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Performance of SRI principles on growth, yield and profitability of rice (*Oryza sativa* L.)

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Abstract
A field experiment was conducted at Birsa Agriculture University, Research Farm, Western Section, Kanke, Ranchi during the 2011 and 2012 *kharif* season to evaluate different components of system of rice intensification principles on growth parameters, yield attributes, yield and economics of rice on clay loam soil in eastern plateau & eastern ghat of India. To assess the contribution of each component of SRI. The experiment was planned with eight treatments {(T_1: use of 8-12 day old seedlings, one seedling transplanting at a spacing of 25 cm x 25 cm, weed management with conoweeder (4 times), saturation of water management, and use of (75%) inorganic along with (25%) organic, T_2: T_1 with 3 seedlings per hill (instead of one seedling), T_3: T_1 with 21 day old seedlings(instead of 12 day old seedlings), T_4: T_1 with 20 x 10 cm spacing (instead of 25 x 25 cm spacing), T_5: T_1 with only inorganic source of nutrient (instead of organic + inorganic), T_6: T_1 with herbicide + manual weeding 40DAT (instead of conoweeding), T_7: T_1 with 5±2 cm standing water during crop growth (instead of saturation water management), and T_8: Conventional transplanting (21 day old nursery; spacing of 20 cm x 15 cm; 3 seedlings/hill with 5±2 cm standing water during crop growth) were tested in three times replicated RBD. Rice crop grown with all six principles of SRI recorded significantly higher plant height (118.4cm), total tiller per meter^2 (339), leaf area index (3.5) dry matter accumulation (g /m^2), crop growth rate (g/m^2/day), number of panicle per meter^2 (272), 1000 grain weight (29.9g), Panicle length (26.8cm), Panicle weight (4.6g), number of filled grains per panicle (139), number of unfilled grains per panicle (28) and improved grain yield and straw yield was 33.3%, 28.3% and 23.6%,18.9% higher under all six principles of SRI compared to SRI with 21 days old seedling and conventional transplanting. Due to lower cost of production and higher yields, all six principles of SRI fetched higher net returns over old aged seedling.

Key words: Conventional transplanting rice, System of rice intensification, SRI, yield attributes, growth parameters, economics.

Introduction

Rice is the staple food for about 50 per cent of the world's population that resides in Asia, where 90 per cent of the world's rice is grown and consumed in Asia. For India, it is estimated that the demand, of rice will be 140 million tons in 2025 for 70 per cent over the next 30 years. India has the largest area under rice (43.0 million ha) accounting for 29.4 per cent of the global rice area and it stood next only to China in the world with respect to rice production.

Irrigated rice occupies about 50 per cent total rice area and contribution nearly 70 per cent to total rice production of the country with an average yield of 3.1 t ha^{-1}. India's food security largely depends on irrigated rice which consumes nearly 50-60 per cent our finite fresh water resources. Conventional rice transplanting requires about 900-2200 mm of water (average 1500 mm) depending on the water management, soil and climate factor. It is estimated that rice needs about 3000-5000 litters of water to produce one kg of grain which is three to five times more than the other cereals like wheat, corn etc. So rice will have to be produced on less land with less usage of water, labour and chemicals.

The System of rice intensification results in saving of 30-40 per cent irrigation water; 85 per cent on seed, chemical fertilizers, and promotes soil microbial activity which improves the soil health. SRI even offers advantages for seed multiplication Saving on seed cost as the seed requirement is less, Saving on water as alternate wetting and drying method is followed, Cost of external inputs gets reduced as chemical fertilizers and pesticides are not used Incidence of pests and diseases is low as the soil is allowed to dry intermittently. More healthy and tasty rice as a result of organic farming practices. Higher yields due to profuse tillering, increased panicle length and grain weight Seed multiplication with less quantity of parent seed. Farmers can produce their own quality seed**.**

Because of the growing population, farmers will need to produce more rice with improved quality to meet future consumer demand.

This additional rice will have to be produced on less land with less water, less labour and fewer chemicals. Evaluation of SRI with certain package of crop management showed that it not only had the benefit of reducing the water requirement for rice cultivation but also increased the productivity. (Thiyagarajan *et al*., 2005) [15]. There is always a growing demand for rice in India due to ever growing population. So to sustain present food sufficiency and also to meet future food requirements, India has to realize an annual growth rate of at least three per cent in productivity of rice. So increasing the growth rate and productivity. There is a method of rice farming known as System of Rice Intensification (SRI).

