Original Research Article

Unravelling the growth potential of rice under modified rice cultivation system in Tamil Nadu, India

Abstract

There is a need for increasing rice productivity to cope up with increasing population and water shortages, especially in Tamilnadu, India. Efforts were made in the past, mainly to increase the genetic potential of the crop, by developing high yielding varieties. However, adoption of improved agronomic practices and production technologies could further increase the productivity besides saving water. System of Rice Intensification (SRI) comprises the various altered agronomic practices and is proved to be an effective cultivation method by enhancing the rice growth and productivity. It is important to understand influence of individual practices and their combinations on rice growth and productivity for deriving the maximum growth and yield advantages of SRI features. A field experiment was conducted at Tamil Nadu Agricultural University, Coimbatore, Tamilnadu to study the growth responses of rice to different practices of SRI viz., 14 days old seedling with single seedling per hill, square planting pattern with wider spacing, Alternate Wetting and Drying (AWD) method of irrigation and, use of cono-weeders to control weeds. It was found that planting younger seedlings with single seedling per hill greatly increased dry matter assimilation in rice plants and the use of cono-weeders encouraged the tiller production in rice. The treatments with complete SRI practices produced 3 times higher number of tillers and panicles per hill and 38.9 percent more dry matter content than conventional practices. SRI practices could be adopted by the farmers to boost the growth attributes of rice and to achieve higher rice productivity in Tamilnadu.

Keywords: System of Rice Intensification, alternate wetting and drying, cono-weeding, rice growth.

Introduction

Oryza sativa L. seeds of the Poaceae family, commonly known as paddy, is one of the most important grains as half of the world population consumes it. It occupies a major position in food supply and has a major role in food security, especially in the Asian continent, where it is the staple food [1]. The land area available for rice production has increased from 30.5 million hectares in 1950 to 43.66 million hectares in 2019-2020. Total production of rice increased from 23.50 million tons in 1950 to 118.87 million tons in 2019-2020 and the productivity increased from 771 kg/ha in 1950 to 2722 kg/ha in 2019-2020 [2]. Rice is a most versatile crop growing from altitudes below sea level to hilly regions and from temperate regions to dry regions covering about 118 countries [3].

Even with the increase in production and cultivation area over time, the average productivity of rice in India still has a lot of space to improve. Rice is also one of the most water-consuming crops, accounting for around 40 percentage of global irrigation water [4]. Coupling with the increased water shortages due to climate change and increased human consumption, the production of rice is not enough to meet the needs of future population. There is a need for technologies to improve the productivity and reduce water usage of rice. System of Rice Intensification (SRI) is one of such technologies that is gaining attention in recent decades. The SRI and its principles originated from Madagascar region from the work of a priest [5] and from his technical writings during the 1980s. The set of principles widely used for SRI are 14 days old seedlings planted in square pattern and wider spacing 25 cm x 25 cm at a rate of one seedling per hill, weeding done by cono-weeders or a rotary hoe and alternate wetting and drying (AWD) method of irrigation for water saving. The views of researchers towards SRI suggest that there were an increase in productivity of rice cultivated under SRI practices [6]–[8]; while others report that SRI did not influence productivity positively than conventional rice cultivation method [9], [10]. SRI practices are not a defined set that is universally applicable. Rather, they should require research and modification of various components as per specific location and needs [11]. A five-year study conducted in India at 25 different locations followed by farmers survey have shown that SRI method promoted the rice growth and increased the yield in irrigated rice tracts [12]. Nevertheless, there are only few studies that analyzed the influence of each practice of SRI on growth and productivity. Thus, a field study was aimed to observe the effect of younger seedlings, wider and square planting, AWD irrigation and cono-weeding practices of SRI and their combinations on growth characteristics and productivity of Rice.

