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**Research Paper**

# Effect of different components of SRI on yield, quality, nutrient accumulation and economics of rice (*Oryza sativa*) in *tarai* belt of northern India

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## ABSTRACT

A field experiment was conducted on a Typic Hapludoll soil in Indo-gangetic plains of India during the 2008 and 2009 rainy seasons to find out the effect of irrigation schedules and plant spacing on yield, quality, nutrient uptake and economics of two rice (*Oryza sativa* L.) varieties under system of rice intensification (SRI) and compare the performance of SRI with conventional transplanting. Treatments under SRI included 12 combinations of 3 irrigation schedules, *viz.* irrigation at 1, 3 and 5 day(s) after disappearance of standing water (DADSW), 2 spacings (20 cm × 20 cm, 25 cm × 25 cm) and 2 varieties ('Pant Dhan 4', 'Arize 6444'), alongwith two control treatments of conventional cultivation of each variety. The experiment was set in a RBD with three replications. Irrigation at 1 and 3 DADSW increased uptake of N, P and K in grains, which enhanced grain protein content and milling percentage, and improved grain yield by 8.6 and 5.9% over 5 DADSW (5.82 t/ha), respectively. Net returns and B:C ratio were also better with irrigation at 1 and 3 DADSW. Wider spacing resulted in 4.2% higher yield with better grain quality and 10.8% higher net returns over closer spacing. Yield-wise and profit-wise, both the varieties were suitable for cultivation under SRI. However, 'Arize 6444' recorded higher N uptake and protein content. The uptake of P and K was higher in grains of 'Pant Dhan 4' which showed higher milling percentage. Between two methods, SRI improved N, P and K uptake, milling percentage and protein content. Grain yield was 16.9% higher under SRI compared to conventional method (5.22 t/ha). Due to lower cost of production and higher yields, SRI fetched 56% higher net returns over conventional transplanting.

***Key words*** **:** Conventional transplanted rice, Irrigation schedule, Milling quality, Nutrient uptake, Spacing, System of rice intensification, Varieties

Rice forms staple food for more than half of the world-population and the world demand for rice will grow continuously**.** Though, India has the largest area under rice in the world, but its productivity level of 2.2 t/ha (Economic Survey, 2010) is far below the neighbouring country, China (> 6.0 t/ha) and the world average (4.0 t/ha). To overcome low yields, system of rice intensification (SRI) has been projected as a potential method of rice culture. Husain *et al.* (2004) reported 30% yield advantage from SRI in Bangladesh and Namara *et al.* (2003) showed an even larger benefit (44%) in Sri Lanka.

Rice is the largest consumer of irrigation water. In the Indo-gangetic plains of India total water requirement of rice varies from 1566 mm in clay-loam to 2262 mm in sandy-loam soil (Tripathi, 1990). About 50-80% of total water input percolates deep in soil profile and only 30-40% is utilized consumptively (Sharma, 1989; Koga, 1992). The SRI method which envisages alternate wetting and drying may help reduce water losses and improve productivity. Under any method of cultivation, optimum water supply is the most important factor governing availability and uptake of essential nutrients, growth, yield and quality of the rice. However, optimum ground space available to each plant is also important for exploitation of available resources. In SRI, a wider spacing is recommended, which leads to vigorous root growth and profuse tillering, however it may be variety dependent and location specific. The square geometry at wider spacing facilitates the movement of mechanical weeder, which is one of the other essential components of SRI technique. Crop geometry and irrigation may influence the growth and yield of different genotypes to a varying degree. A variety with shy tillering and short stature requires to be planted closer, while a tall and profusely tillering one may require wider spacing to produce desired number of healthy and productive shoots per unit area. Likewise, different varieties may respond differently to moisture stress. Thus, the effects of

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key production components, like genotype, irrigation regime and crop geometry on productivity of rice need to be investigated for making any policy on the cultivation of rice with SRI method, especially in the water-scarce areas.

There have been some studies world-over, which compared (SRI) with conventional (recommended) and local practices. The results have been inconsistent. However, higher yield of rice with SRI compared to best management practices have also been reported by some researchers. Hence, the present investigation was carried out to study the effect of irrigation and spacing on grain yield and quality, nutrient uptake, and economics of two rice varieties under system of rice intensification and compare the SRI with conventional transplanting.

