



Significance of system of rice intensification (SRI) on rice productivity, plant and soil nutrition- An overview

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Abstract

Substantial loss of water through percolation which reduces the crop water productivity in flooded rice cultivation. Sustainable agricultural practices that can lead to higher productivity, optimum use of capital labor, less input cost and less requirement of water. There are several strategies to bridge the yield gaps and the system of rice intensification (SRI) is one of the promising approaches for achieving sustainable rice production and increasing food security of small-scale producers. SRI, significantly harmonizes the elements of soil, water, light and plant, it allowed the plants to achieve their fullest potential. SRI is found to be an integrated agro-ecologically sound approach to irrigated rice. It is also a designer novelty that competently uses scarce resources. SRI was found to benefit farmers more in terms of more income with less input, given higher yield with lower investment and beneficial to poorer households. Yield was also found to be higher in SRI with 8 t ha⁻¹ as against 3 t ha⁻¹ under conventional paddy. Along with better nutrient uptake also maintains soil health sustainably. Therefore, the system of rice intensification is the best option for rice production in order to meet up with the demand of the increasing population along with mitigating green house gases (GHGs) production from rice fields. In this paper, significance system of rice intensification on rice productivity, plant and soil nutrition has been reviewed and discussed.

Keywords: GHGs, plant nutrition, rice, soil health, SRI, sustainability

Introduction

Rice (*Oryza sativa* L.) is one of the major food crops of the world for most populous countries and a bastion for the rural population and their food security. It has been cultivated under submerged or flooded conditions by the growers for various reasons. Apart from other reasons, the main thing was to control weeds and they believed that rice perform better in standing water. However, rice is only a flood-tolerant plant, not one that benefits from constantly saturated soil. An added advantage of flooding a paddy field is to increase low soil pH towards neutral. Such conditions favor release of P element from aluminum or ferrous coated P. The cut-off of soil oxygen supply, hence, leads to a rapid decrease of redox potential and thus a gradual release of soluble Mn, Fe and methane and led to poor nitrogen uptake and photosynthesis (Randriamiharisoa, 2002) [52], thereby, following traditional method of rice cultivation under submergence with poor soil aeration ardently affect the crop productivity.

Conventional transplanting method of rice accounts for 21 per cent of operational cost and critically it takes energy of more than 25 labors ha⁻¹ day⁻¹. Due to scarcity of water and labor, the area under transplanted rice in world is declining. Depleted soil productivity and abridged groundwater level are the main challenges in current rice cultivation. It is recognized that 4000 litres of water used to produce 1 kg of rice in many areas and even more water usage in certain states of India (Sharma *et al.*, 2018) [41]. Water availability for agriculture and for rice cultivation, in particular, will be very scarce in future and hence, we need to explore a new sort of water-saving technology for rice cultivation.

Whereas, SRI method follows alternate wetting-drying method of irrigation and transplanting of single plant in one clump at distances of 25×25 or 30×30 cm. The uniqueness of this system is transplanting of sprouted seeds between 7th and 9th day. The current practices of transplanting is after 4 to 8 weeks and often 5 to 10 plants in one clump that cause trauma as roots take 12 to 14 days for establishing after transplanting. By this conservative way of dense planting (50 - 60 clumps m⁻²), plant roots can get struggled to grow widely and deeply which momentous in low nutrient uptake. Yield from SRI (3042 kg ac⁻¹) and conventional (1874 kg ac⁻¹) practices showed difference of 62.3 percent (Vishnudas, 2006) [56].

The practices that bring different rice plant phenotype in physiological and morphological terms are simple, but they change radically a number of things that rice farmers have done for several thousand years. These practices made sense because they appeared to reduce risk, but in fact, we now realize, they suppress productive potential. According to proponents, SRI encompasses a set of five principles in contrast to conventional system, each of them fairly simple, but working synergistically with others in order to achieve higher grain yield (Uphoff *et al.*, 2000) [52]. The System of Rice Intensification first originated in Madagascar around Antsirabe in the 1980s. This methodology for growing rice was developed by a French Jesuit priest, Henri de Laulanie, and it enabled its practitioners to increase grain yield from national average of 2 t ha⁻¹ to 8 t ha⁻¹ or more just by changing management practices (Association Tefy Saina, 1992) [2]. Father Henri de Laulanie, who developed SRI in Madagascar observed two things *viz.*, (a) rice plants have

very great tillering potential and (b) the best yields of rice are obtained with soil aeration. Based on these observations, he formulated the following principles (Uphoff and Randriamiharisoa, 2002) [52].

