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System of Rice Intensification: A Review on Resource Conserving Method of Rice Crop Establishment

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A B S T R A C T

Rice is commonly grown by transplanting one month-old seedlings into puddled and continuously flooded soil which leads to higher losses of water through puddling, surface evaporation and percolation. Excessive pumping of water for puddling causes problems of declining water table and poor quality water for irrigation. High water need, seed amount, labor costs and labor requirements for TPR have reduced profit margins. During the past years efforts have been tried to find out alternatives to the traditional method of rice cultivation. System of rice intensification a resource conservation method is found to be an efficient alternative to increase the rice production as it require less water, less seed, reducing cost of cultivation and saving labor over time.

Introduction

Rice is the second largest cereal crop and is the staple food of nearly one half of the world population. Developing countries accounts for 95% of the total production, with china and India alone responsible for nearly half of the world output. It is grown over 161.4 m. ha. area with production of 749.8 m. t. of paddy and an average productivity of 4.6 t/ha (Anonymous, 2014). In India, it is cultivated on about approximately42.75 m. ha. area with production of 154.5 m. t. paddy and productivity of 2.41 t/ha (USDA, 2016).Conventionally, rice is grown by transplanting one month-old seedlings into puddle and continuously flooded soil. The advantages of the conventional / traditional system include increased nutrient availability (e.g. iron, zinc, phosphorus) and weed suppression (Surendra *et al.*, 2001). Puddling, in the conventional transplanting system cause the formation of hard pan below the plough-zone and reduces soil permeability. It leads to water loss through puddling, surface evaporation and percolation. Water resources, both surface and underground, are shrinking and water has become a limiting factor in rice production (Farooq *et al.*, 2009). About 80%of the available water resources world-wide are used by the agricultural sector (Sujono, 2007). Currently, on-farm availability of fresh water is reducing due to many reasons (Uphoff, 2006). Irrigated rice makes the highest water demand. By 2025, it is estimated that 15-20 million hectares of irrigated rice lowlands, which provide three quarters of the world's rice supply, are expected to suffer some degree of water scarcity (IWMI, 2007). It is also estimated that to eliminate hunger and under nourishment for the world's population by 2025, the additional water requirements may be equivalent to all freshwater withdrawal used today for agriculture, industrial and domestic purposes (SIWI, 2005). In recent years, there has been a shift from conventional transplanted rice to non-conventional production systems. These are resource conserving and economical such as direct seeded rice (DSR) and system of rice intensification (SRI). System of rice intensification emerged as an alternative to enhancing the rice production using less water, seeds, chemical fertilizers and labor.

The system of rice intensification was developed in Madagascar during the 1980s after two decades of observation and experimentation (Laulanie, 1993). Application of SRI principles has helped small farmers in that country to greatly increase their grain yields, from 2 t ha^{-1} to 8 t ha^{-1} and sometimes more (Hirsch 2000; Uphoff and Randriamiharisoa, 2002) on soils that were evaluated as poor or very poor (Johnson 1994).

SRI method is focus on improving the growing environment of rice plants, above and below ground, by improving the management of plants, soil, water and nutrients, to stimulate the growth of bigger and better root systems and the number and activity of beneficial soil organisms (Hidayati *et al.,* 2016). The validity of SRI concepts and methods has been seen now in 42 countries, from Panama to the Democratic People's Republic of Korea. The governments in China, India, Indonesia, Cambodia, and Vietnam, where two thirds of the world's rice is produced, have come to accept and promote these alternative methods based on their own evaluations and experience (Uphoff *et al.,* 2011). In India, research institutes have initiated experimental trials on SRI across the country in several states including, Tamil Nadu, Andhra Pradesh, Orissa, Tripura, Punjab, Haryana, West Bengal, Chattisgarh, Karnataka, Assam, Bihar, Himachal Pradesh, Uttarakhand, Jammu and Kashmir and Madhya Pradesh to promote among farmers SRI in paddy cultivation (Grihtlahre *et al.,* 2012). The advantages of application of SRI method compared to the conventional method are less seed requirement, water savings up to 50%, reduction in the use of inorganic fertilizers by 50% if coupled with 50% organic fertilizer, or some combination of organic fertilizer and biological fertilizer, production costs reduced by 20%, and increasing yield (Hutabarat, 2011). The specific operational practices that derived from Laulanie's work can be stated as follows: i) Transplanting of young seedlings at 8–12 days, when they are at 2–3 leaf stage ii) Transplanting of one seedling per hill with a spacing of 25 x 25 cm in a square pattern iii) Apply water during vegetative growth stage at an interval 3 to 6 days.