## MATERIALS AND METHODS

The field experiment was carried out at G. B. Pant University of Agriculture and Technology, Pantnagar (29$^o$ N latitude, 79.29$^o$ E longitude and 244 m above the mean sea level), Uttarakhand, during *kharif* 2008 and 2009. The study site is located in *tarai* (young alluvial soils with shallow to medium water table) belt of India and is characterized by a sub-humid and sub-tropical climate. During 2008, mean maximum temperature during crop period was 30.6$^0$C, while the mean minimum was 22.8$^0$C. During 2009, mean weekly minimum temperature was equal to and maximum temperature 2.4$^0$C higher than 2008. Crop season rainfall was 1986 mm and 983 mm during 2008 and 2009, respectively. Soil of the experimental site has been classified as Typic Hapludoll (Mollisols). Surface soil (0-15 cm depth) was sandy loam in texture, high in organic C (0.89%) and available P (32.8 kg/ha), and low in available N (245 kg/ ha) and K (128.3 kg/ ha).

The experiment had 14 treatments comprising 12 combinations of 3 irrigation schedules (irrigation at 1, 3 and 5 day(s) after disappearance of standing water (DADSW); 2 spacings (20 cm × 20 cm and 25 cm × 25 cm), and 2 varieties ('Pant Dhan 4' and 'Arize 6444') under SRI, and 2 controls (conventional transplanting of 'Pant Dhan 4' and 'Arize 6444' i.e., 4-5 weeks old seedlings, 20 cm × 10 cm spacing, chemical weed control, irrigation at 1 DADSW). The treatments were arranged in a factorial randomized complete block design replicated thrice. The experiment had 42 plots of size 4 m × 4 m each. The rice seedlings were raised on a raised-bed of size of 1.25 m x 8 m with wet-bed method.

Under SRI method, 12 days old and under conventional transplanting 4-5 weeks old seedlings were transplanted in puddled soil. The crop was fertilized with 120 kg N, 26.2 kg P, 33.2 kg K and 25 kg $ZnSO_4$/ha. Of the total N, ninety kg N was supplied through fertilizers (urea and diammonium phosphate) and 30 kg N through vermicompost (1.5 t/ha). Phosphorus and K were supplied through diammonium phosphate and muriate of potash, respectively, after taking into account the P and K supplied by the vermicompost. Half of N including 30 Kg N from vermicompost and entire amount of P, K and $ZnSO_4$ were applied as basal dose before puddling/land preparation. The remaining amount of N was top-dressed in two equal splits, the first at tillering and the second at panicle initiation stage. After the establishment of the crop, irrigations were scheduled at 1, 3 and 5 DADSW. However, for the period from panicle emergence to 15 days before maturity, a shallow submergence was maintained in all the plots. Due to high rainfall during 2008 total number of irrigations was 5 at 1 DADSW and 4 for other two irrigation schedules. Conventional transplanted rice was given 5 irrigations. During 2009, number of irrigations under 1, 3 and 5 DADSW was 16, 12 and 9, respectively**.** Crop under conventional transplanting required 12 irrigations. Depth of the every irrigation was kept at 6 cm. The amount of irrigation water applied was measured using parshall flume. To control weeds in SRI plots, conoweeder was run manually between rows of rice crop twice, in both the directions, at 10 and 20 days after transplanting. Under conventional method, weeds were controlled by applying butachlor @ 1.5 kg/ha at 4$^{th}$ day after transplanting followed by one hand weeding in the 3$^{rd}$ week after transplanting.

Data on plant height, grain yield, straw yield, grain quality parameters and nutrient uptake were recorded at crop maturity. Standard procedures were used for chemical analysis of soil and plant samples. The economic-parameters (gross returns, net returns and B: C ratio) were worked on the basis of prevailing market prices of inputs and outputs. The data were analyzed by using the 'Analysis of Variance Technique' for factorial randomized block design (FRBD) as per the procedures described by Rangaswamy (2006). The treatment means were compared at 5% level of significance.

## RESULTS AND DISCUSSION

### *Growth and yield*

Applying irrigation at 1 or 3 DADSW resulted in significantly taller plants and 8.6 and 5.9% higher grain yield, respectively, compared to 5 DADSW (5.82 t/ha). Yield was alike between 1 and 3 DADSW. The similar trend was observed for straw yield (Table 1). Lower growth and yield under delayed irrigations could be due to development of water stress in plants, resulting in reduced cellular growth (Hasiao, 1973), lowering down of leaf-water potential (Bagg and Turner, 1976), closer of stomata (Salisbury and Ross, 2009) and decline in radiation-use efficiency (Whitefield and Smith, 1989). Frequent irrigations (at 1, 3 DADSW) created favourable moisture regimes which enabled the crop plant to grow lavishly by providing conducive micro-climate and increasing solubility, absorption, translocation and assimilation of nutrients by the plants for various physiological processes.

