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Influence of Drip Irrigation and Fertigation Levels on Physiological Characters and Yield of Aerobic Rice (*Oryza sativa* L.)

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ABSTRACT

Background: Water shortage is becoming severe in many rice growing areas in the world. Conventional method of irrigation, which not only consumes huge water, but also causes severe water and nutrient losses under anaerobic condition. Introduction of aerobic rice, growing high yielding rice in non-puddled and non-flooded aerobic soil with the support of external inputs like supplementary irrigation, manures and fertilizers can reduced water use and increase rice production.

Methods: Study on different levels of drip irrigation and fertigation on physiological characters and yield of aerobic rice was conducted during summer 2022 and 2023 at research farm of wetland in Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu. The experiment was laid out in randomized complete block design with thirteen treatments, replicated thrice.

Result: The findings revealed that drip fertigation @ 100% PE up to 30 DAS+150% PE up to 60 DAS+200% PE up to 90 DAS with 125% RDF (25% through NF+75% through WSF) resulted significantly higher leaf area index (5.84 and 5.95), chlorophyll index (SPAD) (41.5 and 42.3) and grain yield (4315.9 and 4446.1 kg ha^{-1}) respectively than all other treatments during both summer 2022 and 2023. However, significantly lower leaf area index (2.70 and 2.91), chlorophyll content (31.9 and 32.2) and yield (2301.0 and 2364.8 kg ha^{-1}) observed with fertigation at 50% PE up to 30 DAS+100% PE up to 60 DAS+150% PE up to 90 DAS with 75% RDF (75% through NF+25% through WSF), respectively in summer 2022 and 2023.

Key words: Aerobic rice, Chlorophyll content, Fertigation, Leaf area, Normal fertilizer, Water soluble fertilizer.

INTRODUCTION

Rice (*Oryza sativa* L.) holds significant global importance as the predominant staple food crop in Asia, catering to over half of the world's population. Ensuring rice security is vital for food security in the region, with 90 per cent of rice consumption occurring in Asia. In India, rice cultivation covers a vast area of 46.27 million hectares, making it the largest rice-growing country, with a production of 129.4 million metric tons and an average productivity of 2.80 metric tons per hectare. Specifically, in Tamil Nadu, rice is cultivated across 2.21 million hectares, yielding a production of 7.90 million metric tons and an average productivity of 3.56 metric tons per hectare. These statistics underscore the critical role rice plays in sustaining livelihoods and nourishing populations across the globe (Indiastat, 2021-22). Traditional rice production involves submerged conditions with approximately 5 to 10 cm deep standing water throughout the crop growth period. This system requires around 3000 to 5000 litres of water for producing one kg of grain which is about twice or even more than that for wheat or maize (Joshi *et al*., 2009). The groundwater table is declining in many rice growing regions at an alarming rate and 60% of the total irrigation water is diverted for rice cultivation (Vijayakumar *et al*., 2018). The water use efficiency of conventional transplanted rice is very low (3-4 kg/ha mm). The increasing scarcity of fresh water for agriculture and the competing demand from the non-agricultural sector threaten the sustainability of the irrigated rice ecosystem. To cope up with scarcity, development and adoption of water-saving technologies is crucial to overcome the declining

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irrigation water availability for the agricultural sector (Subramanian *et al*., 2008; Vijayakumar *et al*., 2019). The International Rice Research Institute (IRRI) developed aerobic rice technology, wherein the crop is established in non-puddled, non-flooded fields and rice is grown like an upland crop with adequate inputs and supplementary irrigation when rainfall is insufficient (Prasad, 2011). Aerobic rice with micro irrigation practices leads to sustainable rice production for immediate future to address water scarcity with more benefits and environmental safety in the scenario of global warming by reduced methane emission is an added advantage (Parthasarathi *et al*., 2012). Drip irrigation can reduce water use (>50%) and provide higher productivity in many crops (Singh *et al.* 2019a, Subramanian *et al.* 2021). Surface (1607-1733 litres) and subsurface (938–1110 litres) drip irrigation significantly reduced quantity of water needed to produce 1 kg of paddy compared to conventional continuous flooding (4658-5508 litres) (Singh *et al*., 2019a). Drip fertigation is a valuable tool in modern agriculture, enabling sustainable and water-efficient practices that contribute to increased productivity and resource conservation. Contrarily, traditional fertilisation may result with major nutrient losses due to leaching, percolation and volatilization (Rekha *et al*., 2015). Addressing these issues requires an introduction of drip irrigation in aerobic rice is one of the water-saving methods of growth of rice by direct seeding in un-puddled conditions without standing water and irrigating similar to another upland cereal crop. Keeping this in view, an attempt was made to evaluate the physiological characters and yield of aerobic rice (*Oryza sativa* L.) under drip irrigation system.

