Productivity analysis of aerobic rice in the lowlands of Southern Kerala

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Abstract

A field experiment was conducted at the Cropping Systems Research Centre, Karamana, Kerala to assess the adaptability and water productivity of aerobic rice system in the lowlands of southern Kerala. The water productivity of four rice varieties [PTB 52 (Aiswarya), MO 16 (Uma), MAS 946-1 (Sharada) and PMK (R) 3] were studied under two moisture regimes – aerobic (30 per cent depletion of available soil moisture) and flooded conditions. The experiment was laid out in randomized block design, with five replications, under both the moisture regimes. Aerobic rice recorded higher water productivity (0.68 kg m^{-3}) than the conventional flooded rice (0.42 kg m^{-3}). The variety, MAS 946-1 recorded the highest water productivity of 0.60 kg m^{-3}. Among the four varieties tested, MAS 946-1, the first aerobic rice variety released from UAS, Bengaluru and the KAU rice varieties Aiswarya and Uma, proved superior for aerobic conditions in southern Kerala.

Key words: Water productivity, MAS 946-1, Flooded rice, Aerobic rice, Rice varieties

Introduction

In Kerala, despite considerable investment and special attention given to rice, the fact remains that the area and production of the crop continues to decline. According to Department of Economics and Statistics (2013), the rice area of the state has drastically declined from 4.71 lakh ha (1995-96) to 2.13 lakh ha (2010-11) with the production declining from 9.53 lakh tonnes to 5.23 lakh tonnes. Sixty per cent of rice crop cultivated in Kerala is rainfed (Leenakumary, 2009). Thus monsoon vagaries clubbed together with water scarcity has been threatening the very existence of paddy fields in many areas of Kerala. Water scarcity, especially during the summer season, has discouraged the farmers from cultivating rice. At a time when the traditional paddy fields are being wantonly reclaimed for real estate development and cultivation of other crops, attempts are needed for retaining the rice areas so as to serve for food security and environment security. To combat this, water saving irrigated rice production systems that require less water than the traditional flooded rice need to be explored.

International Rice Research Institute (IRRI) developed the "aerobic rice technology" to address the water crisis in tropical agriculture, with a mission of "more rice with less water". In aerobic rice systems, the crop is established in non-puddled, non-flooded fields (Singh et al., 2008) and rice is grown like an upland crop (unsaturated condition) with adequate inputs and supplementary irrigation when rainfall is insufficient (Bouman, 2001). Irrigation is applied to bring the soil water content in the root zone up to field capacity after it has reached a certain lower threshold level (Bouman and Tuong, 2001). Achieving high yields under irrigated but aerobic soil conditions requires new varieties of aerobic rice that combine the drought-resistant characteristics of upland varieties with the high-yielding

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characteristics of lowland varieties (Lafitte et al., 2002). It should be responsive to high inputs and should tolerate flooding also. The existing varieties which perform well under lowland conditions have also to be screened for their adaptation and performance with respect to growth and physiological attributes, green house gas emission potential, water productivity and yield performance under the aerobic situation. Aerobic rice, in general, yields less when compared to the conventional lowland rice. Patel et al. (2010) reported that the yield difference between aerobic (average yield, 1.67 Mg ha^{-1}) and flooded rice (average yield, 2.31 Mg ha^{-1}) ranged from 18.4 to 37.8 per cent. As it is a new system of rice production, agro techniques for aerobic rice need to be standardized.

In this context, a study was carried out to identify a rice variety suitable for aerobic rice production system in the lowlands of Kerala and to assess the water productivity of aerobic rice as against flooded rice.

Materials and Methods

The experiment was conducted during the summer seasons 2010-11 and 2011-12 in the lowlands of the Cropping Systems Research Centre, Karamana, Thiruvananthapuram, Kerala. This research centre is geographically located at 8^{0}29' N latitude, 76^{0}58' E longitude and at an altitude of 33 m above mean sea level.

The soil of the experimental site was sandy clay loam belonging to the taxonomical order Oxisol. It was acidic in reaction (pH 5.50) and high in organic carbon content (1.09%), medium in available nitrogen (285.60 kg ha^{-1}), available phosphorus (15.90 kg ha^{-1}) and available potassium (164.00 kg ha^{-1}) status.

A humid tropical climate prevails over the experimental site. The mean maximum temperature ranged between 30.2^{0}C to 33.9^{0}C and 29.4^{0}C to 33.0^{0}C during first and second years respectively, while the minimum temperature ranged between 24.4^{0}C to 25.9^{0}C and 19.2^{0}C to 26.1^{0}C during the first year and the second year, respectively. The mean maximum relative humidity ranged from 84.4 per cent to 93.6 per cent and 85.3 per cent to 99.0 per cent during first and second years respectively, while the minimum relative humidity ranged from 64.4 per cent to 80.9 per cent and 51.7 per cent to 79.9 per cent during first and second years respectively. A total rainfall of 275.3 mm and 181.9 mm was recorded during the cropping period of first year and second year respectively.

