RESEARCH ARTICLE

Optimizing Irrigation Scheduling and Land Configurations of Furrow Irrigated Aerobic Rice

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ABSTRACT

Field experiments were conducted during *pishanam* 2015 and 2016 at Central Farm, Agricultural College and Research Institute, Killikulam. The experiment was laid out in a factorial randomized block design with three replications. Experimental treatments comprised of three irrigation scheduling and three bed widths. Rice crop was raised under furrow furrow-irrigated raised bed system (FIRB) system. Response of the crop to the different treatments indicated that growth parameters viz., plant height and Dry Matter Production (DMP) were highest in crop raised in bed width of 1.0 m accommodating five rows per bed and irrigating the crop daily. Raised bed of 1.0 m bed width accommodating five rows per bed and irrigating crop daily resulted in higher grain yield (3874 and 3789 kg ha^{-1} during 2015 and 2016, respectively) and Water use Efficiency (4.39 and 4.24 kg ha^{-1} mm^{-1} during 2015 and 2016, respectively) than other irrigation scheduling and land configurations.

Keywords: *Aerobic rice; Furrow irrigated raised bed system (FIRB); Grain yield.*

INTRODUCTION

Demand for rice will increase by 1.0 per cent every year. Increased rice productivity is the key to food and nutrition security and poverty alleviation in many Asian countries. Water has become so scarce or expensive that lowland rice cannot be maintained anymore. Rainfall is insufficient for lowland rice production, but water is sufficient for aerobic rice. There is a need for precised water or irrigation management technologies to mitigate the risks in water availability, which is uncertain in time and quantity. Rice grown in saturated soil culture on raised beds (SSC-RB) reduced the amount of irrigation water by about 32 per cent compared with conventional methods (Borrell *et al.,* 1997). Raised bed system involves growing rice on raised beds with a shallow water table (about 10 cm below the surface of the beds) by maintaining a shallow water depth in the furrows. Tabbal *et al.* (2002) also reported reduced water inputs and increased water productivity of rice grown under just-saturated soil conditions, compared with traditional flooded rice in Philippines. Aerobic rice can be grown on raised beds between furrows to channel irrigation water onto the field. Raised-bed systems are being pioneered in the Indo-Gangetic Plains of India (Gupta *et al.,* 2002). Raised bed-planted rice (BPR) saved 45–51% water but lowered grain yield by 52–53% compared with Transplanted rice (Sharma *et al.,* 2002). Dry seeding of rice reduced yield by 41–54% on raised beds compared with transplanted rice and there were no significant differences in water productivity among flat and raised bed treatments (Singh *et al.,* 2002). Raised beds are formed by moving soil from the furrows to the area of the bed, thus raising its surface level. The furrows serve as irrigation channels, drains and traffic lanes. Generally, two to six rows are planted on the top of each bed for rice crop (Naresh *et al.,* 2011). Keeping these facts in mind, this research was conduct to study the effect of different irrigation schedules and bed widths for aerobic rice under furrow irrigation system.

Materials and Methods

Field experiments were conducted at the Department of Farm Management, Agricultural College and Research Institute, Killikulam, Tamil Nadu, India from 2015 to 2016. The region is characterized as semi-arid tropical climate, located at 8° 46' N latitude and 77° 42' E longitude. The mean annual rainfall (30 years) at Killikulam is 736 mm distributed over about 40 rainy days. The rainfall is monsoon type, with a south-west monsoon from June to September and a north-east monsoon from October to December. The mean maximum and minimum temperature of the location were 33.4 ^{0}C and 23.6 ^{0}C respectively. The relative humidity ranges from 60 to 80 per cent. The experiment was laid out in a factorial randomized block design (FRBD) and the treatments were replicated thrice. Treatments comprised of three raised bed widths and three irrigation scheduling. Treatment details as follows; Factor A - L_1 – Raised bed (0.8 m) and furrow (30 cm) with 4 rows, L_2 – Raised bed (1.0 m) and furrow (30 cm) with 5 rows, L_3 - Raised bed (1.2 m) and furrow (30 cm) with 6 rows; Factor B - I_1 – Irrigation daily, I_2 – Irrigation at two days interval and I_3 – Irrigation at three days interval.

