



# Study on Physiological Parameters and Economics of Rice Cultivation under Different Establishment Methods and Water Management Practices

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## **Authors' contributions**

*This work was carried out in collaboration among all authors. Authors S. Selvakumar, S. Sakthivel and AK designed the study and wrote the protocol. Author S. Selvakumar conducted field experiment and performed the statistical analysis and wrote the first draft of the manuscript. Authors S. Sakthivel, RB, ST and AR facilitated smooth conduct of the field experiment, analyses of the study and monitoring the progress. Authors S. Selvakumar and S. Sakthivel managed the literature searches. All authors read and approved the final manuscript.*

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## **ABSTRACT**

A field experiment was conducted at Tamil Nadu Agricultural University, Agricultural College and Research Institute, Madurai, Tamil Nadu, India, during summer 2019 to study about the changes in physiological parameters of rice under various establishment and water management strategies and

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to find out the suitable method of rice establishment and irrigation management practices for tank irrigated command areas during water scarcity situation. Field experiment comprised of four establishment methods in combination with four irrigation management strategies. Medium duration fine grain rice variety TKM 13 was used for the study. Results of the study revealed that machine transplanting under unpuddled soil combined with irrigation after formation of hairline crack recorded improved physiological parameters and yield. It was on par with machine transplanting under unpuddled soil combined with irrigation when water level reaches 5 cm below soil surface. Higher gross return, net return and B:C ratio were observed with machine transplanting under unpuddled soil combined with irrigation after formation of hairline crack. This was followed by machine transplanting under unpuddled soil combined with irrigation when water level reaches 5 cm below soil. Hence, the result of study concluded that machine transplanting under unpuddled soil combined with irrigation when water level reaches 5 cm below soil surface can be recommended as the suitable technology for the farmers of tank irrigated command area to get higher return with minimum use of resources under water scarcity situation.

*Keywords: Establishment methods; water management strategies; nutrient uptake; physiological influence; economics.*

## 1. INTRODUCTION

Rice is the most important staple food, eaten by more than half of the world's population. In Asia, the term Food security can be well related to Rice security as 90% of rice is consumed in this region. It is suitable to grow under diverse range of agro ecological zones. In India, rice is grown in an area of 79.77 million hectares with the total production of 105.5 million tonnes [1]. In southern parts of India, mostly rice is grown in command areas under tank irrigation system. Major source of water for the tank is rainfall. Due to delayed onset, early withdrawal and decreased quantity of monsoon rains, releasing of water from dams get delayed and the availability of water in tanks for irrigation also get reduced. The rice crop grown in these command areas suffers due to terminal stress and the farmers could not achieve higher yield. Manual transplanting under puddled soil condition is the most common method of rice cultivation. Puddling required 30% of total water required for rice cultivation [2], which also destroyed the soil structure [3], puddling created subsurface hard pan at 15-25 cm, it affected the root growth of the rice. Moreover, manual transplanting required 30 man days ha<sup>-1</sup> [4]. Labour scarcity in agricultural sector is the emerging problem due to migration of labours from the villages to nearby cities that ultimately delayed the transplanting of rice seedlings and caused irrecoverable yield loss [5]. Mechanised transplanting under unpuddled soil condition can be recommended as an alternate strategy for manual transplanting under puddled soil condition, which could save energy and water usage by 31-76 % and 25-26 %

respectively than conventional tillage [6], ensures timely transplanting and attains optimum plant density that attributes to high productivity and returns. Direct sowing of rice using drum seeder is also considered as an alternate rice establishment method for transplanting, it required only two persons to operate the seeder for seeding a hectare of land [7]. In general rice is cultivated like a semi aquatic crop with continuous flooding but it was not necessary, because continuous flooding consumes huge quantity of water. With the available total water, agriculture alone consumed 78.2% of total available water and the availability will shrink to 71.6% in 2025 and 64.6% in 2050 [8]. It created the need to develop the novel technologies that consumes lesser water and produces higher economic returns. Adaption of appropriate water management could save huge quantity of water compared to conventional method of irrigation [9]. Irrigation application after disappearance of ponded water is recommended now a days. Safe alternate wetting and drying (AWD) can also be recommended as an ideal water saving technology that demands irrigation when water depth falls to a threshold depth of below the soil surface with the use of field water tube. Several studies concluded that significant reduction in water input can be achieved by safe AWD without penalty in grain yield [10]. Physiological parameters are much more important for the determination of crop yield and stress tolerating ability of the crop. To know about the changes in physiological parameters of rice under various establishment methods and irrigation management practices, the current study was carried out.

