

Evaluation of fertilizer doses under different planting methods of rice (*Oryza sativa*) in west central table land zone of Odisha

S. MOHAPATRA¹, S.K. TRIPATHY² AND A.K. MOHANTY³

Regional Research and Technology Transfer Station, Odisha University of Agriculture and Technology, Chiplima, Sambalpur, Odisha 768 025

Received: March 2020; Revised accepted: March 2022

ABSTRACT

A field experiment was conducted during 2017–18 and 2018–19 at Chiplima, Sambalpur under West Central Table Land Zone of Odisha, to evaluate fertilizer doses under different planting methods in rice (*Oryza sativa* L.). The values of growth contributing characters like plant height, effective tillers/plant, and leaf-area index increased significantly under mechanical transplanting followed by system rice intensification (SRI) and drum seeding methods. The maximum grain yield, straw yield and benefit : cost (B: C) ratio were recorded with mechanical transplanting (6.5, 7.5 t/ha and 2.6) followed by SRI technique (6.3, 7.2 t/ha and 2.3) and were lowest with manual method of random transplanting (4.6, 5.3 t/ha and 1.8). Application of 120-60-60 kg N-P₂O₅-K₂O/ha increased the panicle length (24.8 cm), filled grains/panicle (155), grain (8 t/ha) and straw (9.2 t/ha) yield and nutrient uptake by grain (113.3, 32.5 and 116.6 kg N, P and K/ha), being higher than the values obtained under soil test based fertilizer application, i.e. 100-50-40 kg N-P₂O₅-K₂O/ha.

Key words: Drum seeding, Fertilizer dose, Planting methods, Rice, System of Rice Intensification, Transplanter, Yield

To assure food security in the rice-consuming countries of the world, rice production should be increased by 50% in these countries by 2025 (FAO, 2009). This additional rice will have to be produced on less land with less usage of water, labour and chemicals (Zheng *et al.*, 2004). Rice cultivation in India is predominantly practiced under transplanted conditions. This technique requires continuous ponding of water and lot of man power. To avoid the difficulties, several other methods of rice cultivation have been developed so far. Among those System of Rice Intensification (SRI), drum seeding, mechanical transplanting technique are gaining acceptance by the growers day by day. The SRI is a water-saving methodology for enhancing the productivity of irrigated rice. The basic principles of SRI are planting young seedling (< 14 days) singly in a square pattern (Stoop *et al.*, 2002). It would be able to increase irrigated area by at least 50%, leading to 50% increase in rice production Thakkar (2005); Thakur *et al.* (2009). Transplanting of rice seedling being a labour-inten-

sive and expensive operation, it needs to be substituted by direct seeding which could reduce labour need by more than 20% in terms of working hour. Use of improve agriculture machinery to tackle the shortage of farm labour is required. The manually operated drum seeder can be used for faster line seeding in wet rice. In irrigated rice-rice cropping system, there is a very limited time between harvesting of one crop to transplanting of the next one. Due to shortage of human labour, farmers are compelled to go for delayed planting which results in yield loss. Use of mechanical transplanter in transplanted rice saves time and labour (Tripathy *et al.*, 2004).

Introduction of high yielding varieties responsive to chemical nutrients brought a spectacular increase in use of chemical fertilizers in rice. Nutrient mining by high yielding varieties were usually more than that applied through chemical fertilizers. This type of nutrient mining over years led to impoverishment of soil fertility and decline in crop productivity Nambiar (1994). Nutrient requirement is estimated as per recommendation of rainy season (*khari*) and winter season (*rabi*) manual, which can be manipulated to some extent on the basis of soil test. But these recommendations are unable to meet the growing requirements of high-yielding crops. Nutrient requirement of a popular

²Corresponding author's Email: santanu_kt@yahoo.co.in

¹Senior Scientist, All-India Coordinated Research Project on Integrated Farming Systems; ²Professor (Agronomy), ³Professor and Associate Director of Research, Regional Research and Technology Transfer Station, Chiplima, Sambalpur, Odisha 768 025

medium duration variety like 'Lalat' of mid nineties cannot be compared with the nutrient requirement of new medium duration varieties like 'MTU 1156' and 'MTU 1010' giving yield to the tune of more than 6 t/ha without lodging. So revising fertilizer dose in high yielding varieties and improve planting methods are essential. In view of above facts the present study was undertaken with the objective to identify suitable nutrient management for maximizing productivity and profitability of rice raised under different planting methods (manual transplanting, SRI, drum-seeded and mechanical transplanting in West Central Table Land Zone of Odisha.

