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Effect of integrated nutrient management in rice (*Oryza sativa* L.) under SRI technique: A review

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Abstract
The system of rice intensification (SRI) is a rice crop management system developed in the 1980s in Madagascar, reportedly enhances yield through synergy among several agronomic management practices with less water requirement. This study was carried out to investigate the effects of rice cultivation methods and nutrient management on growth, physiology and grain yield of rice. The improvement in plant functions resulted into significant gain in grain production. In our earlier efforts, it was also observed improvement in phenotype and physiological functions under SRI compared to conventional method of transplanted rice. Overall, grain yield was increased by 34% with SRI practices due to significant improvement in morphology (Tillering and light interception) and physiology (chlorophyll content and photosynthesis rate) of crop than crops grown with conventional method. This was plausible reason for improvement in yield contributing characteristics and ultimately higher grain yield under SRI than from conventional transplanting method. Lower grain yield was obtained with organic fertilization than INM crop, but it would be of more significance in improving soil health and reduction in environmental hazards. It is also important to note here that organically fertilized SRI crop gave significantly higher yield than both organically and INM crops under conventional transplanted method.

Keywords: rice, integrateded nutrient management, SRI

Introduction
Rice (*Oryza sativa* L.) is a member of poaceae family chromosome number 24 (2n) and most important staple food crop for millions of mankind from dawn of civilization. Among the cereal crops, it serves as the principal source of nourishment for over half of the global population.

Rice is grown in 114 countries across the world on an area about 150 million hectares with annual production of over 525 million tonnes, constituting nearly 11 per cent of the world's cultivated land. More than 90 per cent of the world's rice is produced and consumed in Asia where it is an integral part of culture and tradition. It occupies an area of about 155.2 mha. With the production of 432.41 mt. in the world (Anonymous, 2008) [2]. Rice crop is being traditionally cultivated under continuous submerged conditions, some alternate methods have to be searched to minimize the water requirement of rice crop.

The system of rice intensification was developed by a Jesuit agriculturist Fr. Henri De Laulanie (1993) [15] in Madagascar. System of rice intensification (SRI) is a recent breakthrough in rice production technology. This is a new method of rice (*Oryza sativa* L.) culture. This is an environment and ecologically benign method that increases productivity and resource-use efficiency of irrigated rice by changing the way of managing soil, plants, water and nutrients.

SRI system of cultivation is slowly gaining momentum all over the world including India. There is ample scope to increase productivity of rice by altering the environmental conditions that modify microclimate and soil conditions, which ultimately reflect phenotypic expression with the Genotype x Environment interactions. One of the sound principles of SRI is, wider spacing of plants leading to greater root growth and better tillering potential.

An INM plays a vital role in sustaining both the soil health and crop production on long term basis (Singh *et al.* 2004) [34]. The productivity and quality of rice crop can be possible by adopting better agronomic practices and replacing conventional varieties with high yielding improved varieties, which have the potential to fit in the current cropping system, particular location and soil types. Proponents of SRI recommend the use of organic fertilization (compost) instead of chemical fertilizer. Organic resources are largely biological in origin and they have several nutrients in their composition which on decomposition are released in to soil. Application of vermicompost in combination with NPK fertilizers results in higher content of total Nitrogen compared to FYM in combination with NPK fertilizers are control. It also resulted in higher content of phosphorus significantly (Kale *et al.* 1992) [19]. The casting by Earthworms was seen to improve, the soil organic matter and nutrient status by recycling available nutrients especially N, P, K, Ca and Mg.

Vermicompost are materials that improve the porosity aeration drainage and water holding capacity of soil. They have a vast surface area producing strong absorbability and retention of nutrient. Vermicompost contain nutrients that can be readily taken up by the plants as nutrient, exchangeable phosphorus and soluble K, Ca and Mg (Garg and Gupta, 2006) [16]. Vermicompost and FYM application leads to a better environment for root development also improves soil water holding capacity, the fact that the use of organic fertilizers improves soil structure, nutrient exchange and maintains soil health has raised interests in INM or organic farming.

