Indian Journal of Agricultural Sciences **95** (2): 140–144, February 2025/Article
https://doi.org/10.56093/ijas.v95i2.141872

Impact of establishment methods, variety and crop spacing on rice (*Oryza sativa*) productivity using drip irrigation

S VALLAL KANNAN[1]* and V RAVIKUMAR[2]

Agricultural Engineering College and Research Institute, Tamil Nadu Agricultural University, Kumulur, Tamil Nadu 621 712, India

Received: 03 September 2023; Accepted: 24 December 2024

ABSTRACT

An experiment was conducted during during winter (*rabi*) season of 2018–2021 at Agricultural Engineering College and Research Institute, Kumulur, Tamil Nadu to develop a compendium technology for a drip irrigation system by combining suitable establishment methods along with variety and spacing to achieve productivity enhancement in rice (*Oryza sativa* L.) productivity and efficiency enhancement in a drip irrigation system. The experiment was laid out in a split-split plot design (SSPD) replicated thrice. Two methods of the establishment of direct seeding in a raised bed and transplanting in a flatbed was the main plot treatment; three medium duration of ADT 54, TKM 13 and CR 1009 sub-1variety was the sub plot treatment; and three different spacing of 20 cm × 10 cm, 20 cm × 20 cm, and 25 cm × 25 cm was the sub-sub plot treatment. Results revealed that direct seeded rice in a raised bed by using TKM 13 at 20 cm × 20 cm combined with recommended agronomic practices for medium duration variety is the best compendium technology for achieving the higher productive tillers of 375/m^2, number of filled grains of 45,375/m^2, grain yield of 6,080 kg/ha, net return of ₹64,059/ha, Benefit:Cost ratio (B:C) of 2.37 in addition to the water use efficiency of 6.61 kg/ha-mm and water productivity of ₹10.57/m^3 in drip method of irrigation system in rice cultivation.

Keywords: Crop geometry, Drip irrigation, Method of establishment, Water productivity, Water use efficiency

Rice (*Oryza sativa* L.) is a vital food crop cultivated worldwide, with production spanning at least 114 countries, over 50 of which yield 100,000 tonnes or more annually. India comes in first with a yearly production of 265.099 million metric tonnes (FAOSTAT 2024). India's rice cultivation requires 2,020 cubic meters of water for every tonne produced, which is significantly higher than the global average of 1,325 m³/t (FAO 2015). The plant space and their geometry influence on interception of solar radiation, foliage spread, dry matter production and growth rate of crops (Anwar *et al.* 2011). Planting geometry affects tillering and the formation of spikelets/panicle, both of which are critical for unit area of production of rice yield. The productivity of water can be enhanced by implementing improved practices of irrigation management. (Bouman and Tuong 2001). The water use efficiency is also enhanced by enhancing yield and reduction in usage of water (Singh *et al.* 2014). Under water-scarce conditions, the relationship between water applied and corresponding yield is important to optimize crop production.

A drip irrigation system supports better crop growth by reducing the evaporation of water from soil and loss through percolation from the deeper layer and maintaining optimum soil moisture saturation. Sidhu *et al.* (2019) reported that drip irrigation saves 40–50% of the water applied to rice and enhanced water productivity. The cost involved in an irrigation system of drip is based on the lateral number (spacing) and the dripper (spacing) numbers or emitter numbers per unit area, in addition to the main components. Good design and well operation of drip irrigation system support enhanced irrigation efficiency compared to surface irrigation. However, lack of good design of drip system or lack of scientific operation of irrigation system results in lower irrigation efficiency compared to the potential of drip irrigation system and reduces its acceptance and adoption. With this background, the research was executed to develop a compendium technology by combining suitable establishment methods, variety and crop geometry to increase rice production with higher water productivity.

MATERIALS AND METHODS

An experiment was conducted during winter (*rabi*) season of 2018–2021 at Agricultural Engineering College

[1]Coastal Saline Research Centre, Ramanathapuram, Tamil Nadu; [2]Centre for Water and Geospatial Studies, Water Technology Centre, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu. *Corresponding author email: vallalkannan.s@tnau.ac.in

and Research Institute, Kumulur (72.2376 m amsl), Tamil Nadu. The experimental plot soil texture was sandy clay loam having a field capacity of 25% and a bulk density (1.63 g/cm^3). It receives 881.412 mm of average rainfall with mean relative humidity (RH) of 88.46% (max) and 57.24% (min), respectively, with an average monthly relative humidity of 60.5%. The temperatures of 35.73°C and 24.48°C were the average maximum and minimum temperature, respectively.

