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Influence of System of Rice Intensification (SRI) Practices on Growth Characters, Days to Flowering, Growth Analysis and Labour Productivity of Rice

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Abstract: Field experiment was conducted during dry season of 2003 at Tamil Nadu Agricultural University Farm, Coimbatore to study the effect system of rice intensification (SRI) practices on growth characters and growth analysis of rice. The experiment replicated thrice was laid out in randomized block design. The treatment combination of 14 days old seedlings planted at 25×25 cm spacing+water saving irrigation and SRI weeding significantly recorded taller plants (109 cm), total dry matter production (12012 kg ha^{-1}) and LAI (7.69). However, the tiller density per m^2 was significantly recorded higher (624) in the treatment combination of 14 days old seedlings+15×10 cm spacing+water saving irrigation+conventional weeding. During wet season the number of days to first flowering (85 DAS) was significantly recorded in the treatment combination of 14 days old seedlings planted at 20×20 cm spacing+conventional irrigation, weeding and nitrogen while during dry season (2003) the combination of seedlings from dapog nursery (14 days old) planted at a spacing of 15×10 cm under limited irrigation of 2 cm on hair-line crack development+conventional weeding significantly recorded days to first flowering (80 DAS). Between panicle initiation (PI) to flowering (FL) and between FL to maturity stage the CGR, RGR and NAR were significantly increased by the treatment combination of 14 days old seedlings, wider spacing of 25×25 cm, limited irrigation of 2 cm with incorporation of weeds and disturbing the soil through SRI weeding using rotary weeder.

Key words: Rice, SRI practices, growth characters, growth analysis

INTRODUCTION

In India, rice occupies about 44.6 million hectares with a production of 86.0 million tonnes and it continues to hold the key to sustain food production by contributing 20 to 25 percent of agriculture GDP and assures food security in India for more than half of the total population (Anonymous, 2002). Though India tops the list in terms of area constituting 28% of world's rice (Ram and Vyas, 1997), the productivity is very low compared to leading rice growing countries. The major constraint in rice production is lack of suitable crop management practices and sufficient irrigation facilities. Considering the future food requirements, competition from non–agricultural uses for fresh water and more amount of water currently used in rice cropping, new SRI methods of rice cultivation identified aiming at less water requirement and higher crop productivity. The practice of SRI is not only aiming at maximum yield but rather to promote the higher productivity of land, labour, capital and water in ways that benefit the farmer especially poor one.

The plant height, tiller density, Total Dry Matter Production (TDMP) and Leaf Area Index (LAI) are the main growth factor which may directly reflected to grain yield. Growth analysis parameters like Crop Growth Rate (CGR) are the product of LAI and Leaf Area Ratio (LAR). Relative Growth Rate (RGR) measures the increase in dry matter with a given amount of assimilatory material at a given point of time and Net Assimilation Rate (NAR) is the net gain in total dry matter per unit leaf area per unit time. It was against this background that the field investigation was carried out to study the system of rice intensification (SRI) practices on growth characters and growth analysis of rice.

MATERIALS AND METHODS

Field experiment was carried out at Tamil Nadu Agricultural University, Coimbatore, during dry seasons of 2003. The soil of the experimental field was a deep, moderately well drained clay loam, low in available N (244 kg N ha^{-1}), medium in available P (17.2 kg P_2O_5 ha^{-1}) and high in available K (560 kg K_2O ha^{-1}). The electrical

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conductivity of the soil was 0.80 ds m^{-1} and the pH was 8.2. The amount of rainfall received during the cropping period was 356.2 and 214.8 mm distributed over 22 and 13 rainy days during wet and dry seasons, respectively.