On the other hand, continuous application of organic fertilizer alone on rice field resulting low yield and low N and K content at the mid-tillering stage of rice plant (Javier *et al*. 2004) [18]. This implies that the need of integrated nutrient management for rice production. Therefore the combined use of organic manures and inorganic fertilizers help in maintaining yield stability through correction of marginal deficiencies of secondary and micronutrients, enhancing efficiency of applied nutrients and providing favourable soil physical conditions (Gill and Walia, 2014). Integrating nutrient management aims for efficient and judicious use of all the major sources of plant nutrients in an integrated manner (Farouque and Takeya, 2007).

In association with this most of the scientist concluded that 50% organic sources and 50% from inorganic sources and 50% from inorganic sources is the best combination in rice based cropping system to improve soil physico-chemical properties, yield and nutrient uptake capacity of rice (Wolie and Admassu, 2016 and Sharma, 2013) [45, 26].

Integrated use of organic and inorganic sources of nitrogen in SRI system not only improves the soil fertility, yield and quality of rice, but also improves the soil health for sustainable production.

Effect of SRI technique on growth parameters, yield attributes and yield of rice

Growth Character

Laulanie *et al*. (1993) [15] reported that the practices utilized in SRI are not necessarily new. It is their combination that creates different growth dynamics for rice plants as use of 14 days old seedlings, planted singly and widely spaced 25×25 cm. SRI combines all of these practices proposes active soil aeration with a rotary weeder in particular as well.

Berkelaar *et al.* (2001) reported that in SRI system transplanting only one seedling per hill, aged 8-15 days with spacing at 20×20 cm, weeding the crop at least three times at intervals of ten days and intermittently irrigating the fields. Contributions that could be made by using organic manure to meet out nutritional requirement and by soil-aerating with weed control, as recommended for SRI, were not considered due to limited availability of organic materials and mechanical weeders at the time of the study.

Fernandes *et al.* (2002) reported that spacing for SRI varied from 25×25 cm to 35×35 cm. Most studies reported that SRI is more labour demanding than conventional rice. It is hypothesized that soil biological factors are very important for SRI synergy. Flooding and draining of water requires good access to control of water. The long period soil is drying the ultimately soil cracking and reduce yield as compare to the continuously wet soil. Most studies reported a significant saving in the amount of seed used to establish the rice field. Fewer chemical and pesticide inputs can translate into healthier food.

Satyanarayana *et al.* (2007) reported that *Thulo attey* responded positively to SRI. Wider spacing in SRI creates condition conducive for uninhibited root growth that ensures better access to light and air there by creating condition that generate higher grain yield.

Krishna *et al.* (2008) reported that highest number of tillers with 20 days old seedling. Seedlings planted at 30×30cm resulted in more number of productive tiller/hill (29.6) as compare to the seedling planted at 25×25cm (27.5) and are significantly different from the seedling planted at 20×20cm (24.1).

Ridder *et al.* (2008) reported that wider spacing with square planting is followed in SRI. The row to row distance and within a row plant to plant distance is maintained at 25 × 25 cm with a plant population of about 16 per square meter. There are several easy ways to transplant at the suggested spacing. E.g., knots are tied at 25-25 cm interval on a long rope and used as a guide to transplant one row after the other. However, markers are also available to help transplanting. It is understood from various studies that wider spacing allows more sunlight to reach the plant's lower leaves and that can result in higher photosynthetic activity.

Krishna *et al.* (2009) reported that planting in square method with wider spacing of 40×40cm resulted in profuse tillering under SRI method of rice cultivation which might have facilitated plant for better utilization of the resources.

Anitha *et al*. (2011) conducted an experiment to compare the system of rice intensification (SRI) with the best management recommendations and farmers practices of rice (*Oryza sativa* L.) production. The experimental variables included combinations of number of seedlings and age (10 days-old single vs. 20 days-old two seedlings per hill), spacing (25×25cm vs. 20×15cm), irrigation (intermittent irrigation vs. continuous flooding), and weed control (cono-weeder vs. manual weeding) treatments, besides farmers practice (control). The SRI gave more yield due to wider spacing, planted newly seedlings, intermittent irrigation and weed control with cono-weeder.

