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Yasa Geeth Naga Venkata Maruthi Manikanta
Department of Agronomy, Lovely Professional University, Punjab, India

Kangujam Bokado
Department Of Agronomy, Lovely Professional University, Punjab, India

Barkha
Department Of Agronomy, Lovely Professional University, Punjab, India

Gayatri Kumari
Department Of Agronomy, Lovely Professional University, Punjab, India

Corresponding Author
Kangujam Bokado
Department Of Agronomy, Lovely Professional University, Punjab, India

A research review on system of rice intensification (SRI)

Yasa Geeth Naga Venkata Maruthi Manikanta, Kangujam Bokado, Barkha and Gayatri Kumari

Abstract
To meet future food needs, it is very important to increase productivity while reducing factors used for production such as land and water. One potentially promising technology for yield enhancement is the System of Rice Intensification (SRI) developed in Madagascar in the mid-1980s. It was developed unconventionally and is now recognized and implemented in over 50 countries. System of Rice Intensification is a set of improved rice processing methods based on several key ingredients and adapted to local conditions. Although the System of Rice Intensification has standard agricultural methods for growing transplanted rice such as sowing, transplanting, irrigation, weed control, and nutrition, there are significant differences in practice. Rice reacted more productively, resulting in unprecedented plant growth. The aim is to optimize the growth and development of aboveground and underground parts *i.e.* shoots and root parts which inwards increase yields. The System of Rice intensification system is the best choice for rice production to meet the needs of a growing population.

Keywords: System of rice intensification, less inputs, water saving, high yield, productivity

Introduction
Rice (*Oryza sativa* L.) is among the most significant cereal crops which belong to the Poaceae family or Gramineae. It is a dietary staple for over 60% of the world's population followed by wheat. Asia produces and consumes around 90% of the world's rice. Rice is a submerged crop that consumes the most water and irrigation. To produce 1 kg of rice grains, the crop uses 3000-5000 liters of water. In Asia, more than 80% of the developed freshwater resources are used for irrigation and about half of it is used for rice production (Dawe *et al.*, 1998) [8]. Rapid depletion of water resources threatens the sustainability of irrigated rice and, consequently, the food security and livelihoods of rice producers and consumers (Tuong *et al*., 2004) [26]. There is also strong evidence that water scarcity has arisen in rice-growing areas, where rice farmers need technology to tackle water scarcity, and that rice should be sought because of water scarcity (Tuong and Bouman, 2002) [25]. One of the most promising technologies that save water and environment in rice cultivation is the System of Rice Intensification (S.R.I). The French Priest Father Henri de Laulanie in Madagascar developed the system for rice intensification (S.R.I) in the 1980s in an effort to find sustainable agricultural practices which lead to higher productivity, and optimum use of capital and labor, less input cost, and less requirement of water. The System of Rice Intensification (SRI), which is one of the strategies for growing rice under regulated water management, is recognized to contribute to the rising food demand while also guaranteeing water security and environmental balance as well. The System of Rice Intensification is a way of harmonizing the elements of soil, water, light, and plant to allow the plant to achieve its fullest potential, which is frequently hidden when inadequate practices are implemented (Zotoglo, 2011) [29]. Unlike traditional rice cultivation, the System of Rice Intensification includes an alternative to wet drying for rice fields (Kepha, Bancy, and Patrick, 2014) [10]. The main aim of this review is to show the various practices of SRI and the advancement in various traits of the system of rice intensification (SRI) than the conventional methods of rice planting.

SRI Practices
1. Generally for SRI the seedlings of 10-15 days are used for transplanting.
2. Individual seedlings are planted with minimal time intervals from the nursery and transplanted at a shallow depth (1-2 cm).
3. Increase the correct plant spacing by planting a 20 x 20 cm or 25 x 25 cm square with

rope or marker (or 30 x 30 cm or even wider if the soil is very fertile).
4. Up to panicle initiation: Irrigate to 2.5 cm depth after the water ponded earlier disappears and hairline cracks are formed on the soil surface. Irrigation is required up to a depth of 2.5 cm after one day when the ponded water evaporates after the stage of panicle initiation.
5. 10-12 days after transplanting and continuing until the canopy closes, walk between rows, move vertically across the field, and inter-cultivation with mechanical weeds every 10-12 days.
6. Recommendation of using cow dung, green manure, organic fertilizers, and vermicompost. Chemical fertilizers can be used, but they do not have such a beneficial effect on the soil system.