The performance of the four rice varieties, viz. PTB 52 (Aiswarya), MO 16 (Uma), MAS 946 – 1 (Sharada) and PMK (R) 3 were studied under two moisture regimes – aerobic (30 per cent depletion of available soil moisture) and flooded. The important varietal characters are given in Table 1.

Table 1. Varietal characteristics

	Rice variety			
Characteristics	PTB 52 (Aiswarya)	MO 16 (Uma)	MAS 946 – 1 (Sharada)	PMK (R) 3
Released from	RARS,Pattambi	RRS, Moncompu	UAS, Bengaluru	RRS, Paramakudi
Duration(days)	120-125	115-120 (*Mundakan*) 120-135 (*Virippu*)	105-110	110-115
Bran colour	Red	Red	White	White
Grain type	Long, bold	Medium, bold	Medium, slender	Long, bold
Stress tolerance	Resistant to blast, blight and BPH	Resistant to BPH and GM biotype 5	Blast disease tolerant	Drought tolerant
Special characters	Suited for first and second crop seasons	Dormancy upto 3 weeks	First aerobicrice variety, suitable for dry sowing	Non-lodging

Considering the convenience in water management, the experiment was laid out in two separate lay outs, one for the aerobic condition and the other for the flooded condition. A buffer strip of 3 m was maintained in between the two. The experiment was laid out in randomized block design, with five replications, under both the moisture regimes.

Aerobic condition was maintained by giving irrigation at 30 per cent depletion of the available soil moisture. The following formula was used for calculating the volume of water required for irrigation.

Volume of water required = Depth of irrigation water x Wetted area

The irrigation depth was fixed as 2.24 cm, using the following formula based on the field capacity (FC) and permanent wilting point (PWP) values which were measured using pressure plate membrane apparatus. The FC and PWP were estimated as 20.6 and 10.6 per cent respectively. Depth of root zone was estimated as 20 cm. Irrigation was given at 3 days interval.

$$d = \frac{FC - PWP}{100} \times \frac{70}{100} \times Asi \times Di$$

Where, d = Depth of irrigation water, mm.
FC = Field capacity, %
PWP = Permanent wilting point, %
Asi = Apparent specific gravity, g cm^{-3}
Di = Depth of root zone, cm

The measured volume of water (336 litre plot^{-1}) was applied through a V- notch, using the following formula (Misra and Ahmed, 1989):
Flow, $Q = 1.443\ H^{2.50}$
where,
Q = Flow, cubic feet second^{-1}
H = Upstream head, feet

Flooded condition was maintained by keeping the water level at about 2-3 cm upto 7 days after sowing. Thereafter water level was maintained at 5 cm throughout the crop period with occasional drainage. Water was drained 13 days before harvest (KAU, 2011). Wooden pegs, painted white and suitably marked to indicate 5 cm depth were fixed at the centre of the plots. The details of irrigations given during the first and second years of experimentation are given in Table 2.

Water productivity for the total biomass was estimated using the formula proposed by Kijne et al. (2003) and expressed as kg m^{-3}.

$$WP = \frac{\text{Total biomass}}{\text{Total water utilized}}$$

Total biomass includes grain yield and straw yield.

Table 2. Details of irrigations given during the first and second years of experimentation

Treatments	Crop duration (days)		No. of irrigations		Irrigation requirement (mm)		Rainfall Received (mm)		Totalwater utilised (mm)	
	I year	II year	I year	II year	I year	II year	I year	II year	I year	II year
Flooded rice										
V_1 (Asiwarya)	108	105	22	25	1080.00	1230.00	275.30	181.90	1355.30	1411.90
V_2 (Uma)	120	120	25	28	1230.00	1380.00	275.30	181.90	1505.30	1561.90
V_3 (MAS 946 – 1)	108	105	22	25	1080.00	1230.00	275.30	181.90	1355.30	1411.90
V_4 (PMK (R) 3)	108	105	22	25	1080.00	1230.00	275.30	181.90	1355.30	1411.90
Aerobic rice										
V_1 (Asiwarya)	108	105	20	29	448.00	649.60	275.30	181.90	723.30	831.50
V_2 (Uma)	120	120	24	33	537.00	739.20	275.30	181.90	812.30	921.10
V_3 (MAS 946 – 1)	108	105	20	29	448.00	649.60	275.30	181.90	723.30	831.50
V_4 (PMK (R) 3	108	105	20	29	448.00	649.60	275.30	181.90	723.30	831.50

The total water utilized is the sum of irrigation water and rainfall received.