Materials and Methods

Experimental details: A field experiment was conducted at wetlands of Tamil Nadu Agricultural University, Coimbatore (10.98 ^{o}N, 77.00 ^{o}E), Tamil Nadu state in India during summer season of 2021. A short duration variety ADT 43 was chosen for this experiment. The weather data was collected from Agro Climate research Centre and soil data acquired from the soil analysis in Tamil Nadu Agricultural University. The soil at the experimental site was clay loam in texture with a pH of 8.2, EC of 0.5 dS m^{-1}, low nitrogen content of about 225 kg ha^{-1}, low carbon (0.56%) but high in Phosphorous (54.1 kg ha^{-1}) and Potassium (290 kg ha^{-1}). The average maximum temperature of 34 ^{o}C, average minimum temperature of 23.9 ^{o}C and 121 mm of rainfall over a period of 10 rainy days and 2 more days of light rainfall prevailed during cropping period. The average bright sunshine hours about 7.9 hours and average daily solar radiation of about 14.9 MJ m^{-2} was observed and average daily evaporation was 6.8 mm d^{-1} during the experiment. The treatments were selected in a way to add each practice to conventional rice cultivation and SRI in different combinations to observe their influence on rice growth and yield. The treatments were laid out in a randomized complete block design with four replications. The treatment details are represented in Table 1.

Table 1. Treatment details of the experiment

Treatment	Nursery duration	Plant spacing	Method of Irrigation	Weeding method
T_1	14	25 x 25	Continuous Flooding	Manual weeding
T_2	14	25 x 25	Continuous Flooding	Cono weeder
T_3	14	25 x 25	Alternate wetting and Drying	Manual weeding
T_4	14	25 x 25	Alternate wetting and Drying	Cono weeder
T_5	21	15 x 10	Continuous Flooding	Manual weeding
T_6	21	15 x 10	Alternate wetting and Drying	Manual weeding

T_4 = complete SRI, T_5 = conventional

The field was prepared by puddling twice with roto-puddler three days prior to transplanting. Each plot with a dimension of 5 x 5 m was separated from nearby plots with channels of 1 m width and buffer bunds of 30 cm in width for prohibiting water movement from one plot to others. Recommended dose of fertilizers (150:50:50 N: P: K) for the study region was applied to all treatments [13].

AWD Irrigation was done by installing a field water tube in the plot with 10 cm of it sticking out and 20 cm was submerged inside the soil. The irrigation was done to flood the field to about 2 to 3 cm above the soil layer and allowed to dry till the water level reaches more than 10 cm below the soil layer. A practice named "safe-AWD" given by Bouman *et al.* (2007) was adopted where the field was irrigated sufficiently during the week of peak flowering to prevent yield losses due to water stress. Conventional treatments were irrigated using continuous flooding where the water level is maintained at 5 cm above the soil. Cono-weeding was done at 10 days interval till 45 days after transplanting in two directions in a crisscross pattern. Manual weeding was done as per need when the weeds are above threshold level. Weeding was done once in 10 days to remove the weed growth in the plots with alternate wetting and drying irrigation. The irrigation channels and the buffer channels were kept weed free by hand weeding.

Biometric observations: Plant height, number of leaves, number of tillers, dry matter production and leaf length and width were taken at three stages viz., vegetative stage at 35 days after sowing (DAS), flowering stage at 65 DAS and before maturity at 90 DAS. The dry matter production was taken from plants in the plot, omitting border rows to avoid border effect. The non-destructive observations were taken from five randomly tagged plants in each plot, following the procedures given by Gomez (1972). Dry matter content was measured after drying the plants in a hot air oven at 70 ^{o}C for 48 hours.

Leaf area index was calculated using the dimensions of flag leaf (the length and maximum width of the leaf) and a K-factor formulated by [16] using the formula given below. The K-factor value for rice varieties with leaf length to width ratio falling in the range 19 to 45 for the dry season was taken from [16]

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

where

K = factor for leaf area (0.74 for dry season was used)

L = length of flag leaf in centimetres (third leaf from the top)

W = maximum width of third leaf in centimetres

Statistical analysis

The observed data were statistically analysed for significance using analysis of variance (ANOVA) as per randomized complete block design. The mean dataset was then arranged in descending order and grouped or differentiated using Duncan multiple range test (DMRT) with 5% significance level and the results are presented in the Table 2.

Results and Discussion

Plant Height: Significant differences among treatments in various biometric parameters were observed. At all three stages, treatment with complete SRI practices such as 14-day seedling (younger seedling), 25 x 25 cm spacing, cono-weeding and AWD irrigation (T_4) had significantly taller plants (90.98 cm) which was on par with other treatments with early transplanting and wider spacing while compared to treatments with 21 days old seedlings and closer spacing (T_5). The Treatment with younger seedling, cono-weeding and conventional flooding irrigation (T_2) had second-tallest plants during flowering (73.30 cm) and maturity (89.65 cm) stages (Figure 1.).

