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Impact of Irrigation and Fertigation Levels on Growth, Yield Components and Yield of Aerobic Rice (*Oryza sativa* L.) under Drip System

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ABSTRACT

Back ground: More than half of the world's population depends on rice, which is grown in transplanting conditions. Due to the global water crisis, irrigated rice systems are no longer sustainable. Therefore, cultivating aerobic rice with drip irrigation and fertigation meets the crop water and nutrient requirements, results in the optimal yield.

Method: A field experiment was conducted during *summer* 2022 and 2023 at Research Farm of Wetland in Tamil Nadu Agricultural University, Coimbatore, to evaluate the performance of aerobic rice under drip irrigation and fertigation levels on growth and yield of Co-51 variety. The experiment was laid out in randomized complete block design with combination of thirteen treatments, replicated thrice.

Results: Among different treatments, 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 superior growth characters *viz*., higher plant height (92.54 and 95.95 cm), no. of tiller m^{-2}(469.78 and 478.42), total drymatter production m^{-2} (988.21 and 1025.42 g m^{-2}), no. of filled grains panicle^{-1} (107.5 and 114.5), total no. of grains panicle^{-1} (122.6 and 127.1), fertility percentage (87.7% and 90.1%) and lower no. of ill filled grains panicle^{-1} (15.1 and 12.6), grain yield (4316 and 4446 kg ha^{-1}) and straw yield (5528 and 5775 kg ha^{-1}) as compared to others, during summer 2022 and 2023, respectively.

Key words: Aerobic rice, Fertigation, Grain and straw yield, Pan evaporation (PE).

INTRODUCTION

Globally, rice (*Oryza sativa* L.) is the most predominant staple food in Asia, consumed by more than a half of the world's population. In Asia, rice security is closely related with food security as 90% of rice is consumed in this region. In India the rice is being cultivated in 46.27 m ha, which is the largest area among all rice-growing countrieswith the production of 129.4 mt and the average productivity of 2.80 t ha^{-1}. In Tamil Nadu rice is cultivated in an area of 2.21 m ha, production of 7.90 m t and the average productivity of 3.56 t ha^{-1} (IndiaStat, 2021-22). On the other hand, the annual amount of water available per capita is decreasing. One hectare of rice field irrigated by flooding method consumes more than 20,000 m^3 of irrigation water and thereby evapotranspiration consumes 6000 to 8000 m^3 (Kruzhilin *et al.,* 2017). Conventional method of irrigation, which not only consumes huge water, but also causes severe water and nutrient losses under anaerobic condition (Naik *et al*., 2015). Traditional, rice farming practises not only waste water but also affect the ecosystem and diminish the efficacy of fertiliser use. Consequently, better water management is required for the cultivation of rice. Numerous strategies are being pursued to reduce water requirement of rice, such as alternate wetting and drying, system of rice intensification (SRI) and aerobic rice. In an aerobic rice, the crop is established in areas which are neither puddled nor flooded and rice is grown in an unsaturated environment with sufficient inputs and supplemental irrigation when precipitation was insufficient (Mandal *et al*., 2019). The water productivity of rice under aerobic conditions was 32-88 per cent higher than under flooded conditions. Drip fertigation enables the direct

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delivery of nutrients at the position of a substantial amount of actively growing roots and enables accurate adjustment of water and nutrient supplies to meet the crop requirements. Since, nutrients are applied to a limited soil volume, the fertilizer use efficiency also high. Contrarily, traditional fertilisation may result with major nutrient losses due to leaching, percolation and volatilization (Rekha *et al*., 2015). Hence, it is the need of the hour to elucidate existing information on the use of drip irrigation to rice for future strategies. Taking these points into account an investigation was carried out to evaluate the performance of different levels of drip irrigation and fertigation on growth, yield attributes and yield of aerobic rice.

