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Impact of establishment methods and nutrient management practices on growth, yield and economics of rice (*Oryza sativa* L.)

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Abstract
Crop establishment methods such as Direct Seeded Rice (DSR) and Integrated Nutrient Management (INM) are key to sustainable, high-yield farming. DSR reduces water and labor costs, while INM balances chemical fertilizers with organic matter to maintain long-term soil health. Hence, to evaluate the effect of establishment methods and nutrient management practices on growth, yield and economics of wheat, a field experiment was conducted during Kharif seasons of 2024 and 2025 at the Research Farm of School of Agriculture, Abhilashi University, Chailchowk, Mandi (H.P.). The experiment was laid out in a split-plot design with three replications. Main plots with two establishment methods and sub plots with three nutrient management practices. Among the main plots, transplanted method of rice establishment resulted in significantly higher values of growth attributes (plant height and dry matter accumulation) and yield attributes (number of grains per panicle) which resulted in significantly higher grain yield of rice over direct seeded method. Among the sub plots, inorganic and integrated nutrient management behaving alike resulted in better crop growth, yield attributes and grain yield of rice compared to organic nutrient management. Transplanted rice resulted in highest net returns while direct seeded rice had the highest net returns per rupee invested. Inorganic nutrient management provided the highest net returns and net returns per rupee invested.

Keywords: Direct seeded rice (DSR), transplanted rice, inorganic, organic, integrated nutrient management (INM)

Introduction
Rice (*Oryza sativa* L.) forms the staple food for more than half of the world's population. Globally rice is cultivated over an area of 165 million hectares, and recorded a production of 504.27 million tonnes with an average productivity of 1903 kg/ha during 2023-24. In India, crop is grown throughout the year occupying nearly 51.37 million hectares with production of 150.18 million tonnes and productivity of 2929 kg/ha during 2023-24. In Himachal Pradesh, rice was cultivated over 67.30 thousand hectares during 2023-24, yielding 130.05 thousand metric tonnes with a productivity of 1933 kg/ha (Indiastat.com, 2024).
The sustainability and productivity of rice is highly influenced by the methods employed in the establishment of rice. Traditionally rice in India is established through transplanting (25-30 days old seedlings) into a puddle paddy field, making it cumbersome, costly and labour intensive (Bharti *et al*. 2025) [1]. Continuous flooding for rice cultivation is not only a huge drain on already scarce freshwater resources but often results in low water productivity. Puddle transplanting of rice can lead to soil compaction and reduced infiltration rates, adversely affecting the growth and yield of the subsequent wheat crop (Kumar *et al*. 2018) [7]. Looming water crisis, rising wage rates and the stagnant productivity of the rice-wheat cropping system have compelled researchers and farmers to seek alternative methods of rice establishment. Hence, there is a dire need to develop alternative production system for rice where energy, labour and water could be judicially used for sustainable crop culture and direct seeded rice can be such option. Though direct seeded rice method of rice cultivation generally gives lower grain yield compared to conventional transplanting method, but the production of grain can be enhanced through the suitable crop management practices (Hetta *et al*. 2024) [5].
Besides crop establishment, nutrient management practices play an important role in enhancing the production of transplanted as well as direct seeded rice. Chemical fertilizers are able to boost crop yield as they are potential sources of high amount of nutrients in easily available forms. But now the indiscriminate use of chemical fertilizers alone has led to the environmental pollution and deterioration of soil health. The use of organic manures has capability to maintain soil health on sustainable basis, but low availability of organics and low nutrient content are the major constraints for the adoption of organic agriculture in country. Under the situation, integrated nutrient use of organics in particular farmyard manure with inorganic fertilizers has been identified as feasible option to sustain crop yield and improve soil health (Meena *et al*. 2020) [9]. Considering all the above facts, therefore, the present investigation was undertaken to evaluate the impact of establishment methods and nitrogen management on growth, yield and economics of rice.

Materials and Methods
Experimental site and weather conditions
The experiment was carried out at Research Farm, School of Agriculture of Abhilashi University, Chailchowk, Mandi (H.P.) during Kharif seasons of 2024 [5] and 2025. The experimental site was situated at 31˚33' N latitude and 77˚00' E longitudes with the elevation of 1411 m above

mean sea level. The soil of experimental field was slightly acidic in reaction (5.6), medium in organic carbon (0.75%), low in available nitrogen (232 kg/ha), medium in available phosphorus (18.41 kg/ha) and potassium (198 kg/ha). Agro-climatically, Mandi represents the mid hill-sub humid zone and high hill temperate wet agro climatic zone of Himachal Pradesh which is characterized by cool winters (October to November) and mild summers (March to April).

