higher WUE in SRI over CR perhaps may be due alternate wetting and drying cycle providing improved growth conditions (Lin *et al*., 2009) and reduced leaching and volatilization losses of nutrients. In SRI the WUE ranged from 1.29 to 2.88 kg/ha-mm at 10cmx10cm and 20cmx20cm recorded for 'Pusa Sugandh-2' and 'RC Maniphou-7', respectively whereas it varied from 0.79 to 1.61 kg/ha-mm for CR. 'RC Maniphou-7' recorded the highest WUE for both SRI (2.88 kg/ha-mm) and CR (1.61 kg/ha-mm). The highest WUE under SRI was recorded at 20cmx20cm and the lowest at 10 cm × 10 cm for all the varieties evaluated. Lower WUE at 25 cm × 25 cm could be due to lower to grain yield obtained at this spacing. Lower WUE was observed for CR as compared to all the SRI spacing combinations except 'Pusa Sugandh-2' which did not respond to SRI and recorded highest yield under CR. More irrigation applied to maintain 5-10 cm floodwater level in CR resulted in lower WUE. This finding is in conformity with Rajeshwar and Aariff Khan (2008). The local cv '*Attey*' under conventional system was the least water efficient producing only 0.79 kg/ha-mm which was less than half of 'RC Maniphou-7' (1.61 kg/ha-mm).

Economics

The highest net return (₹ 72,750) and benefit :cost ratio (2.09) was recorded for SRI 20 cm × 20 cm spacing in 'RC Maniphou-7' which was followed by 'RCPL 1-87-8' (₹70,150 and 1.92) (Table 2). The net return and benefit : cost of all the SRI spacing was higher than the CR except 'Pusa Sugandh-2' which gave the lowest net return of

Table 2. Effect of plant spacing on yield, water use efficiency and economics under system of rice intensification (SRI) and conventional rice (CR) in different varieties (Data pooled over two years)

Methods	Grain weight/ hill (g)	Test weight (g)	Harvest index	Grain yield (t/ha)	% change in yield over CR	WUE (kg/ha-mm of water)	Net return (×10^3₹/ha)	Benefit : cost ratio
RCPL 1-87-8 (*medium duration rice*)								
SRI: 25cm×25cm	55.4b	22.8b	44.85b	4.88b	9.7	2.09c	57.85	1.58
SRI: 20cm×20cm	53.6b	22.5b	51.06a	6.26a	40.8	2.68b	70.15	1.92
SRI: 15cm×15cm	34.2f	21.9bc	37.72ef	4.24cd	-4.7	1.84d	53.25	1.55
SRI: 10cm×10cm	22.3i	21.6c	37.11f	4.13d	-7.2	1.77ef	52.50	1.53
Conventional	24.5i	22.6b	37.08f	4.45c		1.57h	58.75	1.34
Pusa Sugandh-2 (*medium duration rice*)								
SRI: 25cm×25cm	40.4e	21.8c	37.14f	3.25e	-17.7	1.38j	42.90	1.11
SRI: 20cm×20cm	38.3e	21.4c	38.07e	3.87d	-2.0	1.64g	45.50	1.20
SRI: 15cm×15cm	19.5j	20.7c	36.19g	3.12e	-21.0	1.32j	41.40	1.14
SRI: 10cm×10cm	15.6k	20.5	36.02g	3.04e	-23.0	1.29k	39.75	1.11
Conventional	31.5g	22.6b	38.82de	3.95d		1.38j	47.15	1.20
RC Maniphou-7 (*long duration rice*)								
SRI: 25cm×25cm	60.1a	24.2a	44.19b	4.75b	4.8	2.03c	59.15	1.62
SRI: 20cm×20cm	58.8a	23.7a	49.74a	6.73a	47.6	2.88a	72.75	2.09
SRI: 15cm×15cm	34.5f	22.9b	41.41c	4.24cd	-7.0	1.81de	56.50	1.57
SRI: 10cm×10cm	23.4i	22.1bc	39.16d	4.12d	-9.7	1.76ef	55.00	1.46
Conventional	26.7h	23.7a	39.39d	4.56d		1.61g	57.25	1.37
Local cultivar Attey (*long duration rice*)								
SRI: 25cm×25cm	48.4c	21.8c	41.95c	3.45e	52.7	1.46i	51.00	1.40
SRI: 20cm×20cm	43.6d	21.4c	40.59d	4.10d	81.4	1.74f	54.50	1.56
SRI: 15cm×15cm	18.8j	20.8cd	40.83cd	3.34e	47.8	1.42ij	50.00	1.37
SRI: 10cm×10cm	15.1k	20.5d	40.05d	3.18e	40.7	1.35j	48.50	1.29
Conventional	20.4j	19.8e	31.13h	2.26f		0.79l	44.65	1.12
SEm±	0.7	0.2	0.3	0.12		0.2		
CD (P=0.05)	2.2	0.6	0.9	0.37		0.6		