1. Rice is not an aquatic plant: Even though rice can survive under flooded conditions, most of the rice plant's roots remain in top 6 cm of soil and most of them degenerated by the time rice plants entered into reproductive phase under continuous submergence.
2. Rice seedlings lose much of their growth potential if they are not transplanted before the start of fourth phyllochron of growth (*i.e.* 15 days after emergence). So, early transplanting should be done.
3. Trauma to seedlings and roots should be minimized during transplanting.
4. Wider spacing of plants lead to greater root growth and tillering.
5. Soil aeration and organic matter create beneficial conditions for plant root growth, plant vigor and health, to resist damage from pests and diseases.

Based on above principles, following practices were developed under system of rice intensification.

1. Transplanting very young seedlings of 8 - 12 days old with just two small leaves.
2. Transplanting seedlings carefully and quickly to have minimum trauma to the roots.
3. Transplanting singly, only one seedling per hill instead of 3 - 4 together which causes root competition.
4. Widely spaced to encourage greater root and canopy growth.
5. Transplanting in a square pattern 25 cm x 25 cm or wider spacing of 30 cm x 30 cm, 40 cm x 40 cm even up to 50 cm x 50 cm with the best quality soil.
6. Keeping the soil well drained than continuously flooded up to vegetative growth period.
7. Early and frequent weeding with rotary weeder.
8. Application of organic manures

Effort of applying these practices should be followed in combination to achieve better results. The SRI was promoted by the Association Tefy Saina, an NGO in Madagascar and the Cornell International Institute for Food and Agriculture Development (CIIFAD) in USA. The SRI is now under practice in 32 countries around the world (CIIFAD Country Report, 2005).

Comparison of SRI and normal method of rice cultivation

1. **Nursery management:** Raised seed bed should be prepared by mixing FYM in the soil either on polythene covers, banana sheaths etc. or on soil itself.
 - a. **Seed rate:** Five kg of seed per hectare is sufficient as against 50.0 - 62.5 kg ha⁻¹ in normal rice.
 - b. **Age of the seedlings:** Transplanting should be done with 8 - 12 days aged seedlings with two small leaves as against 25 days and above in normal rice.
2. **Transplanting:** Seedlings should be removed carefully from the nursery without disturbing the roots of the plant along with mud and single plant should be transplanted in main field. Before transplanting, the main field should be drained off.
3. **Wide spacing:** Wider spacing of 25 cm × 25 cm in square pattern should be maintained for aeration and for

easy intercultural operations as against more hills per m² in traditional method.

4. **Weeding:** Naturally weed growth is more in these fields because there is no stagnated water, weeding should be done with rotary weeder or cono weeder with 10 days interval for 4 times starting from tenth day after planting. It churns the soil and the weeds are incorporated in the soil, which in turn are useful as organic manure. It increases soil aeration and soil health.
5. **Water management:** The soil should be kept moist but not saturated by providing alternate wetting and drying.
6. **Manures and fertilizers:** More of organic manures (10 t ha⁻¹) should be used and chemical fertilizers should be reduced.

Significance of SRI on rice productivity

SRI practices on the West Coast of Madagascar produced 6.83 t ha⁻¹ grain yield but standard practices produced only 2.84 t ha⁻¹ (Rajaonarison, 2000) [29]. Hirsch (2000) [14] observed that on the rice sector in Madagascar SRI yields in Antsirabe and Ambohitra areas ranged between 6.7 and 10.2 t ha⁻¹ and 7.7 and 11.2 t ha⁻¹, respectively. Mc Hugh *et al.* (2002) [24] opined that SRI methods proved with a significantly higher grain yield of 6.4 t ha⁻¹ compared to conventional practices of 3.4 t ha⁻¹. In SRI plots, grain yields were 6.7 t ha⁻¹, 5.9 t ha⁻¹ and 5.9 t ha⁻¹ under alternate wetting and drying (AWD) irrigation, non-flooded irrigation and continuously flooded rice, respectively. Longxing *et al.* (2002) [20] revealed that high biomass by large individual plants and dry matter accumulation after heading accounted for 40 per cent of the total dry matter. More than 45 per cent of material from stem and sheath contributed to grain yield in SRI and facilitates a heavier and deeper root system. Root growth may get restricted to top 20 cm soil, when old seedlings (25- 45 days) were transplanted compared to root growth beyond 30 cm soil depth when young seedlings of 8 day old were transplanted (Barison (2002) [5]. Roots of rice plants have least competition under wider spacing through that growth is stimulated by utilization of sunlight and space for the canopy expansion thereby increasing yield attributes and yield (Rajesh and Thanunathan, 2003) [30]. Barison (2003) [4] found that SRI plants had considerably greater root length density in lower soil horizons (0-20 cm) compared with roots of plants of the same variety conventionally grown in same soil and it was 2.3 times more at 30 to 40 cm depth, and 3.8 times more at 40 to 50 cm depth. Sarath and Bandara (2003) revealed that higher grain yield production in the SRI farming system may attributed to vigorous and healthy growth, development of more productive tillers and leaves ensuring greater resource utilization compared with conventional transplanting and broadcasting systems. Mulu (2004) [25] reported that shorter phyllochrons and more tillering when 8 and 15 day old seedlings were transplanted than those of 20 and 25 days old seedlings. San-oh *et al.* (2004) [39] observed that single seedling hill⁻¹ produced more dry matter and better root system than three seedlings hill⁻¹. Rice plants in SRI farming system grow vigorously, producing more tillers and leaves ensuring enhanced resource utilization and more dry matter as grain, resulting in greater grain production compared to conventional transplanting and broadcasting systems (Vijayakumar *et al.*, 2005) [55]. Wider the spacing provided, the tillers per hill