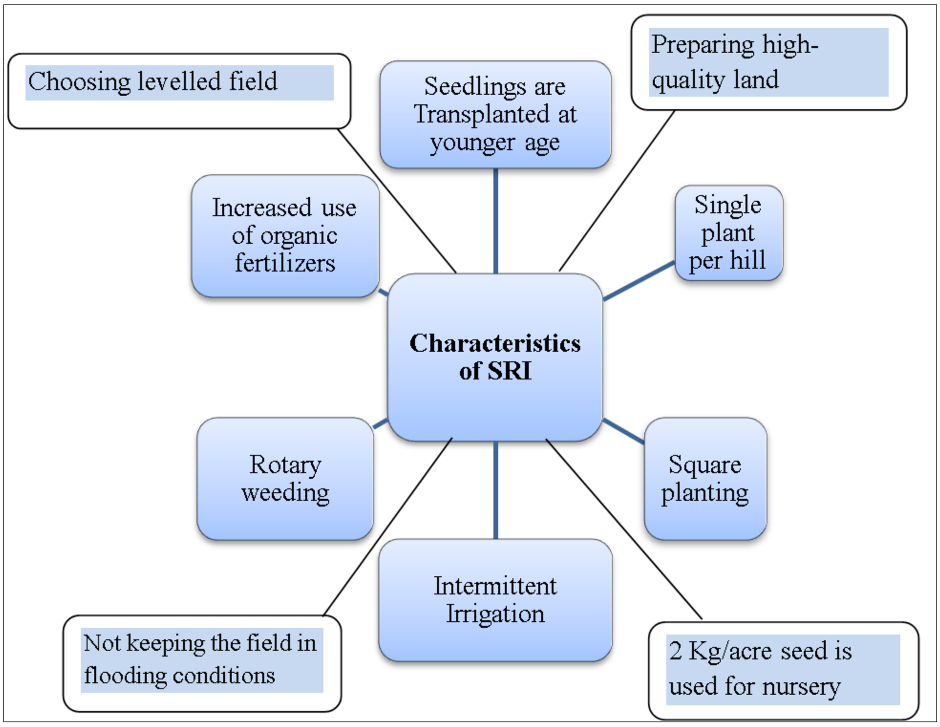

Fig 1: Different characteristics and practices of SRI

Effect of System of Rice Intensification on growth, yield and economics of rice: System of Rice Intensification (SRI) can be practiced with any variety, but seeds are to be selected carefully. Only one seedling per hill will be transplanted in square planting. It also reduces the use of multiple external inputs (Stoop *et al*., 2002) [22]. Rice crops emit high amounts of greenhouse gasses and methane (CH_4) (Ciais *et al*., 2013) [6]. By the introduction of the System of Rice Intensification, the emission of CH_4 is decreased due to the intermittent irrigation which inwards increases the soil permeability and soil redox reactions (Tyagi *et al*., 2010) [27]. Rice intensification and transplanting procedures were found to be more efficient in minimizing weed infestation and nitrogen removal by weeds, resulting in improved yield characteristics and yield (Singh *et al*., 2021) [21]. Kumar *et al*., 2021 [11] observed all growth and yield parameters were highest in the SRI, which was statistically at par with conventional puddled transplanted rice (CPTR) utilizing 12 days old seedlings in most parameters.