MATERIALS AND METHODS

The research was conducted at the wetland research fields of Tamil Nadu Agricultural University in Coimbatore, Tamil Nadu during two consecutive summer seasons in 2022 and 2023 to assess the effect of irrigation regime and fertigation level on physiological characters and yield of rice under drip system. The experiments were laid out in a randomized complete block design with 3 replications. These treatments were designed with different irrigation levels and fertilizers used with varying doses. The details of the treatments were given below Table 1. The experimental site is located at 11°_N, 77°_E coordinates and 426.7 meters above mean sea level (MSL) and clay loam with composition of 27.18% sand, 12.56% silt and 42.53% clay. Soil tests indicated that alkaline pH of 8.2, high organic carbon content (0.65%), low in nitrogen (225 kg ha^{-1}), medium in phosphorus (18 kg ha^{-1}) and high level of potassium (595 kg ha^{-1}). The field was ploughed and harrowed properly for sowing. Paddy seed (Co-51) was sown in dry soil with the spacing of 20×10 cm. The rainfall received during the cropping was measured by an automatic rain gauge installed in the automatic weather station. The rainfall received during the period is 78.40 and 17.5 mm and the effective rainfall was 47.04 and 10.5 mm and it was worked out by using the daily water balance sheet method during the summer season 2022 and 2023. The 16 mm laterals were laid out at 80 cm distance between the laterals and the emitter's spacing was 40 cm. The emitter discharge rate was 4 litre/h. Based on the evaporation value from the open pan evaporimeter the drip irrigation was given every third day as per the treatments. The fertilizer recommendation for the crop was 100:50:50 kg NPK ha^{-1}, from which entire dose of P_2O_5 and K_2O and 50 % of N were applied as basal remaining 50% of N in two equal splits at 30 and 60 DAS applied for treatment soil application of fertilizer through normal fertilizers (T_{10} to T_{13}). Normal fertilizer used for soil applications were Urea, di ammonium phosphate (DAP), single super phosphate (SSP), muriate of potash (MOP) and for fertigation calcium ammonium nitrate (CAN), mono ammonium phosphate (MAP) and potassium nitrate (KNO_3) as water soluble fertilizer. The two years mean data on various characters were statistically analyzed as suggested by Gomez and Gomez (1984). Wherever statistical significance was observed critical difference (CD) at 0.05 level of probability was worked out for comparison. The observations were recorded in experiment on five randomly tagged plants at centre of in each plot and the mean value was recorded as leaf area index and chlorophyll content (SPAD).

Leaf area index

Leaf area index (LAI) is the ratio of leaf area to ground area. Leaf length and breadth of the third leaf from the top was measured from five randomly selected plants during 90 DAS. The numbers of leaves were also counted in the same sampling plants and leaf area index was calculated as suggested by Palaniswamy and Gomez (1974), using the formula as below:

$$\text{LAI} = \frac{\text{L} \times \text{B} \times \text{K} \times \text{Total numbers of green leaves hill}^{-1}}{\text{Spacing (cm}^2\text{)}}$$

Where,

L- Length of the third leaf from top (cm).

B- Breadth of the third leaf from top (cm).

K- Constant (0.75).

