RESEARCH ARTICLE

Studies on the Growth and Yield of Rice under Various Establishment Methods and Water Management Strategies in Tank Irrigated Command Areas

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ABSTRACT

To study the effect of various establishment and water management practices on rice, a field experiment was conducted at Periyar Vaigai Command (PVC) during summer 2019. The experiments comprised of four establishment methods in main plots *viz.,* conventional transplanting (M_1), machine transplanting under puddled soil (M_2), machine transplanting under unpuddled soil (M_3) and sowing with seed drill (M_4); four irrigation management practices in sub plots *viz.*, farmers' irrigation practice (I_1), Irrigation after formation of hairline crack (I_2), irrigation when water level reaches 5 cm below soil surface (I_3) and irrigation when water level reaches 10 cm below soil surface (I_4). The results of the study revealed that machine transplanting under unpuddled soil recorded 6.5 per cent higher yield compared to conventional manual planting. Among the irrigation management strategies, irrigation after formation of hairline crack recorded 8.1 per cent higher yield compared to farmer's irrigation practice, which was comparable with irrigation when water level reaches 5 cm below soil surface. Significant interaction was observed with establishment methods and irrigation management practices. This study concluded that machine transplanting under unpuddled soil combined with irrigation when water level reaches 5 cm below soil surface will be the suitable management technology to be adopted by the rice growing farmers in tank irrigated command areas.

Keywords: *Establishment methods; Irrigation management; Growth; Yield and Water productivity.*

INTRODUCTION

Rice is the most important staple food, eaten by more than a 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. Worldwide, water for agriculture is getting increasingly scarce and it is estimated that by 2025, 15–20 million ha of irrigated rice fields may suffer from water scarcity (CGIAR, 2016). In India alone drought will cause as much as 40% yield loss, amounting to 6,500 crores annually. In southern parts of India, mostly rice is grown in command areas under tank irrigation system. 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 suffer terminal stress and the farmers could not achieve higher yield.

Farmers are mostly following manual transplanting under puddled soil condition and puddling alone requires 200 mm of water, which is 16.12% of total water requirement. Puddling causes subsurface hardpan at 15-25 cm, it affected the root growth of the rice, which in turn reduced the nutrient availability (Boparai *et al*., 1992) and it required more energy for field preparations (Kumar and Ladha, 2011). To overcome these problems, machine transplanting in unpuddled soil condition can be an alternate strategy, which alsoensures optimum plant population. Direct sowing under puddled soil is also an effective technology to reduce labour requirement rather than transplanting, because transplanting required about 300 to 350 man hrha^{-1} (Goel *et al*., 2008) but the TNAU drum seeder required only 16 man hr ha^{-1} to sow the seeds for a hectare of land (Chandrasekhrarao *et al*., 2013). Moreover, labour scarcity in agricultural

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sector is the emerging problem due to migration of labours from the villages to nearby cities.

Continuous flooding is the common practice followed by the farmers and it consumes large quantity of water. Adopting appropriate irrigation management strategies will save huge quantity of water and helps to bringmore area under cultivation. It also avoid complete crop failures under water deficit situations. Irrigation after the disappearance of ponded water will improve soil aeration and enhance the water use efficiency. Safe alternate wetting and drying can be recommended as a water saving technology that demands irrigation when water depth falls to a threshold depth of below the soil surface by using the field water tube. Several studies revealed that safe AWD significantly reduced the water input without penalty in rice grain yield (Samoy *et al*., 2008). It is highly essential to evolve the most suited irrigation management strategy under various establishment methods of rice cultivationthat could be recommended to the rice growing farmers in command areas. Hence, a field experiment was conducted to evaluate the growth and yield of rice under various establishment methods and irrigation management strategies to sustain rice production.