## 2. MATERIALS AND METHODS

A field investigation was carried out in rice field of Tamil Nadu Agricultural University, Agricultural College and Research Institute, Madurai, Tamil Nadu, India. The experimental site was located at 9°54' N latitude and 78°54' E longitude at an altitude of 147 m above MSL. Soil texture is sandy clay loam, pH of the soil was 7.2, organic matter of the soil was 0.81%, soil available N-242.6 kg ha<sup>-1</sup>, available P-16.9 kg ha<sup>-1</sup> and available K- 432.7 kg ha<sup>-1</sup>. The experiment was laid out in strip plot design with 16-treatment combination and three replication. The treatments comprised of four different methods of establishment viz., conventional transplanting (M<sub>1</sub>), machine transplanting under puddled soil (M<sub>2</sub>), machine transplanting under unpuddled soil (soil was ploughed to fine tilth, leveled and irrigated to bring the soil to saturation) (M<sub>3</sub>) and sowing with seed drill (TNAU drum seeder was used for sowing of seeds) (M<sub>4</sub>) in main plot and four irrigation management methods in sub plots, consisted of water management practices viz., farmers' irrigation practice (continuous submergence of 5 cm throughout the crop period) (I<sub>1</sub>), Irrigation after formation of hairline crack (each irrigation was given to the depth of 2.5 cm) (I<sub>2</sub>), irrigation when water level reaches 5 cm below soil surface (each irrigation was given to the depth of 2.5 cm) (I<sub>3</sub>) and irrigation when water level reaches 10 cm below soil surface (each irrigation was given to the depth of 2.5 cm) (I<sub>4</sub>). Medium duration fine grain rice variety TKM 13 was used in this experiment. It has the test weight of 13.5 g. 150:50:50 kg of nitrogen, phosphorus and potash was applied. Full dose of phosphorous was applied as basal, nitrogen and potash were applied in three equal splits each as basal and during tillering and panicle initiation stages. The proline content was estimated during panicle initiation stage and expressed in μmol g<sup>-1</sup>. Nutrient uptake viz., nitrogen, phosphorous and potash were also estimated from this experiment during harvesting stages and values were expressed in kg ha<sup>-1</sup>.

### 2.1 Physiological Parameters Observed

#### 2.1.1 Crop Growth Rate (CGR)

Crop Growth Rate (CGR) was observed at active tillering to flowering and flowering to harvest stages and the results were expressed in g m<sup>-2</sup> day<sup>-1</sup> by using following formula

$$CGR = W_2 - W_1 / P (t_2 - t_1)$$

Where,

W<sub>1</sub> and W<sub>2</sub> are whole plant dry weight (g) at time t<sub>1</sub> and t<sub>2</sub> respectively  
t<sub>1</sub> and t<sub>2</sub> are the initial and final day of period of observation, respectively  
P is the plant spacing adopted (m<sup>2</sup>)

#### 2.1.2 Leaf Area Index (LAI)

Leaf area index (LAI) was observed at active tillering to flowering stages by using following formula

$$LAI = \frac{L \times W \times K \times \text{Number of leaves plant}^{-1}}{\text{Land area occupied by plant}}$$

Where,

L - Length of leaf (cm)  
W - Width of leaf (cm)  
K - Correction factor (0.75 for wet season and 0.763 for dry season).