Experimental design and treatment details

This experiment was laid out in a split plot design with two establishment methods in main plots (M_1 - Direct seeded rice, M_2 – Transplanted rice) and three nutrient management practices (S_1 - Organic nutrient management i.e. FYM @10 t/ha + Jeevamrit as basal and at 21 days interval, S_2 - Inorganic nutrient management i.e. 100% recommended dose of nitrogen and S_3 - Integrated nutrient management i.e. FYM @10 t/ha + 50% recommended dose of nitrogen) in sub plots. The six treatments were comprised with a gross plot size of 4.0 m × 3.0 m and three replications for each treatment. The total gross plot area was 12.0 m^2. The net plot size was decreased to 8.0 m^2 (3.2 m × 2.5 m) for observational purposes**.**

Crop management

Field was prepared with the help of a tractor drawn disc plough followed by two harrowing and planking. The field was levelled properly to facilitate the layout. In direct seeded rice (DSR) plots, the seeds of rice hybrid PAC 807^+ were sown in line 20 cm apart using seed rate of 60 kg/ha. On the same day, nursery for transplanted rice (TPR) was established. The nursery field separately from the main field was ploughed and harrowed twice with the help of tractor to form a fine seed bed. This was followed by preparation of 10 cm raised seed beds of 8.0 m length × 1.25 m width (10 m^2 area) separated by 30 cm wide water alleys across the width of nursery field manually. After the beds were prepared, seeds of rice hybrid PAC 807^+ were sown in rows at 10 cm apart using a seed rate of 400 g per bed (nursery beds were prepared according to 1000 m^2 to plant 1 ha with seed of 40 kg/ha). A thin water film maintained for initial two days and afterwards seed bed was irrigated when necessary. In TPR plots, after 21 days, rice seedlings were manually transplanted with a spacing of 20 cm x 10 cm. Puddling was done and 1-2 cm of standing water was maintained while transplanting. Prior to the final cultivation in DSR plots or final puddling in the TPR plots, a full dose of FYM on dry weight basis was applied as per treatments and thoroughly mixed into the soil. The recommended dose of fertilizer (RDF) was 90:40:40 kg/ha of N:P: K. The N, P and K were supplied through urea, single super phosphate and muriate of potash, respectively. At the time of sowing and transplanting, the full dose of phosphorus and potassium was uniformly applied as basal along with half of the nitrogen dose as per treatments. The remaining half of nitrogen was applied in two equal splits—first at 25 days after sowing and transplanting and second at 45 days after sowing and transplanting as top dressing as per treatments. Jeevamrit (2 litres) was prepared on the farm itself using ingredients; cow dung (100 g), cow urine (100 ml), jaggery (20 g), pulse floor (20 g), soil (2 g) and water (2 liters). The prepared solution was kept for 48 hours in the shadow for fermentation. Thereafter, dilution of 10 per cent from the concentrated Jeevamrit was prepared and used at the rate of 500 l/ha in the organic nutrient management treatment. The application of Jeevamrit was done as basal (at the time of sowing and transplanting), and thereafter at about 21 days intervals, till the maturity of rice crop. In order to manage the weeds, two hand weedings were done at 25 and 45 days after sowing and transplanting in DSR and TPR plots. For DSR**,** one pre-sowing irrigation was given to ensure proper seedbed moisture. For TPR, two pre-transplanting irrigation were given to facilitate puddling and transplanting. There was sufficient precipitation during the experimentation year for vegetative and reproductive growth of DSR and TPR. But in TPR, to maintain standing water during critical growth stages, two irrigations were applied when required. In TPR, field water level was maintained to 5 cm, one week after transplanting, and maintained till panicle initiation. Afterwards, 3 cm water level was maintained till dough stage. At the time of harvesting, border rows and destructive sampling areas were excluded. Harvested grain was manually threshed, and yields were calculated based on the net plot area.

Observations Recorded

The data gathered included growth [plant height (cm), number of tillers (per m^2) and dry matter accumulation (g/m^2)] and yield traits [number of panicles (per m^2), number of grains per panicle, grain yield (kg/ha) and straw yield (kg/ha)]. Plant height was measured in centimetres (cm) with the help of scale from the base to tip of the plant. Fresh plant samples from 50 cm x 50 cm quadrate were cut from the ground level. The dry matter (g/m^2) was worked out after drying the plants in oven to constant weight at 70°C. Number of tillers and effective tillers per square meter was counted by placing quadrate of 1m x 1m size. From randomly selected panicles from each plot, the number of grains per panicles was noted. Grain and biological yield per plot were noted and then converted to kilograms per hectare (kg/ha). Grain yield computed from the net harvested plot area was adjusted to 12% moisture content. Straw yield per plot was obtained by subtracting grain weight from biological yield from individual plot produce. Economics per treatment was obtained by calculating the gross returns and net returns both in terms of Rs. per hectare. The net returns per rupee invested were calculated by dividing the net returns by the cost of cultivation.