MATERIALS AND METHODS

The experiment was laid out during *rabi* 2017–18 and 2018–19 at Regional Research and Technology Transfer Station of Orissa University of Agriculture and Technology, Chiplima, Sambalpur under West Central Table Land Zone of Odisha at (21° 27' N and 83° 58' E and 150.75 m above mean sea-level). The soil of the experimental field was sandy clay loam with pH 6.6, bulk density 1.50 g/cm³, porosity 39.28%, infiltration rate 0.26 cm/hr, water holding capacity 25.56% on weight basis, organic carbon 0.43% and available N (KMnO₄ method), P (Olsen) and K (NH₄ OHC method) content of 232, 9.4 and 158 kg/ha respectively. Rain fall received during the crop growth period was 50 mm (6 rainy days) in 2017-18 and 62 mm (9 rainy days) in 2018-19, respectively during winter season.

The experiment was laid out in split plot design, replicated thrice with 24 treatment combinations. The treatments comprise of four different planting methods (Random method of transplanting, Mechanical transplanting by transplanter, Drum seeding and SRI method of planting in main plot and six fertilizer doses, N-P₂O₅-K₂O kg/ha, 60-30-30, Recommended fertilizer dose for Odisha, i.e. 80-40-40, 100-50-50, 120-50-50, Soil test based fertilizer application, i.e. 100-50-40, No fertilizer as sub plots. The recommended fertilizer dose for Odisha during *rabi* for high yielding variety is 80-40-40 kg N-P₂O₅-K₂O/ha. Since soil is low in available N and P₂O₅, So 25% more than the recommended dose of N and P₂O₅ was applied in treatment in soil test based fertilizer treatment. The seedbed was prepared by puddling with repeated ploughing followed by laddering. Weeds were removed and irrigation was gently provided to the bed as and when necessary. Rice variety 'MTU 1156' was used for the experiment. For SRI, sprouted seeds were sown as broadcast in two portable trays containing soil and Farm yard manure. Thin plastic sheets were placed at the base of the trays to protect water loss. The moisture of the trays was controlled accurately by applying water every day, which ensured proper growth of all the seedlings in the trays. Fifteen days old seedlings

were transplanted in the prepared plot just after uprooting and this process was completed within one hour. One seedling was used for SRI transplanting in square pattern (25 × 25 cm). For mechanical transplanting, mat type seedlings of specific plant density and age were placed in the trays of the transplanter. Seedlings grown on polythene sheets get their root entangled forming a root mat. The width of the polythene sheet was kept 1 m. The length of the sheet was taken 7 m and It was spread over the surface of the field. The soil sieved in 3 mm wire mesh was mixed with farm yard manure in the ratio of 3:2 respectively. The soil mixture was spread uniformly up to a depth of 2 cm over the polythene sheet. The sprouted seeds were sown uniformly over the polythene sheet and covered with thin layer (3 mm) of soil mixture. Water was applied once in a day up to 7 days by using rose-cane and after that water was given by flooding the bed not exceeding 50% of the height of the seedlings. Frequency of watering was maintained as per the requirements to avoid drying of seedling mats. Seedlings become ready to transplant after 21 days when the height of plant was about 15 cm with 3–4 leaves. Then the seedling –mats are cut into strips of 22 × 60 cm to fit into the tray of the transplanter. The inter-row spacing of the transplanter was 22.5 cm and intra row spacing was 12 cm. For drum seeded technique, sprouted seeds were sown in 8 rows drum seeder. In the plots where crop establishment was through transplanting, 32 days old seedling were transplanted at the spacing of 20 × 10 cm using 2–3 seedlings/hill.