In Jharkhand, SRI is becoming very popular among farmers now a days but it has been observed that several times farmers could not fetch the optimum grain yield of rice in SRI system due to lack of knowledge because they are unable to follow all the six principles of SRI. Therefore, it is very essential to know the contribution of each component, so that farmers could adopt the most important few components which play crucial role in increasing rice yield. Hence, the present investigation was carried out to study the effect of SRI principles on growth parameters, yield attribute and economics of rice.

Materials and Methods

A field experiment was conducted at Birsa Agriculture University, Jharkhand, Ranchi, Kanke, (23^0 17'N latitude, 85^0 10' E longitude and 625 m above mean sea level altitude), Jharkhand, during *kharif* 2011 and 2012. This place has a subtropical climate with hot and dry summer comparatively cool rainy season followed by moderate winter with mean annual rainfall of 895.3 mm and.1331.3 mm in 2011 and 2012. During 2012, mean maximum temperature during crop period was 28.5 ^{0}C, while the mean minimum was 17.4 ^{0}C. During 2013, mean weekly maximum temperature and minimum temperature was 27.3 ^{0}C and 18.4 ^{0}C. The soil of the experimental site was clay loam in texture (30.0% sand, 38.4% silt and 31.6% clay). The soil was acidic in reaction (pH 6.1) and organic carbon (0.33%). The fertility status revealed that the soil was low in available nitrogen (263.4 kg N /ha) medium in available phosphorus (15.9 kg P_2O_5/ha) and medium in available potassium (137.5 kg K_2O/ha).

There were altogether eight treatments, T_1 comprised of all six principles followed in SRI whereas in treatments T_2 to T_7 one principle of SRI was replaced with that of corresponding conventional method of transplanting {(T_1: use of 8-12 day old seedlings, l transplanting at a spacing of 25 cm x 25 cm, weed management with conoweeder (4 times), saturation of water management, and use of (75%) inorganic along with (25%) organic, T_2: T_1 with 3 seedlings per hill (instead of one seedling), T_3: T_1 with 21 day old seedlings(instead of 12 day old seedlings), T_4: T_1 with 20 x 10 cm spacing (instead of 25 x 25 cm spacing), T_5: T_1 with only inorganic source of nutrient (instead of organic + inorganic), T_6: T_1 with herbicide + manual weeding 40DAT (instead of conoweeding), T_7: T_1 with 5±2 cm standing water during crop growth (instead of saturation water management), and T_8: Conventional transplanting (21 days old nursery; spacing of 20 cm x 15 cm; 3 seedlings/hill with 5±2 cm standing water during crop growth)} was arranged in a RBD replicated thrice. The experiment had 24 plots of gross size 5.0 mx4.0 m each.The well levelled land of 100m^2 area was selected foe raising nursery. Two types of nurseries were raised separately. For the conventional 15 kg/ha seeds was required and 5 kg for SRI of seeds was required for nursery. The recommended dose of nutrients @ 150 kg N, 75 kg P_2O_5 and 90 kg K_2O ha $^{-1}$ were applied through urea, single super phosphate and muriate of potash respectively. Half amount of nitrogen & full amount of phosphorus and two third of potassium were applied in experimental field as basal before transplanting and the rest amount of nitrogen was top dressed in two equal splits at active tillering stage and panicle initiation stage. The one third of potash was applied as splits at the time of panicle initiation.

Hand weeding, weeding by conoweeder and use of herbicide was done as per treatments. For chemical weed control herbicides namely Butachlor @ 1.0 kg a.i/ha pre emergence and 2, 4-D @ 0.5 kg/ha post emergence was applied in treatment.

The irrigations were given as and when required depending upon the intensity of rains. Water level of 5±2 cm was maintained in treatment under conventional method during the crop growth period. In SRI, water level was maintained at soil saturation level by intermittent light irrigation coinciding with alternate wetting and drying.

Data on growth parameter, yield attribute characters, grain yield and straw yield were recorded at crop maturity. The economics- parameters (gross returns, net returns and B:C ratio) were worked out on the basis of prevailing market prices of inputs and outputs the data were analyzed by using the Analysis of Variance Technique for randomized block design (RBD) as per the procedure described by Gomez and Gomez (1984). The treatment means were compared at 5% level of significance.