Based on the previous years findings of individual technologies, the main objective was fixed to study only the combined effect of this individual technologies as a package under SRI practices. The experiment was laid out in a randomized block design replicated thrice. The selected package of treatment details were as follows:

Treatment	Seedling age	Spacing (cm)	Irrigation	Weeding
T_1	21	15×10	Conventional	Conventional
T_2	21	15×10	Water saving	Conventional
T_3	14	15×10	Conventional	Conventional
T_4	14	15×10	Water saving	Conventional
T_5	21	20×20	Conventional	Conventional
T_6	21	20×20	Conventional	SRI weeding
T_7	21	20×20	Water saving	SRI weeding
T_8	14	20×20	Conventional	Conventional
T_9	14	20×20	Conventional	SRI weeding
T_{10}	14	20×20	Water saving	SRI weeding
T_{11}	21	25×25	Conventional	Conventional
T_{12}	21	25×25	Conventional	SRI weeding
T_{13}	21	25×25	Water saving	SRI weeding
T_{14}	14	25×25	Conventional	Conventional
T_{15}	14	25×25	Conventional	SRI weeding
T_{16}	14	25×25	Water saving	SRI weeding

The recommended rate of N, P and K (120:38:38 kg ha^{-1}) was applied as urea (46% N), single Superphosphate (16% P_2O_5) and Muriate of Potash (60% K_2O), respectively. Nitrogen was applied as urea in four splits *viz*., 1/6 at 7 DAT (days after transplanting) 1/3 at 21 DAT, 1/3 at PI (panicle initiation), 1/6 at FF (first flowering) was applied. The full dose of P_2O_5 was applied basally to all the treatments. Potassium in the form of Muriate of Potash (60% K_2O) was applied in four splits viz., 25% at 7 DAT and 25% each at AT (active tillering), PI and FF stages. Zinc sulphate at the rate of 25 kg ha^{-1} was applied as basal to the crop during both the seasons. In Conventional Irrigation (CI) irrigation was given to 5 cm depth one day after disappearance of ponded water from planting to maturity. Irrigation was stopped 10 days prior to harvest. Whereas in Water Saving Irrigation (WSI) irrigation to 2 cm depth on development of hairline-crack was given throughout the crop growth period. Irrigation was stopped 10 days prior to harvest.

In conventional weeding the emulsifiable concentrate of butachlor at the rate of 1.25 kg ha^{-1} was applied as pre-emergence weedicide by mixing with sand (50 kg ha^{-1}) at 3 DAT with about 2 cm of standing water and hand weeding was done twice (20 and 45) DAT Whereas in SRI weeding hand operated rotary weeder was used to incorporate weeds with simultaneous stirring up of soil. It was operated between the rows in both the directions. Totally five mechanical weedings were given to SRI weeding plots at 7 days interval during both wet and dry seasons from 12 days after transplanting.

The amount of rainfall received during the cropping period was 356.2 and 214.8 mm distributed over 22 and 13 rainy days during wet and dry seasons, respectively. The LAI of rice was worked out as per the method proposed by Palaniswamy and Gomez (1974) using the formula

$$LAI = \frac{L \times W \times K \times \text{number of leaves per hill}}{\text{Spacing } (cm^2)}$$

where

L = Maximum length of 3rd leaf blade from the top (cm)
W = Maximum width of the same leaf (cm)
K = Factor of 0.75 for Kharif and 0.73 for Rabi season rice.

The labour productivity was calculated for each treatment and expressed in rupee output per rupee labour cost. The labour productivity was worked out as follows Gross income in rupees ha^{-1}

$$\text{Labour productivity} = \frac{\text{Gross income in rupees ha}^{-1}}{\text{Labour cost in rupees ha}^{-1}}$$

The CGR during the growth period was calculated as suggested by Buttery (1970) and expressed in g^{-2} day^{-1}.

$$CGR = \frac{W^2 - W^1}{P(t_2 - t_1)} \; g^{-2} \, day^{-1}$$

W_1 and W_2 = Initial and final dry weight of plant material per unit ground area (g), respectively
t_1 and t_2 = Initial and final days of observation, respectively
P = Ground area occupied by each hill (cm^2)

The RGR during crop growth was calculated as suggested by Enyi (1962) and expressed in mg g^{-1} day^{-1}.

$$RGR = \frac{(\log_e W_2 - \log_e W_1)}{t_2 - t_1} \text{mg g}^{-1} \, day^{-1}$$

W_1 and W_2 = Initial and final dry weight of plant material per unit ground area (g), respectively
t_1 and t_2 = Initial and final days of observation, respectively

The NAR during the crop growth period was worked out as suggested by Enyi (1962) and expressed in cm^2 g^{-1} day^{-1}.