Method of establishment, suitable variety and spacing: The experiment was conducted in a split-split plot design (SSPD) and it was replicated thrice. Two methods of establishment were considered as main plot treatments, viz. direct seeded under a raised bed (M_1) and transplanting under a flatbed (M_2); three varieties were considered sub-plot treatments, viz. ADT 54 (V_1), TKM 13 (V_2), CR 1009 sub-1 (V_3) and different geometry (spacing) was considered sub-sub-plot treatments, 20 cm × 10 cm (rectangular) (50 hills/m^2) (S_1); 20 cm × 20 cm (square) (25 hills/m^2) (S_2); 25 cm × 25 cm (square) (16 hills/m^2) (S_3).

The main field was prepared under two sets of conditions, one in dry condition and another in wet condition. Under dry conditions, primary tillage and secondary tillage were adopted to get fine tilth. Beds and channels formed at 60 cm × 30 cm spacing with a height of 25 cm and 50 m length under dry conditions. Three different varieties of rice seeds were sown in beds according to specific spacing treatments. Under wet conditions, pre-germinated seeds were sown in the dapog method of nursery on the same day of seeding on a raised bed. 18-days old seedlings were transplanted in a flatbed.

In both conditions, drip irrigation lines were laid out at the spacing of 90 cm with emitters spaced 60 cm apart having a discharge rate of 4 L/h and positioned at the center of the beds. Fields were irrigated at 100% potential evaporation (PE) on alternate days and fertigated with a 100% recommended fertilizer dose of 150:60:60 NPK kg/ha. Full dose of P was applied as basal through 375 kg/ha of superphosphate, and N and K were supplied through 326 kg of urea and 100 kg of muriate of potash through drip once in every 6 days. Total water applied for direct seeded rice was 920 mm and 960 mm for transplanted rice (40 mm for puddling) and the same quantity was applied irrespective of variety and spacing through a drip system of irrigation.

The irrigation scheduling was done for drip system of irrigation based on daily potential evaporation values during the crop growth period, and period of irrigation was computed as follows:

$$\text{Irrigation hours (h)} = \frac{\text{ETc (mm)}}{\text{Application rate (mm/h)}} \times 100$$

$$\text{Actual evaporation or crop evapotranspiration (ETc) (mm)} = ET_0 \times \text{Crop factor}$$

$$\text{Reference evaporation or evapotranspiration } (ET_0) \text{ (mm)} = \text{Previous day evaporation} \times \text{Pan factor.}$$

Rice crop factors at initial stage (1.15), crop developmental stage (1.23), reproductive stage (1.14), and maturity stages (1.02) were considered with a constant pan factor of 0.70 (FAO 1986).

The yield parameters, viz. tillers having panicle, filled grain numbers, test weight, and yield of grain and straw were recorded, and an economic analysis on cultivation cost, gross return, net return and Benefit:Cost (B:C) was calculated. Water use efficiency was measured by determining the dry weight of grain yield (kg/ha) and dividing that by irrigation plus rainfall (ha mm). The data were statistically analyzed by following the procedure of Gomez and Gomez (1984).

RESULTS AND DISCUSSION

The outcome of the research revealed a specific aspect of treatments and combined influence of treatments on yield parameters yield of grain, water use efficiency, and water productivity, along with economics.