produced are higher (44) than closer spacing. Due to mutual competition in cluster planting, initially more primary tillers were observed and ultimately lesser tillers per hill (Janarthanan, 2008) [15]. Raju and Sreenivas (2008) [31] noticed significantly higher root dry weight, root volume, grain yield and less water requirement in SRI than conventional method, irrespective of varieties during wet season on clay loam soils of Godavari delta. During *kharif*, the combination of young seedling, one seedling, square planting and cono-weeding showed its superiority by registering the highest tillers m^{-2} (367), dry matter production (8664 $kg\ ha^{-1}$), root length (22.6 cm), root dry weight (741 $kg\ ha^{-1}$) and root volume (23 $cc\ hill^{-1}$) in short duration rice variety ADT 43 (Sridevi and Chellamuthu, 2008) [46]. SRI method of cultivation recorded significantly higher growth parameters, grain and straw yields and yield attributes compared to conventional method of cultivation at all growth stages irrespective of nutrient sources (Wijebhandara *et al.*, 2009). In SRI, plant roots can spread in all directions, and all leaves receive enough sunlight to be photosynthetically active. The closer planting in conventional practice leads to constrained tillering and shading of plants' lower leaves which makes them senesce early, especially at latter phase. These leaves become ineffective, parasitic, consume from the plant's supply of photosynthates rather than contributing to it (Uphoff *et al.*, 2009) [55].

Ravindra Adusumilli and Bhagya Laxmi (2010) [35] compared yield results, input use, economic returns, water requirements and management under SRI in farmer's field and noticed 18 per cent yield advantage with increase in net returns per hectare (52 per cent) due to reductions in the cost of production. There was a reduction of 19 per cent in straw yield on SRI farms, reflecting an increase in harvest index. Chandrapala *et al.* (2010) [30] stated that the square geometry with wider spacing, planting of single seedling $hill^{-1}$ (SRI) found to reduce the above and below ground competition, enhanced solar radiation interception and nutrients uptake which resulted in more number of grains panicle $^{-1}$ (121) and grain yield of 5.45 $t\ ha^{-1}$. The SRI method of cultivation recorded significantly higher yield and higher N, P, K and Zn uptake and also noticed higher residual soil N compared to traditional method of cultivation (Weijebhandara *et al.*, 2011) [59]. Venkateswarlu (2012) [53] observed that total number of tillers $hill^{-1}$, number effective tillers $hill^{-1}$ and number of filled grains per panicle increased by 119, 56.67 and 13.30 per cent respectively in SRI compared to farmers' practice; which resulted in increase of grain (23.69 per cent) and straw (32.03 per cent) yields in SRI over farmers' practice. With SRI, the yield was 9.90 $t\ ha^{-1}$ compared to 3.83 $t\ ha^{-1}$ in conventional practice i.e. 158 per cent more than the later. And water use reported that 1.026 $m^3\ m^{-2}$ in SRI against 2.882 $m^3\ m^{-2}$ in conventional practice, which was less by 35.6 per cent. This provides evidence that SRI can be practiced in water scarce regions (Zacharia Katambara, 2013) [62]. Masthana Reddy *et al.* (2013) [23] proved that rice under SRI and traditional method of transplanting with 100 per cent recommended NPK fertilizer application significantly improved the grain yield of 76.56 $q\ ha^{-1}$ and 64.76 $q\ ha^{-1}$ respectively. Sri Ranjitha and Reddy (2014) [44] noted that cultivation through system of rice intensification (SRI) could increase rice yields two to three folds compared to current yield levels. Plant height, dry matter production, tillers and productive tillers and yield