Results and Discussion

Growth characters

Plant height, total tillers per meter^2, leaf area index, dry matter accumulation and crop growth rate is an important index for assessment of crop performance. The rice crop had varied significantly with the advancement of crop growth with the advancement in age. At maturity, all six principles of SRI recorded maximum plant height (26.8%, 22.8%), total tillers per meter^2 (30.2%,26.7%), leaf area index (24.2%, 22.9%), dry matter accumulation (27%, 21.4%) and crop growth rate (69.6%,51.8%) as compared to the old aged seeding (21 days old seedling and conventional transplanting). which was at par with the SRI with 3 seedlings per hill, SRI with inorganic source, SRI with 20 x10 cm spacing, SRI with standing water and SRI with herbicide and manual weeding respectively. Among SRI with 21 days old seedling and conventional was accounted for the lowest growth characters at maturity respectively. The greater spacing in SRI leading to lower competition between the plant thus favorable better growth and development of plant height and total tillers (Patwardhan and Patel, 2008) [10]. The transplanting of young seedling to produce more phyllochron before entering the reproductive phase compared to older seedling and it provide sufficient nutrient for vegetative growth and also for reproductive phase which ultimately leads to increase plant growth. Planting young seedling at their second or third phyllochron stage did not disturb the rapid tillering and rooting which begin at the fourth phyllochron stage (Berkelaar and uphoff, 2001). The peak tiller production time was enhanced in system of rice intensification than conventional method of cultivation resulting in higher number of tiller per m^2 (Thavaprakash *et al*., 2008) [14]. As that system of rice intensification increased supplying capacity of the soil which in turn resulted in higher leaf growth rate and higher leaf area index. The higher leaf area index might be due to higher no of tiller putting forth more leaves resulted higher leaf area index. SRI promotes more vigorous growth leaf area index than the normal planting (Zheng *et al*., 2004) [21]. SRI increased plant height, total tillers per m^2 and leaf area index indicating higher chlorophilic area improving photosynthesis efficiency of plant which in turn resulted in higher dry matter accumulation per m^2 (Singh *et al*., 2005) [12-15]. CGR showed a continuously increasing trend throughout the vegetative stage this might be due to better vegetative growth under system of rice intensification at all the stages thus improving the crop growth rate (Vijaykumar *et al.*, 2006 and Thakur, 2009) [17-18, 13].

Yield attributes

The SRI principles had significant effect on yield attribute and yield of rice. Number of panicles per m^2, panicle length, panicle weight, number of filled grains per panicle was singnificantly higher under all six principles of SRI as compared to old aged seedling i.e. 21 days old seedling and conventional transplanting. The SRI with 21 days old seedling produce 20.4%, 21.2%, 58.6% and 34% less number of panicles per m^2, panicle length, panicle weight, filled grains per panicle instead of 12 days old seedling. The use of SRI with 3 seedlings /hill(instead of one seedling/hill) was recorded 1.4%, 2.6%, 2.2% and 1.7% minimum number of panicles per m^2, panicle length, panicle weight, filled grains per panicle. In SRI with herbicide and manual weeding (instead of conoweeder) 4.2%, 7.6%, 17.9% per and 6.2% less number of panicles per m^2, panicle length, panicle weight, number of filled grains per panicle was obtained as compared to the all six principles of SRI. Similarly the effect of SRI with inorganic source recorded 2.6%, 3.4%, 9.5%, and 2.1% less number of panicles per m^2, panicle length, panicle weight, number of filled grains per panicle as compared to all six principles of SRI. but SRI principles did not significant affect 1000 grains weight.

The favourable condition for formation of higher number of effective tillers also resulted in production of higher number of panicles. Almost similar was obtained by Hussain *et al*. (2004) [6].The maximum weight of 1000-grains was obtained from the SRI than old aged seedling This might be due to the favourable soil condition created due to the alternate wetting and drying in SRI method. The wider spacing of SRI that encouraged proper crop growth and development and assimilates synthesis in the grains. Similar finding were observed by Hussain *et al*., 2004 [6] and Hossain *et al*., 2003 [5]. For the formation of more number of productive tillers such as increase in CO_2 assimilation rate, delay in the senescence of flag leaf and effective translocation of photosynthates from source to sink resulted in production of higher number of panicle with longer panicle (Watanabe and Yoshida, 1970) [20]. Under SRI cultivation biomass-portioning efficiency increases distinctively, Higher translocation of assimilates *viz.*, dry matter, carbohydrates, nitrogen, and their conversion rates enhanced the grain filling and spike weight in SRI rice (Wang Shao Hua *et al.*, 2002) [19].Under younger seedlings combination, increased leaf area and subsequent increase in photosynthetic activity were exhibited through increased biomass production as a major portion of photosynthates accounted for dry matter and all these factors favoured the yield components under SRI practices. Wider spacing was the reason for less below and above ground competitions for better grain filling, higher grain weight and more number of filled grains per panicle. Optimum supply of irrigation water with mechanical weeding resulted in higher nutrient availability subsequently resulting in better source to sink conversion and in turn enhanced the production of more total number of seeds and filled seeds per panicle (Lu *et al.*, 2005) [7]. SRI, tillers and grains per panicle were increased by having more space between plants, which respond positively in their greater exposure to sunlight and circulatory air but closer spacing (20 cm x 10 cm) caused greater sterility percentage than wider spacing (Verma *et al*., 2002) [16].