Anchal *et al.* (2012) reported that wider spacing (25×25cm) under SRI system of rice cultivation recorded significantly taller plant than the closer spacing (20×20cm). Plant gets sufficient space above the ground (shoot) and below the ground (root) to grow which increased the light transmission in the canopy leading to greater plant height.

Yield and yield attributing characters

Hussain *et al.* (2003) reported that under SRI system there was higher number of total tillers/hill. The maximum number of effective tillers/hill and 1000-grain weight. The finding closely resembles to that of uphoff (2001). He noted biological yield (11.65 t/ha) and harvest index (48.62%) in his finding.

Bommayasamy *et al.* (2009) reported that closer spacing 20 x 20 cm spacing had higher number of effective tiller/m^{-2} (491). But number of filled grain/panicle (116.7) were lower resulting in significantly higher grain (8 t/ha) and straw yield (9 t/ha).

Manjunatha *et al.* (2009) conducted an experiment during the *kharif season* of 2005 in Karnataka, India to investigate the influence of age of seedlings under different systems of rice intensification. Treatment combinations comprised three methods of planting (normal method, SRI system and traditional method) and five seedling ages (9, 12, 15, 18 and 21 days) that were laid out in split-plot design with three replications. IET-16933 was used as test variety. The spacing followed were 20×10 cm (M1), and 25 × 25 cm. Data on the effects of the methods of planting and seedling age on the straw and grain yields and yield components (panicles per hill, panicle length, grains per panicle, and test weight/1000-grain weight). Planting of 9-day-old (6071 kg/ha) or 12-days-old (6018 kg/ha) seedlings gave significantly higher grain yields than 15-days-old (5792 kg/ha), 18-days-old (5771 kg/ha) and 21-days-old (5721 kg/ha) seedlings.

Thakur *et al*. (2009) reported that the system of rice intensification (SRI) holds a great promise in increasing the rice productivity.

Rath (2010) reported that wider spacing significantly better as compared to closer spacing in terms of root growth and xylem exudation rates, leaf number and leaf sizes, canopy angle, tiller and panicle number, panicle length and grain number per panicle, grain filling and 1000-grain weight and straw weight. Spacing practices gave their highest grain yield with the spacing of 20×20cm however. SRI yielded 40% more than the conventional practice. At this spacing, canopies also had the highest leaf area index (LAI) and light interception during flowering stage. The lowest yield was recorded at 30×30cm spacing under both the practices, as a result of less plant population (11 m^{-2}), despite improved hill performance. During the ripening stage, hills with wider spacing had larger root dry weight, produced greater xylem exudates and transported these towards shoot at faster rates.

Sreedhar *et al*. (2010) reported that there was influence of seedlings age and spacing on rice yield under System of Rice Intensification (SRI). Transplanting was done with 12, 14 and 16-days old seedlings under 30×30, 25×25 and 20×20cm spacing. Observations were recorded for tillers per hill, plant height, filled grains per panicle, spikelet fertility, 100-seed weight, raw seed yield, graded seed yield, germination percentage, speed of germination, shoot length, root length and vigour index. In general, 16-days-old seedlings planted at 25×25cm spacing recorded the highest yield and its attributes.

Larijani *et al*. (2012) reported that under SRI system the different growth phase like tillering, panicle initiation, flowering and plant height were measured for the nine sets of nutrition methods. At maturity, the final plant height, yield and yield components were assessed. The results indicated more tiller number (28%), more chlorophyll content at panicle initiation stage (28%) and flowering time (13.5%), more panicle/m^2 (60%), number of filled grains/m^2 (20.6%), grain per panicle (19.6%) and more grain yield (30.6%) with combined use of organic and chemical fertilizer compared with chemical fertilizer alone.

Singh *et al.* (2012) [23] reported that spacing of 25×25cm resulted in higher grain and straw yield and better economic return than 30×30cm. Further, significantly more panicles/m^2 was recorded with 25×25cm as compared 30×30cm spacing.