After panicle initiation, maintain just a thin layer of water, 1–2 cm, until 15 days before harvest iv) manual or mechanical weeding to control the weeds and to aerate the soil v) use of compost as organic matter instead of inorganic fertilizers (Uphoff *et al.,* 2011; Barison and Uphoff, 2011). These practices improve the growth and functioning of rice plants and enhance the numbers and diversity of the soil biota that contribute to plant health and productivity (Stoop *et al.,* 2002; Uphoff, 2003; Randriamiharisoa *et al.,* 2006; Mishra *et al.,* 2006).

Performance of different rice genotypes under SRI

Rice hybrids exhibited highest yield potential under SRI method, due to profuse tillering capacity, lodging tolerance, greater stress resistance and wide ecological adaptability (Yan Qingquan, 2002; Rao *et al.*, 2006; Uphoff, 2004; Sowmya, 2008). Rice hybrid 'PHB 71' recorded significantly higher grain yield (12.6%), harvest index (8.0%), plant height, leaf area index (LAI), tillers/hill, panicles/hill and grains/panicle during both the years compared to 'NDR 359'(Ram *et al.*, 2014) mainly because hybrid genotypes possess heterosis resulting in vigorous root system, greater source size, higher number of tillers, grains/ panicle and leaf area than the inbred variety (Dey *et al.*, 2006). Singh *et al.*, 2014 evaluated eleven hybrid rice (JRH-4, JRH-5, JRH-8, JRH-10, JRH-11, PRH-10, NPH-207, NPH-567, NPH-4113, NPH-369 and NPH-999) with IR -36 as a control under SRI method of cultivation. Among these hybrids, PRH-10 recorded significantly highest chlorophyll content, dry matter, LAI,CGR, RGR, NAR, root length, root: shoot ratio and grain yield (9.95 t/ha) over the rest of hybrids followed by NPH-567.The lowest values of these parameters were noted in IR-36.Choudhary *et al.*, (2010) tested the field performance of 6 rice hybrids ('KRH 2', 'Arize 6444','PHB 71', 'Indam 100-001', 'PRH 10' and 'Indam 100-003') under system of rice intensification, with inoculation of 3plant growth-promoting rhizobacteria. Higher grain yield was recorded in 'KRH 2' (5.52 tonnes/ha), which is at par to 'Arize 6444' (5.23 tonnes/ha) and 'PHB 71' (4.93 tonnes/ha), but significantly higher than 'Indam 100-003' (4.59 tonnes/ha), 'PRH 10' (4.32 tonnes/ha) and 'Indam 100-001' (3.16 tonnes/ha). Performance of five different rice varieties (Khandagiri, Lalat, Surendra, Hybrid CRHR-7 and Savitri) was compared under System of Rice Intensification (SRI) and current transplanting system (CTS). SRI practices significantly improved the harvest index, percentage of effective tillers, panicle length, and various yield components in all the varieties. Among the varieties, in absolute terms, CRHR-7 and Savitri gave the highest grain yield, under SRI management, while Khandagiri produced the least grain. Similarly, Savitri and CRHR-7 had significantly higher number of tillers and panicles per hill than the others (Thakur *et al.*, (2011).The hybrid PSD-1 performed better in terms of growth and development of the crop, yield components resulting in significantly higher grain yield (4835 kg ha^{-1}) over BPT-5204 (4453 kg ha^{-1}). Nutrient uptake was also significantly greater withPSD-1 over BPT-5204 (Sowmya, 2008).BRRI dhan29 had a significantly higher grain yield and highest number of effective tillers/m^{2}than BRRI dhan28, BRRI dhan35, BRRI dhan36 and BRRI Hybrid dhan 1 under SRI practices (Latif *et al.*, 2005). Ranjitha *et al.*, (2013) reported significantly higher grain yield of hybrid KRH-2 over the other two cultivars *i.e.*, Vasumathi and Krishnahamsa. Veerabhadram, 2013 evaluated four hybrids and eleven varieties for seed yield and quality under system of rice intensification at ICRISAT DRR Farm, Patancheru, Hyderabad. The medium duration rice hybrids (KRH-2, PA6201) gave highest grain yield associated with more number of panicle bearing tillers, high root density, dry matter production and filled grains per panicle. The cultivar HRI-152 gave more seed yield of 66.23 q ha-1 than PR-115 and 17 A/R10 which yielded 60.82 and 52.01 q ha-1respectivelyunder SRI method of rice cultivation (Mahajan and Sarao, 2009).Singh *et al.*, (2015) reported that long duration variety Swarna produced more grain and straw yield than followed by BPT 5204, IR 64 and Lalat. For yield attributes Swarna was significantly superior to IR-64 and Lalat but remained at par with BPT-5204 as Swarna andBPT-5204 being long duration varieties gets more time to complete the life cycle in comparison to medium duration varieties i.e. IR-64 and Lalat. Rice cultivar 'PHB 71'exhibited significantly higher grain yield, straw yield and harvest index, plant height, tillers/hill, LAI, dry-matter accumulation with delayed flowering and physiological maturity and effective tillers/m2, grains/panicle and test weight over 'Pusa RH-10 (Vishwakarma *et al.*, 2016).

