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Effect of different novel establishment methods of rice (*Oryza sativa*) and nutrient management practices for productivity and profitability: A review

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Abstract
Rice (*Oryza sativa*) is the staple food for more than half of the population of the world. The productivity and sustainability of rice-based systems are threatened by the inefficient use of inputs (fertilizer, water, and labour), increasing scarcity of resources, especially water and labour; climate variability, emerging energy crisis and rising fuel prices, rising cost of cultivation and emerging socio-economic changes such as urbanization, migration of labour, preference for nonagricultural work, and concerns about farm-related pollution. Method of establishment influences the performance of rice through its effect on growth and development. At transplanting time, acute labor shortage results in increased labor wages and delay in the transplanting operation. Manual transplanting also results in a non-uniform and inadequate seedling population. These problems necessitated the introduction of mechanized rice transplanting to achieve timely planting and better crop stands.

Keywords: Rice establishment methods, Nutrient management, LCC

1. Introduction
Rice (*Oryza sativa* L.) is considered as the "Global Grain" and is the most staple food crop in Asia. The productivity and sustainability of rice-based systems are threatened by the inefficient use of inputs (fertilizer, water, and labour), increasing scarcity of resources, especially water and labour; climate variability, emerging energy crisis and rising fuel prices, rising cost of cultivation and emerging socioeconomic changes such as urbanization, migration of labour, preference for non-agricultural work, and concerns about farm-related pollution. Method of stand establishment influences the performance of rice through its effect on growth and development. Although, transplanting has been reported to be the best establishment method, some alternatives like dry and wet direct seeding are being explored to reduce cost of cultivation on account of high labour and water requirement. Nutrient management provides an approach for feeding the plants with nutrients as and when required. Integrated use of organic manures and chemical fertilizers has advantages over use of only organic manures or chemical fertilizers. Since sourcing of organic manure is difficult and the crop response to them during initial stages is not as spectacular, compared to the chemical fertilizers, an integrated approach of plant nutrition involving the judicious mix of organic, chemical and microbial sources could be helpful to sustain optimum yield and to restore the residual soil fertility.

2.1 Performance of different establishment methods of rice on growth and yield parameters
Jnanesha and Ashish Kumar (2017) [5] reported that significantly higher plant height (102.5 cm, 109.7 cm) was recorded in transplanted method of paddy whereas the lowest plant height was observed in direct seeded crop (98.9 cm, 99.3 cm). Transplanted gave more plant height as compared to direct seeding on flat soil. It may be due to availability of soil moisture through flooding providing good conditions for germination and initial crop growth. Similarly, significantly higher number of tillers per hill was recorded in transplanted method of paddy cultivation (23.1 & 21.6 respectively). However, number of effective tillers didn't differ significantly was noticed among different crop establishment methods but numerically higher values were observed in DSR method (17.4 cm). Panicle length and 1000 grain weight was not differ significantly but numerically higher value in panicle length was recorded in transplanted method of crop establishment. Similarly dry matter accumulation is also not significant was

noticed among different crop establishment method. This attribute is might be due to more space, sunlight and nutrients availability in transplanted crop whereas higher weed densities in direct seeded crop hinders the development of panicle length and other yield attributes in direct seeded crop. Significantly higher grain yield was noticed during the year 2013-14 (64.8 q/ha). However, there was no significant difference was noticed during the year 2014- 15. Similar trend was noticed with respect to straw yield also. However, Harvest index didn't differ significantly among different crop establishment method was noticed. This might be attributed due to (1) uneven or poor CE, (2) inadequate weed control, (3) higher spikelet sterility than in puddled transplanting, (4) higher crop lodging, especially in wet seeding and broadcasting, and (5) insufficient knowledge of water and nutrient management (micronutrient deficiencies).