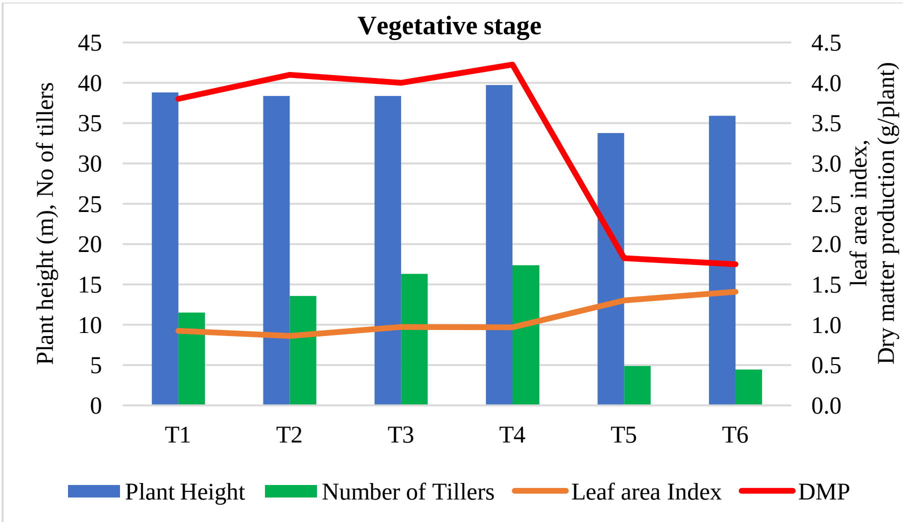
Cono-weeding and early transplanting (younger seedling) favored the plant growth and produced taller plants. This might be due to active growth of younger seedlings through effective utilization of nutrients and other resources with extended growth period for assimilating photosynthates during vegetative phase in the main field after transplanting. Similar results were reported in previous studies in which plants under SRI cultivation recorded taller plants than in conventional method [17]–[19]. This might be due to increased growth of rice plants in vegetative stage with less competition between the plants and also due to less weeds by cono weeding.

Number of tillers per hill: The highest number of tillers per hill (31.95) was observed in the treatment with 14 days seedlings, 25 x 25 cm spacing, cono-weeding and AWD irrigation (T_4), followed by treatments T_2 and T_1 except at vegetative stage during which the treatment T_3 had higher tiller number per hill than T_4. Though the number of tillers were high in treatments with wider spacing than treatments with dense planting, the tiller density per unit area was always higher in T_5 and T_6 than other treatments at all stages of rice (Table 2).

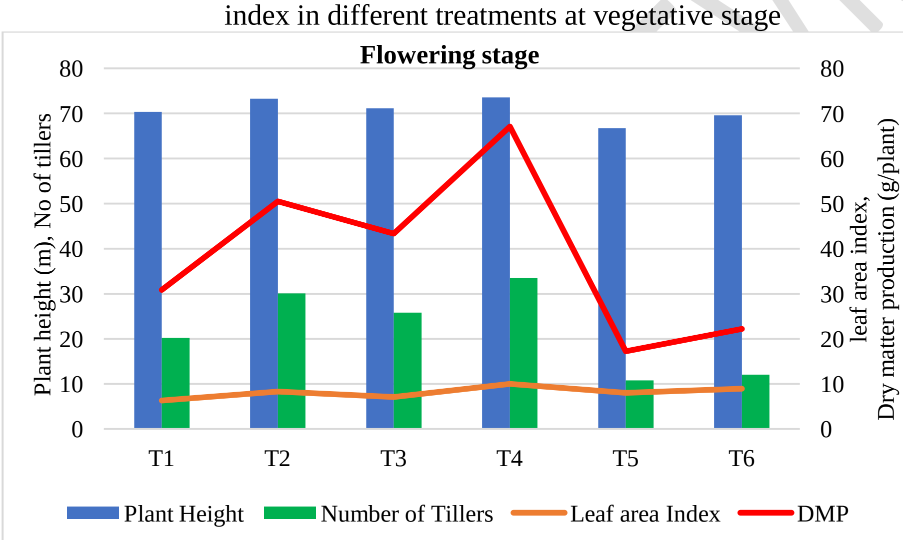
The increased number of tillers could be attributed to the physiology of rice plants termed phyllochron which is the interval between emergence of successive leaves or tillers and root to form a phytomere from the main stem/tiller. The younger seedlings established at 4^{th} phyllochron exhibited vigorous growth compared to 21 days age seedlings which was established at 6^{th} phyllochron in the main field. The robust growth of young seedlings and increased soil aeration due to cono-weeding might have helped in emergence of new tillers [7], [20].