Leaf chlorophyll estimation (SPAD)

Chlorophyll content of leaves was recorded as described by Peng *et al.* (1993) using the Chlorophyll meter (SPAD-502, Soil Plant Analysis Development, Minolta Camera Co. Ltd., Japan). The readings were recorded from fully expanded upper most leaves in five randomly chosen plants at 90 DAS. The average values were worked out and expressed as Chlorophyll index.

Grain yield

After harvesting, the plants from each net plot were manually threshed, and the yield from each plot was sun-dried, cleaned, winnowed, and weighed. The grain yield was then calculated at a moisture content of 14% and expressed in kilograms per hectare (kg/ha).

RESULTS AND DISCUSSION

The mean values were higher in summer season of 2023 when compared with 2022 season with respect to leaf area index, chlorophyll content (SPAD) and grain yield (kg ha^{-1}).

Leaf area index and leaf chlorophyll index

Irrespective of growth stages the physiological parameters like leaf area index and chlorophyll index were greatly influenced by different irrigation regimes and fertigation levels. The influence of drip irrigation and fertigation treatments on growth characters of aerobic rice had significant relation and increased as increases the fertigation levels throughout the growth period during season of 2022 and 2023 (Table 2). The results were reported that application of DF @ 100% PE up to 30 DAS+150% PE up to 60 DAS+200% PE up to 90 DAS with 125% RDF (25% through NF+75% through WSF) (T_9) was noted significantly superior leaf area index (5.84 and 5.95) and chlorophyll content (41.5 and 42.3) during summer 2022 and 2023, respectively as compared to other treatments. But this was found to be on par with treatment T_6 and T_8 in both 2022 and 2023, but on par with T_{12} in summer of 2023 with respect to leaf area index. Whereas, treatment T_9 also shown as on par results with T_6 with pertained to leaf chlorophyll index in both years of experimentation. However, significantly lower leaf area index (2.70 and 2.91), chlorophyll content (31.9 and 32.2) was recorded with DF @ 50% PE up to 30 DAS+100% PE up to 60 DAS+150% PE up to 90 DAS with 75% RDF (75% through NF+25% through WSF) (T_1) during both the season of 2022 and 2023 respectively.

The treatment DF @ 100% PE up to 30 DAS+150% PE up to 60 DAS+200% PE up to 90 DAS with 125% RDF (25% through NF+75% through WSF) (T_9) was recorded superior LAI. This might be due to the soil moisture and N induced enhancement in the leaf area and these were in line with Rajwade *et al*. (2018), who found increased rice growth by N application rates (Parthasarathi *et al*., 2018). The photosynthetic activity of plant depends upon leaf area. During current investigation, the LAI was increased with increase of water and nutrient supply throughout the crop growing period which favours the better translocation of photosynthates. This could be due to production of higher number of leaves with increase in leaf area and delayed leaf senescence by production of phytohormones, which was in similar with the findings of (Vanitha and Mohandass, 2014 and Naik *et al*., 2021). And these may be attributed to the production of higher number of tillers and leaves because of higher uptake of moisture and nutrients due to maintenance frequent application of irrigation and use of water-soluble fertilizers. Similar results were conformity with Rekha *et al.* (2015) and Naik *et al.* (2021). Lower irrigation and fertigation levels (T_1) resulted in a decrease in Leaf Area Index (LAI) possibly caused by reduced turgor pressure due to moisture stress. This condition adversely affected leaf cell expansion, leading to a reduction in LAI. Similar observations were also made by Ramdass and Ramanadan (2017).

Table 1: Treatments details.