MATERIAL AND METHODS

The field experiment was conducted during summer 2019 at Agricultural College and Research Institute, Tamil Nadu Agricultural University, Madurai, Tamil Nadu, India. The experimental field comes under Periyar Vaigai Command area and is located at 9˚54' N latitude and 78˚54' E longitude at an altitude of 147 m above MSL. Soil texture was sandy clay loam. pH of the soil was 7.2, organic matter of the soil was 0.81%, soil available N was 242.6 kg ha^{-1}, available P was 16.9 kg ha^{-1} and available K was 432.7 kg ha^{-1}. The experiment was laid out in strip plot design with 16 treatment combinations and three replications. The treatments comprised of four different methods of establishment *viz*., conventional transplanting (M_1), machine transplanting under puddled soil (M_2), machine transplanting under unpuddled soil (M_3) and sowing with seed drill (M_4), respectively in main plots and four irrigation management methods in sub plots *viz*., farmers' irrigation practice (continuous submergence of 5 cm throughout the crop period) (I_1), Irrigation after formation of hairline crack (irrigation was given to the depth of 2.5 cm) (I_2), irrigation when water level reaches 5 cm below soil surface (each irrigation was given to the depth of 2.5 cm) (I_3) and irrigation when water level reaches 10 cm below soil surface (each irrigation was given to the depth of 2.5 cm) (I_4). The medium duration fine grain rice variety TKM 13 was used for experimentation. All the nutrient and weed management practices were followed as per TNAU recommendation. All the biometric observations like plant height (cm), tillers m^{-2},drymatter production (DMP) (kg ha^{-1}), root length (cm), root dry weight (g plant^{-1}) and root volume (cc plant^{-1}) were observed during physiological maturity and yield attributes *viz*, number of productive tillers m^{-2}, number of grains per panicle, panicle length, panicle weight and yield *viz*, grain yield, straw yield and harvesting index were recorded during harvest of the crop. These data were analysed statistically by following Gomez and Gomez (1984) method. Wherever the treatment differences were found significant (F test), critical differences were worked out at five per cent probability level and the values were furnished. Treatment differences that were not significant denoted as "NS".

RESULTS AND DISCUSSION

Plant height

Significantly higher plant height was observed with conventional method of transplanting (M_1) and recorded plant height of 108.0 cm compared to conventional manual transplanting (Table 1). Hugar *et al*., (2009) also observed that conventional method of transplanting produced taller plants. Among the irrigation management practices, taller plants were observed with farmers' method of irrigation (I_1) (109.6 cm) and it was on par with irrigation after formation of hairline crack (I_2). Continuous flooding increased the meristamatic cell activity and cell elongation that resulted in increased stem growth rate, ultimately promoted the plant height of rice (Chowdhury *et al*., 2014). The plant height was significantly decreased with increasing moisture stress (Sariam and Anuar, 2010).

Total number of tillers

Among the establishment methods, machine transplanting under unpuddled soil (M_3) produced distinctly more number of tillers m^{-2}(Table 1). However, it was on par with machine transplanting under puddled soil (M_2) (Table 1). Mechanical transplanter could produce optimum depth of planting under unpuddled soil condition and maintained optimum plant population (Kamboj *et al*., 2013 and Islam *et al*., 2014), Hossain *et al.,* 2017 stated that buried hill, floating hill or missing hill were not observed with machine transplanting under unpuddled situation, more over the more number of tillers m^{-2} under machine transplanting might be due to planting of more number of seedlings per hill, which resulted in increased number of tillers m^{-2} and efficient utilization of growth resources (Haque*et al*., 2016). Lesser number of tillers m^{-2} (298) was observed in sowing with seed drill, it might be due to poor establishment and population maintenance (Table 1).

Table 1. Effect of establishment methods and irrigation management practices on plant growth parameters of rice

Treatment	Plant height (cm)	Tillers m^{-2}	Drymatter production (kg ha^{-1})	Root length (cm)	Root dry weight (g)	Root volume (cc $hill^{-1}$)
Main plot						
M_1	108.0	362	13174	27.1	9.49	53.5
M_2	101.5	410	13370	28.5	10.05	54.1
M_3	102.7	419	13946	31.7	10.61	59.3
M_4	94.9	298	12335	25.8	8.69	51.3
SEd	2.5	8	312	0.8	0.19	1.2
CD (0.05)	6.1	20	765	1.8	0.47	3.0
Sub plot						
I_1	109.6	366	13497	24.6	9.94	54.7
I_2	105.6	422	14233	26.5	10.21	58.8
I_3	102.0	411	13961	29.8	10.09	55.0
I_4	90.1	290	11134	32.3	8.62	49.7
SEd	1.9	8	249	0.9	0.27	2.0
CD (0.05)	4.6	19	610	2.2	0.66	4.9
M X I						
SEd	5.0	13	450	1.4	0.40	2.8
CD (0.05)	NS	29	1021.13	NS	NS	NS
I x M						
SEd	4.7	13	409	1.5	0.44	3.2
CD (0.05)	NS	28	912.10	NS	NS	NS