Statistical analysis

The collected data were analyzed using the analysis of variance (ANOVA) technique as outlined by Gomez and Gomez (1984) [3] under the context of a split plot design. A least significance test was used to analyze the treatment effects at a 5% level of significance.

Results and Discussion

Effect of Establishment Methods and Nutrient Management Practices on Growth Attributes

The study found that the impact of establishment methods and nutrient management practices on growth attributes of crop at harvest was statistically significant (Table 1). Growth parameters of rice *viz,* plant height and dry matter accumulation were significantly increased with transplanted method of rice establishment over direct seeding. Transplanting method of rice establishment might have maintained more favourable soil moisture conditions for

plant growth and resulted in improved vegetative growth (Dileep *et al*. 2018) [2]. But, direct seeding method produced significantly a greater number of tillers per square meter over transplanted method of rice establishment. The observed differences in the number of tillers per square meter among both rice establishment methods could be attributed to the fact that direct seeding of rice into non-puddled soil with higher seed and closer spacing resulted in higher plant density than transplanted method of rice establishment. Though increase in spacing under transplanting method resulted in vigorous plant growth than direct seeding method (Kumar *et al*. 2018) [7]. Among nutrient management treatments, inorganic nutrient management *i.e*. 100 per cent recommended dose of nitrogen and integrated nutrient management comprised of FYM @10 t/ha + 50 per cent recommended dose of nitrogen remaining at par with each other produced significantly taller plants, higher number of tillers and dry matter accumulation of rice than organic nutrient management comprised of FYM @10 t/ha + *Jeevamrit*. Improvement in growth attributes owing to fertilizers application under inorganic and integrated nutrient management might be due to more nutrient availability, particularly nitrogen which stimulates cell division and cell elongation thus enhanced the vegetative growth. Organic sources of nutrients in combination with inorganic fertilizers might have provided essential macro as well as micronutrient to the crop and made soil condition congenial for better vegetative growth. Similar results were also reported by Kumar *et al*. (2014) and Nayak *et al*. (2020) [8, 10].

Table 1: Effect of establishment methods and nutrient management practices on growth attributes of rice (mean of two years)

Treatment	Plant height (cm) at harvest	Number of tillers (per m^2) at harvest	Dry matter accumulation (g/m^2) at harvest
Establishment methods			
Direct seeded rice	93.6	288	724.4
Transplanted Rice	99.6	268	827.6
SEm±	1.8	5	33.16
CD (P=0.05)	5.5	14	99.5
Nutrient management practices			
Organic nutrient management	84.1	232	582.2
Inorganic nutrient management	104.3	305	897.3
Integrated nutrient management	101.6	296	848.5
SEm±	2.8	5	35.1
CD (P=0.05)	8.5	14	105.4

Effect of Establishment Methods and Nutrient Management Practices on Yield Attributes

The yield contributing character of rice *viz*. number of panicles per square meter was significantly higher due to direct seeded rice over transplanted rice (Table 2). This might be due to the higher population of rice plants in direct seeding due to lack of intra row spacing. Significantly higher number of grains per panicle was recorded with the transplanted method over direct seeded method of rice establishment. The enhanced root system of transplanted rice resulted in greater nutrient and water uptake, contributing to increased panicle development and higher grain counts per panicle (Thapliyal *et al*. 2020) [14]. Among nutrient management treatments, significantly higher number of panicles per square meter and number of grains per panicle were recorded with the inorganic nutrient management, which remained statistically at par with the integrated nutrient management treatment comprised of FYM @10 t/ha + 50 per cent recommended dose of nitrogen.

Under inorganic and integrated nutrient management, rapid supply of nitrogen from chemical fertilizers at the initial crop growth stages and steady supply of nitrogen from the mineralization of FYM throughout the growing season might have led to higher yield and yield components (Harish *et al*. 2017) [4].