After the harvest of previous crop the experimental field was ploughed once with soil turning plough and cross harrowed two times. After each ploughing, planking was done to level the field and obtain the fine tilth and lay out was done. The specific quantity of each fertilizer was calculated on the basis of gross plot size and as per treatment. The half quantity of nitrogen and full quantity of phosphorus and potassium were broadcasted in the field during final land preparation. The rest half dose of nitrogen was top dressed in two splits, at 21 and 45 days after planting (DAT). The crop was harvested manually by serrated edged sickles at physiological maturity when panicle had about 85% ripened spikelets and upper portion of spikelets look straw coloured. At the time of harvesting the grains were subjected to hard enough, having less than 14% moisture in the grains. The harvesting of net plot area was done separately and the harvested material from each net plot was carefully bundled and tagged after drying for three days in the field and then brought to the threshing floor. The bundle of harvested produce of each net plot was weighed after sun drying for recording biological yield. Threshing of each bundle of individual plot was done manually by wooden sticks. The grain yield of individual plot after win-

nowing was recorded. The quantity of straw per plot was calculated by subtracting the weight of grains from biological produce. Yield of both grain and straw was expressed in t/ha. The rice grain samples were collected and ground into fine powder and pass through a 40 mm sieve and used for chemical analysis to find out the nitrogen, phosphorus and potassium uptake. Nitrogen was estimated by Kjeldahl's method, phosphorus by Vanadomolybdophosphoric yellow colour method and potassium content was determined using flame photometry method (Jackson 1973). The yield parameters were recorded and the economics was calculated at the prevailing price of inputs and produce. Statistical analyses were done using the F- test, the procedure given by Gomez (1984).

RESULTS AND DISCUSSION

Growth and yield attributes

Taller plants (92.2 cm) were recorded with the mechanical transplanting method, which was statistically at par with the SRI method (90.5 cm) and significantly superior to random transplanting at harvest (Table 1). It might be due to more space, sunlight and nutrients available to wider spaced plants in all the methods than close spaced plants in random method, which facilitated the plants to attain more height. Shriame and Rajgire (2000) reported that the number of functional leaves and leaf area were higher under wider spacing, which increased the photosynthetic rate leading to taller plant. Younger seedlings have more vigour, root growth and lesser transplant shock because of lesser leaf area during initial growth stages which stimulate the cell division causing more stem elongation and ultimately might have increased plant height where mechanical

method of transplanting was opted (Sangsu *et al.*, 1999). Significantly higher plant height (98.1 cm) was recorded with application of 120-60-60 kg N-P₂O₅-K₂O/ha and it remained at par with soil test based fertilizer application (95.2 cm). Plant height increased mainly due to adequate nutrient supply to the plant which resulted in rapid growth leading to good establishment of root. This might have activated various metabolic processes resulting in better mobilization of synthesized carbohydrates in to growth substances like amino acid and protein which stimulated the rapid cell division and cell elongation. Finally, it resulted in to growth of plant faster as compare to other treatments tested during the course of investigation. The shortest plant height was recorded in treatment without any inorganic fertilizer. It might be due to poor availability of nutrient which caused poor growth and poor nutrient mobilization. (Kumar and Yadav, 1995).

The number of tillers was significantly affected by various planting methods. The higher number of tillers/plant (12.0) was recorded in mechanical transplanting which was at par with SRI method and significantly higher to rest of the treatments at harvest. The higher number of tillers/plant might be due to more space, more phyllochron and better fertilizer management. Earlier transplanting reduces the transplanting shock at a more convenient point in the growth cycle when they could rebound faster and had little effect on tiller age (Uphoff and Randriamiharisoa, 2002). Use of polythene sheet for raising seedlings, and dry cultivation of the nursery was beneficial to boost the vigorous root system for early and quick growing of tillers after transplanted in mechanical transplanting.

Higher panicle length (23.0 cm), LAI (4.93) and grains/panicle (153) were recorded in mechanical transplanting

Table 1. Effect of fertilizer doses under different method of planting (pooled data of 2 years) on growth and yield parameters of rice