Shrinivas *et al.* (2017) [13] reported that effect of establishment methods and nutrients on growth parameters of rice dibbling of seeds followed by SRI principles significantly influenced the plant height, number of tillers, leaf area and total dry matter production, root length, root weight and days to maturity. Dibbling of seeds followed by SRI principles recorded significantly higher growth characters. The maximum plant height (93.27 cm), number of tillers/hill (25.17), leaf area/cm2/plant (1658.40), total dry matter (73.91 g), Root length (25 cm) at 90 DAS/T, Root weight (12.5 cm) at 90 DAS/T, Days to maturity (118) were recorded under dibbling of seeds followed by SRI principles which was on par with mechanized transplanted method on growth parameters like plant height (92.40 cm), number of tillers/ hill (22.18), leaf area (1504.50) total dry matter production (66.52 g), root length (24.2 cm), root weight (11.4 g) and days to maturity (120) in *kharif* season. There was a progressive increase in plant height, number of tillers, leaf area and TDMP under Dibbling of seeds followed by SRI principles system of planting when compared to manual transplanted, and mechanized transplanted methods. Wet direct seeded rice by broadcasting produced lesser plant height (86.87 cm), number of tillers/hill (16.85), leaf area (1237.60) and total dry matter production (53.75 g), root length (20.5 cm), root weight (9.7 g) and days to maturity (115). Dibbling of seeds followed by SRI principles which might have established quickly in the field due to wider spacing, less competition, without transplanting and started growing at a faster might be attributed to higher plant height. The number of tillers per plant was significantly higher in Dibbling of seeds followed by SRI principles. Dibbling of seeds in square method with wider spacing might have resulted in profused tillering under Dibbling of seeds followed by SRI principles, which might have facilitated plants for better utilization of the resources. This advantage of Dibbling of seeds followed by SRI principles in enhancing tiller numbers, leaf area and total dry matter production root length, root weight may be attributed to young seedlings used for transplanting at shallow depth and wider spacing, which provided good aeration for better establishment of crop. Higher root dry weight and root length in dibbling of seeds followed by SRI principles also led to proliferation of root system by contributing to higher biomass. Days to maturity was affected by crop establishment methods. The growth duration of manual transplanting was 8 days more than dibbling of seeds followed by SRI principles, whereas, it was 3 days more than wet direct seeded rice by broadcasting. Kumar *et al*. (2015) [7] also reported that manual transplanting was 7 days more and matured later by 7 days compared to dibbling of seeds followed by SRI principles which were due to older seedlings and transplanting shock.

Parameswari and Srinivas (2017) [8] revealed that transplanting method of establishment gave higher grain yield and higher straw yield followed by SRI which was on par with transplanting but significantly superior to direct sown rice under puddled condition. The increase in grain yield recorded under transplanting over SRI and direct sown rice on the onset of monsoon was to the tune of 3.42 % and 13.31 % and 11.19 % and 3 % (mean of two years) respectively. The increased yield attributes might be due to increased growth and development parameters which ultimately resulted in increased grain. The beneficial effect of transplanting method in enhancing the growth through increased height, number of tillers and dry matter production ultimately reflected in higher yield attributing characters *viz*. number of panicles per m^2, number of grains per panicle number of filled grains per panicle.

Ravi Kumar *et al.* (2018) [9] reported that significantly higher plant height (93.42 cm), Tillers (464. Sq.m), Crop dry matter (11474 kg/ha), Grains/panicle (111.6), Test weight (22.7 g), Productive tillers (318 panicles/ sq.m) was recorded with direct seeded rice and on par with transplanted rice. Plant height (92.61 cm), tillers (457 sq.m), Crop dry matter (10381 kg/ha), Grains/panicle (107.4), Test weight (22.7 g), Productive tillers (307 panicles sq.m) and lowest was with aerobic rice. Plant height (91.46 cm), Tillers (358. Sq.m), Crop dry matter (8045 kg/ha), Grains/panicle (104.9), Test weight (21.2 g), Productive tillers (225 panicles sq.m). The highest grain yield, straw yield and harvest index was recorded in direct seeding (5136, 6222 kg/ha and 47.21 respectively) and it was on par with transplanted rice (5060, 5980 kg/ha and 46.85 respectively). These two treatments were significantly superior to aerobic rice (3486, 4268 kg/ha and 41.92 respectively). This might be due to submerged conditions in direct wet seeded rice and transplanted rice that facilitated availability of more mineralized form of N, P and K uptake than that of aerobic rice which encouraged tiller production and contributed to higher dry matter production and grain yield.