MATERIALS AND METHODS

The present study on the effect of drip irrigation and fertigation levels on growth and yield of aerobic rice (*Oryza sativa* L.) was carried out during *summer* 2022 and 2023 on the Research Fields of Wetland in Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India and situated between 11°_N, 77°_E and 426.7 m above MSL. The soil type of the experimental site was clay loam, which belongs to the Noyyal series. The soil test result of the site revealed that pH was alkaline in nature (8.2), organic carbon content was in high (0.65%), low in nitrogen (225 kg ha^{-1}), medium in phosphorus (18 kg ha^{-1}) and high in potassium (595 kg ha^{-1}). During two years of experimentation period the crop was received 78.40 and 17.5 mm of actual rain fall and effective rainfall was 47.04 and 10.5 mm, respectively in *summer* 2022 and 2023. The mean maximum (33.77°C and 32.84°C) and minimum temperatures (23.47°C and 21.03°C) were observed, respectively during both the years of experimentation. The field experiment was taken up in three replicates of randomized complete block design with thirteen treatments. The treatments consisted with various combinations of irrigation levels, dose and type of fertilizers used (Table 1).

Seed of Co-51 variety used and maturing in about 110-120 days was planted at a spacing of 20×10 cm in rows accommodating 500000 plants ha^{-1}. Two uniform irrigations were given to all the treatments immediately after sowing for proper germination and establishment. Drip irrigation was given on every five days interval based on pan evaporation (Epan).

The irrigation was given through PVC pipe after filtering through the screen filter by 7.5 hp bore well. The pressure maintained in the system was 1.5 kg m^{-2}. From the sub main in line laterals are of 16 mm were laid out at spacing of 80 cm with 4lph discharge rate emitters positioned at 40 cm. Drip irrigation was schedule based on open pan evaporation as per the treatment after subtracting the effective rainfall for that period. Surface irrigation (T_{13}) was scheduled by surface method basedat 5.0 cm depth with IW/CPE ratio of 1.20 for rice. The fertilizers used for soil application were urea, di ammonium phosphate (DAP) and muriate of potash (MOP) and for fertigation calcium nitrate, mono ammonium phosphate (MAP) and potassium nitrate (KNO_3) used. 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}). However, fertilizer applied for treatments (T_1 to T_9) was given through fertigation in 26 equal splits at three days interval as per the treatments up to 90 DAS. The observations were recorded in experiment on five random plants at centre of row for growth components *viz.*, plant height, no. of tillers and total drymatter production, grain and straw yield at harvest. The experimental data recorded were subjected to analysis by using Fisher's method of Analysis of Variance (ANOVA). The levels of significance used in F and t test was p=0.05 (Gomez, 1984).

Table 1: Treatment details.

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)
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)
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)
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)
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)
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)
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)
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)
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)
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
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
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
T_{13}:	Surface irrigation @ IW/CPE ratio of 1.20 with soil application of 100% RDF

DF: Drip fertigation; DI: Drip irrigation; PE: Pan evaporation; DAS: Days after sowing; RDF: Recommended dose of fertilizer; NF: Normal fertilizer; WSF: Water soluble fertilizer; CPE: Cumulative pan evaporation.

RESULTS AND DISCUSSION

Growth parameters

The effect of drip fertigation and irrigation treatments on growth characters of aerobic rice had significant relation and increased as increases the fertigation levels throughout the growth period during summer 2022 and 2023 (Table 2). The findings 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) was registered significantly higher plant height (92.54 and 95.95 cm), total no. of tillers m^{-2} (469.78 and 478.42) and total dry matter production (TDMP) (988.21 and 1025.42 g m^{-2}) during summer 2022 and 2023, respectively as compared to other treatments. It was found to be on par with treatment T_6: DF 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) followed by T_8: DF 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) during two years of experimentation. However, significantly lower plant height (72.45 and 73.03 cm), number of tillers m^{-2} (338.59 and 345.52) and TDMP (577.12 and 579.04 g m^{-2}) was recorded with 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) during 2022 and 2023 respectively. In general, the plant ability to grow depends on the availability of moisture and nutrients in continuous manner. The higher plant growth might be due to higher cell elongation and cell division was caused by constant availability of moisture at the root zone and an increase in nutrient uptake by the plant. The experimental outcomes are fall in line with the findings of Govindan and Grace (2012); Karthika and Ramanathan (2019); Naik *et al*. (2021) and Mariyappillai *et al*. (2022). Higher number of tiller production was noted with DF 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) might be due to good crop, root growth and availability of nutrients throughout growth stages which ultimately increased tiller density (Duary and Pramanik, 2019). Dry matter production increased with increased level of water and nutrients (T_9) due to water soluble fertilizer through fertigation resulted in continues supply of nutrients besides maintaining optimum water availability which lead to higher uptake of nutrients which in turn good soil aeration throughout crop growth period might have favored faster cell division and elongation focused ultimately increased plant height, tiller numbers, more number of leaves and leaf area development leading to maintain total dry matter accumulation. Similar evidence was confined with findings of Kombali *et al*. (2016), Yamuna *et al*. (2018) and Mariyappillai *et al*. (2022). 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), Ramadas and Ramanathan (2017) and Naik *et al.* (2021). Govindan and Grace (2012) studied that the non-availability of water to rice causes a decrease in the amount of photo-synthetically active radiation intercepted, which in turn causes a decrease in leaf production, leaf area, plant height, a reduction in tillering and an increase in leaf senescence. But in surface irrigation treatments with soil application of nutrients in two splits, utilization was found lower due to intermittence of partial dry and wet period as soil moisture reduced with time between two applications (Yamuna *et al*., 2018).