Table 2: Effect of sowing methods and nitrogen management on yield attributes and yield of rice (mean of two years)

Treatment	Number of panicles (per m^2)	Number of grains per panicle	Grain yield (kg/ha)	Straw yield (kg/ha)
Establishment methods				
Direct seeded rice	236	50.93	3205	5257
Transplanted Rice	247	53.96	3422	5683
SEm±	3	0.98	69	134
CD (P=0.05)	10	2.95	207	403
Nutrient management practices				
Organic nutrient management	259	56.03	3623	5979
Inorganic nutrient management	249	54.95	3427	5690
Integrated nutrient management	219	46.36	2891	4741
SEm±	4	0.88	66	128
CD (P=0.05)	12	2.65	198	385

Effect of establishment methods and nutrient management practices on yield

Transplanted method of rice establishment significantly increased the grain and straw yields by 9.98 and 11.08 per cent over direct seeded method (Table 2). The yield reduction in direct seeded rice could be attributed to reduced biomass accumulation (Table 4.3) and also, the yield attributing characters such as shorter panicle and lower number of grains per panicle (Table 4.5) has contributed more to difference in yield between the direct seeded and transplanted method of rice establishment (Jnanesha and Kumar 2007). Higher yield under transplanted rice than

direct seeding might be due to better stand establishment, adequate water availability and reduced weed competition (Pattnaik *et al*. 2023) [11]. Among nutrient management treatments, inorganic nutrient management *i.e.* application of 100 per cent recommended dose of nitrogen resulted in significantly higher grain and straw yields which remained statistically at par with the integrated nutrient management treatment comprised of application of FYM @10 t/ha + 50 per cent recommended dose of nitrogen. Application of organics (10 t/ha FYM + Jeevamrit) failed to exhibit significant influence on yield of rice. Inorganic nutrient management treatment resulted in 30.20 and 4.87 per cent more grain yield over organic nutrient management and integrated nutrient management, respectively. Similar results regarding grain yield with inorganic and integrated nutrient management was reported by Punitha *et al*. (2021) [12].

The increase in yield under inorganic nutrient management might be ascribed to sufficient availability of nutrients, which resulted in greater assimilation production and partitioning of dry matter thereby increase the yield. Incorporating organic manure (FYM) with inorganic fertilizers might have increased the availability of major and micro nutrients as well as the activities of heterotrophic bacteria and fungi in soil. This in turn, increased the activity of enzymes that convert unavailable forms of nutrients to available forms, resulting in higher nutrient uptake and an increase in crop yield (Rao *et al*. 2013) [13].

Table 3: Effect of sowing methods and nitrogen management on economics of wheat (mean of two years)

Treatment	Gross returns (₹/ha)	Net returns (₹/ha)	Net returns per rupee invested
Establishment methods			
Direct seeded rice	142819	98515	2.33
Transplanted Rice	158833	106879	2.13
Nitrogen management			
Organic nutrient management	119157	68192	1.34
Inorganic nutrient management	170834	131254	3.33
Integrated nutrient management	162486	108644	2.02

Effect of establishment methods and nutrient management on economics

Transplanted method of rice establishment gave higher gross returns (₹ 158833 per ha) and net returns (₹ 106879 per ha) as compared to direct seeded method (₹ 142819 per ha and ₹ 98515 per ha, respectively) (Table 3). But direct seeded rice resulted in higher net returns per rupee invested (2.33) compared to net returns per rupee invested obtained from transplanted method (2.13) of rice establishment. The higher profitability was primarily driven by significant reductions in the cost of cultivation due to the elimination of nursery raising and transplanting, which saved substantial water and labor. Among nutrient management treatments, maximum gross returns (₹ 170834 per ha), net returns (₹ 131254 per ha) and net returns per rupee invested (3.33) were obtained with the inorganic nutrient management followed by the integrated nutrient management comprised of 50 per cent recommended dose of nitrogen + FYM @ 10 t/ha (₹ 162486 per ha, ₹ 1,08,644 per ha and 2.02, respectively). The effect of treatments on economic returns is in accordance with the higher yield of rice with lower cost of cultivation.

Conclusions

Transplanted method of rice establishment resulted in 9.98 per cent higher rice grain yield over direct seeded rice. But adoption of DSR led to the higher net returns per rupee invested thus ensure that DSR can be a sustainable and economically viable alternative to conventional transplanting. Inorganic nutrient management *i.e.* application of 100 per cent recommended dose of nitrogen to rice found effective in increasing crop growth, yield and economic returns. But, integrated nutrient management *i.e.* 50 per cent recommended dose of nitrogen + FYM @10 t/ha had similar effect as of inorganic nutrient management and can ensure long term sustainability.

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