Leaf Area Index: Leaf area index was found to be higher in treatments with closer spacing than wider spacing treatments during vegetative stage while, treatment with all SRI practices had larger LAI (9.81) than treatment T_5. Closer spaced treatment with AWD irrigation T_6 maintained the second-highest LAI values (9.31) throughout the growth period. The LAI was highest during flowering stage and began to reduce after the end of grain filling stage. The SRI treatment T_4 had much broader leaves and higher number of leaves because the younger seedlings got an opportunity to have longer growing period in the main field and less competition for resources under wider spacing, that resulted in higher LAI [18], [21]–[23].

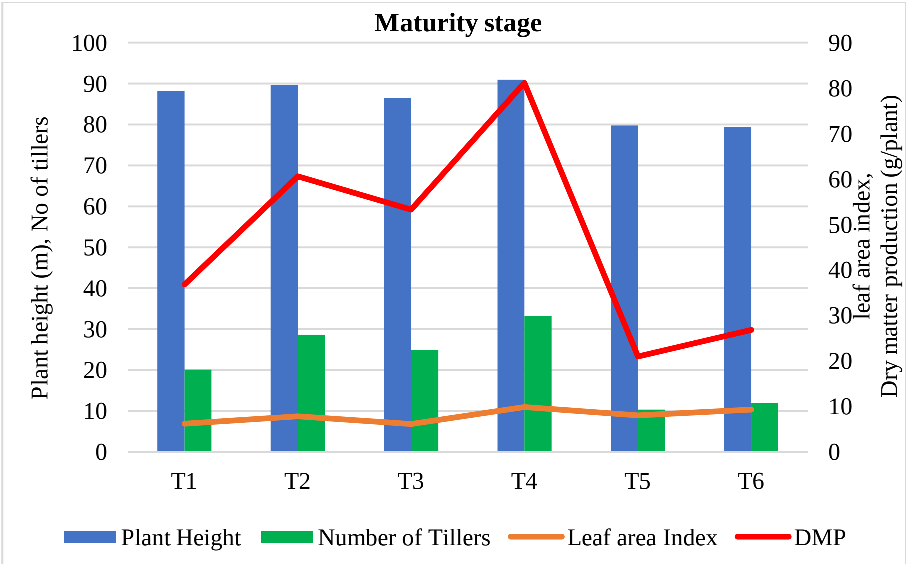
Number of panicles per hill: The number of panicles were highest (30.88) in complete SRI treatment (T_4) which was followed by a treatment (T_2) with cono-weeding (27.58), indicating the positive effect of cono weeding on tiller and panicle production. Mandal *et al.*, (2013) also stated that SRI treatments had higher panicle density, grain filling efficiency and superior yield than manually weeded treatments. The number of panicles is directly influenced by the number of tillers. Number of panicles greatly influences grain yield and the ability of plants to sink nutrients into the seed. Panicle length varied significantly among treatments and it was observed that the difference in panicle length among treatments was not based on SRI practices. Conventional treatments had similar panicles lengths as that of SRI treatments.



a) Plant height, number of tillers, number of panicles, leaf area and dry matter production index in different treatments at vegetative stage



b) Plant height, number of tillers, number of panicles, leaf area index and dry matter production in different treatments at flowering stage