Table 1.1: Difference in growth parameters of plants in SRI and conventional methods of cultivation

S. No	Parameter	SRI	Conventional treatment	Reference
1.	Plant height	108.6 cm	104.3 cm	Vijayakumar *et al*., 2006 [12]
2.	Plant height	119.4 cm	115.4 cm	Tejendra *et al*., 2011 [24]
3.	Plant height	119.6 cm	113.2 cm	Kumar *et al*., 2021 [11]
4.	Plant height	135.73 cm	133.12 cm	Midya *et al*., 2021 [14]
5.	LAI	7.62	5.58	Vijayakumar *et al*., 2006 [12]
6.	LAI	1.55	1.48	Kumar *et al*., 2021 [11]
7.	Number of tillers m^{-2}	475	452	Vijayakumar *et al*., 2006 [12]
8.	Number of tillers m^{-2}	308	281	Kumar *et al*., 2021 [11]

The plant gets sufficient space, sunlight, and nutrients for their growth and development in the SRI method of rice cultivation due to square planting. In addition to that the intermittent wetting and drying application of water makes the plant aerated and helps to reduce the weed infestation in the field. So, the growth and development of the plant increases in SRI method as shown in Table 1.1. In addition to water-saving, cost savings, and resistance to biotic and abiotic stress, great attention is paid to the high yield potential of the System of Rice Intensification (SRI) (Namara *et al*., 2004) [16]. Under the System of rice intensification, the nutrient management strategies of (Effective Micro-organism solution) EM+ Vermicompost were found to be superior in terms of growth of rice, yield qualities, characters, and yield (Behera *et al*., 2021) [3]. Compared to the traditional practice of planting 4-5 seedlings in bunches less than 20 x 20 cm, the system of rice intensification requires fewer seeds. Unlike traditional irrigation methods, which are constantly flooded, rice fields can also be drained during the growing season, thereby reducing the need for irrigation water. (Rejesus *et al*., 2011) [19]. A recent study provides extensive evidence of more than 50% improvement in System of Rice Intensification (SRI) performance in many areas (Takahashi, 2013) [23]. The system of rice intensification is reported to improve the yield of crops and water productivity (Deelstra *et al*., 2018) [9]. Ali *et al*., (2019) [1] also reported that dry weed biomass decreased with decreasing inter-row spacing. The increase in dry weed biomass due to the extended period of weed competition is undoubtedly associated with longer germination times of the weeds and easier growth and development. Improved yield features such as the frequency of productive tillers m^{-2}, panicle length, and quantity of grains $panicle^{-1}$ are ascribed to SRI's higher grain production.

The influence of the interaction of different intervals between rice and periods of weed competition on traits that promote root growth, yield characteristics and yield of rice was still significant during the two-year study period. The data from their work showed that rice plants with the maximum root length (30.9 cm and 30.0 cm) and root biomass (34.5 g and 32.9 g) were harvested in plots with more plant spacing (30 cm x 30 cm) with weed-free conditions. However, the combination of plant spacing with 30 cm x 30 cm did not differ significantly from plant to plant at 25 cm x 25 cm in the interaction of non-competitive weeds in terms of root length and root biomass in both experimental years. Significant reductions in root length and biomass began to occur when the spacing between the rows of grafts was reduced to 20 cm x 20 cm under the same weed-free conditions. The smallest plant spacing (20 cm x 20 cm) with weed control resulted in the shortest root length of rice (12.2 and 11.4 cm) and root biomass (10.0 and 9.6 g). (Chadhar *et al*. 2020) [5]. Similarly, the most fertile tillers per hill (55.8 and 53.4), 1000 kernel weights (24.7 and 23.8 g), and the normal percentage of kernels (81.37 and 79.13%) were recorded at a distance between plants of 30cm× 30cm when there was no competition of weeds, and grain yields between 2010 and 2011 were the highest in the combination (transplant distance 25 cm x 25 cm without weed conditions) (5.6 and 5.6 t ha^{-1}, respectively). The peak values for the fertile tillers $hill^{-1}$, 1000 grain weight, and normal grain ratio were statistically like those observed at a 25 cm x 25 cm replanting interval without weed competition. The lowest rice kernel yield (1.8 and 1.8 t ha^{-1}) was achieved in the interaction of 30 cm × 30 cm spacing of rice transplantation with the full-season competition with the System of Rice Intensification in all treatments. Arbuscular mycorrhizal fungi are also affected by cultural practices. When communities of arbuscular mycorrhizal fungi inhabiting rice roots grown under the rice intensification system (SRI) were compared with those found with conventional cultivation methods, all arbuscular mycorrhizal fungi in roots sampled in the conventional plots belonged to a single genus, Glomus, while in the roots of the rice plants grown in an SRI environment there were gene sequences of both Acaulospora, and Glomus is present. (Watanarojanaporn, N.; *et al.* 2013) [28].

