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Evaluation of Growth and Yield Performance of Aerobic Rice under Different Irrigation Interval in Furrow Irrigated Raised Bed (FIRB) System of Cultivation

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Abstract: With the decline of the already limited water available for rice production, there is a need to adopt water-saving measures such as aerobic rice to meet the challenge of feeding billions of people living and relying on rice. Field experiments were conducted for two years to optimize the suitable raised bed size and irrigation intervals for the aerobic rice production system. The treatments consist of three bed width (0.8m, 1.0 and 1.2m) and three irrigation interval (daily, once in two days and once in three days). The results showed that raising of aerobic rice in Furrow Irrigated Raised Bed (FIRB) of 1.0m width and 30cm furrow and schedule the irrigation once in two days gave higher productive tillers m^{-2}, grain and straw yield. Water use efficiency also higher with this system. So we can save water along with enhanced yield. Due to the higher yields obtained under raising of aerobic rice under FIRB which accommodated four rows of rice in 1.0 m width of raised bed and irrigating the furrow in once in two days gave higher net income and BC ratio. Hence, for getting better yield and economics of aerobic rice, FIRB with a bed width of 1.0m and irrigating the furrow once in two days was optimum under irrigated condition.

Key words: Aerobic rice · FIRB · Irrigation interval · yield

INTRODUCTION

Water is most limited and essential natural resource in agriculture. The dwindling water resources reveal a grim situation for low land puddled rice cultivation. Because of increasing water scarcity, there is a need to develop alternative systems that require less water [1]. There are examples of restriction of cultivation of rice and sugarcane to save water for other domestic purpose during scarcity. To keep up the rice production during irrigation water shortage, alternate methods of cultivation of rice is essential. One such strategy is cultivation of rice under aerobic situation. Aerobic rice could be successfully cultivated with 600 to 700 mm of total water in summer and entirely on rainfall in wet season [2]. Aerobic rice systems, wherein the crop is established *via* direct seeding in non-puddled, non-flooded fields, are among the most promising approaches for saving water [3]. Aerobic rice systems can reduce water application by 44% relative to conventionally transplanted systems, by reducing percolation, seepage and evaporative losses, while maintaining yield at an acceptable level [4].

In India, out of 44 m ha of rice cultivated area, about 50% is irrigated lowland, 35% rainfed lowland, 3% deep water rice and 12% rainfed upland [5]. Farming communities just have to cope with this water scarcity scenario, by reducing irrigation water to their fields. To safeguard the food industry and conserve water, aerobic rice was introduced. It is fundamentally a different approach of rice cultivation where high yielding rice is grown in non-puddled and non-saturated fields with supplementary irrigation and high external inputs [6]. Aerobic rice systems can reduce water application by 44% relative to conventionally transplanted systems, by reducing percolation, seepage and evaporative losses, while maintaining yield at an acceptable level [4]. Among the cereals, rice requires more amount of water for per unit of dry matter production. For aerobic rice cultivation,

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furrow irrigated raised bed seems to be potential technology to raise rice crop with less water [7]. In this context, field experiments were carried out to evaluate and optimize the suitable bed width under furrow irrigated raised bed system and irrigation interval to maintain sufficient moisture for better growth of aerobic rice.

MATERIALS AND METHODS

A field experiment was conducted during 2014-16 under rainfed condition at Agricultural College Farm, Madurai situated in Southern zone of Tamil Nadu at 9° 54'N latitude and 78 °54' E longitude with an altitude of 147 meters above the mean sea level. The experimental plot containing sandy clay loam soil having 0.49% organic carbon, 291.0 kg ha^{-1} available nitrogen, 19.50 kg ha^{-1} available phosphorous, 290.0 kg ha^{-1} available potassium and 8.32 pH.