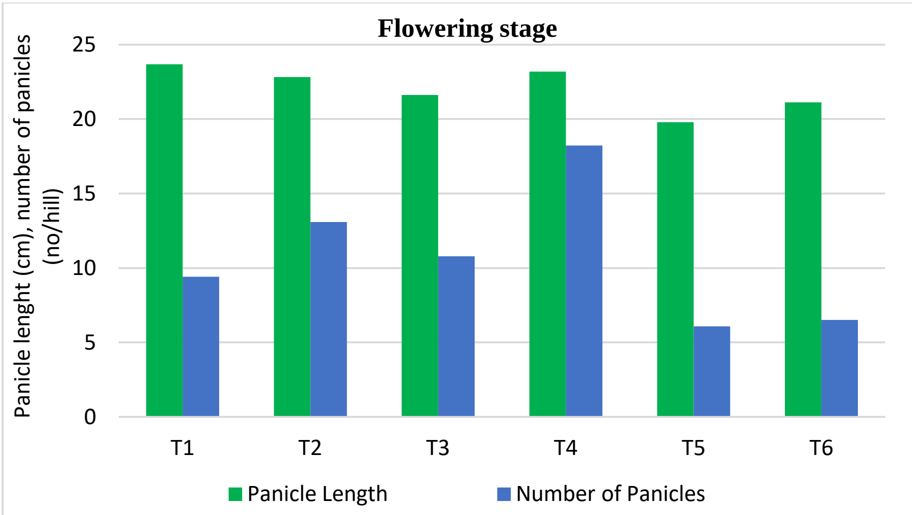


c) Plant height, number of tillers, number of panicles, leaf area index and dry matter production in different treatments at maturity stage

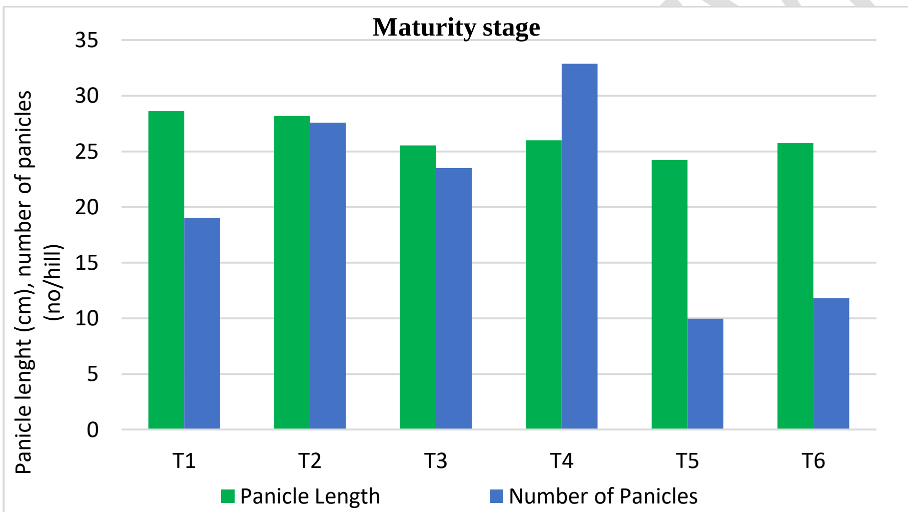
Figure 1(a- c). Influence of conventional and SRI practices on growth of rice

Dry matter production: Dry matter accumulation per plant was also higher in complete SRI (T_4) treatment (73.80 g/plant). The treatments T_2 and T_3 were at par with each other with 69.85 g/plant and 68 g/plant respectively. Cono weeded plots produced second highest biomass at all stages (Table 2) as a result of profuse tillering and increased root growth in cono weeded treatments. Similar findings were reported in many earlier studies [25]–[27].

The results of past studies demonstrated an increase in biomass accumulation in SRI treatments [17], [19], [28], [29]. Dry matter production at maturity stage was 38 percent more in modified cultivation practice (T_4) than the conventional rice cultivation. Cono weeding with wider spaced treatment (T_2) produced 14 % more biomass than conventional treatments.



a) Panicle length and number of panicles per hill at flowering stage



b) Panicle length and number of panicles per hill at maturity stage

Figure 2. panicle length and number of panicles per hill for treatments at a) flowering stage and b) maturity stage

Table 2. Growth characteristics of rice plants under conventional and SRI treatments at three different stages 1) vegetative stage 2) flowering stage and 3) maturity stage