were significantly higher under SRI compared to other rice production methods in practice were evidenced by Parameswari *et al.* (2014) [26]. SRI compared to conventional method of rice cultivation (CMRC) proved that irrespective of varieties it increased the production potential by increasing grain yield and reduced the requirement of seed need, water and chemical fertilizer (Kalyan Jana *et al.*, 2015) [16] and different SRI practices enhanced the growth and grain yield by 68.25 per cent over the traditional practice (Sridevi and Chellamuthu, 2015) [47]. Sureshkumar *et al.* (2016) also evidenced that SRI method of cultivation enhanced the growth, yield of rice compared to conventional method of rice cultivation through INM practices. SRI method of rice cultivation can potentially improve the rice productivity along crop water productivity (Chetankumar *et al.*, 2017) [66]. Anshuman Nayak *et al.* (2018) [64] opined that performance of SRI in rice-mustard cropping system profoundly improved the agronomic traits of rice.

Significance of SRI on plant nutrition

Kronzucker *et al.* (1999) [17] found that repeated wetting and drying of soil under SRI method would provide N in both form as NH_4^+ and NO_3^- from the organic N pool, thereby significantly increased the uptake of N. Barison (2002) [5] proved that considerably higher N and K and lower P concentration in foliage at later stages, reflecting better uptake of nutrients at later stages of crop growth in SRI method of cultivation. Vijayakumar *et al.* (2005) [55] advocated that N uptake increased significantly under SRI compared with conventional methods of cultivation. Limei Zhao *et al.* (2009) [19] concluded that N uptake and agronomic N use efficiency (ANUE) increased significantly under SRI compared with traditional flooding (TF) method of cultivation, while at higher N application rates N uptake and ANUE with SRI was significantly lower than TF. Zhang *et al.* (2009) [63] noticed that SRI produced greater and deeper root system which enhanced water and nutrient uptake, responsible for greater transport of root-sourced cytokinins. Wardana *et al.* (2010) [57] observed that N uptake and use efficiency increased under system of rice intensification, using LCC readings by reduced N fertilizer rate. Weijebhandara *et al.* (2011) [59] found significantly higher uptake of N, P, K and Zn in grains and residual available N, P and Zn under SRI method of cultivation compared to traditional method of cultivation. Sadhana and Velayutham (2012) [38] reported significantly higher uptake of N, P and K by rice under SRI. Higher N uptake and organic carbon content were observed in SRI by Singh (2013) [43] compared to conventional method of cultivation. Priyanka Gautam *et al.* (2013) [28] recorded increased uptake of N, P and K under system of rice intensification without depleting soil nutrient pool significantly as well as increasing grain and straw yields. Riton Chowdhury *et al.* (2014) [37] observed that NPK content and uptake in grain and straw were favorably influenced by SRI method of cultivation and gave higher gross and net return with application of FYM combined with inorganic sources of NPK alone. Sri Ranjitha and Reddy (2014) [44] revealed that SRI and conventional method perform equally but SRI was significantly superior in NPK uptake when organic manure was applied compared to application of inorganic fertilizers alone. Rakesh Kumar *et al.* (2015) [32] opined that nutrient uptake (N, P and K) by grain and straw as well as total uptake in rice crop were significantly higher with integrated

crop management and SRI compared to conventional transplanting method of rice production.