Treatment	Plant height (cm)	Effective tillers/hill	LAI at flowering	Panicle length (cm)	Panicle weight (g)	Filled grains/panicle	1,000-grain weight (g)
<i>Planting methods</i>							
Random planting	82.6	7.6	3.40	21.8	2.4	152	20.6
Mechanical planting	92.2	12.0	4.93	23.0	3.5	153	21.8
Drum seeded	89.9	8.4	4.61	22.5	3.3	153	21.3
SRI	90.5	10.0	4.70	22.7	3.4	153	21.5
SEm±	1.1	0.7	0.19	0.2	0.1	0.2	0.2
CD (P=0.05)	3.8	2.3	0.66	0.7	0.5	0.6	0.7
<i>Fertilizer doses (N-P₂O₅-K₂O kg/ha)</i>							
60-30-30	82.6	9.0	3.43	21.6	2.5	152	20.1
80-40-40	90.4	9.6	4.67	22.7	3.3	153	21.2
100-50-50	93.3	9.9	5.06	23.7	3.6	154	22.2
120-60-60	98.1	11.0	5.97	24.8	4.3	155	23.3
100-50-40	95.7	9.5	5.05	23.5	3.6	154	22.0
No fertilizer	72.5	8.7	2.28	19.1	1.6	149	19.1
SEm±	1.4	0.3	0.13	0.2	0.1	0.2	0.2
CD (P=0.05)	3.9	0.9	0.37	0.7	0.3	0.7	0.7

SRI, System of Rice Intensification; LAI, Leaf-area Index

method followed by SRI method (22.7 cm, 4.7 and 153). Plant established by mechanical transplanting method had an opportunity of availing more inter and intra plant spacing, thus making better use of growth factors to increase the length of panicle and filled grains/panicle. Reduced panicle length under random transplanting method might have been due to lesser intra plant space leading to high plant density resulting in more competition for space and all inputs. Higher number of tillers/plant in mechanical transplanting method increased the leaf area that covered the ground area, hence enhancing the leaf area index (4.93). High leaf area index is associated with increased assimilation of food material through photosynthesis on account of vigorous root and shoot growth, which ultimately led to higher dry matter production. Similar results have been reported by Hussain *et al.* (2012).

Significantly higher number of tillers/plant (11) and leaf area index (5.97) were recorded with 120-60-60 kg N-P₂O₅-K₂O/ha which were at par with soil test based fertilizer application as compared to rest of the treatment. It might be attributed to adequate nutrient availability which provided favourable condition for better synthesis of growth favouring constituents in plant system. The lower number of tillers and LAI was recorded under no fertilizer treated plot mainly due to inadequate nutrient supply system. Results are in agreement with findings of Pandey *et al.* (2010). Increasing levels of fertilizer dose, progressively enhanced the filled grains/panicle, panicle weight and 1000 grain weight up to 120-60-60 kg N-P₂O₅-K₂O/ha, which was significantly higher than that of rest of the fertilizer doses. The lowest was recorded with 60-30-30 kg N-P₂O₅-K₂O/ha and no fertilizer application treatment. Effective translocation of assimilates to the sink might have resulted in sound filling of grains as revealed by highest number of filled grains/panicle. Better performance under 120-60-60 kg N-P₂O₅-K₂O/ha in respect of yield attributes of rice, confirms the findings of Dubey *et al.* (1983)

Yield

Grain and straw yield of rice were significantly influenced by planting methods (Table 2). Method of planting increased grain yield from 32.6 to 41.3% over conventional random planting. The crop established under wider spacing in mechanical transplanting method resulted in significantly higher grain yield (6.5 t/ha) followed by SRI method (6.3 t/ha) and the lowest grain yield under random transplanting method (4.6 t/ha). Mechanical transplanting method recorded an increase of 3.2, 6.6 and 41.3% yield over SRI, drum seeding and random planting method, respectively. Higher yield under mechanical transplanting method was due to better crop growth and development resulting in higher value of yield attributes which had di-

rect bearing on the grain yield. Higher number of tillers per unit area, panicle length, panicle weight and filled grains/panicle in case of mechanical transplanting method as compared to other method of crop establishment might be responsible for superiority of this treatment over others in respect of grain yield. The increase in grain yield in machine planting was in agreement with the results reported by Dixit *et al.* (2007), Krishna *et al.* (2008), Manjunath *et al.* (2009) and Venkateshwarlu *et al.* (2011). Straw yield of rice were also higher (7.5 t/ha), where rice crop was established by mechanical transplanting method followed by SRI method (7.2 t/ha). Higher number of tillers/plant with moderate plant height and better performance of yield attributing character ultimately increased the biomass in the mechanical transplanting method of rice establishment. The lowest yield (4.6 t/ha) was recorded with random transplanting method due to less number of effective tillers/plant and increased inter and intra plant competition for available growth resources on account of heavy weed infestation.