Method of establishment of rice on grain yield and economics in drip irrigation system: The results indicated that higher grain yield, economics, and B:C were recorded in the direct seeded method of establishment in comparison with the transplanted method of planting under drip irrigation (Table 1). This might be due to the optimum soil saturation and better root aeration for better crop growth which is attributed to higher yield parameters and yield under aerobic conditions. The results indicated that in sandy loam, water movement was faster, with soil moisture showing greater vertical distribution compared to lateral distribution (Aiswarya *et al.* 2024). The direct seeded method of sowing is recommended for drip systems of irrigation in rice cultivation. Kombali *et al.* (2015) indicated the performance of drip system of irrigation in aerobic rice cultivation. The results of fertigation through a drip system at 1.5 Potential Evaporation (PE) in combination with 100% fertilizer recommended dose through conventional fertilizer resulted in higher panicle weight (3.97 g), productive tillers (25.1/hill), total grains/panicle (167.6), and grain yield (5,451 kg/ha). Soman *et al.* (2018) conducted a trial of rice under flood irrigation, drip irrigation, and sprinkler irrigation. The results highlighted that drip irrigation significantly achieved a higher rice grain yield of 6,950 kg/ha with a water use efficiency of 17.1 kg/ha-mm against to flooded method of irrigation (6,225 kg/ha).

Effect of variety on grain yield and economics in drip irrigation system: The experiment was undertaken during the *rabi* season, and the rice variety suitable for rice cultivation is the medium-duration variety. The findings revealed that among three medium-duration rice varieties, TKM 13 recorded higher grain yield, net return, and BCR and proved higher efficiency under drip irrigation systems (Table 2) with a low difference among the varieties. This might be due to the suitability of variety under dry conditions with semi-dwarf, high tillering and higher yield potential. Adekoya *et al.* (2014) concluded that cultivating water-efficient and drought-tolerant rice is feasible using drip irrigation, which supports comparable grain yields and enhances water productivity. According to Banumathy *et al.* (2016), TKM 13 achieved 11.2% yield improvement with

Table 1 Effect of establishment methods on yield parameters, grain yield, economics, and water use efficiency in drip irrigation system

Treatment	Productive tillers (m^2)	Filled grains (m^2)	Grain yield (t/ha)	Net return (₹/ha)	Benefit:Cost	Water use efficiency (kg/ha-mm)
M_1, Direct-seeded	278	32272	5.31	51976	2.11	5.77
M_2, Transplanted	238	27525	4.59	41299	1.88	4.78
Mean	258	29899	4.95	46638	2.00	5.28
SED	1.24	964	0.26	-	-	0.07
CD (P<0.05)	2.78	1452	0.41	-	-	0.14

Table 2 Effect of variety on yield parameters, grain yield, economics and water use efficiency in drip irrigation system

Treatment	Productive tillers (m^2)	Filled grains (m^2)	Grain yield (t/ha)	Net return (₹/ha)	Benefit:Cost	Water use efficiency (kg/ha-mm)
V_1, ADT 54	253	29078	4.71	43007	1.92	5.02
V_2, TKM 13	344	39416	5.26	51161	2.10	5.62
V_3, CR 1009 sub1	177	2123	4.88	45745	1.98	5.20
Mean	258	29899	4.95	46638	2.00	5.28
SED	0.98	678	0.23	-	-	0.04
CD (P<0.05)	1.42	1242	0.38	-	-	0.11

the grain yield of 5,201 kg/ha, in relation to the national check variety, IR 64.

Effect of spacing on grain yield, economics and water use efficiency in drip irrigation system: Per-plant productivity, or per-unit productivity, depends on the crop geometry and provides favorable conditions for the effective utilization of resources. Among the three spacing recommended (20 cm × 10 cm), modified square method (20 cm × 20 cm), and wider spacing and square method recommended for system of rice intensification (SRI) (25 cm × 25 cm), modified square method (20 cm × 20 cm) performed higher grain yield of 4.94 t/ha and net return of ₹45,861/ha and also higher water use efficiency of 5.26 kg/ha-mm (Table 3) under drip irrigation system. This might be due to the availability of uniform resources of nutrients and water attributed to higher grain yield and resulted in higher net income. Suganthi *et al.* (2017) studied the influence of drum seeding and SRI on rice yield. Higher growth characters, yield parameters and rice yield were achieved in SRI. This might be due to sufficient resources without crop competition. The findings indicated that both 20 cm × 15 cm and 20 cm × 20 cm planting geometries exhibited similar crop growth rates and also dry matter production at all stages of the crop (Mahato and Adhikari 2017). Aparna *et al.* (2022) reported that among various crop geometries, 20 cm × 15 cm spacing resulted in higher growth, yield attributes and over all yield of black rice.