Baskar *et al.* (2013) reported that system of rice intensification as influenced by nursery techniques and spacing. The nursery techniques such as mat and conventional type nursery to raise seedling for SRI and conventional method with two cultivars *viz.*, CORH 3 hybrid and ADT 43 varieties and sub plot consisted three square crop geometry levels *viz.*, 25×25 cm, 30×30cm and 35×35cm, with three replications. The results revealed that, tillering behaviour, phyllochron and grain yield did not vary due to nursery techniques. Regarding crop spacing tillering behaviour, phyllochron and rate of leaf appearance was faster in widely planted rice cultivars compared to 25×25cm spacing. Light interception percentage was higher in CORH 3 and also closer spacing intercepted the more light than wider spacing. Regarding yield, the performance CORH 3 was superior over ADT 43 as it produced 16.9 per cent higher yield of 25×25cm for varieties (ADT 43), 30×30cm for hybrid (CORH 3) is optimum for obtaining higher grain yield.

Rao *et al.* (2014) reported that the treatment combinations of four different ages of seedlings (8,12,16 and 20 days old) and four planting patterns (20×20cm, 25×25cm, 30×30 and 35×35cm). Transplanting of 12 days old seedlings resulted in the highest growth stature, yield attributes, yield and net returns. Planting pattern of 25×25cm recorded higher growth, yield attributes, yield and returns and the lowest with planting pattern of 35×35cm.

Effect of Integrated Nutrient Management on growth parameters

Verma *et al.* (2008) [44] observed that application of NPK (100:40:60 kg/ha) along with blue green algae @ 10 kg/ha in rice Cv. Pusa Basmati-1 resulted highest plant height (19.53cm), dry weight (45.64g), number of effective tillers/hill (19.86), number of filled grains/Panicle (139.33), grain yield (49.16 q/ha), stover yield (65.83 q/ha) and harvest index (42%).

Dutt and Chauhan (2010) [13] noted that applications of NPK+ FYM increased the plant height, number of tillers and uptake of N, and K in a newly developed terraced land in upland rice.

Shankar and Laware (2011) [31] observed that the maximum grain yield was noted in plants treated with 2 ton ha^{-1} organic fertilizer and it was (4662.71 kg ha^{-1}) for plant treated with combination of chemical fertilizer + 1.5 ton ha^{-1} organic fertilizer. An increase in the grain yield at the above mentioned treatments was may be due to the increase of 1000-seed weight, panicle number, number of fertile tiller, flag leaf length, number of spikelet, panicle length and decrease number of hollow spikelet per panicle.

Gautam *et al.* (2012) [17] reported that the higher level of fertilizers and FYM significantly influenced the growth development yield attributes and yield of rice.

Priyanka *et al.* (2013) [30] tested the combinations of three FYM levels (0, 10 and 20 t ha^{-1}) and three fertilizer levels (0, 50 and 100% of the recommended NPK) in main plots and two spacing (20 cm × 20 cm and 30 cm × 30 cm) in sub plots in split plot design, replicated three times. Growth parameters and yield of rice increased consistently and significantly with increase in FYM and fertilizer levels. Significantly highest grain, straw and biological yield were recorded with FYM 20 t ha^{-1} and application of chemical fertilizers at recommended dose gave significantly highest grain and straw yield.

Effect of Integrated Nutrient Management on yield attributes and yield of rice

Murali *et al.* (2001) reported that application of vermicompost @ 5.0 t ha^{-1} resulted significantly higher number of panicles $hill^{-1}$, number of filled grains $panicle^{-1}$ and grain yield (4.89 t ha^{-1}) of basmati rice as compared to without vermicompost (4.07 t ha^{-1}) due to more nutrients availability with vermicompost application.

Das *et al.* (2002) [10] studied the effect of various combinations of vermicompost and FYM with chemical fertilizer in rice. They reported that yield and yield components increased more by integrated application of vermicompost and chemical fertilizers as compared to their application alone. The maximum rice yield was obtained with combined application of vermicompost and chemical fertilizers (50:50). Presence of plant growth influencing substances such as plant growth hormones and humic acid in vermicompost might be a possible factor contributing to increase yield.

Yadav (2006) observed that results of 18 years reported that the substitution of 25-50% N-through FYM along with 50-75% recommended dose of NPK through chemical fertilizer to rice provided more yield as compared to 100% fertilizers alone.