Grain and straw yield were affected significantly due to various nutrient management practices. Application of 120-60-60 kg N-P₂O₅-K₂O/ha resulted in 42.5% increase in yield from lowest dose of 60-30-30 kg N-P₂O₅-K₂O/ha and 61.2% over control (no fertilizer). Significantly higher grain (6.7 t/ha) and straw (7.7 t/ha) yield of rice were obtained with the application of 100-50-50 kg N-P₂O₅-K₂O/ha., which was at par with soil test based application, as compared to rest of the treatments. This might be due to increased yield attributes, viz. number of effective tillers, length of panicle, number of grains/panicle, weight of panicle which resulted in higher yield. Further, sufficient nutrient management which contributed to increased dry matter production as well. The better vegetative growth coupled with high yield attributes resulted in higher grain and straw yield of rice (Sengar *et al.*, 2000). The lowest grain yield was recorded in without application of any inorganic fertilizer. This was due to poor growth and metabolic process and lesser number of grain/panicle. The results are in accordance with Reddy *et al.* (2004).

Interaction effect

The interaction effect between planting methods and different fertilizer doses was found to be significant (Table 3). Mechanical transplanting by transplanter with 120-60-60 kg N-P₂O₅-K₂O/ha produced significantly higher grain yield (9.0 t/ha) over other treatment combinations but was at par with same fertilizer dose along with SRI method (8.5 t/ha). The lower yield (5.1 t/ha) was recorded with lowest fertilizer dose (60-30-30 kg N-P₂O₅-K₂O/ha) in mechanical method of transplanting. The better performance of crop in above combinations was the outcome of enhanced growth

Table 2. Influence of fertilizer doses under methods of planting (pooled data of 2 years) on yield, nutrient uptake and economics of rice

Treatment	Nutrient uptake by grain (kg/ha)						Net returns ×10 ³ ₹/ha	Benefit: cost
	Grain yield (t/ha)	Straw yield (t/ha)	N	P	K	Cost of cultivation ×10 ³ ₹/ha		
<i>Planting methods</i>								
Random planting	4.6	5.3	62.2	16.4	59.9	45.63	36.64	1.8
Mechanical planting	6.5	7.5	89.6	23.8	89.1	44.41	72.82	2.6
Drum seeded	6.1	7.0	83.5	22.1	82.9	46.71	62.55	2.3
SRI	6.3	7.2	85.7	22.8	84.8	49.36	62.90	2.3
SEm±	0.1	0.3	3.4	0.9	3.6		4.40	0.1
CD (P=0.05)	0.4	1.0	12.0	3.2	12.6		15.52	0.3
<i>Fertilizer doses (N-P₂O₅-K₂O kg/ha)</i>								
60–30–30	4.6	5.2	60.5	12.2	59.2	45.63	36.02	1.8
80–40–40	6.2	7.1	85.3	23.1	81.8	46.75	63.72	2.4
100–50–50	6.7	7.7	97.2	25.9	91.9	47.87	72.75	2.5
120–60–60	8.0	9.2	113.3	32.5	116.6	48.96	94.94	2.9
100–50–40	6.7	7.7	93.3	25.5	88.7	47.57	72.75	2.5
No fertilizer	3.1	3.5	31.9	8.3	36.9	42.38	12.20	1.3
SEm±	0.1	0.2	2.4	0.6	2.4		3.02	0.1
CD (P=0.05)	0.4	0.6	6.7	1.8	6.9		8.68	0.2

Sale price (₹/t): rice grain, 17,500; rice straw, 800

measured in terms of plant height, tiller number and improved yield attributes that resulted in higher yield (Sekhar *et al.*, 2009)

Nutrient uptake

Higher NPK uptake by grain (89.6, 23.8 and 89.1 kg/ha) was recorded with mechanical transplanting method as compared to the other treatment, while lower NPK uptake by random method of transplanting (Table 2). This is attributed to the higher tiller number and dry matter production by younger seedlings ultimately resulting in higher straw and grain yield and nutrient removal. This is also attributed to deeper and more prolific root system developed by young seedling grown under mechanical transplanting method where plants get well aerated conditions (Barison, 2002). Various nutrient managements affected significantly nutrient uptake by rice. The maximum NPK uptake (113.3, 32.5 and 116.6 kg/ha) was recorded by the application of