Comparison of individual treatments on yield parameters, economics and water use efficiency in drip irrigation system: The higher number of productive tillers, viz. 278, 344, and 275/m^2, was recorded under direct seeding (M_1), TKM 13 (V_2), and 20 cm × 20cm (S_2) as individual treatments compared to transplanted (M_2), other varieties and other spacing treatments. A similar trend was also observed in all the parameters, such as filled grains and grain yield. Soman *et al.* (2018) also obtained higher yield attributes and were proven higher at water and fertilizer management through drip irrigation systems. Drip irrigation enhances soil

Table 3 Effect of spacing on yield parameters, grain yield, economics and water use efficiency in drip irrigation system

Treatment	Productive tillers (m^2)	Filled grains (m^2)	Grain yield (t/ha)	Net return (₹/ha)	Benefit:Cost	Water use efficiency (kg/ha-mm)
S_1, 20 cm × 10 cm (Rectangular)	246	27184	4.42	37189	1.80	4.71
S_2, 20 cm × 20 cm (Square)	275	30071	4.94	45861	1.98	5.26
S_3, 25 cm × 25 cm (Square)	197	48960	4.22	33541	1.72	4.50
Mean	239	35405	4.53	38864	1.83	4.82
SED	1.04	864	0.14	-	-	0.06
CD (P<0.05)	1.96	1328	0.31	-	-	0.13

temperature and moisture, improves nutrient availability, facilitates water and nutrient uptake by roots, boosts crop growth and yield, and minimizes evaporation and nitrogen loss (Wang *et al.* 2024)

A net return of ₹51,976/ha, ₹51,116 L/ha, and ₹4,586 L/ha was recorded higher under direct seeding (M_1), TKM 13 (V_2), and 20 cm × 20 cm (square method) (S_2) as individual treatments compared to transplanted (M_2) methods of establishment, other varieties, and other spacing treatments. In BCR, a similar trend (2.11, 2.10 and 1.98) was observed.

The higher water use efficiency of 5.77, 5.62, and 5.26 kg/ha-mm was recorded under direct seeding (M_1), TKM 13 (V_2) and 20 cm × 20 cm (square method) (S_2) as with respect to other treatments. The higher yield was contributed by higher yield parameters under saturated soil conditions, drought tolerance of variety and uniform availability of resources might be reason for achievements of higher water use efficiency. Water productivity also recorded a similar trend. The savings in the quantity of water, increase in water productivity and grain yields under aerobic rice systems of rice cultivation in the drip method of irrigation have also been reported by Soman *et al.* (2018). Additionally, rice cultivation under drip irrigation demonstrated greater water indices. In the dry season, higher water productivity is exhibited in the drip method of irrigation compared to surface flooding, as observed by Samoy-Pascual *et al.* (2022). Guo (2024) reported that a short irrigation cycle, balanced soil moisture, and distinct dry-wet interfaces can increase a crop's leaf area index and biomass accumulation, enhance root activity, direct photosynthetic products to aboveground parts, and ultimately boost crop yields.

Combination effect of treatments on crop production, economics and water use efficiency under drip irrigation system: The combined effect of treatments on crop production and water use efficiency was studied for the purpose of providing compendium technology for drip irrigation systems (Supplementary Table 1).

A combination of direct seeded sowing methods with TKM 13 at spacing of 20 cm × 20 cm (square method) ($M_1V_2S_2$) reported a higher number of productive tillers (375/m^2), filled grains (4,537/m^2), grain yield of 6,080 kg/ha, net return of ₹64,059/ha, benefit-cost ratio of 2.37, water use efficiency of 6.61 kg/ha-mm, and water productivity ₹10.57/m^3 compared to other treatment combinations. Direct seeding under saturated conditions with optimum soil moisture, drought tolerance and high-yielding variety with uniform availability of resources with less crop-crop competition is perhaps the reason for higher yield and other benefits.