Grain yield was calculated after harvesting the net plot area individually; threshing, winnowing, drying and recording the dry weight, and straw yield was recorded after drying straw harvested from each net plot under sun to a constant weight.

Results and Discussion

Grain Yield and Straw Yield

Water management practices, varieties and their interaction had no significant impact on grain yield and straw yield during the first year of experimentation (Table 3). However, among the varieties, MAS 946 -1 recorded the highest grain yield (2.90 Mg ha^{-1}) and PMK (R) 3 recorded the highest straw yield (2.87 Mg ha^{-1}).

Table 3. Effect of water management practices and varieties on grain yield and straw yield

Treatments	Grain yield (Mg h^{1})		Straw yield (Mgha^{1})	
	I year	II year	I year	II year
Water management practices (W)				
W_1 (FR)	2.59	2.96	2.72	3.50
W_2 (AR)	2.55	2.56	2.58	3.05
SE m (±)	0.13	0.05	0.13	0.06
CD (0.05)	NS	0.147	NS	0.183
Varieties (V)				
V_1 (Aiswarya)	2.71	2.68	2.68	2.86
V_2 (Uma)	2.47	2.91	2.40	3.15
V_3 (MAS 946 – 1)	2.90	3.09	2.65	3.25
V_4 (PMK (R) 3)	2.21	2.38	2.87	3.85
SE m (±)	0.19	0.07	0.19	0.09
CD (0.05)	NS	0.208	NS	0.259
Interaction (W x V)				
w_1v_1	2.77	2.89	2.89	3.12
w_1v_2	2.43	3.13	2.49	3.46
w_1v_3	2.94	3.33	2.83	3.48
w_1v_4	2.21	2.50	2.67	3.95
w_2v_1	2.64	2.46	2.47	2.59
w_2v_2	2.51	2.68	2.31	2.84
w_2v_3	2.85	2.84	2.47	3.03
w_2v_4	2.20	2.26	3.08	3.74
SE m (±)	0.27	0.10	0.27	0.13
CD (0.05)	NS	NS	NS	NS

FR – Flooded Rice AR – Aerobic Rice

During the second year, grain yield and straw yield recorded under two water management practices varied significantly with W_1 (Flooded rice) recording the highest grain yield (2.96 Mg ha^{-1}) and straw yield (3.50 Mg ha^{-1}). Flooded rice had significant effect on productive tiller count and this would be attributed to highest grain and straw yield. Aerobic condition significantly reduced grain yield (13.5 per cent lower than that recorded under flooded condition), mainly through reduction in productive tiller count, number of spikelets per panicle and filled grain percentage. Decrease in the relative yield of aerobic rice compared to flooded rice was also reported by George et al. (2002), Bouman et al. (2005) and Peng et al. (2006).

Among the varieties, V_3 (MAS 946 -1) and V_2 (Uma) were at par in terms of grain yield (3.09 and 2.91 Mg ha^{-1}, respectively) and significantly superior to V_1 (Aiswarya) and V_4 (PMK (R) 3). Better performance of these varieties could be attributed to significantly higher productive tiller count and lower sterility percentage recorded by the two. PMK (R) 3 had significantly higher straw yield (3.85 Mg ha^{-1}) followed by MAS 946 -1 (3.25 Mg ha^{-1}), Uma (3.15 Mg ha^{-1}) and Aiswarya (2.86 Mg ha^{-1}). This was due to the higher vegetative growth, as evident from increased plant height and leaf area of PMK (R) 3 compared to other varieties. Though this variety had higher shoot biomass as observed by Martin et al. (2007), the increased cost for shoot growth represented clear diversion of assimilates towards the shoot which might have decreased the grain yield.

On pooled analysis, the varieties varied significantly with respect to straw yield under aerobic culture with the variety PMK (R) 3 recording the highest straw yield of 3.41 Mg ha^{-1}. Varieties did not vary in grain yield under aerobic condition (Table 4).