Significance of SRI on soil nutrition

Modification of plant, soil, water and nutrient management practices under SRI could enhance plant nutrient uptake by 91 per cent for N and K and 66 per cent for P while the nutrient accumulation ratio for plants grown with SRI method was higher (5: 1: 4.9) than conventional practice (3.9: 1: 4.1). The higher nutrient accumulation lead to more vigorous plant growth and higher yields due to changes in capacities of the plant itself, particularly its root system (Barison, 2002) [5]. Increase in organic carbon content under SRI is attributed to direct incorporation of organic matter (FYM) to soil that enhanced soil nutrient availability in a sustained manner over transplanted puddled rice under continuous flooding (TPR) was evidenced by Choudhury *et al.* (2007) [9]. Revathi (2009) [6] advocated that SRI had lower NPK (213, 22, 480 and 210, 15, 514 kg ha⁻¹) in post harvest soil because of better nutrient uptake by plants (69, 29, 114 and 66, 28, 112 kg ha⁻¹) during *kharif* and *rabi*, respectively. Yasuhiro Tsujimoto *et al.* (2009) [61] reported that soil organic carbon content was higher (21.6 to 33.6 g kg⁻¹) in SRI practice and lower (10.0 to 26.8 g kg⁻¹) in conventional field. The mineralizable nitrogen, ranged from 54.2 to 158.7 mg kg⁻¹ was linearly related to rice grain yield, extremely low levels of extractable phosphorus and low CEC was recorded in conventional field soils while these values were relatively higher in SRI. At similar available nutrient status SRI resulted in higher productivity, nutrient uptake and marginally higher nutrient use efficiency without depleting soil available nutrients compared to standard transplanting (Mahender Kumar *et al.*, 2012) [21]. Mahender Kumar *et al.* (2013) [22] observed higher productivity and available N, P and K status of soil in SRI over normal transplanting /standard transplanting methods. Total N and organic carbon per cent found to be significantly higher in both SRI - organic (16 - 22 and 12 - 20 per cent) and SRI - organic + inorganic (3 - 13 and 5 - 10 per cent) treatments over best management practices (BMP), but not much difference observed in total P status (Gopalakrishnan *et al.*, 2013) [13]. Growth of rice plants improved with increasing levels of fertility due to continuous supply of nutrients on addition of organics in SRI (Priyanka Gautam *et al.*, 2013) [28] and similar concept of maintaining soil nutrient availability was recorded by Singh *et al.* (2014) [43]. Thatchinamoorthy and Rexlin Selvin (2015) [45] observed that adoption level of SRI technology among farmers depends on reduction in application of fertilizer and irrigation water and maintaining the soil fertility status on the basis of low input technology.

Significance of SRI on soil microbial population

Gayathry (2002) [12] emphasized that population of soil heterotrophic bacteria and *Phosphobacteria* profusely increased due to planting younger seedlings (14 days old), limited irrigation, weed incorporation and green manuring. Triveni *et al.* (2006) [49] revealed that weed incorporation resulted in increased population of *Azospirillum* at 50 per cent flowering stage and *Azotobacter* at panicle initiation stage. The CFU g⁻¹ soil total bacteria, fungi, actinomycetes and *Azotobacter* were higher in SRI compared to conventional method of rice cultivation. The phosphorus-solubilizing bacteria found to be less in SRI compared to

conventional method. Alternate wetting and drying irrigation practices in SRI provide alternate oxidized and reduced conditions to the soil hence both aerobic and anaerobic microorganisms could survive and die in above said situations there by their continuous decomposition supplies nutrients to the soil (Ceasay *et al.*, 2006) [6]. Ancy Francis (2007) [7] reported more bacteria (2.7 CFU g⁻¹) and fungi (4.2 CFU g⁻¹) in Integrated Crop management (ICM) and SRI, respectively. *Phosphobacteria* (9.3 CFU g⁻¹) was found more in standard transplanted rice and fluorescent *Pseudomonas* (3.7 CFU g⁻¹) in ICM. The active soil aeration due to SRI water management practices enhanced the growth of *Phosphobacteria* and N-fixing bacteria by alternatively wetting and drying the soil (Uphoff *et al.*, 2009) [50]. Under different organic sources, the total and individual population of different microorganisms was higher in wheat straw amendment followed by green manure and FYM application, respectively in long term experiment (Bedi *et al.*, 2009) [6]. Gopalakrishnan *et al.* (2013) [13] opined that cultivation of rice under SRI enhanced favorable condition for beneficial soil microbial population to prosper compared with current trend of recommended best management practices (BMP).

This review paper emphasized that the role and significance of SRI method of rice cultivation as key strategy that can bring sustainability to the rice crop productivity through improved plant and soil nutrition. Plant nutrition is the major aspect to come out with full potential of any crop genetic potentiality. Where, this plant nutrition or crop uptake cannot be enhanced without maintaining a sustainable nutritious soil. As a designer agronomic practice, SRI can help in maintaining the soil health with low energy inputs available. The average rice yield with SRI is almost 2 to 3 times more than conventional paddy cultivation. The percent increase in seed yield per hectare under SRI method was 30-50 over traditional method. Also research reports revealed that the net income increase with the increase in size of land holding in both SRI non SRI method of paddy cultivation. Areas with cheap labor availability, SRI method of rice cultivation consider to the best as it produces more yield and realizing higher gross return compared to other rice cultivation methods (Kumar Pramod *et al.*, 2021) [18]. The returns of SRI outweigh the returns of conventional flooding (CF) thus making SRI more profitable. However, it was noted that SRI is more labor intensive as compared to CF. The labor requirement of SRI is high during the initial stages of land preparation and weeding. Further, role of SRI on soil health and mitigating gas production which influences the climate change. So, it is an established alternative way for sustaining plant nutrition cum soil health and rice productivity in water scarce world. The significance SRI and other methods rice cultivation in climate change scenario also to be studied in depth to bring out actual situation of green house emission by rice cultivation.

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