Stage	Treatment	Plant Height	Number of Tillers	LAI	Number of Panicles	Panicle Length	Dry Matter Production
1	T1	$38.80^{a} \pm 1.01$	$15.30^{b} \pm 0.82$	$0.96^{cd} \pm 0.12$	-	-	$4.35^{b} \pm 0.06$
	T2	$38.38^{a} \pm 1.23$	$11.78^{c} \pm 0.17$	$0.86^{d} \pm 0.03$	-	-	$4.08^{c} \pm 0.05$
	T3	$38.35^{a} \pm 1.80$	$19.18^{a} \pm 2.01$	$0.97^{c} \pm 0.06$	-	-	$4.20^{bc} \pm 0.22$
	T4	$39.73^{a} \pm 0.93$	$15.38^{b} \pm 0.59$	$0.94^{cd} \pm 0.16$	-	-	$4.18^{a} \pm 0.10$
	T5	$33.78^{c} \pm 0.66$	$4.90^{d} \pm 0.08$	$1.30^{b} \pm 0.14$	-	-	$1.83^{d} \pm 0.05$
	T6	$35.90^{b} \pm 0.51$	$4.48^{d} \pm 0.01$	$1.41^{a} \pm 0.09$	-	-	$1.75^{d} \pm 0.06$
2	T1	$70.40^{b} \pm 2.16$	$27.48^{c} \pm 2.23$	$7.59^{bc} \pm 0.70$	$11.83^{bc} \pm 1.50$	$23.68^{a} \pm 1.36$	$30.13^{c} \pm 0.71$
	T2	$73.30^{a} \pm 0.67$	$30.13^{b} \pm 1.26$	$8.30^{bc} \pm 1.63$	$13.10^{b} \pm 0.61$	$22.83^{ab} \pm 1.42$	$32.30^{b} \pm 0.71$
	T3	$71.20^{ab} \pm 0.80$	$27.33^{c} \pm 0.67$	$7.08^{c} \pm 0.93$	$10.73^{c} \pm 0.30$	$21.63^{bc} \pm 0.48$	$31.98^{b} \pm 0.13$
	T4	$73.58^{a} \pm 0.55$	$33.60^{a} \pm 1.24$	$9.98^{a} \pm 1.38$	$18.23^{a} \pm 2.52$	$23.20^{a} \pm 0.85$	$34.43^{a} \pm 1.26$
	T5	$66.80^{c} \pm 1.52$	$10.83^{d} \pm 0.94$	$8.04^{bc} \pm 0.34$	$6.08^{d} \pm 0.15$	$19.80^{d} \pm 2.79$	$9.35^{d} \pm 0.39$
	T6	$69.58^{b} \pm 2.53$	$12.05^{d} \pm 0.86$	$8.94^{ab} \pm 0.63$	$6.53^{d} \pm 0.46$	$21.13^{cd} \pm 1.65$	$8.60^{d} \pm 0.26$
3	T1	$88.23^{ab} \pm 3.17$	$25.85^{c} \pm 1.05$	$7.06^{c} \pm 0.97$	$24.55^{c} \pm 2.50$	$28.63^{a} \pm 1.13$	$65.70^{d} \pm 0.73$
	T2	$89.65^{ab} \pm 2.36$	$28.65^{b} \pm 0.65$	$7.78^{c} \pm 1.21$	$27.58^{b} \pm 1.28$	$28.18^{a} \pm 1.59$	$69.85^{b} \pm 0.53$
	T3	$86.43^{b} \pm 1.61$	$24.93^{c} \pm 0.92$	$5.52^{d} \pm 0.57$	$23.50^{c} \pm 0.74$	$25.53^{b} \pm 0.63$	$68.03^{c} \pm 0.81$
	T4	$90.98^{a} \pm 2.2$	$31.95^{a} \pm 0.10$	$9.95^{a} \pm 1.22$	$30.88^{a} \pm 1.34$	$26.00^{b} \pm 0.42$	$73.80^{a} \pm 1.54$
	T5	$79.75^{c} \pm 3.9$	$10.33^{e} \pm 0.90$	$7.98^{bc} \pm 0.29$	$9.98^{d} \pm 0.94$	$24.20^{b} \pm 3.13$	$12.88^{e} \pm 0.15$
	T6	$79.35^{c} \pm 2.63$	$11.90^{d} \pm 1.03$	$9.31^{ab} \pm 0.63$	$11.70^{d} \pm 0.96$	$25.73^{b} \pm 1.87$	$12.73^{e} \pm 0.33$

$^{a-f}$ Mean with the different superscript letters show significant differences ($p < 0.05$)

Conclusion:

The results obtained in the study showed that use of young seedlings resulted in an increase in growth and development of rice and tiller production was augmented by cono weeding. In the earlier days, most advancements in rice cultivation were attained in creating new varieties with high yielding potential, increasing use of N fertilizers and formulating recommended dose of fertilizers during green revolution. Adoption of SRI techniques could be the next right step to enhance the growth and productivity of rice in Tamilnadu.

