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RESEARCH ARTICLE

Assessment of impulse drip irrigation systems on performance on aerobic rice

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SUMMARY

Drip irrigation study was conducted in aerobic rice during dry season (DS) 2011 in Coimbatore, Tamil Nadu, India. Treatments namely; surface, three lateral distances (0.6, 0.8, 1.0 m) with two discharge rates (0.6 or 1.0 lph emitters) and a conventional aerobic rice treatment. Laterals spaced at 0.8 m with 1.0 lph drip fertigation exhibited better performance in yield and its components and achieved better water productivity when compared with the conventional irrigation treatment. Therefore, it is suggested that the lateral spacing of 0.8 m with 1.0 lph drippers when the plants spaced at 20x10 cm through fertigation is adjudged as the best treatment for aerobic rice cultivation in enhancing the values for water productivity and grain yield in the areas of limited water availability.

Key Words : Aerobic rice, Discharge rates, Lateral distance, lph (litre per hour), Micro irrigation

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Rice plants under aerobic systems undergo several cycles of wetting and drying conditions (Matsuo and Mochizuki, 2009). Application efficiency of different surface and pressurized irrigation methods varies and depends on design, management and operation (Holzapfel and Arumí, 2006). Aerobic rice varieties will possess large numbers of spikelets and sufficient adaptation to aerobic conditions such that they will consistently achieve yields comparable to the potential yield of flooded rice (Kato *et al*., 2009). Karlberg *et al.* (2007) reported that two low-cost drip irrigation systems with different emitter discharge rates were used to irrigate tomatoes and concluded that combination of drip systems with plastic mulch increased the yield. Xue *et al.* (2007) reported an average yield of aerobic rice was 4.1 t ha^{-1} with 688 mm of total water input in 2003 and 6.0 t ha^{-1} with 705 mm of water input. Ibragimov *et al.* (2007) compared drip and furrow irrigation in cotton and inferred that 18-42% of the irrigation water could be saved with drip systems with increased irrigation water use efficiency (35-103%) compared to furrow irrigation.

Considering the above, objectives of this experiment were set out to study the performance of aerobic rice, optimize the lateral distance and discharge rate for better grain yield, compare water requirements, water productivity and yield relationship in varied drip-irrigation treatments consisting of three lateral spacings with two levels of emitter discharge rate.

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MATERIAL AND METHODS

The experiment was conducted during dry season 2011 (DS 2011) in the wetlands of Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India. Field experiment design of Randomized Block Design was adopted with three replications using ADT (R) 45 as the test variety. The irrigation was given through PVC pipe (40 mm OD) after filtering through the screen filter by 7.5 HP motor from the bore well.

The pressure maintained in the system was 1.2 kg cm^{-2}. From the sub-main, in-line laterals were laid at a spacing of 0.8 m with 0.6 or 1.0 lph discharge rate emitters positioned at a distance of 30 cm. Irrigation was given based on the open pan evaporation (PE) values (125% PE). The effective rainfall was calculated using water balance sheet method (Dastane, 1974). There were eleven treatments employing three lateral spacings and two discharge rates of emitters. The treatments were: distance between laterals 0.6 m with the spacing of 20 cm between rows of plants and spacing of 10 cm between plants (T_1), distance between laterals 0.6m, spacing between rows of plants from lateral (20x10x10x20) (instead of three rows of 20 cm each) (T_2), lateral distance of 0.8 m, spacing of 20 cm between rows of plants and spacing of 10 cm between plants (T_3), lateral distance of 0.8 m, spacing between rows of plants from lateral (5x20x30x20x5) (instead of four rows of 20 cm each) (T_4), lateral distance of 1.0 m, spacing of 20 cm between rows of plants and spacing of 10 cm between plants (T_5), laterals distance of 1.0 m, spacing between rows of plants from lateral (7.5x15x15xempty bed (25cm) x15x15x7.5) (instead of five rows of 20 cm each) (T_6), laterals distance of 0.8 m, spacing of 20 cm between rows and spacing of 10 cm between plants + 30 per cent more water (T_7), lateral distance of 1.0 m, spacing of 20 cm between rows of plants and spacing of 10 cm between plants + 30 per cent more water (T_8), lateral distance of 0.8 m, spacing between rows of plants from lateral (5x20x30x20x5) (instead of four rows of 20 cm each) with 0.6 lph drippers (T_9), lateral distance of 1.0 m, spacing between rows of plants from lateral (7.5x15x15xempty bed (25cm) x15x15x7.5) (instead of five rows of 20 cm each) with 0.6 lph drippers (T_{10}) and conventional irrigation at IW/CPE ratio of 1.25 at 30 mm depth of irrigation (conventional irrigation) (T_{11}).