The treatments consisting of three bed width allotted in main plots (0.8m, 1.0m and 1.2m width with 30cm furrow) and three irrigation interval in sub plots (irrigating the furrow daily, once in two days and once in three days). It was laid out in split plot design with three replications. The rice variety Anna (4) seeds was directly sown on bed with a spacing of 20 × 10cm. Observation on growth parameter, dry matter accumulation, yield components and yield of grain and straw were recorded and statistically analyzed. Economics were also worked out. Measurement on quantity of irrigation water applied was taken to worked out the Water Use Efficiency (WUE) and it was calculated as follow

$$WUE = \frac{Grain\ yeild\ \ (kg\,/\,ha)}{Total\ water\ \ Used\ \ (mm)}$$

RESULTS AND DISCUSSION

Crop Performance: The plant height of rice crop was significantly affected by the different land configuration during the crop growth period (Table 1). Bed width of 1.0 m (L_2) which accommodated four rows of rice produced taller plants than the other treatments (95.3 and 106.7 cm in 2015 and 2016, respectively). This was closely followed by raising the rice crop under FIRB system with a bed width of 0.8 m (L_1) and they are on par with each other. Regarding the frequency of irrigation, irrigating the crop daily (I_1) recorded the tallest plant of 96.4 and 107.0 cm in 2015 and 2016, respectively when compared to the rest of the treatments. The lowest plant height was recorded with irrigating the furrow at a frequency of once in three days (I_3) in both the years. There was a significant interaction was found between the bed width and frequency of irrigation. Among the treatment combinations, raising the rice crop with a bed width of 1.0 m and irrigating the crop daily (L_2I_1) recorded the highest plant height (99.4 and 111.0 cm during 2015 and 2016, respectively). This treatment was followed by sowing of aerobic rice in raised bed of 0.8 m width and irrigating the crop daily (L_1I_1) recorded a plant height of 97.8 and 106.8 cm during 2015 and 2016, respectively. Raising rice crop in raised bed of 1.2 m width and irrigating the crop once in three days (L_3I_3) recorded the lowest plant height.

The Dry Matter Production (DMP) of rice crop was significantly affected by the different bed width treatments during the crop growth period (Table 1). Bed width of 1.0 m (L_2) which accommodated four rows of rice produced higher DMP than the other treatments (7255 and 7110 kg ha^{-1} in 2015 and 2016, respectively). This was closely followed by raising the rice crop under FIRB system with a bed width of 0.8 m (L_1) and they are on par with each other. Regarding the frequency of irrigation, irrigating the crop daily (I_1) recorded the highest DMP (8028 and 7867 kg ha^{-1} in 2015 and 2016, respectively) when compared to the other treatments. The lowest DMP was associated with irrigating the furrow at a frequency of once in three days (I_3). There was a significant interaction between the bed width and frequency of irrigation.

Table 1: Effect of land configuration and irrigation interval on plant height (cm) and DMP (kg ha^{-1}) of aerobic rice.

	Plant height (cm)								Drymatter production (kg ha^{-1})							
	2015				2016				2015				2016			
Treatment	I_1	I_2	I_3	Mean	I_1	I_2	I_3	Mean	I_1	I_2	I_3	Mean	I_1	I_2	I_3	Mean
L_1	97.8	92.5	89.7	93.4	106.8	100.8	97.7	101.8	8092	7283	6097	7157	7930	7137	5975	7014
L_2	99.4	94.3	92.4	95.3	111.0	105.7	103.5	106.7	8203	7383	6180	7255	8039	7235	6057	7110
L_3	92.1	86.8	84.2	87.7	103.2	97.2	94.3	98.2	7789	7010	5868	6889	7633	6870	5751	6751
Mean	96.4	91.2	88.8		107.0	101.2	98.5		8028	7225	6048		7867	7081	5927	
	L	I	L x I		L	I	L x I		L	I	L x I		L	I	L x I	
SEd	0.9	1.9	0.8		1.5	2.0	1.6		36.6	94.3	42.2		41.5	115.7	43.5	
CD	2.3	4.8	1.9		3.8	5.1	4.0		95.2	235.8	105.5		103.8	289.3	108.7	

Table 2: Effect of land configuration and irrigation interval on number of productive tillers (m^{-2}) and filled grains per panicle of aerobic rice.