Table 2: Growth parameters of aerobic rice as influenced by drip irrigation and fertigation levels at harvest during summer 2022 and 2023.

Treatments	Plant height (cm)		No. of tillers m^{-2}		Drymatter production (g m^{-2})	
	2022	2023	2022	2023	2022	2023
T_1	72.45	73.03	338.59	345.52	577.12	579.04
T_2	75.59	77.87	349.70	357.26	630.55	640.77
T_3	81.47	82.54	407.27	409.65	816.68	846.70
T_4	76.54	77.51	366.11	368.65	670.53	699.59
T_5	80.01	82.03	392.82	398.90	741.53	762.49
T_6	89.22	90.48	447.49	459.32	903.95	931.31
T_7	78.18	79.67	378.52	384.78	697.91	727.90
T_8	85.58	86.26	436.26	438.73	869.87	892.21
T_9	92.54	95.95	469.78	478.42	988.21	1025.42
T_{10}	76.06	77.16	354.59	362.20	646.15	653.63
T_{11}	79.94	81.06	379.34	391.95	735.91	754.30
T_{12}	83.62	85.38	410.17	418.40	840.40	880.50
T_{13}	79.51	80.72	377.04	385.98	718.62	727.01
SE.d	4.26	5.04	28.08	28.49	59.93	64.98
CD ($P\leq0.05$)	8.79	10.40	57.95	58.81	123.70	134.12

Treatment details are given under material and methods.

*Significant at $P\leq0.05$; NS- Non significant at $P>0.05$.

Yield components

Drip fertigation ultimately had significantly positive effect on the yield and yield components of aerobic rice when there were distinct variations in the yield components (Table 2 and 3). DF 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) obtained higher no. of filled grains panicle^{-1} (107.5 and 114.5), total no. of grains panicle^{-1} (122.6 and 127.1), fertility percentage (87.7 and 90.1%) and lower no. of ill-filled grains panicle^{-1} (15.1 and 12.6), during summer 2022 and 2023, respectively. But it was found to be at par with 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) followed by DF 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) with respect to no. of filled grains panicle^{-1} and total no. of grains panicle^{-1}. The lower number no. of filled grains panicle^{-1} (58.2 and 62.4), total no. of grains panicle^{-1} (83.4 and 87.5), fertility percentage (69.8 and 71.3%) and higher no. of ill-filled grains panicle^{-1} (25.2 and 25.1) respectively, during both years of experimentation. The yield attributes of rice tend to be reduced when irrigation was applied at lesser PE rates. Exposure of rice plants to even mild water stress causes tiller mortality and spikelet sterility which, in turn, reduce productive tillers m^{-2}and filled grains panicle^{-1}. Similar findings were accounted by Vijayakumar *et al.* (2019) and Subramanian *et al*. (2023).