The weather parameters prevailed during cropping season were observed in Agromet Observatory in Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India. The average values for maximum, minimum temperature were 30.7^0 C, 22.7^0 C, sunshine hours of 5.7 h d^{-1}. The total evaporation recorded was 628.3 mm with the total precipitation of 533.0 mm. Fertilizer dose of 150:50:50 kg ha^{-1} NPK in the form of water-soluble fertilizers was supplied through fertigation by the ventury flume at a rate of weekly interval splits.

Yield and yield components:

The yield and its components were recorded at the time of harvest. The number of panicles, number of spikelets, filled grain percentage, 1000 grain weight (Test weight), harvest index (HI) were recorded based on the method of Yoshida *et al.* (1971) Harvesting of crop (grain) from each treatment and replication was made from the net plot. After thrashing the grains, weight of the grain was taken. Grain yield per hectare was calculated from the mean plot yield and expressed in kg ha^{-1} at 14 % moisture content. Water productivity was calculated as the weight of grains produced per unit of water input (irrigation and rainfall) as per the formula of Yang *et al.* (2005) and expressed as g grain kg^{-1} of water. The recorded data were subjected to statistical analysis in the Randomized Block Design (RBD) using ANOVA Package (AGRES version 7.01) following the method of Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Effect of drip irrigation treatments on yield components of aerobic rice showed significant differences among the treatments except test weight. Higher number of panicles was produced in T_3 (681.4 panicles m^{-2}), followed by T_1 (664.5 panicles m^{-2}), T_2 (659.4 panicles m^{-2}), T_4 (651.3 panicles m^{-2}) and lesser number in T_{10} (581.9 panicles m^{-2}) (Table 1). The productive tiller number recorded a higher significance (0.824**) with grain yield of aerobic rice (Table 3). Rahman *et al*. (2002) showed that the number of panicles per hill and number of filled grains per panicle significantly decreased with the moisture stress at critical stages of booting, flowering and grains filling. The amount of spikelet sterility is a physiological indicator of whether the fundamentally different alternative to flood-based cultivation could be successful at a given site (Bouman *et al*., 2006). The spikelet numbers per panicle recorded significantly more in T_3 (142.6) and very less in T_{10} (95.4). Increasing the number of spikelets should be a primary target, as this had helped to increase the yield of rice even under water limitation (Peng *et al*., 2008). The filled grain percentage (FGP) also showed a similar response for the micro irrigation treatments. Significantly superior FGP values were registered in T_3 (89.0 %) followed by T_1 (88.1 %), T_2 (84.4 %), T_4 (83.9 %) and the lower in T_{10} (71.1 %) (Table 1). The reduction in spikelet production under reduced water supply might be due to the abortion of spikelets in the secondary rachis branch, as documented by Kato *et al*. (2008) in aerobic rice.

The micro irrigation treatments showed a significant difference for grain test weight. The test weight of aerobic rice on various micro irrigation treatments has no significant difference among the treatments. The reduction in test weight was due to poor translocation of assimilates causing reduction in filling. The number of fertile grains, total number of grains and 100-grain weight significantly decreased when plants were subjected to mild water stress under aerobic condition (Suriyan *et al*., 2010). Harvest index (HI) registered higher value in T_3 (42.8 %), followed by T_4 (42.6 %), T_{11} (41.6 %), T_2 (41.8 %), T_1 (41.4 %) and lower in T_9 (38.8 %) (Table 1). The T_3 treatment possessing higher HI values led to increased contribution for the yield increment. The ability to maintain a higher HI under aerobic conditions has also been reported to be a key factor to higher yields by Lafitte *et al*. (2002). Significantly higher grain yield was registered in T_3 treatment (5793 kg ha^{-1}) followed by T_1 (5554 kg ha^{-1}) with lower yield observed in T_{10} (3819 kg ha^{-1}) (Table 2). Optimal lateral spacing (0.8 m) was reasoned out for such an increase in yield due to an increased water use efficiency than the wider (1.0 m) or narrower (0.6 m) lateral spacing. The present study is in confirmation with the results of previous work with optimum lateral spacing in maize registering higher yield (Bozkurt *et al*., 2006).

Treatment T_1 resulting higher yield is supported by the increased yield, its components and better HI. A positive relation ship (0.697**) to HI with the grain yield obtained in present study. These results are in accordance with the study of Viraktamath (2006). Comparing the discharge variability,

Table 1 : Effect of drip irrigation on yield components of aerobic rice

Treatments	PT	SN	FGP	TW	HI
T_1	664.5	142.2	88.1	22.5	41.4
T_2	659.4	138.0	84.4	21.9	41.8
T_3	681.4	142.6	89.0	23.0	42.8
T_4	651.3	135.0	83.9	21.7	42.6
T_5	637.6	132.9	83.9	21.2	40.5
T_6	627.9	122.7	82.6	21.0	40.0
T_7	623.8	133.9	89.4	22.0	42.8
T_8	621.4	134.1	87.7	21.8	42.0
T_9	616.0	128.4	83.7	21.1	38.8
T_{10}	581.9	95.4	71.1	20.3	39.0
T_{11}	594.3	119.2	78.7	20.5	41.6
Mean	632.73	129.49	83.9	21.6	41.2
S.E.±	7.285	6.607	1.49	0.99	1.05
C.D (P<0.05)	15.196	13.782	3.11	NS	2.20