Growth traits under SRI system of rice cultivation

In SRI planting strategy, there was less trauma to the root system and the plants recover from the shock of transplanting more quickly which preserve the potential of the plant for much greater tillering, faster root growth and grain filling (Uphoff, 2002).Transplanting of younger seedlings increased drymatter production in SRI method as compared to the normal system of cultivation (Uphoff, 2001). Gani *et al.*, (2002) recorded more vigorous vegetative plant growth of seedlings of 7 to 14 d age than 21-d-old seedlings. They produced more effective tillers, biomass, taller plants, and longer roots. Younger seedlings had a longer time to adapt to field condition, therefore the plant height and tiller number produced were higher in the SRI method. In addition, single seedling is planted per hill with a wide spacing in SRI method. It reduces the competition between the plants for nutrients uptake, water, light and air which can significantly increase the growth of individual rice plant under the SRI method (Thakur *et al.*, 2010). In SRI method the leaf area index (LAI) was higher i.e., 1.82 at tillering, 3.65 at panicle initiation, and 4.44 at flowering over the standard method with 4.40, 4.78, and 4.16 in the respective stages (Lokanadhan *et al.*, 2007). Sridevi and Chellamuthu (2015) reported that transplanting of 14 days old seedlings at a spacing of 22.5 cm x 22.5 cm and cono weeding four times at weekly interval had profound contribution for the enhancement of growth parameters like leaf area index, crop growth rate, net assimilation rates, relative growth rate, leaf area ratio and dry matter. The leaf number of rice increases with increasing number of tillers. Likewise, the leaf area increased due to a greater leaf elongation rate which may contribute to making the leaves wider (Thakur *et al.*, 2011). Reddy (2004) observed that BPT-5204 variety flowered 4-5 days earlier under SRI system of cultivation as compared to the traditional method of planting. Singh *et al.*, (2004) reported that 11 days difference in 50 per cent flowering between 21 and 51 days old seedlings in Pusa Basmati-1. Udaykumar (2005) reported that days to 50 per cent flowering and maturity was 4-5 days early (71 and 116) as compared normal method (75 and 120 days) in MTU- 1010 rice variety.