The all six SRI principles, gave significantly higher grain and straw yield (68.0 q/ha & 94.4q/ha) as compared to old aged seedling (SRI with 21 days old seedling and conventional transplanting illustrated in Table-2. As far as contribution of different principles towards yield was concerned, a reduction of 33.3%, 22.7% was observed when 21 days old seedling instead 10 days old seedling was used. The effect was conspicuous with the use of SRI with 3 seedlings per hill instead of one seedling per hill, which resulted 1.7% less grain and straw yield than the all six principles of SRI. While in SRI with herbicide and followed by manual weeding instead of conoweeding realized 10.3%, 7.0% less grain yield as compared to combination of all six principles of SRI. SRI with standing water instead of alternate drying wetting gave 7.7%, 5.3% less yield than combination of all six principles of SRI, where as SRI with inorganic sources observed decrease of 3.9%, 2.8% less yield. As compared to conventional transplanting, the all six principles of SRI gave 26%, 18.4% higher grain yield of rice. Harvest index of rice ranged from 42.5 to 39.9%.There was no significant variation on harvest index was observed among the treatments. SRI method provided the plants better growth conditions (such as wider spacing, better aeration and better utilization of resources), which enabled them to grow vigorously. This has been exhibited in terms of higher leaf area and ultimately higher dry matter production. These enhanced growth parameters might have helped in better filling of spikelets. These results are in agreement with findings of Nayak *et al*. (1998) [8] and Barison (2002) [2]. Maximum grain yield achieved in SRI was due to higher leaf area index (LAI) and light interception at wider spacing between plants gained from open plant structure. This resulted in higher LAI and greater leaf size, leading to a vigorous root system and more adequate room to grow. In the conventional method at closer spacing between rice plants, the number of panicles per unit area increases but with shorter panicles containing fewer grains, resulting in lower yield. This result is in confirmation with result obtained by Pandian, B.J. 2010 [9]. Straw yield is primarily a function of vegetative growth of the crop in terms of plant height, tiller production per unit area, number of leaves per plant etc. A decrease in leaf area causes a reduction in area for interception and absorption of the specific wavelength of light necessary for photosynthesis. More photosynthetic area, leaf area index and total dry matter production after panicle initiation contribute to increased straw yields. Similarly, wider spacing recorded more straw yield than narrow spacing due to more space and nutrients available for the individual plant. The results supported the findings of Vijayakumar *et al*. (2006) [17-18]. An increased conversion of tillers into productive tillers per flowering panicles with the adoption of SRI management. This favourable influence might be due to efficient utilization of resources and less inter-and-intra-space competition under SRI management, which may be assigned as the reason for superiority in such yield attributes of rice and consequently increased yield. (Gani *et al.*, 2002) [3].

Economics

The input use pattern and extent of profit in conventional method cultivation and SRI paddy cultivation has been examined by computing per hectare input use, cost and returns. Average cost of cultivation was Rs.25,944.5/ha under SRI method and Rs. 30,005. Thus, the cost of production was lower in SRI by 15.6% than conventional practices due to reduction in cost of nursery, seed, weeding, irrigation, plant protection chemicals and labour requirement Similar finding was also obtained by (Anjugam *et al*., 2008) [1]. Under all six principles recorded higher net returns (Rs.54132.8) than 21 days old seedling and conventional transplanting due to higher grain and straw yields (Table 3) and also significantly higher B: C ratio (Rs.2.1.) was observed under all six principles of SRI method. The economics of SRI cultivation also indicated higher profit Sarath and Thilak (2004) [11].

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