Figures in a column followed by same letter(s) are not significantly different by DMRT at 5% level of significance (n=5)

Table 3. N, P and K uptake under system of rice intensification (SRI) and conventional rice (CR) in different rice varieties (Data pooled over two years)

Methods	Total N uptake at harvest (kg/ha)	% change in uptake over CR	Total P uptake at harvest (kg/ha)	% change in uptake over CR	Total K uptake at harvest (kg/ha)	% change in uptake over CR
RCPL 1-87-8 (*medium duration rice*)						
SRI: 25×25 cm	96.0c	11.9	34.8c	7.4	67.4c	6.6
SRI: 20×20 cm	105.4b	22.8	37.0b	14.2	77.5b	22.6
SRI: 15×15 cm	82.3e	-5.2	31.0e	-4.3	60.6e	-4.1
SRI: 10×10 cm	81.4e	-6.2	30.5e	-5.9	58.0f	-8.2
Conventional	86.8d		32.4d		63.2d	
Pusa Sugandh-2 (*medium duration rice*)						
SRI: 25×25 cm	70.8f	-18.8	24.0g	-19.5	47.4h	-18.5
SRI: 20×20 cm	82.5e	-5.5	27.7f	-7.0	55.1g	-5.8
SRI: 15×15 cm	68.8f	-21.2	23.5g	-21.1	46.1h	-21.2
SRI: 10×10 cm	67.2f	-23.0	22.0gh	-26.2	45.0hi	-23.0
Conventional	87.3d		29.8e		58.5f	
RC Maniphou-7 (*long duration rice*)						
SRI: 25×25 cm	95.3c	9.8	34.4c	14.0	63.4d	3.6
SRI: 20×20 cm	124.8a	43.8	40.5a	29.0	84.3a	37.7
SRI: 15×15 cm	83.4e	-5.0	29.0ef	-7.6	58.0f	-5.2
SRI: 10×10 cm	81.2e	-7.5	28.2f	-10.2	56.2f	-8.2
Conventional rice	87.8d		33.2cd		61.2de	
Local cultivar Attey (*long duration rice*)						
SRI: 25×25 cm	65.3g	21.2	24.0g	47.4	43.4i	18.9
SRI: 20×20 cm	82.5e	53.1	28.4f	49.5	57.0fg	56.2
SRI: 15×15 cm	71.8f	33.2	23.4gh	25.3	47.8h	31.0
SRI: 10×10 cm	70.1f	30.1	23.4gh	23.2	46.7h	27.9
Conventional	53.9h		19.0i		36.5	
SEm±	0.7		0.5		0.7	
CD (P=0.05)	2.2		1.5		2.2	

Figures in a column followed by same letter (s) are not significantly different by DMRT at 5% level of significance (n=5)

₹39,750 and benefit:cost (1.11) at 10 cm × 10 cm spacing. In SRI the net return and benefit:cost was reduced when spacing was narrowed to 10 cm x 10 cm than 20 cm × 20 cm. All the SRI spacing resulted in higher net returns and benefit:cost as compared to the CR for all varieties except 'Pusa Sugandh-2'. Wider spacing gives plants less competitive environment both above and below the soil that promotes better root growth and higher canopy development which finally results in higher nutrient uptake, better grain filling, more grain weight and thus, higher yield. But this higher grain yield of individual plants does not always magnify on area basis mainly due to less number of plants or hills (Menete *et al*. 2008).

The present study revealed that the optimum spacing for SRI was 20 cm × 20 cm for both medium and long duration varieties. Highest WUE, net return and benefit:cost was also recorded in 20 cm × 20 cm spacing of SRI. Wider spacing though generated higher tillers per hill but it failed to produce corresponding increase in panicles/m^2 perhaps. Narrow spacing between hills showed concurrent increase in panicles/m^2 but shortened panicles with reduced number of grains compounded with fewer tillers per hill resulted in decreased grain yield. The performance of local cultivar under SRI holds promise for a small state like Sikkim, where 70 per cent of rice fields are less than 1 ha and more than 50 per cent of farmers still prefer local cultivars of rice that are cultivated under low input situation. SRI being labour intensive can be adopted by the small, resource poor farmers of Sikkim. Importantly the study suggested that all the varieties may not respond positively to the system of rice intensification under mid hill conditions of Sikkim Himalaya.

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