Leaf area duration (LAD) were recorded at active tillering to flowering stages by using following formula

$$LAD = \frac{L_1 + L_2}{2} \times (t_2 - t_1)$$

Where

L<sub>1</sub> and L<sub>2</sub> are the LAI at time t<sub>1</sub> and t<sub>2</sub>.

These data were analysed statistically by following Gomez and Gomez (1984) [11] method. Wherever the treatment differences were found significant (F test), critical differences were worked out at five percent probability level and the values were furnished. Treatment differences that were not significant were denoted as "NS". Economics viz., cost of cultivation, gross return, net return and B: C were also assessed to know about the profitability.

## 3. RESULTS AND DISCUSSION

### 3.1 Leaf Area Index and Leaf Area Duration

Crop productivity is ultimately determined by the variation in LAI that is an important biophysical parameter because it influenced the light interception and transpiration by the crop canopy [12].

Among the establishment methods, improved LAI at active tillering stage (2.51), flowering stage (4.42 g) and increased LAD at active tillering to flowering stage (104.03) were observed with machine transplanting under unpuddled soil ( $M_3$ ). However, it was on par with machine transplanting under puddled soil ( $M_2$ ) (Table.1). Machine transplanting recorded higher number of seedlings per hill and it also maintained uniform spacing in transplanting, which facilitate increased photosynthetic rate and subsequently increased LAI. Similar findings were observed with Shirame *et al.* [13].

Within the various irrigation management practices, irrigation after formation of hairline crack ( $I_2$ ) documented higher LAI at active tillering (2.51), flowering stage (4.32) and LAD at active tillering to flowering stage (102.30). This was comparable with irrigation when water level reaches 5 cm below soil surface ( $I_3$ ) (Table 1). Maintaining of optimum moisture regime improved nutrient availability and uptake, thus in turn increased number of tillers and delayed senescence of leaves with higher photosynthetic rate. This was in line with Thakur *et al.*, 2010 [14]. Water saving irrigation influenced the soil aeration which facilitated more number of tillers and subsequently improved the photosynthetic rate with increased LAI [15]. Different establishment methods and irrigation management practices have not produced considerable interaction with each other on leaf area index and leaf area duration during summer 2019.

### 3.2 Crop Growth Rate

Among the various establishment methods, crop growth rate was higher with machine transplanting under unpuddled soil ( $M_3$ ) at tillering to flowering stage ( $15.77 \text{ g m}^2 \text{ day}^{-1}$ ) and flowering to harvest stage ( $19.8 \text{ g m}^2 \text{ day}^{-1}$ ) (Table 1). In rice, dry matter production is at a very slow rate up to 30 days after emergence because of the slow growth rate and it increased at a faster rate from 30 to 90 days after emergence. The data revealed that there was a significant variation in dry matter accumulation between treatments. Machine transplanting under unpuddled soil recorded higher dry matter accumulation (6 percent) compared to conventional method of rice transplanting during harvest, which increased crop growth rate (Table 1). The increased CGR was also due to uniform spacing, development of efficient

photosynthetic structure which enabled the plants to intercept higher quantity of radiant energy resulted in higher dry matter production [16].

Increased CGR was observed with irrigation after formation of hairline crack ( $I_2$ ) during active tillering to flowering and flowering to harvest stage, it might be due to better root aeration and root activity, which was comparable with irrigation when the water level reaches 5 cm below soil surface ( $I_3$ ) (Table.1). Due to increased leaf area, dry matter production was increased, which in turn improved CGR. These findings are in accordance with Vijayakumar *et al.* [17] and Archana Rajput *et al.* [18].