	Productive tillers (m^{-2})								Filled grains per panicle							
	2015				2016				2015				2016			
Treatment	I_1	I_2	I_3	Mean	I_1	I_2	I_3	Mean	I_1	I_2	I_3	Mean	I_1	I_2	I_3	Mean
L_1	263	218	168	216	258	214	164	212	56	53	44	51	45	41	37	41
L_2	267	221	170	219	261	217	167	215	66	60	50	59	55	52	43	50
L_3	253	211	161	208	248	206	158	204	46	42	37	42	40	36	28	38
Mean	261	217	166		256	212	163		56	51	44		47	41	36	
	L	I	L x I		L	I	L x I		L	I	L x I		L	I	L x I	
SEd	5.0	4.2	5.1		4.9	4.1	5.0		2.1	2.7	1.7		1.9	2.2	1.1	
CD	13.0	11.0	13.3		12.8	10.8	13.1		5.4	6.8	4.3		4.8	5.4	2.8	

Among the treatment combinations, raising the rice crop with a bed width of 1.0 m and irrigating the crop daily (L_2I_1) recorded significantly highest DMP of 8203 and 8039 kg ha^{-1} during 2015 and 2016, respectively. This treatment was followed by sowing of aerobic rice in raised bed of 0.8 m width and irrigating the crop daily (L_1I_1) recorded a plant height of 8092 and 7930 kg ha^{-1} during 2015 and 2016, respectively. Raising rice crop in raised bed of 1.2 m width and irrigating the crop once in three days (L_3I_3) recorded the lowest DMP. In general irrigating the furrow daily or once in two days had increased the growth parameters than irrigating the furrow at three days intervals. This might be due to insufficient moisture that too at the critical stages of crop growth that could have slowed down the growth processes. The soil moisture kept above the field capacity by the frequent irrigation and good soil aeration throughout the crop growth period due to the raised bed system of cultivation might have favoured the faster cell division and cell elongation which ultimately resulted in higher plant height and dry matter production. The similar findings were earlier reported by [8].

Yield Attributes Performance: The productive tiller m^{-2} and number of filled grains per panicle were significantly influenced by the different bed widths and different irrigation frequencies (Table 2). Bed width of 1.0 m (L_2) which accommodated four rows of rice produced more number of productive tillers m^{-2} (219) which was on par with bed width of 0.8m treatment. Among the irrigation interval, irrigating the furrow daily had more number of productive tiller m^{-2} (261) followed by irrigating the furrow once in two days. The improved performance of higher productive tiller production may due to adequate moisture supply with good aeration which favoured lesser tiller mortality. The similar finding was reported by [9].

Bed width of 1.0 m (L_2) which accommodated four rows of rice produced higher number of filled grains per panicle than the other treatments (59 and 50 during 2015 and 2016, respectively). Regarding the frequency of irrigation, irrigating the crop daily (I_1) recorded the higher values (56 and 47 during 2015 and 2016, respectively) when compared to the rest of the treatments. The lowest number of filled grains per panicle was observed in the crop irrigating once in three days (I_3). There was a significant interaction between the bed width and frequency of irrigation. Among the treatment combinations, raising the rice crop with a bed width of 1.0 m and irrigating the crop daily (L_2I_1) recorded more number of filled grains per panicle (66 and 55 during 2015 and 2016, respectively). This treatment was followed by sowing of aerobic rice in raised bed of 0.8 m width and irrigating the crop daily (L_1I_1) recorded more number of filled grains per panicle of 56 and 45 during 2015 and 2016, respectively. The number of filled grains per panicle was lowest in bed of 1.2 m width and irrigating the crop once in three days (L_3I_3).

Yield Performance: The grain yield was significantly influenced by the different bed widths and different irrigation frequencies (Table 3). Bed width of 1.0 m (L_2) which accommodated four rows of rice produced higher grain yield than the other treatments (3255 and 3126 kg ha^{-1} during 2015 and 2016, respectively). This was followed by raising the rice crop raised under the bed width of 0.8 m (L_1). Regarding the frequency of irrigation, irrigating the crop daily (I_1) recorded the higher grain yield (3355 and 3223 kg ha^{-1} during 2015 and 2016, respectively) when compared to the rest of the treatments. The lowest grain yield was obtained in the treatment irrigating once in three days (I_3). There was a significant interaction between the bed width and frequency of irrigation. Among the treatment combinations, raising the rice crop with a bed width of 1.0 m and irrigating the crop daily (L_2I_1) recorded more yield of 3741 and 3593 kg ha^{-1} during 2015 and 2016, respectively. This treatment was followed by sowing of aerobic rice in raised bed of 0.8 m width and irrigating the crop daily (L_1I_1) recorded more

Table 3: Effect of land configuration and irrigation interval on grain yield (kg ha^{-1}) and straw yield (kg ha^{-1}) of aerobic rice.