Akhtar *et al.* (2011) [1] reported that application of FYM @ 25 tonns, green manure @ 4 tonns, fertilizer @ 150-100-50 kg NPK, FYM @ 25 tons + 150-100-50 kg NPK, green manure @ 4 tons + 150-100-50 kg NPK, 75-50-25 kg NPK, FYM @ 25 tons +75-50-25 kg NPK, green manure @ 4 tons + 75- 50-25 kg NPK per hectare and control.

Sowmya *et al.* (2011) [40] observed that the integrated use of 10 t FYM ha^{-1} along with 50% RDF gave significantly higher grain (5595 kg ha^{-1}) and straw yield (6700 kg ha^{-1}). Saliha *et al.* (2005) studied the effects of FYM in two rice cultivars *viz.* Co.43 and IR-50. They recorded the maximum values of number of panicles m^{-2} (145.4 and 132.6), 1000 grain weight (24.90 and 23.0 g) and grain yield (5.30 and 5.15 t/ha) with application of biocompost followed by FYM and green leaf manures.

Kumar *et al.* (2012) [23] studied the effect of integrated nutrient management and found that combined application of N, P along with organic sources (FYM, press mud, green manures and wheat straw) significantly increased the number of tillers, plant height and yield of rice over fertilizers alone. Incorporation of organics (FYM, press mud and green manures) in combination with fertilizers could maintain sustainable rice yields as well as soil fertility in the reclaimed sodic soil.

Lakshmi *et al.* (2012) [25] observed that the application of 75% chemical fertilizers + vermicompost @ 2.5 t ha^{-1} was better than other combinations closely followed by 50% RDF + 50% prathista organics. Lowest production efficiency was recorded with 100% chemical fertilizers alone. Highest profitable treatment in both the crops and in both fertilizer and without fertilizer effects was 75% chemical fertilizers + vegetable market waste vermicompost @ 2.5 t ha^{-1}.

Khursheed *et al.* (2013) [21] reported that the application of poultry manure and vermicompost along with chemical fertilizers for supply of nitrogen, phosphorus and potassium (NPK) resulted in highest grain yield rice. Soil carbon, labile carbon and water soluble carbon contents also improved with application of organic sources of N application.

Lungmuana *et al.* (2013) [27] observed that the application of chemical fertilizers and vermicompost furnished the highest amount of available phosphorus in the rhizosphere. This experiment clearly brought out the beneficial role of organic amendment on the availability of phosphorus to rice crop particularly at the later stage of growth.

Lal and Sharma (2013) [26] reported that the application of 75% RDF + 25% N through FYM recorded significantly maximum grain and straw yield over recommended P dose of fertilizer.

Tripathi *et al.* (2013) [43] reported that the combination of FYM with 75% NPK recorded the highest grain yield of rice (4.45 t/ha). Which, was at par with 50% NPK+FYM (4.30 t/ha) and 100% NPK + FYM (4.36 t/ha). The residual soil fertility improved considerably with the combined application of inorganic fertilizer and organics. It was concluded that integration of organics (FYM) with inorganics led to 50% saving of inorganic fertilizer without scarifying the yield of rice crop improved soil fertility status.

Sujatha *et al.* (2014) [42] found maximum yield of rice with recommended dose of fertilizers which was at par with 50% RDN as basal +50% at 10 days before PI stage. Among different organic manure treatments, application of 100% RDN through FYM recorded highest amount of NPK in soil after harvest, followed by the application of 50% RDN as basal +50% at 10 days before PI stage through FYM which were at par with each other. The lowest amount of NPK in soil after harvest was recorded with the application of recommended dose of chemical fertilizers followed by 100% RDN through poultry manure.

Kumar *et al.* (2014) [22] found that the application of organic and inorganic source of nutrient in combination increased remarkable yield, yield attributes and nutrient uptake of rice than alone. 125% RDF+5t ha^{-1} vermicompost recorded significantly higher yield, yield attributes and nutrient uptake in cooperation to other treatment and this was followed by 100% RDF + 5t ha^{-1} vermicompost.