PT - Productive Tillers (Panicle m^{-2}); SN - Spikelet Number panicle^{-1}; NS=Non-significant
FGP - Filled Grain Percentage (%); TW- Test Weight; HI - Harvest Index

Table 2 : Effect of drip irrigation on water parameters on aerobic rice

Treatments	IW (mm)	ER (mm)	TWA (mm)	GY (kg ha^{-1})	WP (g kg^{-1})
T_1	444.6	102.4	547.0	5554	1.015
T_2	444.6	102.4	547.0	5326	0.974
T_3	444.6	102.4	547.0	5793	1.059
T_4	444.6	102.4	547.0	5408	0.989
T_5	444.6	102.4	547.0	4475	0.818
T_6	444.6	102.4	547.0	4255	0.778
T_7	555.4	76.1	631.5	4896	0.775
T_8	555.4	76.1	631.5	4969	0.787
T_9	444.6	102.4	547.0	4070	0.744
T_{10}	444.6	102.4	547.0	3819	0.698
T_{11}	510.0	187.9	697.9	4612	0.661
Mean	470.7	105.4	576.1	4834	0.845
S.E.±				82.5	0.0254
C.D (P<0.05)				172.2	0.0530

IW - Irrigation water applied; ER - Effective Rainfall; TWA - Total Water Applied; GY - Grain Yield;
WP - Water Productivity (g grain kg^{-1} of water applied)

Table 3 : The correlation analysis of yield and its components under drip irrigated aerobic rice (n=30)

	PT	SN	FGP	TW	HI	WP	GY
PT	1	0.708**	0.671**	0.578**	0.370*	0.924**	0.824**
SN		1	0.757**	0.382*	0.457**	0.624**	0.684**
FGP			1	0.420*	0.460**	0.532**	0.651**
TW				1	0.397*	0.536**	0.566**
HI					1	0.451**	0.697**
WP						1	0.873**
GY							1

* and ** indicate significance of values at P=0.05 and 0.01 (2-tailed), respectively

the 1.0 lph drippers performed better over conventional irrigation treatment as well as 0.6 lph dripper treatments. The total water applied to the crop through the irrigation water and effective rainfall for the entire growing season was 547 mm in T_1, T_2, T_3, T_4, T_5, T_6, T_9 and T_{10}, 631.5 mm in T_7, T_8 and 697.9 mm in T_{11} treatment (Table 2). There was a mean saving of 21.6 per cent of water when applied through the drip system than the conventional irrigation. Bouman *et al.* (2007) reported that the yields of aerobic rice obtained by farmers around North China Plain were 5.5 t ha^{-1} with sometimes as little as 566 mm of total water input, and with only one or two supplementary irrigation applications.

The water productivity (WP) is a measure of the productivity of water used by the crop. Higher WP was recorded (Table 2) in T_3 (1.059 g kg^{-1}) followed by T_1 (1.015 g kg^{-1}), T_4 (0.989 g kg^{-1}) and T_2 (0.974 g kg^{-1}). The least WP was observed in the conventional irrigation at IW/CPE ratio of 1.25 (T_{11}) (0.661 g kg^{-1}). The results followed the study of Guang-hui *et al.* (2008) with 60% lesser water use coupled with 1.6-1.9 times higher total water productivity in the present study. Mild water stress in aerobic root system sensed soil drying and produced chemical signals that are transmitted to the shoots to close the stomata (decreasing water loss) and limit vegetative growth, thus improving WUE (de Souza *et al.*, 2003). The water productivity showed maximum significance (0.873**) with the yield (Table 3). The water productivity was higher by 1.6 times in T_3 when compared to T_{11} treatment with 54.4 % reduction in water use (Table 2). Present results are in accordance with the study of Guang-hui et al (2008) who reported 60 % lesser water use coupled with 1.6-1.9 times higher total water productivity in the present study.

From the research findings of DS 2011 revealed that the treatment T_3 (lateral spacing of 0.8 m with 1.0 lph dripper discharge rate) recorded better performance over other drip treatments in terms of yield components and WP. Comparing the discharge variability effect, 1.0 lph dripper outperformed 0.6 lph dripper in terms of water productivity, yield and its components. Drip system with lateral spacing of 0.8 m with 1.0 lph drippers could be recommend for aerobic rice cultivation for the areas with limited water availability.

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