T_1	Drip fertigation at 50% PE up to 30 DAS+100% PE up to 60 DAS+150% PE up to 90 DAS with 75% RDF (75% through NF+25% through WSF)
T_2	Drip fertigation at 75% PE up to 30 DAS+125% PE up to 60 DAS +175% PE up to 90 DAS with 75% RDF (50% through NF+50% through WSF)
T_3	Drip fertigation at 100% PE up to 30 DAS+150% PE up to 60 DAS+200% PE up to 90 DAS with 75% RDF (25 % through NF+75% through WSF)
T_4	Drip fertigation at 50% PE up to 30 DAS+100% PE up to 60 DAS+150% PE up to 90 DAS with 100% RDF (75% through NF+25% through WSF)
T_5	Drip fertigation at 75% PE up to 30 DAS+125% PE up to 60 DAS+175% PE up to 90 DAS with 100% RDF (50% through NF+50% through WSF)
T_6	Drip fertigation at 100% PE up to 30 DAS+150% PE up to 60 DAS+200% PE up to 90 DAS with 100% RDF (25% through NF+75% through WSF)
T_7	Drip fertigation at 50% PE up to 30 DAS+100% PE up to 60 DAS+150% PE up to 90 DAS with 125% RDF (75% through NF+25% through WSF);
T_8	Drip fertigation at 75% PE up to 30 DAS+125% PE up to 60 DAS+ 175% PE up to 90 DAS with 125% RDF (50% through NF+50% through WSF);
T_9	Drip fertigation at 100% PE up to 30 DAS+150% PE up to 60 DAS+200% PE up to 90 DAS with 125% RDF (25% through NF+75% through WSF)
T_{10}	Drip irrigation 50% PE up to 30 DAS+100% PE up to 60 DAS+150% PE up to 90 DAS with 100% RDF through soil application of normal fertilizer
T_{11}	Drip irrigation 75% PE up to 30 DAS+125% PE up to 60 DAS+175% PE up to 90 DAS with 100% RDF through soil application of normal fertilizer
T_{12}	Drip irrigation 100% PE up to 30 DAS+150% PE up to 60 DAS+200% PE up to 90 DAS with 100% RDF through soil application of normal fertilizer
T_{13}	Surface irrigation @ IW/CPE ratio of 1.20 with soil application of 100% RDF

PE: Pan evaporation; DAS: Days after sowing; RDF: Recommended dose of fertilizer; NF: Normal fertilizer; WSF: Water soluble fertilizer; CPE: Cumulative pan evaporation

Table 2: Leaf area index and leaf chlorophyll index (SPAD) of aerobic rice as influenced by drip irrigation and fertigation levels during *summer* 2022 and 2023.

Treatments	Leaf area index hill^{-1}		Leaf chlorophyll index	
	2022	2023	2022	2023
T_1: DF @ 50% PE up to 30 DAS+100% PE up to 60 DAS+150% PE up to 90 DAS with 75% RDF (75% through NF+25% through WSF)	2.7±0.15	2.91±0.08	31.9±0.8	32.2±1.1
T_2: DF @ 75% PE up to 30 DAS+125% PE up to 60 DAS +175% PE up to 90 DAS with 75% RDF (50% through NF+50% through WSF)	3.03±0.12	3.1±0.1	33±1.6	33.3±1.8
T_3: DF @ 100% PE up to 30 DAS+150% PE up to 60 DAS+200% PE up to 90 DAS with 75% RDF (25% through NF+75% through WSF)	4.47±0.35	4.66±0.35	35.8±2.2	36.1±2.3
T_4: DF @ 50% PE up to 30 DAS+100% PE up to 60 DAS+150% PE up to 90 DAS with 100% RDF (75% through NF+25% through WSF)	3.56±0.57	3.63±0.04	33.9±0.7	34.2±0.8
T_5: DF @ 75% PE up to 30 DAS+125% PE up to 60 DAS +175% PE up to 90 DAS with 100% RDF (50% through NF+50% through WSF)	4.23±0.32	4.48±0.35	35.2±1.8	36.1±2
T_6: DF @ 100% PE up to 30 DAS+150% PE up to 60 DAS+200% PE up to 90 DAS with 100% RDF (25% through NF+75% through WSF)	5.47±0.37	5.61±0.41	38.2±0.8	38.1±1.1
T_7: DF @ 50% PE up to 30 DAS+100% PE up to 60 DAS+150% PE up to 90 DAS with 125% RDF (75% through NF+25% through WSF)	3.72±0.54	3.8±0.41	34.1±1.1	34.8±1.4
T_8: DF @ 75% PE up to 30 DAS+125% PE up to 60 DAS +175% PE up to 90 DAS with 125% RDF (50% through NF+50% through WSF)	5.17±0.13	5.31±0.56	36.2±1.6	36.7±1.9
T_9: DF @ 100% PE up to 30 DAS+150% PE up to 60 DAS+200% PE up to 90 DAS with 125% RDF (25% through NF+75% through WSF)	5.84±0.29	5.95±0.33	41.5±1.2	42.3±1.2
T_{10}: DI @ 50% PE up to 30 DAS+100% PE up to 60 DAS+150% PE up to 90 DAS with 100% RDF through soil application of normal fertilizer	3.25±0.21	3.42±0.36	33.3±0.6	33.8±0.5
T_{11}: DI @ 75% PE up to 30 DAS+125% PE up to 60 DAS +175% PE up to 90 DAS with 100% RDF through soil application of normal fertilizer	4.05±0.3	4.25±0.47	35±3.3	35.2±3.2
T_{12}: DI @ 100% PE up to 30 DAS+150% PE up to 60 DAS+200% PE up to 90 DAS with 100% RDF through soil application of normal fertilizer	4.83±0.5	4.96±0.48	36.2±2.1	37.1±1.7
T_{13}: Surface irrigation @ IW/CPE ratio of 1.20 with soil application of 100% RDF	3.87±0.12	4.03±0.16	34.5±1.4	34.2±1.5
SE.d	0.5	0.5	2.37	2.46
CD (P=0.05)	1.0	1.0	4.90	5.08