The field was ploughed with tractor drawn disc plough followed by ploughing with cultivator. The clods were broken with rotovator and the field was leveled. After levelling, Raised beds were formed manually

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with a top bed width of 0.8, 1.0, 1.2 m and furrows formed of 15 cm deep and to a width of 30 cm and made good with tilth condition for easy sowing of seeds for early germination. Buffer channels were formed to control the lateral seepage of water from one plot to another. Rice variety Anna - 4 released from Agricultural Research Station, Paramakudi, Tamil Nadu Agricultural University was used for the experimental study. Seeds were soaked in water for 12 hrs and shade dried for 12 hrs. Seeds were directly sown in the well prepared seed bed in lines spaced at 20 x 10 cm. Dates of sowing were on 21st January (2015) and 9th January (2016). One sowing irrigation was uniformly given to all treatments. Application of irrigation water as per the treatments upto the top of the furrow and measured using parshall flume. Irrigation was started on 10 DAS (days after sowing) and finished on 90 DAS. Pre-emergence application of the recommended herbicide, butachlor @ 2.5 litre ha^{-1} was applied uniformly on 5 DAS and subsequently hand weeding were done at 30 and 50 days after sowing to keep the experimental plot free from weeds. Gap filling was done on 10 DAS to maintain the optimum plant population. Healthy crop stand was ensured by adopting recommended package of practices and need based plant protection measures. The recommend dose of fertilizer viz., 120:40:40 kg N_2, P_2O_5, K_2O ha^{-1} were applied to all the plots. The entire P fertiliser was applied as basal in the form of di-ammonium phoshate (18 % N and 46 % P_2O_5). The N fertiliser was applied in the form of urea (46 % N) and applied in four equal splits as basal and tillering, panicle initiation and at heading stages. The potassium fertilizer was applied in the form of murate of potash (60 % K_2O) in four equal splits. The plant population maintained at 40 and 50 no. per m^{-2} in L_1, L_2 and L_3, respectively

Five plants from the net plot area excluding border rows were selected at random and tagged. The tagged plants were used for recording the data pertaining to growth, yield parameters and yield. The height of rice plant was measured on 60 DAS. The height of the tagged plants was measured from cotyledonary node to the base of the last opened leaf and expressed in cm. Five plants per plot were selected at random and were cut close to the cotyledonary leaf node on 75 DAS for estimating DMP. The samples collected were chopped, air dried and then oven dried at 65±5^{o}C until attaining constant weight. Mean weight of samples was recorded and expressed in kilogram per hectare. The total number of tillers in one square meter were counted in each treatment randomly in selected hills on 75 DAS and expressed as No. of productive tillers m^{-2}. The relative leaf water content (RLWC) was estimated as suggested by Bars and Weatherely (1962) and values were expressed as percentage. For RLWC estimation, sample leaves were collected on randomly selected plants at the middle portion of the bed on 60 DAS. The crop was harvested manually in net plot area of individual treatments, threshed, cleaned and dried to maintain 14 per cent moisture content and weighed separately. The weight of the harvested grain was expressed as kilogram per hectare. The data pertained to growth, yield and yield parameters were subjected to statistical analysis by Analysis of Variance (ANOVA) using AGRES (Data Entry Module for AgRes Statistical software version 3.01, 1994 Pascal Intl. Software Solutions). Differences between means were evaluated for significance using least significant differences (LSD) at 5 per cent probability level as suggested by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Growth parameters of rice

Plant growth parameters viz., plant height and DMP of rice crop are significantly affected by the different bed widths and irrigation scheduling. The plant height of rice crop was significantly affected by the different bed width treatments during the crop growth period (Table 1). Bed width of 0.8 m (L_1) which accommodated four rows of rice produced taller plants than the other treatments at 75 DAS (89.1 and 87.3 cm during 2015 and 2016, respectively). This was closely followed by raising the rice crop under FIRB system with a bed width of 1.0 m (L_2) and they are on par with each other. Regarding the frequencies of irrigation, irrigating the crop daily (I_1) recorded the tallest (92.3 and 90.3 cm during 2015 and 2016, respectively) plant when compared to the rest of the treatments. The lowest plant height 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. Among the different treatment combinations, raising the rice crop with a bed width of 0.8 m and irrigating the crop daily (L_1I_1) recorded the highest plant height (94.3 and 92.2 cm during 2015 and 2016, respectively). This treatment was followed by sowing of aerobic rice in raised bed of 1.0 m width and irrigating the crop daily (L_2I_1) recorded a plant height of 93.2 and 91.3 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.

Different bed width treatments and different irrigation frequencies showed a significant difference for DMP of rice on 75 DAS. The DMP of Rice crop was significantly affected by the different bed width treatments during the crop growth period (Table 2). Bed width of 1.0 m (L_2) which accommodated four rows of rice produced higher DMP than the other treatments at 75 DAS (7542 and 7371 kg ha^{-1} during 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 (8028 and 7852 kg ha^{-1} in 2015 and 2016, respectively) plant when compared to the rest of the treatments.