Wider spacing (25 cm × 25 cm) recorded significantly taller plants than the closer spacing (20 cm ×20 cm), due to the fact that under wider spacing, the plants get sufficient space above the ground (shoots) and below the ground (roots) to grow and the increased light transmission in the canopy, leading to greater plant height (Table 1). Shrirame *et al.* (2000) also reported that the number of functional leaves and leaf area were higher under wider spacing, which increased the photosynthetic rate leading to taller plants. Wider spacing gave the yield advantage of 4.2% over closer spacing (5.97 t/ha). Higher grain yield from the wider spacing is the outcome of better growth. Thakur *et al.,* (2010) reported that during the ripening stage, hills with wider spacing had larger root dry weights, produced greater xylem exudates, and transport these towards shoot at faster rates. These features contribute to the maintenance of higher chlorophyll levels, enhanced fluorescence and photosynthetic rates of leaves and supports important yield attributes and grain yield of individual hill than in closely spaced plants. Straw yield was higher under wider spacing due to higher growth.

The two varieties, 'Pant Dhan 4' and 'Arize 6444' field-tested both under SRI and conventional transplanting method, exhibited sharp differences in growth and straw yield. Plants of 'Arize 6444' grew significantly taller and gave higher straw yield than 'Pant Dhan 4'. However, grain yield was similar between two varieties. Both the varieties produced more than 6.0 t/ha grain under SRI method (Table 1). Under conventional method also, a non-significant difference was found. Despite reduction in plant population (hills) per unit area to almost half, SRI produced 16.9% higher grain yield than the conventional method (5.22 t/ha). This could likely be due to the higher

**Table 1.** Effect of irrigation, spacing and varieties on growth, yield, quality and economics of rice under system of rice intensification and conventional transplanting (Pooled data two years)

| Treatment | Plant height (cm) | Grain yield (t/ha) | Straw yield (t/ha) | Milling percentage | Protein content (%) | Cost of cultivation (×10$^3$ ₹/ha) | Net returns (×10$^3$ ₹/ha*) | B : C ratio |
|---|---|---|---|---|---|---|---|---|
| *System of rice intensification* | | | | | | | | |
| *Irrigation schedules (DADSW)* | | | | | | | | |
| 1 | 120.0 | 6.32 | 9.64 | 74.6 | 7.40 | 30.2 | 31.2 | 1.03 |
| 3 | 119.2 | 6.16 | 9.72 | 73.9 | 7.42 | 28.7 | 31.2 | 1.09 |
| 5 | 114.5 | 5.82 | 8.80 | 72.6 | 7.29 | 27.8 | 28.6 | 1.03 |
| SEm± | 1.33 | 0.09 | 0.16 | 0.53 | 0.17 | - | 0.62 | 0.02 |
| CD (P=0.05) | 3.87 | 0.26 | 0.47 | 1.54 | NS | - | 1.80 | NS |
| *Spacings (cm)* | | | | | | | | |
| 20 × 20 | 115.0 | 5.97 | 9.09 | 72.9 | 7.31 | 29.2 | 28.8 | 0.99 |
| 25 × 25 | 120.7 | 6.23 | 9.68 | 74.5 | 7.43 | 28.7 | 31.9 | 1.11 |
| SEm± | 1.09 | 0.07 | 0.13 | 0.43 | 0.14 | - | 0.51 | 0.02 |
| CD (P=0.05) | 3.17 | 0.21 | 0.38 | 1.25 | NS | - | 1.48 | 0.06 |
| *Varieties* | | 0.00 | | | | | | |
| 'Pant Dhan 4' | 110.4 | 6.11 | 9.02 | 74.5 | 7.17 | 28.5 | 30.7 | 1.08 |
| 'Arize 6444' | 125.4 | 6.09 | 9.75 | 72.9 | 7.58 | 29.4 | 30.0 | 1.03 |
| SEm± | 1.09 | 0.07 | 0.13 | 0.43 | 0.14 | - | 0.51 | 0.02 |
| CD (P=0.05) | 3.17 | NS | 0.38 | 1.25 | 0.40 | - | NS | NS |
| *Conventional transplanting (control)* | | | | | | | | |
| 'Pant Dhan 4' | 100.9 | 5.26 | 8.31 | 71.8 | 6.74 | 29.2 | 21.9 | 0.75 |
| 'Arize 6444' | 112.1 | 5.18 | 8.91 | 70.2 | 7.45 | 33.7 | 16.9 | 0.50 |
| SEm± | 2.66 | 0.18 | 0.31 | 1.06 | 0.33 | - | 1.24 | 0.04 |
| CD (P=0.05) | 7.73 | NS | NS | NS | 0.96 | - | 3.61 | 0.12 |
| *Control vs SRI* | | | | | | | | |
| Control | 106.5 | 5.22 | 8.61 | 71.0 | 7.10 | 31.4 | 19.4 | 0.63 |
| SRI | 117.9 | 6.10 | 9.38 | 73.7 | 7.37 | 28.9 | 30.3 | 1.05 |
| SEm± | 2.04 | 0.13 | 0.24 | 0.81 | 0.25 | - | 0.95 | 0.03 |
| CD (P=0.05) | 5.93 | 0.38 | 0.69 | 2.36 | 0.73 | - | 2.76 | 0.09 |