Root growth was markedly greater in SRI plants than in traditional rice plants. The total dry matter production was higher in SRI method of planting than traditional rice, this difference becoming significant during the reproductive stage (Longxing *et al.*, 2002). Maintaining the soil in moist but not flooded conditions provided good aeration for the plant roots. These favorable conditions for growth with SRI methods allowed to complete more phyllochrons of growth, producing more tillers and roots, before the flowering phase (Hidayati *et al.*, 2016). Rupela *et al.*, (2006) reported that rice plants in the SRI plots had about 10 times more root mass, about 5 times more root length density and about 7 times more root volume in the top 30 cm of soil profile as compared with roots in the plots of flooded rice. Satyanarayana *et al.*, (2007) confirmed that the SRI plants have deeper root systems and larger roots compared to those conventionally grown in flooded rice systems. Root growth and root exudation rate hill^{-1} were significantly higher in SRI plant (Thakur *et al.,* 2006)

Yield and its components under SRI system of rice cultivation

SRI is a methodology for increasing the productivity if irrigated rice cultivation by changing the management of plants, soil, water and nutrients by reducing external inputs. It has been raising yields by 32% to 100% and sometimes more, with reduced requirements for water, seed, fertilizer and crop protection (Sato and Uphoff, 2007; Sinha and Talati, 2007). Omwenga *et al.,* (2014) monitored yield parameters like number of tillers, panicles, panicle length and panicle filling during the growth period of the crop to determine the effect of system of rice intensification. Eight days drying period gave the highest yield of 7.13 tons/ha compared with the conventional method of growing rice which gave a yield of 4.87 tons/ha. This was an increase of 46.4% above the conventional method of growing rice. Higher yield attributes like number of productive tillers m^{-2}, length of panicle and numbers of grains panicle^{-1} showed the higher grain yield of 6082 kg ha^{-1} which was significantly higher than conventional method of rice cultivation (5223 kg ha^{-1}) under SRI system (Ponni *et al.,* 2010). The combination of 10 days aged seedlings, 100% nutrients through inorganic sources ($A_{10}F_{100}$WmIs) or 50% through inorganic + 50% through organic sources ($A_{10}M_{50}F_{50}$WmIs), weeds controlled thrice mechanically by cono weeder and irrigation as per SRI i.e., 2 cm at hairline crack development stage gave similar and maximum yield attributes and yield of hybrid rice. This combination ($A_{10}F_{100}$WmIs) produced higher grain yield (7.52 t ha^{-1}) than recommended practices of hybrid rice (6.50 t ha^{-1}) with the increase in grain yield was 13.52% (Verma *et al.,* 2014). Raju *et al.,* (1989) observed more filled grains per panicle and grain yield per plant under SRI method of cultivation. Significantly higher seed yield ha^{-1} was noticed with a spacing of 30 x 30 cm and transplanting 12 days old seedlings (Krishna *et al.,* 2008) under SRI system of cultivation. Babu (2007) recorded higher grain yield in SRI as compared to conventional method. Makarim *et al.,* (2002) found that 15 day old seedlings gave significantly higher grain yields than 21-d-old seedlings when a single seedling was planted hill^{-1}. SRI registered a mean grain yield of 5505 kg ha^{-1} which was significantly higher than conventional method of rice cultivation (4510 kg ha^{-1}). Thus significant superiority of SRI in terms of grain yield was evident due to 22.1 per cent yield increment by SRI. Higher yield attributes like number of productive tillers m^{-2}, length of panicle and numbers of grains panicle^{-1} under SRI attributed the higher grain yield of SRI (Pandiselvi *et al.,* 2010). Bommaiasamy (2005) reported that transplanting of 14 days old seedlings at 20 x 20 cm spacing results in 7.2 % higher yield than 21 days old seedlings under SRI system. Udaykumar (2005) confirmed that SRI recorded significantly higher seed yield of 6136 kg ha-1 compared to traditional method of cultivation (4282 kg ha^{-1}) in MTU -1010 rice variety. The yield attributing parameters viz., number of productive tillers, number of filled spikelets and panicle length were also high with this method.