The lowest DMP was noticed with irrigating the furrow at a frequency of once in three days (I_3). There was a significant interaction between 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 DMP (8203 and 8025 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 8092 and 7930 kg ha^{-1} of DMP 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.

Relative leaf water content (RLWC)

Different bed width treatments and different irrigation frequencies showed a significant difference in RLWC (Table 3). Bed width of 0.8 m (L_1) which accommodated four rows of rice maintained higher values (88.1 and 88.0 per cent during 2015 and 2016, respectively) than the other treatments. This was closely followed by raising the rice crop raised under the bed width of 1.0 m (L_1) and they are on par with each other. Regarding the frequency of irrigation, irrigating the crop daily (I_1) recorded the higher values (88.6 and 88.4 during 2015 and 2016, respectively) when compared to the rest of the treatments for RLWC. The lowest RLWC was noticed in the crop irrigating at a frequency of once in three days (I_3). Among the treatment combinations, raising the rice crop with a bed width of 0.8 m and irrigating the crop daily (L_1I_1) recorded higher values (89.5 and 89.3 per cent during 2015 and 2016, respectively). The lowest values were recorded (83.6 and 83.3 per cent 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).

Yield parameters and yield

Different bed width treatments and different irrigation frequencies showed a significant difference for the number of productive tillers per meter square (Table 3). Bed width of 1.0 m (L_2) which accommodated four rows of rice produced higher number of productive tillers per meter square than the other treatments (305 and 292 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) and they are on par with each other. Regarding the frequency of irrigation, irrigating the crop daily (I_1) recorded the higher values (303 and 297 during 2015 and 2016, respectively) when compared to the rest of the treatments. The lowest number of productive tillers per meter square 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. 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 tillers per meter square (320 and 313 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 tillers per meter square of 302 and 296 during 2015 and 2016, respectively. The number of tillers per meter square was lowest in bed of 1.2 m width and irrigating the crop once in three days (L_3I_3).

The grain yield was significantly influenced by the different bed widths and different irrigation frequencies (Table 5). Bed width of 1.0 m (L_2) which accommodated four rows of rice produced higher grain yield than the other treatments (3438 and 3360 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) and they are on par with each other. Regarding the frequency of irrigation, irrigating the crop daily (I_1) recorded the higher grain yield (3654 and 3574 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 (3874 and 3789 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 grain yield of 3690 and 3616 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).

Water use and Water Use Efficiency

Bed width of 0.8 m (L_1) which accommodated four rows of rice consumed more water than the other treatments (825 and 844 mm during 2015 and 2016, respectively) (Table 6). This was closely followed by raising the rice crop under the bed width of 1.0 m (L_2). Regarding the frequency of irrigation, irrigating the crop daily (I_1) recorded more water use (860 and 874 mm during 2015 and 2016, respectively) when compared to the rest of the treatments. The lowest water use (660 and 685 mm during 2015 and 2016, respectively) was observed 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 daily (L_1I_1) recorded more water use (920 and 932 mm during 2015 and 2016, respectively). The lowest water use (560 and 590 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 7). Bed width of 1.0 m (L_2) which accommodated four rows of rice produced higher WUE than the other treatments (4.36 and 4.16 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 daily (I_1) recorded the higher values for WUE (4.26 and 4.10 kg ha^{-1} 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 daily (L_2I_1) recorded more WUE (4.39 and 4.24 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).

Advantage of raised bed system of aerobic rice cultivation was evident when compared to flat bed system of cultivation. A significant increase in plant height and dry matter production of aerobic rice was observed under raised bed compared to flat bed at 90 DAS (Balamani *et al*., 2012). Among different frequencies of irrigation scheduling tested in aerobic rice cultivation, more frequencies i.e less irrigation interval recorded higher plant height, LAI and DMP in aerobic rice.

The reduction in growth, yield components and yield under shorter raised bed (L_1) is mainly due to reduction in over all population compared to moderate (L_2) and lengthier (L_3) raised bed. Since the plant under L_2 and L_3 experienced mild and severe water stress due to restricted movement and availability of water to the crop rows in the middle of the bed as evidenced from the low RLWC (Table 3). The reduction in DMP and grain yield was minimum between L_1 and L_2 and L_2, maintained higher population when compared to L_1 even subjected to mild water stress in the middle of the raised bed. The number of plant population and water stress was more under L_3 produced more no. of shorter plants with lower dry matter accumulation and eventually with significant reduction in grain yield.