Between the irrigation management practices, irrigation after formation of hairline crack (I_2) recorded higher number of tillers of 422m^{-2}, which was comparable with irrigation when water level reaches 5 cm below soil surface (Table 1). It might be due to better aeration, which enhanced the growth of root and nutrient absorption therefore resulted in more growth and tiller production. The same results were observed by Hameed *et al.* (2011) and Kunnathadi *et al*. (2015).

Table 2. Effect of establishment methods and irrigation management practices on yield parameters and yield of rice

Treatment	Productive tillers m^{-2}	Filled grains $panicle^{-1}$	Fertility percentage	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvesting index
Main plot						
M_1	290	224	91.7	5430	6967	0.438
M_2	304	229	92.3	5573	7067	0.441
M_3	342	249	93.0	5807	7256	0.445
M_4	252	205	90.8	4967	6403	0.437
SEd	7	5	1.4	118	142	0.009
CD (0.05)	16	12	NS	289	347	NS
Sub plot						
I_1	309	233	94.2	5404	6939	0.438
I_2	328	245	92.4	5878	7424	0.442
I_3	314	235	91.5	5658	7269	0.438
I_4	238	194	89.8	4837	6060	0.444
SEd	7	5	2.2	118	164	0.004
CD (0.05)	17	11	NS	290	400	NS
M x I						
SEd	10	6	4.0	174	205	0.013
CD (0.05)	23	15	NS	393	464	NS
I x M						
SEd	10	6	4.3	174	221	0.010
CD (0.05)	23	14	NS	394	505	NS

Various establishment and irrigation management practices showed significant interaction with each other. Machine transplanting under unpuddled soil condition combined with irrigation after formation of hairline crack (M_3I_2) recorded higher tiller number, which was comparable with Machine transplanting under unpuddled soil condition combined with irrigation when water level reaches 5 cm below soil surface (M_3I_3).

Drymatter production

Machine transplanting under unpuddled soil (M_3) produced 5.5 percent higher drymatter production than conventional transplanting (Table 1). This might be due to proper crop establishment because machine transplanting under unpuddled situation that recorded no floating or buried hill and missing hill (Hossain *et al.,* 2017), this in turn increased the number of tillers, number of leaves, leaf area index. Moreover, puddling created sub surface hardpan at 15-25 cm below soil surface (Kukal and Aggarwal, 2003) that hindered the root growth and ultimately affected the nutrient uptake. However, previously mentioned problem was avoided when transplanting was done under unpuddled soil and it promoted higher root growth and nutrient uptake by plant. In the presence of adequate nutrient availability and larger photosynthesizing surface, the drymatter accumulation preceded at a rapid rate leading to its greater accumulation. The results was in line with the findings of Haque *et al.*(2016).

Table 3. Effect of establishment methods and irrigation management practices on total water used and water productivity in rice

Treatment	Consumptive Use (mm)						Water productivity(kg m^{-3})				
	M_1	M_2	M_3	M_4	Mean		M_1	M_2	M_3	M_4	Mean
I_1	1253	1253	1292	1311	1277	I_1	0.43	0.43	0.46	0.38	0.42
I_2	1083	1083	939	1099	1051	I_2	0.54	0.56	0.65	0.50	0.56
I_3	839	839	764	844	822	I_3	0.68	0.68	0.77	0.63	0.69
I_4	764	764	714	749	748	I_4	0.63	0.68	0.74	0.54	0.65
Mean	985	985	927	1001			0.57	0.59	0.66	0.51	

Within the irrigation management practices, higher drymatter production of 14233 kg $ha^{-1}$was recorded with irrigation after formation of hairline crack (I_2). It was comparable with irrigation when water level reaches 5 cm below soil surface (I_3) during summer season (Table 1). The increase in DMP of rice with those treatments might be due to production of loose soil with increased aeration, which also facilitated more access to water and transport of nutrients such as nitrate (Gurovich and Oyarce, 2015). This might have helped better plant establishment with higher tiller production, improved leaf area and thick erect leaves.