Sharda *et al.* (2014) proposed that employing micro-irrigation in direct sown rice could enhance WUE by aligning the supply of water with the needs of the crop, minimizing runoff and drainage losses to the deeper layer, and reducing energy consumption. Rekha *et al.* (2015) reported that the application of a 100% recommended dose of fertilizer through drip fertigation by water-soluble fertilizer recorded higher growth parameters, viz. plant height of 56.70 cm, 50.43 number of tillers/hill, 191.43 number of leaf/hill, grain yield of 6,503 kg/ha and straw yield of 9,285 kg/ha, respectively. According to Soman *et al.* (2018), the technology of drip fertigation provides solutions to water-related challenges while addressing the need for highly efficient input management and improved production efficiencies. According to Meher *et al.* (2020), the optimal approach for enhancing rice productivity involves the adoption of drip irrigation technology. This method allowed for increased productivity with minimal water usage, leading to higher yields. Additionally, it proved a cost-effective irrigation system alternative to the traditional method of irrigation in rice farming and contributes to an ecologically sustainable reduction in overall water consumption for rice crops. Colak (2021) indicated that the drip irrigation system generated higher water use efficiency and performance on productivity against conventional method of irrigation of flooding. As reported by Jain *et al.* (2022), drip fertigation has promoted an increase in rice yield ranging from 14.7–29.9%, surpassing those achieved through traditional flooding methods. Micro-irrigation technologies, including drip irrigation, have proven to be effective in conserving water, especially in water-intensive rice cultivation, without compromising yield. With drip irrigation, aerobic rice cultivation can be successfully managed by ensuring adequate moisture levels in the root zones. Yang *et al.* (2023) reported that surpassing the typical levels of drip irrigation (100–120%) significantly boosts crop yields in comparison to alternative irrigation techniques. Wang *et al.* (2024) suggested that optimized drip irrigation could serve as a valuable guideline for cost-effective irrigation strategies in drought-prone regions.

Among the methods of establishment, direct seeding is the best method of establishment for drip-irrigated rice cultivation with medium duration variety. The square method of sowing with a spacing of 20 cm × 20 cm is the best for drip-irrigated rice cultivation. Direct sowing by using medium-duration rice variety with a spacing of 20 cm × 20 cm in a raised bed (square method) is the best method of rice cultivation under drip irrigation with a lateral spacing of 90 cm and dripper spacing of 60 cm with 4 l/h during *rabi* season for higher production, higher water use efficiency and productivity in the water scare area or water scare season and also the best alternate to conventional method of rice production.

REFERENCES

Adekoya M, Liu Z, Vered E, Zhou L, Kong D, Qin J, Ma R, Yu X, Liu G, Chen L and Luo L. 2014. Agronomic and ecological evaluation on growing water-saving and drought-resistant rice (*Oryza sativa* L.) through drip irrigation. *Journal of Agricultural Science* **6**: 110–19. DOI: 10.5539/jas.v6n5p110

Aiswarya L, Siddharam and Sandeepika M. 2024. Soil moisture distribution pattern under drip irrigation in sandy loam soil using gravimetric method. *Asian Journal of Soil Science and Plant Nutrition* **10**(2): 198–204. DOI: 10.9734/ajsspn/2024/v10i2276

Anwar M P, Juraimi A S, Puteh A, Selamat A, Man A and Hakim M A. 2011. Seeding method and rate influence on weed suppression in aerobic rice. *African Journal of Biotechnology*

10(68): 15259–71. DOI: 10.5897/AJB11.060

Banumathy S, Saraswathi R, Sheeba A, Manimaran R, Sumathi E, Devanathan M, Manickam G, Ramasubramanian G V, Agila R, Jayaraj T and Rajendran R. 2016. Rice TKM 13: A high yielding medium duration fine grain variety. *Electronic Journal of Plant Breeding* **7**: 626–33. DOI: 10.5958/0975-928X.2016.00080.6.

Bouman B A M and Tuong T P. 2001. Field water management to save water and increase its productivity in irrigated lowland rice. *Agricultural Water Management* **49**(1): 11–30.

Bozkurt C Y. 2021. Comparison of aerobic rice cultivation using drip systems with conventional flooding. *The Journal of Agricultural Science* **159**(7–8): 544–56. DOI: 10.1017/S002185962100082

FAO. 1986. Irrigation water management: Irrigation water needs. *Training Manual No. 3*. Food and Agriculture Organization of the United Nations, Via delle Terme di Caracalla, 00100 Rome, Italy.