References

[1] N. K. Fukagawa and L. H. Ziska, "Rice: Importance for Global Nutrition," 2019. [Online]. Available: http://www.riceassociation.org.uk/content/1/18/types-.

[2] Indiastat, "Statevise and Seasonvise Rice Area,Production and productivity," *Ministry of Agriculture & Farmers Welfare, Govt. of India. (ON2873) & Past Issues.*, 2022. https://www.indiastat.com/data/agriculture/rice/data-year/2012-2022 (accessed Mar. 03, 2022).

[3] P. Krishnan, B. Ramakrishnan, K. R. Reddy, and V. R. Reddy, *High-Temperature Effects on Rice Growth, Yield, and Grain Quality*, 1st ed., vol. 111. Elsevier Inc., 2011.

[4] U. Surendran, P. Raja, M. Jayakumar, and S. R. Subramoniam, "Use of efficient water saving techniques for production of rice in India under climate change scenario: A critical review," *J. Clean. Prod.*, vol. 309, no. July 2020, p. 127272, 2021, doi: 10.1016/j.jclepro.2021.127272.

[5] H. De Laulanié, "Intensive Rice Farming in Madagascar," *TROPICULTURA*, vol. 29, pp. 183–187, 2011.

[6] A. K. Thakur, S. Rath, and K. G. Mandal, "Differential responses of system of rice intensification (SRI) and conventional flooded-rice management methods to applications of nitrogen fertilizer," *Plant Soil*, 2013, doi: 10.1007/s11104-013-1612-5.

[7] N. Uphoff, "Agroecological Implications of the System of Rice Intensification (SRI) in Madagascar," *Environ. Dev. Sustain.*, vol. 1, no. 3–4, pp. 297–313, 2000.

[8] L. Zhao, L. Wu, Y. Li, S. Animesh, D. Zhu, and N. Uphoff, "Comparisons of Yield, Water Use Efficiency, and Soil Microbial Biomass as Affected by the System of Rice Intensification," *Commun. Soil Sci. Plant Anal.*, vol. 41, no. 1, pp. 1–12, 2010, doi: 10.1080/00103620903360247.

[9] A. Dobermann, "A critical assessment of the system of rice intensification (SRI)," *Agric. Syst.*, vol. 79, pp. 261–281, 2004, doi: 10.1016/S0308-521X(03)00087-8.

[10] A. J. McDonald, P. R. Hobbs, and S. J. Riha, "Stubborn facts: Still no evidence that the System of Rice Intensification out-yields best management practices (BMPs) beyond Madagascar," *F. Crop. Res.*, vol. 108, no. 2, pp. 188–191, Aug. 2008, doi: 10.1016/J.FCR.2008.06.002.

[11] W. A. Stoop, N. Uphoff, and A. Kassam, "A review of agricultural research issues raised by the system of rice intensification (SRI) from Madagascar: Opportunities for improving farming systems for resource-poor farmers," *Agric. Syst.*, vol. 71, no. 3, pp. 249–274, 2002, doi: 10.1016/S0308-521X(01)00070-1.

[12] B. Nirmala *et al.*, "Integrated assessment of system of rice intensification vs. conventional method of transplanting for economic benefit, energy efficiency and lower global warming potential in India," *Agroecol. Sustain. Food Syst.*, vol. 45, no. 5, pp. 745–766, 2021, doi: 10.1080/21683565.2020.1868648.

[13] Directorate of Agriculture & Tamil Nadu Agricultural University, *Crop Production Guide*

Agriculture 2020. Coimbatore: Tamil Nadu Agricultural University, 2020.

[14] B. A. M. Bouman, R. M. Lampayan, and T. P. Tuong, *Water Management in Irrigated Rice: Coping with Water Scarcity*. Los Banos,Phillippines: International Rice Research Institute, 2007.

[15] K. A. Gomez, *Techniques for field experiments with rice: Layout : Sampling. Sources of error*. Los Baños: The International Rice Research Institute., 1972.

[16] K. M. Palaniswamy and K. A. Gomez, " Length-Width Method for Estimating Leaf Area of Rice 1 ," *Agron. J.*, vol. 66, no. 3, pp. 430–433, 1974, doi: 10.2134/agronj1974.00021962006600030027x.