### 3.3 Proline Content

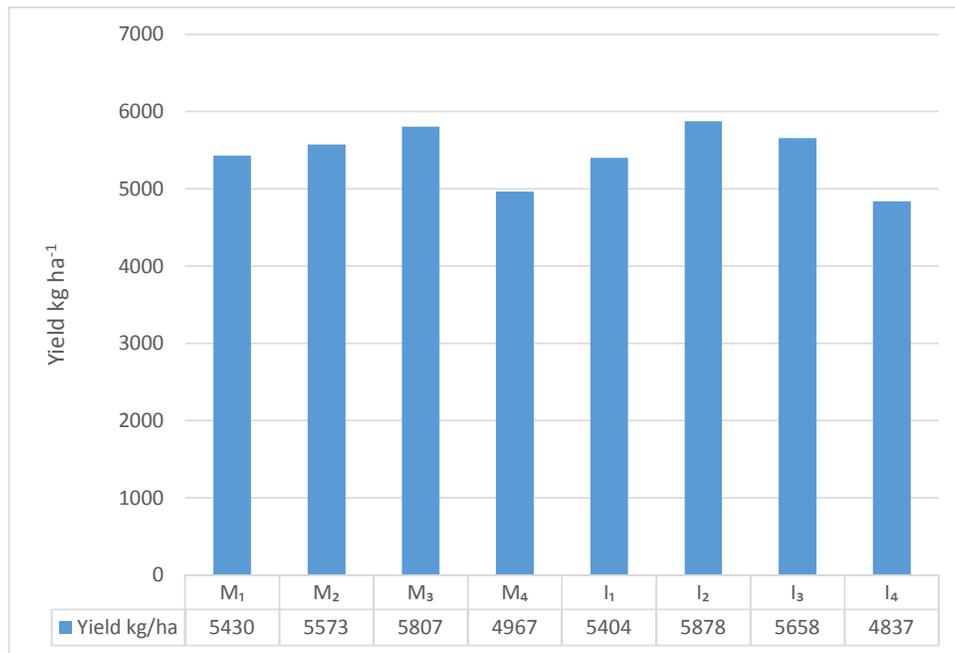
Tissue proline content showed non-significant variation within the methods of establishments. Whereas, among the irrigation management practices, increased proline content was observed with increased period of stress. Higher proline content was observed with irrigation when water level reaches 10 cm below soil surface ( $I_4$ ) (Table 1). Increase in soil moisture decreased the tissue proline content and under continuous flooding period tissue proline content was less [19]. Drought tolerance of the plant was indicated by tissue proline content, there was a strong positive correlation between tissue proline accumulation and drought tolerance. Singh *et al.* [20] recorded that proline accumulated plants recovered rapidly from the drought.

### 3.4 Nutrient Uptake

Among the various establishment methods, increased N, P and K uptake was observed with machine transplanting under unpuddled soil ( $M_3$ ) (Table 1). It might be due to improved root system [21] that improved the nutrient uptake. Puddling increased fertilizer leaching and increased soil reduction. Kumar [22] also reported that increase in organic matter and slight reduction in soil  $p^H$  were observed with unpuddled soil and also machine transplanting recorded uniform planting geometry, uniform depth of planting, reduced plants to plant competition in both root and canopy of the plant that promoted improved root growth and enhanced foliage production, which in turn improved the N, P and K uptake and ultimately produced increased grain filling, grain weight and yield (Fig. 1.).

**Table 1. Effect of various establishment and irrigation management practices on physiological parameter and nutrient uptake of TKM 13 rice variety**