Water saving under SRI system of rice cultivation

The most important feature of SRI Technique was its potentiality to save water. SRI is reported to reduce amount of water applied to the field by about 40-70% compared to the traditional practice of continuous flooding (Sato and Uphoff, 2007; Sinha and Talati, 2007).On an average, 406 mm water was saved under SRI(Mevada *et al.,* 2016), which tuned to 33.47 % saving over farmer's practice (FP). So, for production of 1 kg grains of rice, 2426 liter of water was sufficient under SRI, as against 3743 lit. water required for producing the same quantity under FP, indicating about 35 % higher efficiency of water under SRI over FP. Likewise, WUE was also higher (4.12 kg/ha-mm) under SRI as compared to FP (2.67 kg/ha-mm). Zhao *et al.,* (2010) reported that the total water consumption in SRI was 898.3 mm as compared to traditional flooding (TF) in which it was 1359.8 mm. The irrigation water use was reduced by 57.2% in SRI compared to TF. Water use efficiency (WUE) in terms of grain yield per unit consumed by water increased 91.3% for SRI. Irrigation water use efficiency (IWUE) in terms of grain yield per unit irrigation water improved by 194.9% for SRI compared to TF. Thus, SRI treatment reduced water consumption and increased WUE and IWUE significantly as compared to TF. Higher grain yield coupled with substantial water saving i.e. 35 per cent (Pandiselvi *et al.,* 2010) and 24. 1 Per cent (Pooni *et al.,* 2010) resulted in higher WUE of rice under SRI method. SRI method of transplanting resulted in significantly higher total water productivity (5.9 kg/ha-mm) in upland ecology and (6.2 kg/ha-mm) in lowland ecology as compared to other two methods viz. direct-seeded rice and puddled transplanted rice (Raj *et al.*, 2017).

Physiological traits under SRI system of rice cultivations

SRI methods significantly increased both vegetative and reproductive parameters of rice plants compared to conventional cultivation methods. Photosynthetic rate, chlorophyll content, N and P uptake under SRI cultivation were found significantly higher as compared to the conventional rice cultivation, but no differences were observed in transpiration rate and leaf temperature. Plants in their generative phase especially in the grain-filling phase had the highest photosynthetic and the lowest transpiration rates under SRI system of planting (Hidayati *et al.,* 2016). Due to wider spacing between hills, rice plants showed wider canopy under SRI system than those in conventional method. The wide canopy increases the penetration of light to reach to lower leaves, thus maximizing opportunity for all of the leaves to perform photosynthesis optimally (Terashima and Hikosaka, 1995).Chlorophyll content of fourth leaves from the flag leaf was found to be significantly higher in SRI plants (by 27–73%) compared to current transplanting system (CTS) plants in all the varieties during early ripening or milk grain stage. Similarly, the rate of photosynthesis was also higher for the fourth leaves from the flag leaf at the early ripening stage of SRI plants compared to CTS. Leaves from SRI plants showed photosynthesis rates 48–69% higher than in CTS leaves. The hybrid and long-duration variety maintained significantly higher rates of photosynthesis than did the short-duration variety under both SRI and CTS (Thakur *et al.,* 2011). Previous reports suggests that a well-developed root system enhances the synthesis of cytokinins in roots (Soejima *et al.*, 1995; San-oh *et al.,* 2004), and the rate of leaf senescence is lower in plants that have larger amounts of cytokinins transported into their canopies from the roots (Soejima *et al.*, 1995). Increased transport of cytokinins to above-ground parts of the plant from the roots during ripening is associated with the maintenance of increased rates of photosynthesis in rice (Ookawa *et al.,* 2004; Soejima *et al.,* 1992, 1995). Plants from pattern I (one plant per hill)maintained higher rates of leaf photosynthesis at the middle and late ripening stage due to the maintenance of higher levels of leaf nitrogen and Rubisco than plants from pattern III (three plant per hill). Pattern I plants, which produced a larger number of crown and branched roots, accumulated a larger amount of nitrogen and transported a larger amount of cytokinins from roots to shoot in the ripening stage than pattern III plants (Shan-oh *et al.*, 2006).The highly efficient photosynthetic performance of super high-yielding rice is largely a result of the increased cytokinin content in their roots, contributing to higher grain yield (Shu-Qing *et al.,* 2004).