[17] S. Gopalakrishnan *et al.*, "Assessment of different methods of rice (Oryza sativa. L) cultivation affecting growth parameters, soil chemical, biological, and microbiological properties, water saving, and grain yield in rice-rice system," *Paddy Water Environ.*, vol. 12, no. 1, pp. 79–87, 2014, doi: 10.1007/s10333-013-0362-6.

[18] A. J. Musa, S. H. Abbas, and K. A. Hameed, "Performance of Two Rice (Oryza Sativa L.) Genotypes Under SRI and Conventional Farming Methods in Three Locations in Iraq," *IOP Conf. Ser. Earth Environ. Sci.*, vol. 910, no. 1, p. 012138, 2021, doi: 10.1088/1755-1315/910/1/012138.

[19] E. Pasuquin, T. Lafarge, and B. Tubana, "Transplanting young seedlings in irrigated rice fields: Early and high tiller production enhanced grain yield," *F. Crop. Res.*, vol. 105, no. 1–2, pp. 141–155, 2008, doi: 10.1016/j.fcr.2007.09.001.

[20] A. K. Thakur, S. Rath, S. Roychowdhury, and N. Uphoff, "Comparative performance of rice with System of Rice Intensification (SRI) and conventional management using different plant spacings.," *J. Agron. Crop Sci.*, 2010, doi: 10.1111/j.1439-037x.2009.00406.x.

[21] B. U. Choudhury and A. K. Singh, "System of rice intensification and irrigated transplanted rice," 2007, Accessed: Apr. 05, 2022. [Online]. Available: https://www.researchgate.net/publication/303802165.

[22] K. A. Hameed, A. K. J. Mosa, and F. A. Jaber, "Irrigation water reduction using System of Rice Intensification compared with conventional cultivation methods in Iraq," *Paddy Water Environ.*, vol. 9, no. 1, pp. 121–127, Mar. 2011, doi: 10.1007/S10333-010-0243-1.

[23] M. Vijayakumar, S. D. S. Singh, N. K. Prabhakaran, and T. M. Thiyagarajan, "Effect of SRI (system of rice intensification) practices on the yield attributes, yield and water productivity of rice (Oryza sativa L.)," *Acta Agron. Hungarica*, vol. 52, no. 4, pp. 399–408, 2004, doi: 10.1556/AAgr.52.2004.4.9.

[24] M. K. Mandal, B. Duary, and G. C. De, "Effect of crop establishment and weed management practices on weed growth and productivity of Basmati rice," *Indian J. Weed Sci.*, vol. 45, no. 3, pp. 166–170, 2013.

[25] J. Barison and N. Uphoff, "Rice yield and its relation to root growth and nutrient-use efficiency under SRI and conventional cultivation: An evaluation in Madagascar," *Paddy Water Environ.*, vol. 9, no. 1, pp. 65–78, 2011, doi: 10.1007/s10333-010-0229-z.

[26] A. K. Thakur, S. Rath, D. U. Patil, A. Kumar, and A. Kumar, “Effects on rice plant morphology and physiology of water and associated management practices of the system of rice intensification and their implications for crop performance,” *Paddy Water Environ.*, 2011, doi: 10.1007/s10333-010-0236-0.

[27] K. C. Sahoo, K. Pramanik, and B. S. Rath, “Effect of age seedlings, weed and nutrient management on root growth and nutrient uptake under SRI in Odisha.,” *IJBEAS*, vol. 1, no. 2, pp. 46–50, 2015, Accessed: Oct. 20, 2021. [Online]. Available: www.sbear.in.

[28] L. Zhao, L. Wu, Y. Li, X. Lu, D. Zhu, and N. Uphoff, “Influence of the system of rice intensification on rice yield and nitrogen and water use efficiency with different N application rates,” *Exp. Agric.*, vol. 45, no. 3, pp. 275–286, 2009, doi: 10.1017/S0014479709007583.

[29] A. Dass and S. Chandra, “Irrigation, spacing and cultivar effects on net photosynthetic rate, dry matter partitioning and productivity of rice under system of rice intensification in mollisols of northern India,” *Exp. Agric.*, vol. 49, no. 4, pp. 504–523, 2013, doi: 10.1017/S0014479713000252.