Treatment	Dry matter production (kg ha <sup>-1</sup> )	Leaf area index		Leaf area duration	Crop growth rate (g m <sup>-2</sup> day <sup>-1</sup> )		Proline content (μmol g <sup>-1</sup> )	Nitrogen uptake (kg ha <sup>-1</sup> )	Phosphorous uptake (kg ha <sup>-1</sup> )	Potash uptake (kg ha <sup>-1</sup> )
	At harvest	At active tillering	At flowering	At active tillering to flowering	At active tillering to flowering	At flowering to harvest	At panicle initiation	At harvest	At harvest	At harvest
<b>Main plot</b>										
M <sub>1</sub>	13174	2.41	4.02	96.49	14.98	18.5	1.58	113.51	31.65	89.39
M <sub>2</sub>	13370	2.47	4.24	100.58	15.73	18.2	1.6	115.63	32.17	91.29
M <sub>3</sub>	13946	2.51	4.42	104.03	15.77	19.8	1.57	122.58	34.14	96.05
M <sub>4</sub>	12335	2.28	3.61	88.28	14.69	16.4	1.62	107.26	29.73	81.92
SEd	312.4	0.059	0.099	1.823	0.292	0.573	0.049	2.532	0.787	1.919
CD (P=0.05)	764.5	0.145	0.243	4.460	0.714	1.402	NS	6.195	1.925	4.696
<b>Sub plot</b>										
I <sub>1</sub>	13497	2.41	4.16	98.51	15.54	19.0	1.41	116.11	33.11	91.06
I <sub>2</sub>	14233	2.51	4.32	102.30	16.61	19.5	1.51	125.15	35.00	98.07
I <sub>3</sub>	13961	2.44	4.20	99.64	16.49	19.1	1.61	121.68	33.55	95.35
I <sub>4</sub>	11134	2.31	3.62	88.91	12.52	15.3	1.82	96.05	26.02	74.16
SEd	249.4	0.075	0.104	2.176	0.451	0.660	0.038	2.424	0.748	2.135
CD (P=0.05)	610.2	NS	0.255	5.325	1.104	1.614	0.094	5.932	1.830	5.225
<b>I×M</b>										
SEd	450.34	0.128	0.239	4.456	0.807	1.099	0.094	3.763	1.242	2.988
CD (P=0.05)	1021.13	NS	NS	NS	NS	2.412	NS	8.495	2.781	6.704
<b>M × I</b>										
SEd	409.11	0.137	0.241	4.612	0.878	1.146	0.089	3.692	1.217	3.131
CD (P=0.05)	912.10	NS	NS	NS	NS	2.540	NS	8.307	2.717	7.082



**Fig. 1. Effect of various establishment and irrigation management practices on yield of TKM 13 rice variety**

Sheeja *et al.* [23] also observed that machine transplanting provided more room for both canopy and root growth resulted in increased uptake of nutrients. Nutrient uptake in this experiment was synergistically improved by both unpuddled and machine transplanting. Among the irrigation management practices, enhanced N, P and K uptake was recorded with irrigation after formation of hairline crack (I<sub>2</sub>). It was at par with irrigation when water level reaches 5 cm below soil surface (I<sub>3</sub>). Improved nutrient uptake might be due to increased dry matter production that ultimately recorded improved nutrient content in plants. Irrigation after formation of hairline crack (I<sub>2</sub>) enhanced the nutrient uptake because it had created better soil environment by maintaining optimum air and water with increased microbial biomass that contributed to biological processes of supplying N in plants [24], [25].

Significant interaction was observed with method of establishment and irrigation management practices each other during summer 2019. N, P and K uptake was higher with machine transplanting under unpuddled soil combined with irrigation after formation of hairline crack (M<sub>3</sub>I<sub>2</sub>). It was on par with machine transplanting under unpuddled soil combined with irrigation when water level drops 5

cm below soil surface (M<sub>3</sub>I<sub>3</sub>). Modification of plant, soil and water management practices improved the plant nutrient uptake by improving root activity and enhanced the nutrient availability.

### 3.5 Economics

Yield and cost of cultivation are the prime most factor for determining the economic efficiency and viability of crop. Higher crop productivity with minimum cost of cultivation resulted in higher net returns and B: C ratio.

Various rice establishment methods and irrigation management practices showed variation with cost of cultivation, net income and benefit: cost ratio (Table 2). Cost of cultivation was lesser under sowing with seed drill combined with irrigation when water level reaches 10 cm below soil surface (M<sub>4</sub>I<sub>4</sub>) due to avoidance of labour requirement for transplanting and also reduced number of irrigation. While, conventional transplanting with farmers' practice of irrigation (M<sub>1</sub>I<sub>1</sub>) increased the cost of cultivation. This might be due requirement of more number of labour for transplanting and irrigation.