$$NAR = \frac{W_2 - W_1}{t_2\, t_1} \times \frac{Log_e L_2 - Log_e L_1}{L_2 - L_1} \text{ mg cm}^{-2} \text{ day}^{-1}$$

W_1 and W_2 = Initial and final dry weight of plant material per unit ground area (g), respectively

t_1 and t_2 = Initial and final days of observation, respectively

L_1 and L_2 = Initial and final leaf area (cm^2), respectively

RESULTS AND DISCUSSION

Plant height: The treatment combination of younger seedlings (14 days old), wider spacing (25×25 cm), water saving irrigation, mechanical weeding and split application of N recorded taller plants (Table 1). This might be due to the fact that younger seedlings have more vigour, root growth and lesser transplant shock because of lesser leaf area during the initial growth stages which stimulate increased cell division causing more stem elongation resulting in increased plant height (Kimsangsu *et al*., 1999). Because of increased shoot: root ratio under wider spacing, ultimately the plant gets sufficient space to grow and the increased light transmission in the canopy leads to increased plant height. This is in accordance with the findings of Shrirame *et al*. (2000) who reported that the number of functional leaves, leaf area and total number of tillers $hill^{-1}$ were higher at wider spacing which increased the photosynthetic rate leading to taller plants. The widening of irrigation interval might have resulted in progressive decrease in plant height by the adverse effect on cell division and cell enlargement (Edwin Luikham, 2001). However, water saving irrigation combined with mechanical weeding could enhance the plant height by better aeration and incorporation of weeds as a green manure increased the organic carbon content of the soil. Incorporation of weeds with mechanical weeder increased the root activity which stimulated the new cell division in roots by pruning of some upper roots encouraged deeper root growth thereby increased shoot: root ratio (Uphoff, 2001).

Table 1: Effect of SRI practices on growth characters of rice at flowering stage

Treatments	Plant height (cm)	Tiller density (m^{-2})	TDMP ($kg\ ha^{-1}$)	LAI
T_1	99.4	519	8583	4.43
T_2	96.4	562	8442	4.40
T_3	97.1	551	9893	5.01
T_4	98.3	624	10638	6.18
T_5	105.7	421	9823	4.72
T_6	105.1	431	10143	5.20
T_7	104.3	452	10311	5.58
T_8	103.3	429	9230	4.59
T_9	106.4	414	11383	7.18
T_{10}	103.0	451	10528	5.84
T_{11}	106.0	382	10057	6.69
T_{12}	106.2	404	10780	6.86
T_{13}	106.6	384	11533	7.37
T_{14}	104.2	410	10620	5.95
T_{15}	106.3	396	11273	6.88
T_{16}	108.6	475	12012	7.62
CD (p = 0.05)	3.61	73	636	0.39

TDMP- Total Dry Matter Production; LAI- Leaf Area Index

Tiller density: Closer spacing of 15×10 cm with younger seedlings, limited irrigation and conventional weeding recorded significantly higher tiller production. Though the tiller density of individual hill was higher under wider spacing, considering the population per unit area, the total tiller production was higher with more plant population per unit area under closer spacing (Table 1). Increased tiller production per unit area with decreased plant spacing was reported by Siddiqui *et al*. (1999). Increased tiller density under limited irrigation might be due to maintenance of a thin film of water that will open the soil for both oxygen and nitrogen and promote the root growth during initial growth stages (Uphoff, 2001). In addition increased tiller density was recorded under mechanical weeding which might be due to the fact that cono weeding not only helped in reducing weed competition, but also improved root growth by increasing soil aeration and root pruning (Shad, 1986).

Total dry matter production (TDMP): Younger seedlings (14 days old), wider spacing of 25×25 cm, limited irrigation and mechanical weeding recorded higher TDMP (Table 1). The younger seedlings from dapog nursery contained more N and starch which helped in producing new roots, better root growth and more tiller production resulting in improvement of TDMP (Yoshida, 1981; Rao and Raju, 1987). Increased shoot: root ratio and production of more number of tillers on individual hill basis recorded under wider spacing were the reason for increased TDMP (Rajesh and Thanunathan, 2003). The combination of limited irrigation with mechanical weeding recorded, more TDMP. This might be due to the fact that mechanical weeding increased the soil aeration by dissolved oxygen in irrigation water rather than from the deeper part of the soil thereby increasing shoot: root ratio and LAI subsequently increasing the TDMP (Uphoff, 2002).