The highest dry matter accumulation with irrigation scheduled at higher frequency might be attributed to the fact that increased more no. of irrigations compared to less no. of frequency facilitated higher water and nutrient uptake by the crop coupled with possible reduction in transpiration rate and CO_2 exchange resulted in increased production of photosynthates and their translocation to sink (Shekara and Sharanappa, 2010). The lower dry matter production was noticed in treatments with less no. of irrigation and it might be due to reduction in cell division, cell volume, cell elongation, photosynthesis and biomass production (Belder *et al.,* 2005; Maheswari *et al.,* 2007; Ghosh *et al.,* 2010).

Rice grain yields are highly dependent upon the number of panicle produced per plant which controlled by the plant water status. Kamoshita and Abe (2007) reported that tiller number subsequently increased the both source and sink capacity under supply of irrigation water as more frequencies. The present study also daily irrigation produced more no. of productive tillers than irrigation schedule once in two days and three days. These results are in accordance to the observations of Hasamuzzaman *et al.* (2009). Kadiyala *et al.* (2012) used lower amount of irrigation water about 645 to 967 mm for aerobic rice cultivation compared to transplanted condition. In the present study also water used in the range of 677 to 860 mm under aerobic condition.

Rice crop raised on beds maintain water saving and yield increase compared to transplanted rice (Gupta *et al.,* 2002). Reddy *et al.* (2010) also expressed an increased water productivity under aerobic rice than transplanted rice. Naresh *et al.* (2014) reported that aerobic rice cultivated under wider raised beds saved water at the cost of yield increase compared to shorter bed. They also demonstrated that water saving upto 24 per cent and 8 per cent yield reduction in wider raised bed system of cultivation.

Raised bed dimensions and configurations vary with soil type and available machinery. The ability of the soil to ‘sub’ (i.e. allow the lateral movement of irrigation water into the centre of the bed) is a key determinant of bed dimensions. Present study also bed width of 0.8 m performed better than wider widths. Nevertheless, furrow-irrigated rice production can still be a viable option under water-limiting situations and under certain topographic conditions (Muthukumar *et al.,* 2011).

Furrow irrigated rice is generally irrigated more frequently with minimum the amount of water to the field. The FIRB method of cultivation is an attractive option for traditional method of cultivation which demand more irrigation water. The yield stability under aerobic rice cultivation system should be considered before for large scale adoption of this high water productive system of cultivation.

Table 1. Effect of bed width and frequency of irrigation on plant height (cm) of aerobic rice under FIRB system

Treatments	Frequency of irrigation (I)							
	2015				2016			
Bed width (L)	I_1	I_2	I_3	Mean	I_1	I_2	I_3	Mean
L_1	94.3	89.2	83.8	**89.1**	92.2	87.4	81.8	**87.3**
L_2	93.2	88.0	81.8	**87.7**	91.3	86.1	80.9	**87.5**
L_3	89.4	87.5	79.5	**85.4**	87.3	85.0	78.3	**83.5**
Mean	**92.3**	**88.2**	**81.7**		**90.3**	**86.2**	**80.3**	

	2015		2016	
	SEd	CD (0.05)	SEd	CD (0.05)
L	1.2	2.5	1.1	2.4
I	1.5	3.1	1.4	2.8
LI	2.3	5.1	2.2	5.0

Treatment details are given under Materials and Methods

Table 2. Effect of bed width and frequency of irrigation on DMP (kg ha^{-1}) of aerobic rice under FIRB system

Treatments	Frequency of irrigation (I)							
	2015				2016			
Bed width (L)	I_1	I_2	I_3	Mean	I_1	I_2	I_3	Mean
L_1	8092	7330	6232	**7218**	7930	7170	6082	**7060**
L_2	8203	7985	6437	**7542**	8025	7793	6295	**7371**
L_3	7788	7169	5834	**6930**	7601	7026	5717	**6781**
Mean	**8028**	**7495**	**6168**		**7852**	**7330**	**6031**	

	2015		2016	
	SEd	CD (0.05)	SEd	CD (0.05)
L	122	258	120	253
I	125	266	123	260
LI	211	448	207	440

Treatment details are given under Materials and Methods

Table 3. Effect of bed width and frequency of irrigation on Relative Leaf water Content (%) of aerobic rice under FIRB system

Treatments	Frequency of irrigation (I)							
	2015				2016			
Bed width (L)	I_1	I_2	I_3	Mean	I_1	I_2	I_3	Mean
L_1	89.5	88.4	86.5	**88.1**	89.3	88.2	86.4	**88.0**
L_2	89.0	87.6	84.7	**87.1**	88.9	87.3	84.5	**86.9**
L_3	87.4	86.8	83.6	**85.9**	87.2	86.6	83.3	**85.7**
Mean	**88.6**	**87.6**	**84.9**		**88.4**	**87.3**	**84.7**	