*Based on price of grain and straw as ₹9,000/t and ₹300/t during 2008 and ₹9,500/t and ₹300/t during 2009, respectively number of tillers with larger and heavier panicles under SRI. Krishna *et al*. (2008) reported that SRI produced 0.6 t/ ha higher seed yield than the conventional transplanting (yield 2.28 t/ha).

### *Nutrient uptake and grain quality*

Uptake of nutrients, especially N and P in grains and straw were higher with irrigation at 1 and 3 DADSW than at 5 DADSW, which enhanced grain protein content and milling percentage (Tables 1 & 2). Anurag (2006) reported significantly higher N, P and K uptake under irrigation scheduled at 3 DADSW than at 5 DADSW. Higher nutrient accumulation under 1 and 3 DADSW is ascribed to greater and healthy root growth, increased availability and efficient absorption from the soil and transport of nutrients from roots to shoots and grains, which ultimately improved growth, yield and quality of rice. Under dry soil moisture regimes, plants absorb more K. This was true in the present investigation too. Higher overall nutrient uptake under wetter irrigation regimes resulted from higher contents of nutrients in grain and straw and higher grain and straw yields.

Uptake of N, P and K in grains and straw with 25 cm × 25 cm spacing was higher than with 20 cm × 20 cm spacing (Table 2). The higher uptake of nutrients in widely spaced crop is ascribed to higher root growth and greater volume of soil available to individual hill to absorb water and nutrients under wider spacing. Higher nutrient uptakes under wider spacing have also been reported by Jacob and Syriac (2005). Higher nutrient absorption resulted in the higher milling percentage and protein content in grains under wider spacing. Salem (2006) also observed the higher protein content in rice grains with 25 cm × 25 cm than closer spacing.

Nitrogen is the constituent of chlorophyll and promotes photosynthesis and vigorous growth of the crop plants. Thus, the higher uptake of N in grains and straw of 'Arize 6444' resulted in higher grain protein content than 'Pant Dhan 4'. The content of P and K was higher in grains of 'Pant Dhan 4' which improved milling percentage in this variety. Consequent upon conducive moisture regimes and wider spacing, better nutrient absorption from greater soil volume caused higher uptake of N, P and K in SRI than conventional transplanting (Table 2). Higher content of N

**Table 2**. Effect of irrigation, spacing and varieties on nutrient accumulation in different plant parts under system of rice intensification and conventional transplanting (Pooled data of two years).