Number of days for flowering: The results of the number of days for flowering of experiments I and II are presented in Table 2. The minimum number of days to first flowering was observed in treatment T_5 (14 days old seedlings + 20×20 cm spacing + conventional irrigation + recommended N + conventional weeding) which was comparable to that of T_{10}. Among the treatments studied, the treatment T_{14} (14 days old seedlings + 25×25 cm

spacing + water saving irrigation + LCC based N + SRI weeding) has taken more number of days for flowering. The number of days taken for flowering was earlier with the younger seedlings (14 days old) as well as closer spacing (15x10 cm) under limited irrigation treatment (T_4). This was comparable to that of T_3. Among the treatments studied, T_{13} (21 days old seedlings + 25x25 cm spacing + water saving irrigation + SRI weeding) has taken more number of days (92 DAS) for flowering.

The synergistic effect of the combination of younger seedlings, closer spacing, either conventional irrigation or water saving irrigation and conventional weeding resulted in early flowering than the combination of wider spacing of 25x25 cm and mechanical weeding due to the reason that planting of younger seedlings have taken more number of days for vegetative growth after transplanting (Joseph, 1991). Under higher plant density, more competition among the plants induced quick growth and early flowering (Rao and Raju, 1987). Under 25x25 cm spacing, lesser competition for moisture and nutrients resulted in slower growth and more CHO assimilation per plant (Yang Fu *et al*., 2000). Longer duration for flowering could be attributed to depressed and delayed growth due to moisture stress. These findings are in accordance with Reddy and Kulandaivelu (1987), Balasubramanian (1998) and Edwin Luikhan (2001). Under limited irrigation and mechanical weeding, the soil was disturbed which induces better aeration and more nutrient availability leading to more net and relative assimilation.

Labour productivity: The higher labour productivity was obtained for younger seedling from dapog nursery (14 days old) and wider spacing (25×25 cm) combination in both crops (Table 2). This might be due to the reason that wider spacing required less number of labour for transplanting and weeding operation (Senthilkumar, 2002) and also cono-weeding and limited irrigation gave higher grain yield (Thiyagarajan *et al*., 2002).

Table 2: Effect of system of rice intensification practices on number of days for flowering and labour productivity of rice

	Dry season 2003	Dry season 2003
Treatments	No. of days for flowering (DAS)	Labour productivity (Rs out put/Rs input
T_1	84.33	3.03
T_2	85.67	2.83
T_3	80.67	3.55
T_4	80.33	3.82
T_5	88.00	3.41
T_6	88.67	3.12
T_7	89.33	3.02
T_8	84.00	3.57
T_9	84.00	3.98
T_{10}	86.00	3.66
T_{11}	89.67	3.70
T_{12}	90.33	3.42
T_{13}	91.67	3.66
T_{14}	84.67	4.19
T_{15}	86.00	3.77
T_{16}	86.33	4.05
CD (p = 0.05)	1.57	0.236

Growth analysis: Agronomic practices like seedling age, spacing, irrigation and weed management could alter the growth analysis parameters like Leaf Area Index (LAI), Crop Growth Rate (CGR), Relative Growth Rate (RGR) and Net Assimilation Rate (NAR) and it is a complex interaction between the plant growth and its environment.

During initial growth stages, younger seedlings, closer spacing, either conventional irrigation or water saving irrigation recorded maximum LAI than wider spacing combination (Table 1). This might be due to the reason that closer spacing recorded more number of tillers per unit area thereby resulting in more number of leaves per unit area and subsequently increased LAI (Esther Shekinah, 1996). However, during later growth stages, the interaction effects were well pronounced with age of seedlings, wider spacing, water saving irrigation with mechanical weeding on LAI. The younger seedlings under wider spacing recorded better root growth which facilitated increased cell division and cell enlargement due to increased photosynthetic rate subsequently increasing LAI (Shrirame *et al*., 2000). In addition, water saving irrigation with mechanical weeding favourably, influenced the soil aeration which facilitated more number of tillers and subsequently higher photosynthetic rate for increased LAI (Thiyagarajan *et al*., 2002).