	Grain yield (kg ha^{-1})								Straw yield (kg ha^{-1})							
	2015				2016				2015				2016			
Treatment	I_1	I_2	I_3	Mean	I_1	I_2	I_3	Mean	I_1	I_2	I_3	Mean	I_1	I_2	I_3	Mean
L_1	3528	3082	2283	2874	3369	2960	2192	2760	5719	4814	3744	4713	5182	4182	3819	4361
L_2	3741	3403	2622	3255	3593	3137	2518	3126	6135	5364	4518	5339	5677	4712	4445	4944
L_3	2796	2485	2038	2436	2507	2175	1825	2169	4625	4534	3060	4056	4417	3955	2638	3669
Mean	3355	2990	2257		3223	2758	2167		5503	4904	3701		5092	4282	3634	
	L	I	L x I		L	I	L x I		L	I	L x I		L	I	L x I	
SEd	117.9	132.9	79.9		105.9	122.0	83.1		158.6	198.1	142.7		198.7	217.1	167.7	
CD	318.3	358.7	215.6		285.8	329.3	224.5		428.3	534.8	385.3		536.4	586.2	452.7	

Table 4: Effect of land configuration and irrigation interval on total water use (mm) and water use efficiency (kg hamm^{-1}) of aerobic rice

	Total water use (mm)								Water use efficiency (kg hamm^{-1})							
	2015				2016				2015				2016			
Treatment	I_1	I_2	I_3	Mean	I_1	I_2	I_3	Mean	I_1	I_2	I_3	Mean	I_1	I_2	I_3	Mean
L_1	930	846	700	825	967	880	728	858	3.31	3.85	3.26	3.47	3.06	3.56	3.01	3.21
L_2	850	786	640	759	910	841	685	812	4.00	4.76	4.10	4.29	3.59	4.27	3.68	3.85
L_3	800	731	586	706	816	746	598	720	3.84	3.40	3.18	3.47	3.61	3.20	3.00	3.27
Mean	860	788	642		898	822	670		3.72	4.00	3.51		3.42	3.68	3.23	

grain yield of 3257 and 3128 kg ha^{-1} during 2015 and 2016, respectively. The grain yield was lowest in bed of 1.2 m width and irrigating the crop once in three days (L_3I_3). [10] reported that water stress to rice regardless of method of irrigation caused reduction in photosynthesis, floral development and pollination thereby reducing the yield. This might be the reason of enhanced performance of yield attributing characters associated with irrigating the crop at two days interval as compared to three days interval.

Different bed width treatments and different irrigation frequencies showed a significant difference for straw yield (Table 3). Bed width of 1.0 m (L_2) which accommodated four rows of rice produced higher straw yield than the other treatments (5339 and 4944 kg ha^{-1} during 2015 and 2016, respectively). This was closely followed by raising the rice crop raised under the bed width of 0.8 m (L_1). Regarding the frequency of irrigation, irrigating the crop daily (I_1) recorded the higher values (5503 and 5092 kg ha^{-1} during 2015 and 2016, respectively) when compared to the rest of the treatments. The lowest straw yield was observed in the crop irrigating once in three days (I_3). There was a significant interaction between the bed width and frequency of irrigation. Among the treatment combinations, raising the rice crop with a bed width of 1.0 m and irrigating the crop daily (L_2I_1) recorded more straw yield of 6135 and 5677 kg ha^{-1} during 2015 and 2016, respectively. This treatment was followed by sowing of aerobic rice in raised bed of 0.8 m width and irrigating the crop daily (L_1I_1) recorded more straw yield of 5341 and 4942 kg ha^{-1} during 2015 and 2016, respectively. The straw yield was lowest in bed of 1.2 m width and irrigating the crop once in three days (L_3I_3). Improved grain and straw yield under raising the rice crop with a bed width of 1.0 m and irrigating the crop daily (L_2I_1) might be due to the enhanced plant growth, dry matter accumulation, number of tillers per m^2 and increased number of filled grains per panicle which would have finally resulted in increased grain and straw yield of aerobic rice. Increased availability of soil moisture under this treatment have favoured higher root growth as root activity and enhanced uptake of nutrient from soil which promote all growth and yield attributing component of aerobic rice.