Shrinivas, (2018) [14] reported that (mean of two years) significantly higher was recorded under dibbling of seeds followed by SRI principles method of rice cultivation plant height (91.73 cm), number of green leaves (69.10 $Hill^{-1}$), number of tillers (24.85 $Hill^{-1}$), leaf area (1658.40 cm^2 $hill^{-1}$), total dry matter (72.39g), root length (24.85 cm), root weight (12.1 g), days taken to 50 per cent flowering (92.7 days), days taken to maturity (119 days), number of panicles (455 m^{-2}), panicle weight (3.1 g), thousand grain weight (23.6 g), panicle length (20.1 cm), grain yield (5553 kg ha^{-1}) and straw yield (6810 kg ha^{-1}) and which was on par with mechanized transplanted method of rice cultivation plant height (92.67 cm), number of green leaves (65.37 $Hill^{-1}$), number of tillers (21.86 $Hill^{-1}$), leaf area (1470.75 cm^2 $hill^{-1}$), total dry matter (64.48 g), root length (23.78 cm), root weight (11.1 g), days taken to 50 per cent flowering (89.1 days), days taken to maturity (120 days), number of panicles (436 m^{-2}), panicle weight (3.0g), thousand grain weight (23.2 g), panicle length (19.6 cm), grain yield (5308 kg ha^{-1}) and straw yield (6577 kg ha^{-1}) and significantly superior over manual transplanted method of rice cultivation plant height (92.67 cm), number of green leaves (62.67 $Hill^{-1}$), number of tillers (19.38$Hill^{-1}$), leaf area (1316.00 cm^2 $hill^{-1}$), total dry matter (60.78 g), root length (21.90 cm), root weight (9.9 g), days taken to 50 per

cent flowering (93.4 days), days taken to maturity (82.3 days), number of panicles (394 m^{-2}), panicle weight (2.6 g), thousand grain weight (22.5 g), panicle length (18.6 cm), grain yield (4733 kg ha^{-1}) and straw yield (6044 kg ha^{-1}) and significantly lower plant height was recorded under wet direct seeded rice by broadcasting (69.10 cm), number of green leaves (61.60 $Hill^{-1}$), number of tillers (16.78 $Hill^{-1}$), leaf area (1201.20 cm^2 $hill^{-1}$), total dry matter (52.86 g), root length (20.37 cm), root weight (9.3 g), days taken to 50 per cent flowering (126 days), days taken to maturity (116 days), number of panicles (333 m^{-2}), panicle weight (2.2 g), thousand grain weight (21.6 g), panicle length (16.6 cm), grain yield (4152 kg ha^{-1}) and straw yield (5602 kg ha^{-1}). This might be due to yield advantage due to SRI over direct seeded rice by broadcasting and manual transplanting method was mainly due to more number of tillers production per unit area accompanied by maximum panicle bearing tillers with low spikelet sterility. Since planting of young seedlings of 14 days in main field with immediate establishment have facilitated early initiation of tillers. It is evident that highest tillers production was observed with SRI planting.

Santosh *et al*. (2020) [11] reported that grain yield was significantly affected by different methods of crop establishment. From the analysis, it was evident that there was no statistical difference in grain yield between open (4.45 t/ha), straight row (4.45 t/ha) and SRI (4.75 t/ha) method of transplanting although, SRI produced highest average grain yield. Also, there was no statistical difference in grain yield for random (4.1 t/ha) and dry bed (4.25 t/ha) method of transplanting. A research insisted no significant yield advantages for SRI over 'best management practices' (BMPs) documented experimentally except from Madagascar trials. Grain yield was found significantly higher in case of SRI method of crop establishment technique than that of conventional technique in both the years. The pooled mean value was also found to be higher in case of SRI technique than that of conventional method.