| Treatment | N uptake (kg/ha) | | | P uptake (kg/ha) | | | K uptake (kg/ha) | | |
|---|---|---|---|---|---|---|---|---|---|
| | Grain | Straw | Total | Grain | Straw | Total | Grain | Straw | Total |
| *System of rice intensification* | | | | | | | | | |
| *Irrigation schedules (DADSW)* | | | | | | | | | |
| 1 | 64.4 | 52.3 | 116.7 | 24.8 | 11.4 | 36.1 | 25.0 | 129.0 | 154.0 |
| 3 | 62.9 | 53.0 | 115.8 | 22.8 | 10.6 | 33.4 | 25.5 | 136.1 | 161.6 |
| 5 | 58.4 | 44.9 | 103.4 | 20.4 | 9.2 | 29.5 | 23.6 | 121.6 | 145.2 |
| SEm± | 0.99 | 1.04 | 1.36 | 0.37 | 0.18 | 0.38 | 0.39 | 1.81 | 2.25 |
| CD (P=0.05) | 2.88 | 3.02 | 3.95 | 1.08 | 0.52 | 1.11 | 1.13 | 5.26 | 6.54 |
| *Spacings (cm)* | | | | | | | | | |
| 20 × 20 | 60.1 | 47.3 | 107.4 | 21.3 | 10.0 | 31.3 | 23.7 | 122.5 | 146.3 |
| 25 ×25 | 63.7 | 52.8 | 116.5 | 24.0 | 10.8 | 34.8 | 25.7 | 135.2 | 160.9 |
| SEm± | 0.81 | 0.85 | 1.11 | 0.30 | 0.15 | 0.31 | 0.32 | 1.48 | 1.83 |
| CD (P=0.05) | 2.36 | 2.47 | 3.23 | 0.88 | 0.44 | 0.90 | 0.93 | 4.30 | 5.32 |
| *Varieties* | | | | | | | | | |
| 'Pant Dhan 4' | 60.2 | 45.2 | 105.5 | 23.6 | 10.6 | 34.2 | 25.4 | 131.1 | 156.5 |
| 'Arize 6444' | 63.6 | 54.9 | 118.5 | 21.7 | 10.2 | 31.9 | 24.0 | 126.7 | 150.7 |
| SEm± | 0.81 | 0.85 | 1.11 | 0.30 | 0.15 | 0.31 | 0.32 | 1.48 | 1.83 |
| CD (P=0.05) | 2.36 | 2.47 | 3.23 | 0.88 | 0.44 | 0.90 | 0.93 | 4.30 | 5.32 |
| *Conventional transplanting (control)* | | | | | | | | | |
| 'Pant Dhan 4' | 49.7 | 39.0 | 88.7 | 18.9 | 8.5 | 27.5 | 19.7 | 108.5 | 128.3 |
| 'Arize 6444' | 53.2 | 47.7 | 100.9 | 16.4 | 8.1 | 24.5 | 16.5 | 112.1 | 128.6 |
| SEm± | 1.98 | 2.07 | 3.12 | 0.74 | 0.36 | 0.76 | 0.78 | 3.63 | 4.49 |
| CD (P=0.05) | NS | 6.02 | 9.07 | 2.15 | NS | 2.21 | 2.27 | NS | NS |
| *Control vs SRI* | | | | | | | | | |
| Control | 51.4 | 43.4 | 94.8 | 17.7 | 8.3 | 26.0 | 18.1 | 110.3 | 128.4 |
| SRI | 61.9 | 50.1 | 112.0 | 22.6 | 10.4 | 33.0 | 24.7 | 128.9 | 153.6 |
| SEm± | 1.51 | 1.58 | 1.58 | 0.56 | 0.28 | 0.58 | 0.59 | 2.77 | 3.43 |
| CD (P=0.05) | 4.40 | 4.60 | 4.60 | 1.63 | 0.81 | 1.69 | 1.72 | 8.06 | 9.97 |

improved the protein content in grains under SRI. Shekhar *et al.* (2009) also observed higher uptake of N, P and K with SRI than conventional transplanting.

### *Economics*

Average cost of cultivation was ₹28.9 $\times 10^3$/ha under SRI method and ₹31.4 $\times 10^3$/ha under conventional transplanting. Thus, the cost of production was lower in SRI by ₹ 2.3 $\times 10^3$/ha than conventional practice. Lower cost with SRI resulted from lower seed and labour costs. Under SRI method, irrigation at 1 and 3 DADSW recorded higher net returns than 5 DADSW due to higher grain and straw yields (Table 1). The B: C ratio was the highest (1.09) with irrigation at 3 DADSW. Wider planting fetched ₹ 3.1$\times 10^3$ /ha higher net returns with higher B: C ratio over closer spacing, due to higher grain and straw yields and lower cost of cultivation. Wider spacing cut-down the cost of cultivation by ₹0.5 $\times 10^3$ /ha compared to closer spacing mainly due to less cost involved in transplanting.

Growing ‘Arize 6444’ involved higher cost of cultivation mainly due to 9-fold higher cost of seed than ‘Pant Dhan 4’. This was particularly true for raising ‘Arize 6444’ under conventional method which required higher quantity of seed. Under conventional method, ‘Arize 6444’ due to higher production cost largely owing to costly hybrid seed produced lower net returns than ‘Pant Dhan 4’ by 5 $\times 10^3$ /ha. However, under SRI, both the varieties gave similar net returns showing equal potential for cultivation with SRI method. The higher grain and straw yields coupled with lower cost of production culminated into 56.2 % higher net returns from SRI than conventional practice (Table 1). B:C ratio was also higher with SRI method. Sinha and Talati (2007) reported two-fold higher net returns from SRI than conventional practice.

Overall, SRI method of rice culture was better than conventional transplanting as it resulted in higher nutrient uptake, grain yield with better quality and net income. Under SRI, rice should be planted at 25 cm × 25 cm spacing and irrigated at 3 DADSW. Both Ârize 6444’ and ‘Pant Dhan 4’ are suitable for cultivation under SRI, however, Arize 6444’ had higher grain-protein content.

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