The total chlorophyll content is a crucial indicator of crop growth. When using drip irrigation, the rise in chlorophyll levels can be attributed to the synthesis of new chlorophyll pigments facilitated by root zone fertigation, which was in line with findings of Vanitha (2011) and demonstrated significant increases in chlorophyll content through drip biogation. Additionally, under drip irrigation systems, the carboxylation efficiency of rice was enhanced, resulting in a notable improvement in leaf photosynthesis rates and overall canopy photosynthesis (Parthasarathi *et al*., 2018). The drip treatments such as T_9 followed similar increase in photosystem-II efficiency was a result of the presence of sufficient moisture and nutrients in the root zone. This favorable condition helps protect the pigment system by minimizing photo inhibition caused by excessive energy dissipation. Enhanced chlorophyll synthesis with nutrient supplied through drip fertigation and reduced leaf chlorophyllase activity led to higher chlorophyll content (Parthasarathi *et al*., 2017). Stress fewer conditions prevailed during the growth period of rice must have increased the chlorophyll content there by increased greenness owing higher chlorophyll content. These findings were also in conformity with the evidence of Ramdass and Ramanadan (2017).

Grain yield

In the given Table 3, the application of treatment DF @ 100% PE up to 30 DAS+150% PE up to 60 DAS+200% PE up to 90 DAS with 125% RDF (25% through NF+75% through WSF) (T_9) recorded significantly higher grain yield (4315.9 and 4446.1 kg ha^{-1}), respectively in summer 2022 and 2023 than all other treatments, but at par with T_6 followed by T_8 during both years. While, lower grain (2301.0 and 2364.8 kg ha^{-1}) was obtained respectively during 2022 and 2023 with application of DF @ 50% PE up to 30 DAS+100% PE up to 60 DAS+150% PE up to 90 DAS with 75% RDF (75% through NF+25% through WSF) (T_1). The higher grain yield of aerobic rice might be associated with increase in growth and physiological characters were observed under higher moisture regime. These findings were in agreement with outcomes of Ramdass and Ramanadan (2017). A sound source in terms of plant height, number of tillers to support and the number of leaves were rationally able to increase the leaf area and total drymatter and later lead to higher grain yield. These results are in conformity with the findings of (Balaji *et al*., 2015; Parthasarathi *et al*., 2018; Dada *et al*., 2020 and Naik *et al*., 2021). Lower yield was recorded during both the year of experimentation because the lowest fertility percentage observed with drip fertigation at 50% PE up to 30 DAS+100% PE up to 60 DAS+150% PE up to 90 DAS with 75% RDF (75% through NF+25% through WSF) (T_1). This might be owing to less nutrient uptake results in reduced soil moisture levels at root zone depth, which prevents assimilates from being transferred to the grains. Similar findings were too accounted by Kombali *et al*. (2016).