Table 1.2: Difference in Yield between SRI and conventional methods of cultivation (Grain yield)

S. No	Yield for SRI treatment	Yield for conventional treatment	Reference
1.	3.436 t/ha	3.340 t/ha	Singh *et al.*, 2021 [21]
2.	6.7 t/ha	5.7 t/ha	Mboyerwa *et al.*, 2022 [13]
3.	6.020 t/ha	5.280 t/ha	Kumar *et al.*, 2021 [11]
4.	4.580 t/ha	4.119 t/ha	Shanmugasundaram *et al.*, 2021 [20]
5.	6.10 t/ha	4.00 t/ha	Duttarganvi *et al.*, (2016)
6.	6.21 t/ha	5.92 t/ha	Midya *et al.*, 2021 [14]

The increase in plant growth and development leads to the increases in the yield attributing characteristics of the plant which makes the SRI more efficient than the conventional method in case of production which is shown in Table 1.2. A minimum of 100kg of rice seeds are required for one hectare of broadcasting, while 30-60kg of seeds are required for planting.

However, the System of Rice Intensification (SRI) only requires 4-10 kg of seed per hectare. This reduces the cost of production resources and labor costs for farmers. System of Rice Intensification typically includes early transplanting (less than 15 days) of one or two seedlings per shallow transplant, with wide spacing (20 x 20 cm or more) and alternating wetting and drying (Berkhout and Glover, 2011) [4]. With Green manure -SRI, the average yield of soil tillage m^{-2} is 456 m^{-2} higher than with the traditional method of rice cultivation, equal to 390 m^{-2}. Increased panicle length and numbers of grains $panicle^{-1}$ were also observed under green manure - SRI than in the conventional method of rice cultivation. Green manure SRI registered higher grains $panicle^{-1}$and length of a panicle of 148 and 22.19 cm respectively. (Watanarojanaporn; *et al*. 2013) [28]. The grain yield of rice was influenced by the adoption of green manure -SRI. Increased mean grain yield of 6450 kg ha^{-1} was registered by the adoption of green manure - SRI which was higher than the conventional method of rice cultivation. The conventional method of rice cultivation recorded the grain yield of 5510 kg ha^{-1}. The green manure SRI method recorded a 17.0 percent yield increment over the conventional method. Cost economics of both methods of rice cultivation revealed that the cost of cultivation was comparatively lesser in green manure SRI than in the conventional method of rice cultivation. The mean cost of cultivation of twenty-one on-farm demonstrations for SRI and conventional methods was Rs.55100 ha^{-1} and Rs.67500 ha^{-1} respectively. Adoption of Green manure-SRI was found to reduce the cost of cultivation by Rs.12400 ha^{-1}.

Table 1.3: Difference in B:C between SRI and conventional methods of cultivation (B: C ratio)

S. No	B:C for SRI treatment	B:C for conventional treatment	Reference
1.	1.42	1.06	Singh *et.al.*, 2021 [21]
2.	1.46	1.2	Nirmala *et.al.*, 2021 [17]
3.	1.99	1.54	Midya *et.al.*, 2021 [14]

The increase in production and reduction in cost of production makes more profit to the farmers. So, the benefit cost ratio will be higher as compared to the conventional method of rice production as shown in Table 1.3.

Conclusion

The System of rice intensification technique not only can save the water and cost but also will stabilize the environment as it involves the use of organic manures. From System of rice intensification highest growth parameters, grain yield and highest benefit cost ratio was recorded. As the SRI technique is best suitable for conserving the water and helps in cost cuttings for the usage of seeds for nursery and labour charges. SRI provides the farmer to grow the rice with less or minimal quantity of water. By adopting the SRI technique, the farmer can save the existing land from deterioration by reducing the use of chemical fertilizers and gets the highest yields.

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