FAO. 2015. *Latin America and the Caribbean Food and Agriculture*. Food and Agriculture Organization of the United Nations Regional Office for Latin America and the Caribbean, Santiago, 2014. ISBN 978-92-5-108149-5

FAOSTAT. 2024. Rice production statistics. *Food and Agriculture Organization Statistical Database*. www.fao.org.

Gomez K A and Gomez A A. 1984. *Statistical Procedures for Agricultural Research*. John Wiley and Sons, New York.

Guo H and Li S. 2024. A review of drip irrigation's effect on water, carbon fluxes, and crop growth in farmland. *Water* **16**: 2206. https://doi.org/10.3390/w16152206

Jain P K, Bhatt G D and Singh M. 2022. A study on saving water using drip irrigation technologies in paddy and enhancing yield. *International Journal of Research in Agronomy* **5**(1): 13–18.

Kombali G, Nagaraju, Rekha B, Sheshadri T, Anusha S and Mallikarjuna G B. 2015. Performance of aerobic rice under drip fertigation. *The Ecoscan* **9**(1–2): 503–05.

Mahato M and Adhikari B B. 2017. Effect of planting geometry on growth of rice varieties. *International Journal of Applied Sciences and Biotechnology* **5**(4): 423–29. https://doi.org/10.3126/ijasbt.v5i4.18041

Meher W, Sagar P, Kumar K, Meher G S and Priyabhavana G. 2020. Integration of on-farm drip irrigation system in rice cultivation (more crop per drop). *International Journal of Creative Research Thoughts* **8**: 3555–61.

Rekha B, Jayadeva H M, Kombali G, Nagaraju and Mallikarjuna G B. 2015. Growth and yield of aerobic rice grown under drip fertigation. *The Ecoscan* **9**(1–2): 435–37.

Samoy-Pascual K, Lampayan R M, Remocal A T, Orge R F, Tokida T and Mizoguchi M. 2022. Field water management practices for enhancing rice productivity and water use efficiency. *Field Crops Research* **287**: 108669.

Sharda R, Mahajan G, Siag M, Singh A and Chauhan B S. 2014. *(In) Proceedings of workshop on "Drip Irrigated Rice" (side event) at 4th International Rice Congress*, Bangkok, October 27–31.

Sidhu H S, Jat M L, Singh Y, Sidhu R K, Gupta N, Singh P, Singh P and Gerard B. 2019. Sub-surface drip fertigation with conservation agriculture in a rice-wheat system: A breakthrough for addressing water and nitrogen use efficiency. *Agricultural Water Management* **216**(1): 273–83.

Singh L, Beg M K A, Akhter S, Qayoom S, Lone B A, Singh P and Singh P. 2014. Efficient techniques to increase water use efficiency under rainfed ecosystems. *Journal of AgriSearch* **1**(4): 193–200.

Soman P, Singh S, Balasubramaniam V R and Choudhary A. 2018. On-farm drip irrigation in rice for higher productivity and profitability in Haryana, India. *International Journal of Current Microbiology and Applied Sciences* **7**(2): 506–12.

Suganthi M, Subbiah G, Venkatramanan R, Kumaravel P and Gopi H. 2017. Influence of rice establishment technique on growth and yield of paddy (*CO51*). *Agriculture Update* **12**: 121–23.

Vijaya Aparna B, Anny Mrudhula K, Prasad P V N and Ravi Babu M. 2022. Effect of planting geometry and nitrogen levels on growth parameters, yield attributes and yield of black rice. *The Pharma Innovation Journal* **11**(9): 2260–64.

Wang C, Li S, Huang S and Feng X. 2024. A review of the application and impact of drip irrigation under plastic mulch in agricultural ecosystems. *Agronomy* **14**: 1752. https://doi.org/10.3390/agronomy14081752

Wang Y, Sun H and Wang L. 2024. Optimizing drip use efficiency. *International Journal of Agricultural Sustainability* **22**(1): 2437214. 10.1080/14735903.2024.2437214

Yang P, Wu L, Cheng M, Fan J, Li S, Wang H and Qian L. 2023. Review on drip irrigation: Impact on crop yield, quality, and water productivity in China. *Water* **15**(9): 1733. https://doi.org/10.3390/w15091733