Quality of rice

Saha *et al.* (2007) studied the grain quality parameters and reported that organic nutrient sources performed better with regard to chemical and physico-chemical properties of soil and cooking quality of rice than inorganic fertilizers. Singh *et al.* (2007) [35] also observed significant improvement in nutritional quality with combined application of two or more organic sources in rice cultivar Pusa Basmati-1.

Kharub *et al.* (2008) [20] reported that the inorganic and organic fertilizer application with farm yard manure @ 22.5 t ha^{-1} in rice. They observed protein content in grain (8.13-8.52%) was at par under all the treatments, but the protein yield was significantly higher under inorganic compared to under organic sources, except under the highest dose (30 t ha^{-1} in rice) of FYM.

Nutrient uptake by crop

Bhadoria *et al.* (2003) [7] reported that uptake of N, P and K by rice plants was significantly greater with FYM and inorganic fertilizers than all other commercial manures *viz.*, processed city waste, vermicompost and oil cake pellets.

Das and Ram (2006) [5] obtained that the application of 50% RDF+5tonns FYM ha^{-1} which were at par with application of RDF+SSP Incubated with FYM + 5tonns FYM ha^{-1}. Higher available nutrient status of soil was observed when organic were combined with inorganic compared to organic fertilizer alone.

Pandey *et al.* (2007) [29] reported that the integration of organic and inorganic manures significantly increased the nutrient uptake (NPK) in rice.

Kumar *et al.* (2008) reported that application of 2/3 fertilizer dose + 1/3 vermicompost recorded maximum uptake of nitrogen and 3/4 fertilizer + 1/3 vermicompost recorded maximum uptake of phosphorus and potassium in paddy crop.

Sahu *et al.* (2009) reported that nitrogen uptake by rice crop was found higher with conjunctive use of organic and inorganic fertilizers along with bio-fertilizers (PSB and BGA).

Kumari *et al.* (2010) reported that the uptake of N, P and K by rice was 31.69% 25.98% and 23.74% higher with inorganic fertilizers as compared to farm yard manure.

Economics

Barik *et al.* (2006) [6] reported that highest gross return in wet season rice was obtained in treatment with 50 per cent RDF along with vermicompost @ 10 t ha^{-1} which was significantly higher than the treatment with 75 per cent RDF along with FYM @ 10 t ha^{-1}. However, the net returns and benefit cost ratio appeared to be comparable between both the treatments.

Singh *et al.* (2007) [35] reported that the maximum net profit of Rs. 4588/ha was obtained with 0.95 B: C ratio under the treatment of 50% NPK + FYM 5 t ha^{-1}.

Singh and Singh (2007) [35] reported that the application of 10 t sesbania along with 100% NPK for both the crop gave the highest net return and benefit: cost ratio and produced significantly higher biomass in term of rice equivalent yield. Among the organic manure, the overall performance the green manure was best followed by FYM. The result showed a possibility of saving 50% NPK fertilizer in rice.

Shekhar *et al.* (2009) [32] reported that the hybrid PHB-71 resulted in $6.5x10^5$/ha additional net return and significantly higher B: C ratio (1.56) over inbred cultivars NDR-359. Similarly closer spacing 20x20cm gave $7.5x10^3$/ha higher net ratio and significantly higher B; C ratio (1.59) then wider spacing 30 x 30 cm.

Dey *et al.* (2010) [11] reported that residual available P_2O_5 and K_2O increased with the increase in FYM. The highest benefit: cost ratio (1.27) was found with 10.0 tones FYM ha^{-1} 50% N.P. and K.

Conclusion

In conclusion, most of the findings revealed that some valuable benefits of integrated nutrient management over sole application of the individual fertilizer sources in improving yield and nutrient uptake and physico-chemical properties of the soil in rice under SRI. Overall, grain yield was increased by 34% with SRI practices due to significant improvement in morphology (tillering and light interception) and physiology (chlorophyll content and photosynthesis rate) of crop than crops grown with conventional method. This was plausible reason for improvement in yield contributing characteristics and ultimately higher grain yield under SRI than from conventional transplanting method. In association with this, most of the scientist concluded that 50% from organic sources and 50% from inorganic sources is the best combination in rice based cropping system to improve soil physico-chemical properties, yield and nutrient uptake capacity of rice.

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