This showed that the interaction effect of seedling age, spacing, irrigation and weed management was more pronounced due to their enhanced complementary effect. The younger seedlings combination recorded higher CGR, RGR and NAR due to more relative and net assimilation of the plant thereby increasing the specific leaf weight and dry matter of the plants condition (Ono, 1982). Biomass production in a plant community is positively correlated with crop growth rate. Increased LAI registered under younger seedlings combination might have resulted in higher CGR (Rao *et al*., 1998). The wider spacing recorded more CGR, RGR and NAR due to lesser competition among the plants that will boost more CHO assimilation leading to more TDMP (Obulamma and Reddy, 2002). However, during initial growth stages, closer spacing recorded more CGR and NAR due to more number of tillers and leaves per unit area. Subsequently increased DMP favourably influenced growth analysis parameters. A perusal of mean data on CGR, RGR and NAR revealed that under limited irrigation, the values decreased due to low soil moisture besides mechanical impedance (Ghildyal and Tomar, 1982; Balasubramanian, 1998).

Table 3: Effect of SRI practices on CGR, RGR and NAR of rice at different growth stages of rice

	CGR (g m^{-2} day^{-1})			RGR (mg g^{-1} day^{-1})			NAR (mg cm^{-2} day^{-1})		
Treatments	51 DAS-PI	PI-FL	FL-Maturity	51 DAS-PI	PI-FL	FL-Maturity	51 DAS-PI	PI-FL	FL-Maturity
T_1	33.46	12.83	17.61	115.77	17.12	16.56	1.0422	0.2304	0.4164
T_2	23.11	11.22	11.98	79.67	21.10	10.15	0.9423	0.3208	0.3710
T_3	33.60	15.95	13.94	106.74	23.37	12.21	0.8612	0.3256	0.3719
T_4	31.21	19.28	18.13	109.43	28.16	14.38	0.7711	0.3419	0.4201
T_5	15.09	24.38	13.51	109.73	45.93	11.33	0.6098	0.5512	0.3729
T_6	18.05	23.39	12.99	136.63	43.39	11.11	1.0932	0.5949	0.3372
T_7	22.60	21.12	13.06	156.83	37.44	11.48	1.3091	0.5305	0.3261
T_8	29.29	17.22	16.57	133.57	29.59	15.03	1.1818	0.4343	0.4677
T_9	36.54	22.97	22.79	170.89	34.09	16.47	1.2068	0.4143	0.4744
T_{10}	26.23	21.76	17.04	126.18	35.68	13.76	1.0002	0.4652	0.4115
T_{11}	10.26	28.35	17.10	131.61	55.75	13.39	0.7602	0.6040	0.3750
T_{12}	11.96	27.82	19.42	137.63	55.01	14.87	0.8647	0.6056	0.4198
T_{13}	14.30	28.67	23.13	143.83	55.05	16.25	1.2282	0.6139	0.4633
T_{14}	18.57	24.61	17.74	122.83	45.59	14.14	0.7719	0.5473	0.4232
T_{15}	19.66	26.39	21.61	130.19	46.74	15.88	1.0751	0.5859	0.4616
T_{16}	20.17	29.10	25.79	130.99	51.98	17.45	0.7099	0.6535	0.4748
CD (p = 0.05)	3.24	2.65	2.77	20.32	6.83	1.31	0.1461	0.1006	0.0416

CGR - Crop Growth Rate; RGR - Relative Growth Rate; NAR - Net Assimilation Rate

However, the combination of the treatment with limited irrigation and mechanical weeding favourably influenced all the growth analysis parameters due to better aeration and increased root activity. Better root growth positively influenced all the above ground parts of the plant. Due to increased leaf area, net assimilation and relative assimilation were increased per unit area (Table 3).

Under the present day constraints and scarcity for irrigation water the result of the experiment clearly revealed that the planting of 14 days old younger seedlings raised under dapog method of nursery planted at a spacing of 25×25 cm adopting water saving irrigation schedule (2 cm on development of hairline crack) with SRI weeding practice was found optimum to achieve higher growth and productivity of rice.

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