120-60-60 kg N-P₂O₅-K₂O/ha, which was at par with 100-50-50 kg N-P₂O₅-K₂O/ha and soil test based fertilizer application (100-50-40 kg N-P₂O₅-K₂O/ha). This might be due to higher LAI coupled with higher dry matter production. Minimum nutrient uptake was recorded in no fertilizer application plots. It might be due to inadequate availability of nutrients. The results are in close proximity of Talathi *et al.* (2009).

Economics

Analysis of economics factors like cost of cultivation, net return, and B:C ratio are important to evaluate the profitability of experiment. Grain yield was major factor which caused differences in net income and net return per rupees invested. The highest benefit: cost ratio (2.6) was recorded with mechanical method of transplanting, which was at par with SRI (2.3) and drum seeded method of planting (2.3). The higher benefit cost ratio in this method was attributed

Table 3. Effect of interaction of planting methods and fertilizer doses (pooled data of 2 years) on grain yield (t/ha)

Planting methods (P)	Fertilizer doses (kg/ha) (F)					
	60-30-30	80-40-40	100-50-50	120-60-60	100-50-40	No fertilizer
Random planting	3.2	5.9	4.8	6.2	5.2	2.4
Mechanical planting	5.1	7.0	7.4	9.0	7.1	3.6
Drum seeded	5.0	5.6	7.2	8.1	7.4	3.2
SRI	5.1	6.4	7.5	8.5	7.1	3.5
		F × P	P × F			
SEm±		0.3	0.3			
CD (P=0.05)		0.8	0.8			

to higher net returns (₹72,820/ha) and reduced cost of cultivation (₹44,410/ha). This was supported by findings of Dixit *et al.* (2007) and Manjunath *et al.* (2009). Increasing levels of fertilizer doses progressively enhanced the net returns and benefit cost ratio up to 120–60–60 kg N-P₂O₅-K₂O/ha and was significantly higher than with rest of the fertilizer levels tried. Net returns and benefit cost ratio (₹72,750/ha, 2.5) with 100-50-50 kg N-P₂O₅-K₂O/ha were comparable with soil test based fertilizer application (₹72,750/ha, 2.5), while the lowest net returns and B: C ratios were recorded without application of any inorganic fertilizer (Table 2).

Hence for rice grown under mechanical method of planting resulted in higher growth and yield, and B: C ratio in West Central Table Land Zone of Odisha. Complementing 120-60-60 kg N-P₂O₅-K₂O/ha and soil test based fertilizer application recorded higher yield and economics of rice.