2.2 Performance of different establishment methods of rice on nutrient uptake

Sushil Kumar and Verma (2018) [15] reported that crop establishment methods, conventional till-wet direct seeded rice and zero till-direct seeded rice recorded significantly higher uptake of N, P,kand Zn by grain, straw and both. This might be due to higher and lower dry matter accumulation recorded with conventional till-wet direct seeded rice and zero till-direct seeded rice, respectively.

Divya Pyngrope *et al*., (2017) [3] reported that significant and highest grain yield (5.34 t/ha) was reported in treatment (SRI +120 kg Nitrogen/ha), however treatments (MTR +120 kg Nitrogen/ha) and (SRI + 90 kg Nitrogen/ha) showed statistical parity with treatment. Further, highest straw yield (10.26 t/ha) was reported in treatment (SRI +120 kg Nitrogen/ha), while treatments (MTR + 90 kg Nitrogen/ha), (MTR + 120 kg Nitrogen/ha), (SRI + 60 kg Nitrogen/ha) and (SRI + 90 kg Nitrogen/ha) were at par with treatment (SRI +120 kg Nitrogen/ha). The increased grain yield under SRI could be attributed to the higher root growth which enabled them to access to nutrients from much greater volume of soils. It helped to capture all the essential nutrient elements important for plant growth and thereby leading to higher tillering and grain filling.

Divya Pyngrope *et al*., (2019) [4] reported that application of 120 kg N/ha recorded significantly higher N, P and K uptake in rice compared to the rest of the N levels. Every increment of 40 kg N/ha from 0 to 120 kg N/ha increased the total N uptake by 49.55, 34.30 and 27.17 %, total P uptake by 40.33, 27.06 and 20.3 2% and total K uptake by 32.43, 20.70 and 17.25 %, respectively.

Shanker Dutt Thapliyal, *et al*., (2020) [12] reported that different establishment methods had significant effect on nitrogen, phosphorus and potassium uptake by straw and their total uptake by rice crop. Maximum nitrogen, phosphorus and potassium uptake by grain (56.6, 11.1 and 22.92 kg/ha, respectively) and straw (36.6, 2.63 and 41.34 kg/ha, respectively) and their total uptake (106.8 kg/ha, 14.6 kg/ha and 120.3 kg/ha, respectively) were found in TPR. Puddling in transplanted rice limits percolating water in the field and retains a saturated soil profile, which inhibits nitrification (prevent oxidation of NH_4^+). So leaching loss would have been checked and more nitrogen might have retained in ammonical form leading to more nitrogen availability under transplanted condition which favoured higher nitrogen uptake. More phosphorus uptake by rice under transplanted establishment method might be due to greater phosphorus availability and more grain and straw yield. The higher uptake of potassium in transplanted method might be due to higher nutrient concentration under puddled conditions by the formation of slurry type of structure which restricted water and nutrient losses to the lower depth and provided better opportunity for diffusion and uptake of nutrients and proliferation of roots with in the deep puddled layer.

Deeksha *et al*., (2021) [2] reported that significantly highest N uptake in grain and straw was observed under treatment normal sowing time (N S T1) as compare to delay sowing time (D S T2). However, the establishment methods seeding through drum seeder (D S1) recorded significantly highest N uptake in grain and straw which was at par with treatment line sowing (L S3). The significantly highest P uptake in grain and straw was observed under treatment normal sowing time (N S T1) as compare to delay sowing time (D S T2). However, the establishment methods seeding through drum seeder (D S1) recorded significantly highest P uptake in grain and straw which was at par with treatment line sowing (L S3). The significantly highest K uptake in grain and straw was observed under treatment normal sowing time (N S T1) as compare to delay sowing time (D S T2). However, the establishment methods seeding through drum seeder (D S1) recorded significantly highest K uptake in grain and straw which was at par with treatment line sowing (L S3). Significantly higher nutrient uptake in direct seeding method as compared to other treatment might be due to the greater and healthy root growth, which increased availability, efficient absorption of nutrients from the soil and transport of nutrients from root to shoot and grains.