Water use and Water Use Efficiency: Bed width of 0.8 m (L_1) which accommodated four rows of rice consumes more water than the other treatments (825 and 858 mm during 2015 and 2016, respectively). This was closely followed by raising the rice crop under the bed width of 1.0 m (L_2) (Table 4). Regarding the frequency of irrigation, irrigating the crop daily (I_1) recorded more water use (860 and 898 mm during 2015 and 2016, respectively) when compared to the rest of the treatments. The lowest water use was obtained in the treatment irrigating once in three days (I_3). Among the treatment combinations, raising the rice crop with a bed width of 1.0 m and irrigating the crop

Table 5: Effect of land configuration and irrigation interval on economics of aerobic rice.

Treatments	Cost of Cultivation (Rs./ ha)	Gross income (Rs./ ha) 2015	2016	Mean	Net income (Rs./ ha) 2015	2016	Mean	B C ratio (Rs./ ha) 2015	2016	Mean
L_1I_1	32,000	58004	58775	58390	29297	26775	28036	1.92	1.84	1.88
L_1I_2	31,360	61302	55618	58460	26643	24258	25451	1.85	1.77	1.81
L_1I_3	30,733	42958	41188	42073	12233	10455	11344	1.40	1.34	1.37
L_2I_1	30,080	64047	67512	65780	40326	37432	38879	2.34	2.24	2.29
L_2I_2	29,478	70406	61406	65906	34566	31927	33247	2.17	2.08	2.13
L_2I_3	28,889	49338	47313	48326	20457	18424	19441	1.71	1.64	1.68
L_3I_1	29,440	57746	55374	56560	28300	25934	27117	1.96	1.88	1.92
L_3I_2	28,851	46774	44852	45813	17917	16001	16959	1.62	1.55	1.59
L_3I_3	28,274	35118	33672	34395	6844	5398	6121	1.24	1.19	1.22

daily (L_1I_1) recorded more water use (930 and 967 mm during 2015 and 2016, respectively). The lowest water use (586 and 598 mm during 2015 and 2016, respectively) was observed in bed of 1.2 m width and irrigating the crop once in three days (L_3I_3).

Different bed width treatments and different irrigation frequencies showed a marked difference for water use efficiency (Table 4). Bed width of 1.0 m (L_2) which accommodated four rows of rice produced higher WUE than the other treatments (4.29 and 3.85 kg ha^{-1} mm^{-1} during 2015 and 2016, respectively). This was closely followed by raising the rice crop raised under the bed width of 0.8 m (L_1). Regarding the frequency of irrigation, irrigating the crop once in two days (I_2) recorded the higher values for WUE of 4.00 and 3.68 kg ha mm^{-1} during 2015 and 2016, respectively when compared to the rest of the treatments. The lowest WUE was observed in crop irrigating once in three days (I_3). Among the treatment combinations, raising the rice crop in bed width of 1.0 m and irrigating the crop once in two days (L_2I_1) recorded more WUE (4.76 and 4.27 kg ha^{-1} mm^{-1} during 2015 and 2016, respectively). The WUE was lowest in bed of 1.2 m width and irrigating the crop once in three days (L_3I_3). Water saving under raised bed system of rice cultivation compared with flooded cultivation was attributed mainly due to elimination of continuous seepage and percolation losses, reduction in evaporation and elimination of water needed for mail field preparation. [11] also reported that reduction in irrigation water use by 60 per cent in dry seeded rice on raised bed compared with flooded transplanted rice. Water use efficiency (WUE) can be increased either by increasing the yield or by reducing the quantity of water applied. WUE was found to be decreasing with increasing levels of irrigation.