Table 3: Yield (kg ha^{-1}) of aerobic rice as influenced by drip irrigation and fertigation levels during *summer* 2022 and 2023.

Treatments	Grain yield (kg ha^{-1})	
	Summer-2022	*Summer*-2023
T_1: DF @ 50% PE up to 30 DAS+100% PE up to 60 DAS+150% PE up to 90 DAS with 75% RDF (75% through NF+25% through WSF)	2301±132.3	2364.8±127.1
T_2: DF @ 75% PE up to 30 DAS+125% PE up to 60 DAS +175% PE up to 90 DAS with 75 % RDF (50% through NF+50% through WSF)	2625.1±58.5	2714.8±255.6
T_3: DF @ 100% PE up to 30 DAS+150% PE up to 60 DAS+200% PE up to 90 DAS with 75% RDF (25% through NF+75% through WSF)	3523.4±182	3606±73
T_4: DF @ 50% PE up to 30 DAS+100% PE up to 60 DAS+150% PE up to 90 DAS with 100% RDF (75 % through NF+25% through WSF)	2784.6±151.4	2921.2±127.8
T_5: DF @ 75% PE up to 30 DAS+125% PE up to 60 DAS +175% PE up to 90 DAS with 100% RDF (50% through NF+50% through WSF)	3189.7±486.9	3294.9±213.6
T_6: DF @ 100% PE up to 30 DAS+150% PE up to 60 DAS+200% PE up to 90 DAS with 100% RDF (25% through NF+75% through WSF)	3984.7±305.5	4117.9±271.9
T_7: DF @ 50% PE up to 30 DAS+100% PE up to 60 DAS+150% PE up to 90 DAS with 125% RDF (75% through NF+25% through WSF)	2917.9±68.7	3041.7±53.8
T_8: DF @ 75% PE up to 30 DAS+125% PE up to 60 DAS +175% PE up to 90 DAS with 125% RDF (50% through NF+50% through WSF)	3711.4±202.8	3804.5±270
T_9: DF @ 100% PE up to 30 DAS+150 % PE up to 60 DAS+200% PE up to 90 DAS with 125% RDF (25% through NF+75% through WSF)	4315.9±155	4446.1±153.3
T_{10}: DI @ 50% PE up to 30 DAS+100% PE up to 60 DAS+150% PE up to 90 DAS with 100% RDF through soil application of normal fertilizer	2680±197.1	2728.5±316.7
T_{11}: DI @ 75% PE up to 30 DAS+125% PE up to 60 DAS +175% PE up to 90 DAS with 100% RDF through soil application of normal fertilizer	3102.3±336.5	3198±466.5
T_{12}: DI @ 100% PE up to 30 DAS+150% PE up to 60 DAS+200% PE up to 90 DAS with 100% RDF through soil application of normal fertilizer	3662.2±87.9	3735±272.2
T_{13}: Surface irrigation @ IW/CPE ratio of 1.20 with soil application of 100% RDF	3001.8±153.9	3122.7±135.7
SE.d	311.17	316.7
CD (P=0.05)	642.25	652.61

*Significant at P≤0.05; NS-Non significant at P>0.05.

CONCLUSION

The field experimental results revealed that physiological parameters *viz*., leaf area index and SPAD meter values were positively correlated with different drip irrigation and fertigation levels and higher grain yield was reported in drip fertigationat 100% PE up to 30 DAS+150% PE up to 60 DAS+200% PE up to 90 DAS with 125% RDF (25% through NF+75% through WSF) in aerobic rice.

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Conflict of interest

Authors have declared that there was no competing interest exist.

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