2.3 Performance of different establishment methods of rice economics

Jnanesha and Ashish Kumar (2017) [5] reported that gross return differ significantly with transplanted method recorded significantly higher gross returns during both the years (Rs 110304 and Rs 104958 respectively). This is due to higher yield obtained under transplanted rice inturn results in increasing in gross return. Whereas, DSR recorded significantly higher net returns (Rs 73232 &70895) and benefit cost ratio (2.29 & 2.22) during both the years compared to transplanted method. This attribute is due to saving in labour and water inturn results in increasing in net

return and benefit cost ratio.

Choudhary and Suri (2018) [1] found that the SRI has a higher benefit cost ratio than conventional transplanting practices. Saddam *et al*. (2019) [10] claimed that the SRI gross return (Rs. 1,29,000.5/ha) and net return(Rs. 67,050.5/ha) was higher than the conventional method (gross return Rs. 78,444/ha and net return Rs. 27,168/ha) of rice cultivation.

Deeksha *et al*., (2021) [2] reported that significantly highest gross return was observed under treatment normal sowing time (N S T1) registered as compare to delay sowing time (D S T2). However, the establishment methods seeding through drum seeder (D S1) recorded significantly highest gross return which was at par with treatment line sowing (L S3). Significantly highest net return was observed under treatment normal sowing time (N S T1) registered as compare to delay sowing time (D S T2). However, the establishment methods seeding through drum seeder (D S1) recorded significantly highest net return and it was at par with treatment line sowing (L S3). The data indicate that the significantly highest B: C ratio was observed under treatment normal sowing time (N S T1) as compare to delay sowing time (D S T2). However, the establishment methods seeding through drum seeder (D S1) recorded significantly highest B: C ratio which was at par with treatment line sowing (L S3).

Khilendra *et al*., (2021) [6] reported that transplanting method of establishment (CM_1) was recorded significantly higher gross return. Moreover, lowest gross return was registered under treatment unpuddled dry direct seeding (CM_3). However, in case of different weed management practices treatment weed free (WM_1) was noticed higher gross return and lowest gross return was observed under treatment weedy check (WM_2).The significantly higher net return was registered under transplanting method of establishment (CM_1). Further, lowest net return was registered under treatment unpuddled dry direct seeding (CM_3). However, lowest B: C ratio was observed under treatment unpuddled dry direct seeding (CM_3).

In conclusion the findings of the various studies clearly indicated the now a days different types of establishment practices are followed for rice cultivation. For example direct methods like 1. Drum sowing, 2. Wet sowing, 3. Dry sowing and transplanting methods like 1. SRI and 2. Machine transplanting. Based on the area, climatic condition, availability of the resources it will become varied. Conventional transplanting is the popular establishment method but now a day it was very cost effective due to nursery raising, transporting of seedling to the main field and transplanting. During the peak period time of farm operation the availability of labour become scarce, at the time the farmers are switching to direct seeding rice cultivation methods and machine transplanting is also one of the alternative method at particular period of rice cultivation. Sustainable rice productivity also increased by adopting the new methods like system of rice intensification. SRI is better options of crop raising as it saves considerable labour, time and water requirement and also there is the possibility for increasing the cropping intensity and also recorded significant yield improvement when compare to the conventional practices. Similarly, the yield potential of a cultivar could be exploited to a maximum extent by judicious management of applied nitrogen. The actual yield advantage depends on the agronomic management including that of nitrogen management. As nitrogen deficiency is universal, significant yield increase due to nitrogen use is common.

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