Seed quality traits under SRI system of rice cultivation

The SRI method of cultivation considerably increases the seed yield and seed quality in traditional rice varieties when grown organically (Fernandes and Uphoff, 2002). Udaykumar (2005) reported that better seed quality parameters under SRI method like higher germination per cent (95.56), root length (5.44 cm) and shoot length (5.49 cm) higher values of speed germination (31.11) and vigour index (991) compared to that under normal method. Kanaka Durga *et al.*, (2015) reported that the twelve days old seedlings planted at 25 × 25 cm recorded 100% germination, with longer seedlings and seedling high vigour index I. Seed produced with SRI under spacing of 25 cm x 25 cm recorded higher germination (98.60%) as compared to conventional (95.0 %) with close spacing of 20 x15 cm. The vigour index was significantly higher with SRI. The better seed quality produced under SRI may be due to higher test weight values (Singh *et al.*, 2013). Seed quality parameters viz., seedling length (root length and shoot length, separately), seedling dry weight and vigour index recorded significantly higher values in SRI method (Kumar, 2014).

Grain quality traits under SRI system of rice cultivation

SRI was found better over traditional method in respect of grain quality of rice. Hulling, milling and head rice recovery in rice improved significantly under SRI over conventional method and this might be attributed to the improvement of root activity, dry matter accumulation and grain filling (Mandal *et al.*, 2014). Milling percentage and head rice recovery were significantly higher (4.4% and 4.8 % during wet and dry season respectively) under SRI as compared to non-SRI (Satyanarayana *et al.*, 2004) due to higher grain weight. Grain quality parameters such as the grain length (7.77 mm), amylose content (25.83%), alkali spreading value, Fe (2.06 ppm) and Zn (13.23 ppm) content (polished rice) recorded significantly higher values in SRI method compared to grain length (7.47 mm), amylose content (25.09%), alkali spreading value, Fe (1.77 ppm) and Zn (12.07 ppm) content (polished rice) under conventional transplanting (CT) (Kumar, 2014).