Machine transplanting under unpuddled soil condition combined with irrigation after formation of hairline crack recorded higher drymatter production (15109 kg ha^{-1}), which was comparable with machine transplanting under unpuddled soil and irrigation when water level reaches 5 cm below soil surface. It was mainly due to improved growth parameters (Hossain *et al.,* 2017).

Root studies

Different method of establishment and water management practices influenced the root length; root volume and root dry weight. Machine transplanting under unpuddled soil (M_4) and irrigation when water level drops 10 cm below soil surface (I_4) registered the longer root length of 31.7 and 32.3 cm, respectively (Table 1). Non-availability of surface moisture increased the root length to extract moisture from the deeper layer.

Unpuddled machine transplanting (M_3) improved the root volume and root dry weight (Table 1) was due to better root activity compared to conventional puddled transplanting. Because under puddled condition, soil structure was destroyed, subsurface impervious hardpan was developed and lower depth of puddled soil had high bulk density, which in turn affected root growth in puddled transplanting (Garg *et al*., 2000), whereas under unpuddled soil, structure was maintained that enhanced the root growth and nutrient availability. The similar results were observed by Huang *et al*., (2011).

Irrigation after formation of hairline crack (I_2) favoured the root growth in terms of root volume and dry weight. It was on par with irrigation when water level reaches 5 cm below soil surface (I_3) (Table 1). Because in both the treatments the soil was kept with optimum moisture and aerated condition, this helped the plant root to get oxygen and water easily. This might favoured the better root growth in the recent study and Thakur *et al*., (2010), reported similar findings.

Yield attributes

More number of productive tillers (342m^{-2}) and grains per panicle (249) were observed with machine transplanting under unpuddled soil (M_3) (Table 2). This might be due to higher number of productive tillers, increased nutrient availability in soil, improved root activity, increased nutrient uptake, maintenance of optimum plant population per unit area, uniform depth of planting by machine transplanting under unpuddled soil (Haque *et al*., 2016). Uniform spacing increased the production of productive tillers and grains per panicle (Haque *et al*., 2016). Singh *et al.,* (2019) also confirmed that yield attributes like number of productive tillers m^{-2} and number of filled grains per panicle were higher under transplanting of rice under unpuddled condition compared to transplanting under puddled soil condition.

Among the irrigation management practices, irrigation after formation of hairline crack (I_2) recorded improved yield attributing characters of rice *viz*., number of productive tillers m^{-2}, number of grains panicle^{-1}, which was comparable with irrigation when water level reaches 5 cm below soil surface (I_3) (Table 2). Yield attributes closely linked with drymatterproduction during panicle formation (Pham *et al.,* 2004). Better aeration in the soil, profused root system and increased uptake of all other nutrients contributed for favourable growth attributes, which in turn produced higher yield attributes. This is in line with conclusions of Veeraputhiran *et al.,* (2010). Higher tiller production under irrigation after formation of hairline crack favoured production of higher number of productive tillers, due to the enhanced nutrient uptake and development of more floral and fruiting bodies *i.e.,* this treatment produced panicle with high productive components, which helped the sink to receive the photosynthates from assimilating surface and store effectively under favourable soil plant water status (Satyanarayana *et al.,* 2007).

Rice establishing methods and irrigation management practices showed significant interaction during summer season 2019. Machine transplanting under unpuddled soil with irrigation after formation of hairline crack (M_3I_2) registered more number of filled grains panicle^{-1} (Table 2). It also saved water to the tune of 27.7 % over conventional transplanting with farmers' irrigation practice (M_1I_1) (Table 3). This falls in line with the findings of Satyanarayana (2005) and Haque *et al.,*(2016).