REFERENCES

- Barison, J. 2002. Nutrient use efficiency and intensive SRI rice cultivar system in Madagascar, pp. 1–19. Master Thesis submitted to Cornell University, Ithaca USA.
- Dixit, A., Khurana, J., Singh, J. and Singh G. 2007. Comparative performance of different paddy transplanters developed in India- A Review. *Agricultural Reviews* **28**(4): 262–269.
- Dubey, O.P., Namdeo, K.N., Verma, S.N., Singh, S., Mishra, V.P. and Pande, P.C. 1983. Response of paddy varieties to levels of nitrogen under rain fed conditions. *Indian Journal of Agronomy* **28**(2): 134–136.
- FAO. 2009. *FAO Database 2009 for Rice Area*. Food and Agriculture Organization, Rome. Accessed on 7 August 2019.
- Gomez, K.A. and Gomez, A.A. 1984. *Statistical Procedures for Agricultural Research*, John & Wiley and Sons, Singapore.
- Hussain, A., Bhat, M.A. and Gaine, M.A. 2012. Effect of number and age of seedling on growth, yield, nutrient uptake and economics of rice under system of rice intensification in temperate condition. *Indian Journal of Agronomy* **57**(2): 133–137.
- Jackson, M.L. 1973. *Soil Chemical Analysis*, pp. 183–204. Prentice Hall of India Pvt. Ltd., New Delhi
- Krishna, A., Biradorpatil, N.K. and Chanappagoudar, B.B. 2008. Influence of SRI Cultivation on seed yield and quality. *Karnataka Journal of Agriculture Science* **21**(3): 1369–1372.
- Kumar, A. and Yadav, D.S. 1995. Use of organic manure and fertilizer in rice wheat cropping system for sustainability. *Indian Journal of Agricultural Sciences* **65**(10): 703–707.
- Manjunatha M.V., Masthana Reddy, B.G., Shashidhar, S.D. and Joshi, V.R. 2009. Studies on the performance of self propelled rice transplanter and its effect on crop yield. *Karnatak Journal of Agriculture Sciences* **22**(2): 385–387.
- Nambiar, K.K. 1994. Soil fertility and crop productivity under long-term fertilizer use in India, 234–67. Indian Council of Agricultural Research, New Delhi, India.
- Pandey, V.P., Singh, M.M. and Singh, G.R. 2010. Effect of moisture regime and integrated nutrient supply system performance and water use efficiency of transplanted rice. In: *Abstracts, National Seminar on Soil Security for Sustainable Agriculture*, during 27–28 February, 2010, held at College of Agriculture, Nagpur, Maharashtra, India. p. 23.
- Reddy, M.M., Reddy, M.D. and Reddy, B.B. 2004. Effect of N₂ management through organic and inorganic sources on yield of rice. *Journal of Research, ANGRAU* **31**(3): 7–12.
- Sangsu, K., Bokyeong, K., Mingyu, C., Nambyun, B., Weonyoung, C. and Seconyong, L. 1999. Effect of seedling age on growth and yield of machine transplanted rice in southern plain region. *Korean Journal of Crop Science* **44**: 122–128.
- Sekhar, E., Mankotia, B.S. and Dev, S.P. 2009. Productivity and economics of rice (*Oryza sativa*) in system of rice intensification in North-Western Himalayas. *Indian Journal of Agronomy* **54**(4): 423–427.
- Sengar, S.S., Wade, L.J., Baghel, S.S. and Singh, R.K. 2000. Effect of nutrient management on rice in rainfed lowland of south east Madhya Pradesh. *Indian Journal of Agronomy* **45**(2): 315–322.
- Shrirame, M.D. and Rajgire, H.J. 2000. Effect of spacing and seedling number per hill on growth attributes and yield of rice hybrid under low land condition. *Journal of Soil and Crop* **10**(1): 109–113.
- Stoop, W.A., Uphoff, N. and Kassam, A. 2002. A review of agriculture research issue raised by the system of rice intensification (SRI) from Madagascar: opportunities for improving farming system for resource-poor farmers. *Agriculture System* **71**: 249–274.
- Thakkar, H. 2005. More rice for less water. Infochange News and Features, June 2005. In: <http://www.infochangeindia.org>.
- Thakur, A.K., Chaudhari, S.K., Singh, R. and Kumar Ashwani. 2009. Performance of rice varieties at different spacing grown by system of rice intensification in eastern India. *Indian Journal of Agriculture Sciences* **79**(6): 443–447.
- Talathi, M.S., Pinjari, S.S., Ranshur, N.J., Bhondave, T.S. and Suryawansi, J.S. 2009. Response of hybrid rice to green leaf manure, FYM and Chemical fertilizer. *International Journal of Agriculture Science* **5**(2): 501–509.
- Tripathy, S.K., Jena, H.K. and Panda, P.K. 2004. Self propelled rice transplanter for economizing labour, *Indian Farming* **54**: 23–25.
- Uphoff, N. and Randriamiharisoa, R. 2002. Reducing water use in irrigated rice production with the Madagascar System of Rice Intensification. (In) *Water Wise Rice Production – International Rice Research Institute, Manila, Philippines*, pp. 71–87.
- Venkateswarlu, E., Sambasiva Rao N. and Rama Prasad, D. 2011. On farm evaluation of mechanical transplanting of rice (*Oryza sativa*.) against traditional method. *The Andhra Agricultural Journal* **58**(1): 9–11.
- Zheng, J., Joang, X. and Tang, Y. 2004. The system of rice intensification (SRI) for super high yields of rice in Sichuan Basin. (In) *Proceedings of the 4th International Crop Science Congress*, held at Brisbane, Australia, during 26 September 01 October, 2004. <http://www.ciifad.cornell.edu/sri/countries>.