Incidence of insect pests and diseases under SRI system of rice cultivation

Rice crop is damaged by a large number of insect pests, natural enemies and disease that cause an overall estimated yield loss of 21-51%(Arya and Chander 2012).Very few reports are available on the insect pests, natural enemies and disease scenario in SRI system (Karthikeyan *et al.,* 2007), some of which are reviewed here. Low pest incidence in rice grown under SRI due to vigorous and healthy growth of plant coupled with wider spacing had been reported by Ravi *et al.*, (2007). Two rice varieties viz. Deku (local variety) and CAU R-1(improved variety) were investigate and compare the occurrence of insect-pests, natural enemies and diseases in SRI and traditional system of rice cultivation under north-east region conditions of India. The pooled results of two cropping seasons revealed that prevalence of stem borer, blue beetle, case worm, leaf folder and gundhi bug/m^2 were lower in both the varieties under SRI system as compared to traditional system. Among diseases the incidence of blast, sheath blight, brown spot, false smut, bacterial leaf stripes and bacterial blight was found to be lower in SRI in both the varieties as compared to a higher level of incidence under traditional systems (Pathak *et al.,* 2012). Karthikeyan *et al.,* (2010) reported that the incidence of stem borer was significantly lower in SRI (4.82% in Jyothi and 2.35% in CORH 2) during the vegetative phase compared to standard method of cultivation (9.75% in Jyothia and 9.85% in CORH 2), while at the reproductive phase there was no significant difference between the two systems of cultivation. The incidences of whorl maggot and caseworm were lower under SRI system but the incidence of leaf folder was higher in the crop under SRI than the standard system. Padmavathi *et al.,* 2009 observed that yellow stem borer damage was high at all stages of crop growth period and its damage (dead hearts) at maximum tillering stage was low in cv. Shanti grown under SRI (7.0%) as compared to conventional method (11.4%). At reproductive stage, the damage (white ear heads) was high in SRI (28.3%) than conventional method (21.2%). Ravi *et al.,* (2007) reported low white ear heads damage in BPT 5204, ASD 19, Swarna and ADT 46 under SRI method due to vigorous and healthy growth of plant coupled with wider spacing. Shengfu *et al.*, (2002) recorded that incidence of rice sheath blight was less when planted at 33.3 cmx 33.3 cm (58.4%) spacing or 40 cm x 40 cm (54.6%) spacing under SRI than that with traditional cultivation (70%).

Economic benefits from system of rice intensification

Ponni *et al.,* (2010) compared the rice cultivation under system of rice intensification (SRI) and conventional method. The study revealed that the cost of cultivation was comparatively lesser in SRI than conventional method. The mean cost of cultivation for SRI and conventional method was Rs. 20,944 ha^{-1} and Rs. 23,111ha^{-1}, respectively. Thus it is evident that adoption of SRI was found to reduce the cost of cultivation by Rs.2167ha-1.SRI registered a total income of Rs.61, 000 ha^{-1} and net profit of Rs.40, 056 ha^{-1} as compared to Rs.52, 167 ha^{-1} and Rs. 29,056 ha^{-1}, respectively under conventional method. Higher BC ratio was also associated with SRI (2.91) than conventional method (2.26). Ram *et al.,* (2014) concluded that use of10 days old seedlings of hybrid rice ‘PHB 71’ at spacing of 25 cm × 25 cm is most suitable to increase productivity and profitability of transplanted rice under Eastern Utter Pradesh conditions. Nayak *et al.,* (2016) evaluated economic advantages of SRI practices of paddy transplanting as compared to conventional method in Odisha. The yield differences showed that farmers growing paddy by SRI method could get a 6.6 q more paddy as compared to traditional method of transplanting. Benefit: cost ratio indicates that SRI method was more effective as if we invest one rupee the total return would be 2.18 whereas in case of traditional method this figure would be 1.45. Thus it can be concluded that with less inputs farmers can earn more.SRI could fetch 16.8 and 23.7%higher gross return, 36.7 and 51.7% higher net return and16.3 and 21.3% higher return re^{-1} invested than conventional transplanting and drum seeding, respectively as per mean yield. This was mainly because of higher yields obtained in SRI as compared to the other two methods during both the years (Mohanty, *et al.*, 2014).The net returns and benefit-cost ratios were higher for SRI farms due to higher productivity of paddy cultivation (Durga and Kumar, 2013).

SRI is a new technology of rice crop establishment that enhance the productivity of the crop with minimum use of resources such as seeds, water, capital and labor. The practices of SRI such as single seedling per hill and wider spacing helps the rice plants to better utilize the water and nutrients thereby increase the water and nutrient use efficiency. Yield of different varieties was significantly higher in SRI as compared to traditional transplanting. Within SRI, the different varieties performed differentially. So, there is need to develop varieties that respond better under SRI practices.

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