**Table 2. Effect of various establishment and irrigation management practices on economics of TKM 13 rice variety**

Treatment	Cost of cultivation (₹ha <sup>-1</sup> )	Gross Return (₹ha <sup>-1</sup> )	Net Return (₹ha <sup>-1</sup> )	B:C ratio
M <sub>1</sub> l <sub>1</sub>	50166	111337	61171	2.22
M <sub>1</sub> l <sub>2</sub>	50166	122050	71884	2.43
M <sub>1</sub> l <sub>3</sub>	48366	119197	70831	2.46
M <sub>1</sub> l <sub>4</sub>	47916	100626	52710	2.10
M <sub>2</sub> l <sub>1</sub>	47966	112476	64510	2.34
M <sub>2</sub> l <sub>2</sub>	47966	125060	77094	2.61
M <sub>2</sub> l <sub>3</sub>	46166	119763	73597	2.59
M <sub>2</sub> l <sub>4</sub>	45716	107201	61485	2.34
M <sub>3</sub> l <sub>1</sub>	44316	122688	78372	2.77
M <sub>3</sub> l <sub>2</sub>	44466	127795	83329	2.87
M <sub>3</sub> l <sub>3</sub>	43416	122353	78937	2.82
M <sub>3</sub> l <sub>4</sub>	43116	110244	67128	2.56
M <sub>4</sub> l <sub>1</sub>	42766	104567	61801	2.45
M <sub>4</sub> l <sub>2</sub>	42466	114717	72251	2.70
M <sub>4</sub> l <sub>3</sub>	40966	110989	70023	2.71
M <sub>4</sub> l <sub>4</sub>	40366	84495	44129	2.09

Chandrasekhrarao *et al.* [7] observed that TNAU seed drill recorded substantial saving in cost of cultivation due to avoidance of nursery preparation and transplanting. Kumar *et al.* [21] also found that the production cost could be reduced with the field water tube method of irrigation.

Higher gross return, net return and B:C ratio of 127795, 83329, 2.87, respectively were observed with machine transplanting under unpuddled soil with irrigation after formation of hairline crack (M<sub>3</sub>l<sub>2</sub>), which showed negligible difference with machine transplanting under unpuddled soil combined with irrigation when water level reaches 5 cm bellow soil surface (M<sub>3</sub>l<sub>3</sub>). Higher grain yield obtained with those treatment (Fig. 1.) might be the reason for additional income that reflected in treatment efficiency. Rani and Jayakiran [26] also stated that higher B: C ratio was observed with machine transplanting compared to conventional method of transplanting. Chandrapala *et al.* [27] observed that irrigation after formation of hairline crack produced higher net returns and B:C ratio due to higher grain yield. In addition to that Mitra *et al.*, [28] and Singh *et al.* [29] also observed that higher B: C ratio was recorded in mechanized transplanting under unpuddled soil compared to puddled transplanting and drum sowing.

#### 4. CONCLUSION

Results of the study concluded that TKM 13 rice variety might be suitable to grow under deficit irrigation that was proved by proline increase under moisture stress condition. Among the establishment methods, machine transplanting under unpuddled soil recorded improved physiological parameters like crop growth rate, leaf area index, leaf area duration, yield and N, P, K uptake. Among the irrigation management practices, irrigation after formation of hairline crack recorded higher physiological parameter, yield and increased uptake of N, P, K, which was on par with irrigation when water level reaches 5 cm below soil surface. Machine transplanting under unpuddled soil combined with irrigation after formation of hairline crack recorded higher gross return, net return and B:C ratio. This was followed by machine transplanting under unpuddled soil combined with irrigation when water level reaches 5 cm below soil with minimum difference from the aforesaid treatment. Hence, it can be recommended that machine transplanting of rice under unpuddled soil combined with irrigation when water level reaches 5 cm below soil surface might be the best suitable technology for water deficit condition, which also produced higher return with minimum use of water in tank irrigated command area.

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## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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