Yield

In the Table 4, the grain and straw yield (4316 and 5528 kg ha^{-1} in 2022) and (4446 and 5775 kg ha^{-1} in 2023) was recorded with 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) was recorded significantly higher than all the treatments but on par with T_6: DF 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) and 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) during both season in 2022 and 2023, respectively. While, lower grain (2301 and 2365 kg ha^{-1}) and straw yield (3412 and 3403kg ha^{-1}) were obtained during summer 2022 and 2023 with application of 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). The grain yield in any crop is depends upon the photosynthetic source it can build up. A sound source in terms of plant height, number of tillers to support and the number of leaves were rationally able to increase the total drymatter and later lead to higher grain yield. Production and partitioning of drymatter are vital for determination of overall yield of the crop. These results are in conformity with the findings of Anusha, (2015), Balaji *et al*., (2015); Rekha *et al*., (2015); Parthasarathi *et al*., (2018); Dada *et al*., (2020) and Naik *et al*., (2021). The higher grain yield was recorded with might be owing to higher conducive situation for efficient water and nutrients uptake which boost their growth and yield attributes through supply of more photosynthates towards the reproductive sink. This results were in corroborates with the findings of Duary and Pramanik (2019). Lower yield was recorded during both the years of experimentation because the lowest fertility percentage observed with drip fertigation at 50% PE up to 30 DAS+100%

Table 3: Yield attributes of aerobic rice as influenced by drip irrigation and fertigation levels at harvest during summer 2022 and 2023.

Treatments	No. of filled grains panicle^{-1}		No. of ill-filled grains panicle^{-1}		Total no. of grains panicle^{-1}		Fertility percentage (%)	
	2022	2023	2022	2023	2022	2023	2022	2023
T_1	58.2	62.4	25.2	25.1	83.4	87.5	69.8	71.3
T_2	62.6	64.9	24.9	24.7	87.5	89.5	71.5	72.5
T_3	91.0	95.2	22.1	21.3	113.0	116.6	80.5	81.7
T_4	68.3	70.2	24.3	23.3	92.7	93.5	73.7	75.1
T_5	84.4	89.7	23.1	22.4	107.4	112.1	78.5	80.0
T_6	102.3	108.2	17.1	15.5	119.4	123.6	85.7	87.5
T_7	72.8	76.7	24.2	23.1	97.0	99.8	75.0	76.9
T_8	98.1	105.7	19.1	18.4	117.1	124.1	83.7	85.2
T_9	107.5	114.5	15.1	12.6	122.6	127.1	87.7	90.1
T_{10}	66.3	68.0	24.8	24.6	91.2	92.6	72.8	73.4
T_{11}	81.4	86.2	24.5	23.8	105.9	110.0	76.8	78.3
T_{12}	93.2	98.8	20.3	19.6	113.5	118.5	82.1	83.4
T_{13}	76.7	81.6	23.8	22.8	100.4	104.5	76.3	78.1
SE.d	4.9	5.2	1.8	1.6	5.3	5.7		
CD (P≤0.05)	10.1	10.7	3.8	3.3	10.9	11.7		

Treatment details are given under Material and Methods.

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

Table 4: Yield (kg ha^{-1}) of aerobic rice as influenced by drip irrigation and fertigation levels during summer 2022 and 2023.

Treatments	Summer-2022			Summer-2023		
	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	HI	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	HI
T_1	2301	3412	0.40	2365	3403	0.41
T_2	2625	3670	0.42	2715	3659	0.43
T_3	3523	4629	0.43	3606	4847	0.43
T_4	2785	3910	0.42	2921	4056	0.42
T_5	3190	4208	0.43	3295	4316	0.43
T_6	3985	5016	0.44	4118	5183	0.44
T_7	2918	3994	0.42	3042	4188	0.42
T_8	3711	4963	0.43	3805	5063	0.43
T_9	4316	5528	0.44	4446	5775	0.44
T_{10}	2680	3776	0.41	2728	3782	0.42
T_{11}	3102	4218	0.42	3198	4319	0.42
T_{12}	3662	4730	0.44	3735	5025	0.43
T_{13}	3002	4124	0.42	3123	4105	0.43
SE.d	311	323	0.01	316	347	0.03
CD ($P \le 0.05$)	642	666	0.03	652	715	0.06

Treatment details are given under Material and Methods.

*Significant at $P \le 0.05$; NS- Non significant at $P > 0.05$.

PE up to 60 DAS+150% PE up to 90 DAS with 75% RDF (75% through NF+25% through WSF). 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). There was no significance difference in harvest index among the treatments during both the year of experimentation.

CONCLUSION

The present study summarised 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) through drip fertigation was ideal for getting higher growth, yield components and yield as compared to soil application of 100% RDF with normal fertilizers during summer 2022 and 2023.

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