Table 4. Effect of water management practices and varieties on grain yield and straw yield (pooled over years)

Treatments	Grain yield (Mg ha^{-1})		Straw yield (Mg ha^{-1})	
	FR	AR	FR	AR
Varieties (V)				
V_1 (Aiswarya)	2.83	2.55	3.00	2.53
V_2 (Uma)	2.78	2.59	2.98	2.57
V_3 (MAS 946 – 1)	3.13	2.85	3.15	2.75
V_4 (PMK (R) 3)	2.35	2.23	3.31	3.41
SE m (±)	0.14	0.15	0.14	0.18
CD (0.05)	0.441	NS	NS	0.554

FR – Flooded Rice AR – Aerobic Rice

Water Productivity

The water productivity, the ratio of total yield (grain + straw) to total water utilized, varied among the varieties and between the water management practices. During the first and second years (Table 5), significantly higher water productivity (0.69 kg m^{-3} and 0.66 kg m^{-3}, respectively) was recorded by aerobic rice compared to flooded rice (0.39 kg m^{-3} and 0.45 kg m^{-3}, respectively). The increase in water productivity recorded by aerobic rice over flooded rice was 76.92 per cent and 46.67 per cent, respectively during the first and second years of experimentation. The most salient feature of aerobic rice in the present study was the extremely low water input used to realize the reported yields. The combined amount of rainfall and irrigation water from sowing to harvest varied from 777 to 867 mm, compared with 1384 to 1534 mm in flooded rice. Similar findings were reported by Bouman et al. (2002) and Patel et al. (2010). Compared with lowland rice, water consumption in aerobic rice was 43.72 per cent lower and water productivity was 61.90 per cent higher. Martin et al. (2007) also reported that as compared to traditional lowland flooded rice the water consumption by aerobic rice was 50% lower and water productivity was 60% higher.

The effect of varieties on water productivity was also significant, with V_3 (MAS 946 – 1) recording the highest water productivity of about 0.60 kg m^{-3} during both the years of experimentation. It was on a par with V_1 (Aiswarya) and V_4 (PMK (R) 3) with a water productivity of 0.57 kg m^{-3} and 0.55

Table 5. Effect of water management practices and varieties on water productivity, kg m^{-3}

Treatments	Water productivity	
	I year	II year
Water management practices (W)		
W_1 (FR)	0.39	0.45
W_2 (AR)	0.69	0.66
SE m (±)	0.01	0.01
CD (0.05)	0.059	0.033
Varieties (V)		
V_1 (Aiswarya)	0.57	0.52
V_2 (Uma)	0.46	0.51
V_3 (MAS 946 – 1)	0.59	0.60
V_4 (PMK (R) 3)	0.55	0.59
SE m (±)	0.03	0.02
CD (0.05)	0.081	0.043
Interaction (W x V)		
w_1v_1	0.42	0.43
w_1v_2	.0.33	0.42
w_1v_3	0.43	0.48
w_1v_4	0.36	0.46
w_2v_1	0.71	0.61
w_2v_2	0.59	0.60
w_2v_3	0.74	0.71
w_2v_4	0.73	0.72
SE m (±)	0.04	0.02
CD (0.05)	NS	NS

FR – Flooded Rice AR – Aerobic Rice

Table 6. Effect of water management practices and varieties on water productivity, kg m^{-3} (pooled over years)

Treatments	Water productivity	
	FR	AR
Varieties (V)		
V_1 (Aiswarya)	0.43	0.66
V_2 (Uma)	0.38	0.60
V_3 (MAS 946 – 1)	0.46	0.73
V_4 (PMK (R) 3)	0.41	0.73
SE m (±)	0.02	0.02
CD (0.05)	0.051	0.080

FR – Flooded Rice AR – Aerobic Rice

kg m^{-3} respectively during the first year and with PMK (R) 3 (V_4), which recorded 0.59 kg m^{-3} during the second year. On pooled analysis (Table 6) also, varieties showed significant difference in water productivity with the variety, MAS 946 - 1 (V_3) recording the highest water productivities of 0.46 kg m^{-3} and 0.73 kg m^{-3} under flooded and aerobic situations, which was at par with the varieties Aiswarya (V_1) and PMK (R) 3 (V_4) under both the situations. The variety, MAS 946 -1 recorded a water productivity which was 3.51 per cent higher than that of the next best variety Aiswarya during the first year and 1.69 per cent more than the variety, PMK (R) 3 during the second year. Although the variety, Uma recorded higher yield next to MAS 946 -1, this was not reflected in the water productivity. This is probably due to the fact that the duration of the variety, Uma was around 15 days more than that of MAS 946 -1, accounting for more number of irrigations and lower water productivity. These results are in agreement with those of Martin et al. (2007). The interaction between water management practices and varieties was not significant.

Aerobic rice culture is a promising technology under water deficit situations. Compared to conventional flooded rice, the average water productivity of aerobic rice (0.68 kg m^{-3}) was 60.7 per cent higher. The variety, MAS 946 – 1 recorded the maximum water productivity of 0.60 kg m^{-3}. Among the four varieties tested, MAS 946 – 1, the first aerobic rice variety released from UAS, Bengaluru and the KAU rice varieties Aiswarya and Uma, (in terms of yield potential) proved superior for aerobic conditions in southern Kerala.

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