Grain and straw yield

Significantly increased grain and straw yield were observed with machine transplanting under unpuddled soil (M_3) compared to machine transplanting under puddled soil (M_2), conventional method of transplanting (M_1) and sowing with seed drill (M_4) (Table 2). Higher yield of machine transplanting under unpuddled soil (M_1) might be due to improved root mass, increased nutrient availability, improved nutrient uptake, proper transplanting depth, higher hill density, uniform transplanting efficiency, lesser percentage of damaged hill and minimum percentage missing hill (Singh *et al.,* 2019, Hossain *et al.,* 2017 and Haque, 2016).

Improved grain and straw yield was observed with irrigation after formation of hairline crack (I_2). This was on par with irrigation when water level reaches 5 cm below soil surface (I_3) (Table 2).Thismight be due toincreased number of productive tillers m^{-2}, number of grain panicle^{-1}with high fertility percentage. Rotational irrigation (safe alternate wetting anddrying) improved soil aeration andimproved root growth and development, enhanced availability of nutrient throughout the crop growth which enriched yield attributes, thereby it increased rice yield. Ceesay *et al*., (2006) reported that the cycles of repeated wetting and drying improved rice growth and yield through increased nutrient availability.

Significant interaction was observed between establishment methods and irrigation management practices on rice grain and straw yield. Machine transplanting under unpuddled soil combined with irrigation after formation of hairline crack (M_3I_2) was observed with 13% increase in grain yield compared to conventional transplanting with farmers' irrigation practice of 5 cm of continuous flooding (M_1I_1) during summer 2019 (Table 2). It was comparable with machine transplanting under unpuddled soil combined with irrigation when water level reaches 5 cm below soil surface (M_3I_3).This might be due to improved root development, larger canopy, less intra plant competition, improved remobilization of assimilates to grain and higher nutrient availability.

Total water consumed and water productivity

Among the various establishment methods, machine transplanting under unpuddled soil (M_3) consumed minimum water (927 mm) and produced higher water productivity (0.66 kg m^{-3}) as compared to other methods of establishment. Farmers' method of irrigation (I_1) (5 cm of continuous submergence throughout the crop growing season) consumed more water (1277 mm) and produced lesser water productivity. Water productivity was maximum with irrigation when water level reaches 5 cm below soil surface (I_3).

CONCLUSION

From the experimental result, it could be concluded that machine transplanting under unpuddled soil condition improved plant growth parameters *viz*., plant height, tillers m^{-2}, drymatter production, root length, root dry weight and root volume. Among the irrigation management practices, irrigation after formation of hairline crack registered increased growth parameter, which was comparable with irrigation whenwater level reaches 5 cm below soil surface. Yield parameters *viz.,* productive tillers, filled grains panicle^{-1} and grain yield, strawyield also higher withmachine transplanting under unpuddled soil condition and irrigation after formation of hairline crack, which was comparable with irrigation whenwater level reaches 5 cm below soil surface. Higher water productivity was recorded withmachine transplanting under unpuddledsoil condition combined with irrigation whenwater level reaches 5 cm below soil surface.Hence, machine transplanting under unpuddled soil condition and scheduling of irrigation when water level reaches 5 cm below soil surfacecan be recommended to the rice growing farmers in tank irrigated command areasto sustain rice production.

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Ethics statement

No specific permits were required for the described field studies because no human or animal subjects were involved in this research.

Originality and plagiarism

Authors should ensure that they have written and submit only entirely original works, and if they have used the work and/or words of others, that this has been appropriately cited. Plagiarism in all its forms constitutes unethical publishing behavior and is unacceptable.

Consent for publication

All the authors agreed to publish the content.

Competing interests

There were no conflict of interest in the publication of this content

AUTHOR CONTRIBUTIONS

Research grant-AK; Idea-SS; Conceptualization-SS; SS,AK'; Experiments-SS,SS,AK ; Guidance-SS,AK,BR,TS,RA; Writing-original draft-SS;Writing-reviewing &editing-SS,TS, RA

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