Economic Analysis: Among the different treatment combination, raising the crop under raised bed of 0.8 m width and irrigating the crop daily (L_1I_1) recorded higher value for cost of cultivation (Rs.32,000/ha) than other treatments (Table 5). The lowest cost of cultivation (Rs.28,274 /ha) was recorded by raising the crop under raised bed of 1.2 m width and irrigating the crop once in three days (L_3I_3). Among the different treatment combinations, sowing of rice crop under raised bed of 1.0 m width and irrigating the crop daily (L_2I_1) recorded the highest net return (Rs. 38,879 ha^{-1}). This was followed by raising the crop under raised bed of 1.0 m width and irrigating the crop once in two days (L_2I_2). The lowest net return was recorded by raising the crop under raised bed of 1.2 m width and irrigating the crop once in three days (L_3I_3). Among the different treatment interaction, sowing of crop under raised bed of 1.0 m width and irrigating the crop daily (L_2I_1) recorded the highest B:C ratio (2.29). This was followed by raising the crop under raised bed of 1.0 m width and irrigating the crop once in two days (L_2I_2) recorded the B:C ratio of 2.13. The lowest B:C ratio of 1.22 was recorded by raising the crop under raised bed of 1.2 m width and irrigating the crop once in three days (L_3I_3).

CONCLUSIONS

Based on the field experiments it was concluded that for getting better yield and higher water use efficiency aerobic rice may cultivated under furrow irrigated raised bed (FIBR) system had 1.0 m bed width with 30cm furrow and irrigating the furrow once in two days. This system of aerobic cultivation also gave higher net income and benefit cost ratio. Hence, for aerobic rice cultivation furrow irrigated raised bed is a suitable land configuration for better growth, yield and economics.

REFERENCES

1. Bouman, B.A.M., Yang Xiaoguang, Wang Huaqi, Wang Zhiming, Zhao Junfang, Wang Changguiand Cheng Bin, 2002, Aerobic rice (Han Dao): A new way of growing rice in water-short areas, International Soil Conservation Organization Conference, Beijing, China. Tsinghua University Press, pp: 175-181.

2. Shailaja Hittalmani, 2007. Aerobic rice cultivation Brochure, MAS lab, Univ. Agric. Sci., GKVK, Bangalore.
3. Bhushan, D., A. Pandey, M.K. Choudhary, A. Datta, S. Chakraborty and N. Chakraborty, 2007. Comparative proteomics analysis of differentially expressed proteins in chickpea extracellular matrix during dehydration stress. Mol Cell Proteomics, 6: 1868-1884.
4. Bouman, B.A.M., S. Peng, A.R. Castan˜eda and R.M. Visperas 2005. Yield and water use of tropical aerobic rice systems. Agricultural Water Management, 74(2): 87-105.
5. Budhar, M.N., R. Rajendran and B. Chandrasekaran, 2006. Integrated nutrient management for rice grown under SRI and aerobic situations. In Winter School on New Dimensions in Integrated Nutrient Management of Major Field Corps for Sustainable Crop Production (eds Raghjavaiah, *et al.*), Indian Council of Agriculture Research, New Delhi and Directorate of Oilseeds Research, Hyderabad, pp: 177-186.
6. Bouman, B.A.M., L.P. Feng, T.P. Tuong, G.A. Lu and H.Q. Wang, 2007. Exploring options to grow rice using less water in northern China using a modeling approach. II: Quantifying yield, water balance components and water productivity. Agricultural Water Managent, 88: 23-33.
7. Magesh, R., 2008. Evaluation and optimization of raised bed system of rice (CO (R) H3) cultivation. M.Sc thesis submitted to Tamil Nadu Agricultural University, Coimbatore.
8. Bouman, B.A.M. and T.P. Tuong, 2001. Field water management to save water and increase its productivity in irrigated rice. Agricultural Water Management, 49(1): 11-30.
9. Tahir Hussain Awan Inalyat Ali, M. Ehsan Safdar, Mirza M. Ashraf and Muhammad Yaqub, 2007. Economic effect of different plant establishment techniques on rice production. Journal of Agricultural Research, 45(1): 73-80.
10. Peng, S., B.A.M. Bounman, R.M. Visperas, A.R. Castaneda, C. Nie and H.K. Park 2006. Comparison between aerobic and flooded rice : agronomic performance in a long-term (8-season) experiment. Field Crops Research, 96: 252-259.
11. Humphreys, E., C. Meisner, R. Gupta, J. Timsina, H.G. Beecher, Tang Yong Lu, Yadvinder Singh, M.A. Gill Masih, I. Zheng Jia Guo and J.A. Thompson 2005. Water saving in rice - wheat systems. Plant Production Science, 8 (3): 242-258.