	2015		2016	
	SEd	CD (0.05)	SEd	CD (0.05)
L	1.91	4.32	1.89	4.28
I	1.93	4.36	1.91	4.30
LI	2.82	6.41	2.80	6.38

Treatment details are given under Materials and Methods

Table 4. Effect of bed width and frequency of irrigation on No. of productive tillers m^{-2} of aerobic rice under FIRB system

Treatments	Frequency of irrigation (I)							
	2015				2016			
Bed width (L)	I_1	I_2	I_3	Mean	I_1	I_2	I_3	Mean
L_1	302	292	270	**288**	296	285	265	**282**
L_2	320	310	284	**305**	313	289	275	**292**
L_3	288	278	262	**276**	281	272	254	**269**
Mean	**303**	**293**	**252**		**297**	**282**	**265**	

	2015		2016	
	SEd	CD (0.05)	SEd	CD (0.05)
L	12	31	11	28
I	14	33	12	30
LI	22	48	20	45

Treatment details are given under Materials and Methods

Table 5. Effect of bed width and frequency of irrigation on grain yield (kg ha^{-1}) of aerobic rice under FIRB system

Treatments	Frequency of irrigation (I)							
	2015				2016			
Bed width (L)	I_1	I_2	I_3	Mean	I_1	I_2	I_3	Mean
L_1	3690	3237	2894	**3274**	3616	3159	2728	**3168**
L_2	3874	3394	3045	**3438**	3789	3319	2972	**3360**
L_3	3398	3027	2326	**2917**	3316	2966	2279	**2854**
Mean	**3654**	**3219**	**2755**		**3574**	**3148**	**2660**	

	2015		2016	
	SEd	CD (0.05)	SEd	CD (0.05)
L	60	155	59	152
I	62	160	61	155
LI	94	220	92	216

Treatment details are given under Materials and Methods

Table 6. Effect of bed width and frequency of irrigation on total water use (mm) of aerobic rice under FIRB system

Treatments	Frequency of irrigation (I)							
	2015				2016			
Bed width (L)	I_1	I_2	I_3	Mean	I_1	I_2	I_3	Mean
L_1	920	830	725	**825**	932	851	748	**844**
L_2	883	790	696	**790**	894	810	716	**807**
L_3	776	695	560	**677**	797	710	590	**700**
Mean	**860**	**772**	**660**		**874**	**790**	**685**	

Treatment details are given under Materials and Methods *Data statistically not analysed

Table 7. Effect of bed width and frequency of irrigation on water use efficiency (kg ha^{-1} mm^{-1}) of rice under FIRB system

Treatments	Frequency of irrigation (I)							
	2015				2016			
Bed width (L)	I_1	I_2	I_3	Mean	I_1	I_2	I_3	Mean
L_1	4.01	3.90	3.99	**3.96**	3.88	3.71	3.65	**3.75**
L_2	4.39	4.30	4.38	**4.36**	4.24	4.10	4.15	**4.16**
L_3	4.38	4.36	4.15	**4.30**	4.16	4.18	3.86	**4.07**
Mean	**4.26**	**4.19**	**4.17**		**4.10**	**4.00**	**3.88**	

Treatment details are given under Materials and Methods *Data statistically not analysed

CONCLUSION

Raised bed of 1.0 m bed width accommodating four rows per bed and irrigating the crop daily resulted in higher grain yield (3874 and 3789 kg ha^{-1} during 2015 and 2016, respectively) and WUE (4.39 and 4.24 kg ha^{-1} mm^{-1} during 2015 and 2016, respectively) than other irrigation scheduling and land configurations. This research indicated that it is possible to raise rice crop under raised bed aerobic conditions with some precautions. Further, irrigation scheduling fixed based on weather or other climate related parameters is needed. In future, research may be extended to include climatic parameter for water calculation and irrigation scheduling.

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Ethics statement

No specific permits were required for the described field studies because no human or animal subjects were involved in this research.

Originality and plagiarism

I ensure that they have written and submit only entirely original works, and if they have used the work and/or words of others, that this has been appropriately cited.

Consent for publication

All the authors agreed to publish the content.

Competing interests

There were no conflict of interest in the publication of this content.

Data availability

All the data of this manuscript are included in the MS.

REFERENCES

Barrs, H.D. and Weatherly, P.E. 1962. A re-examination of the relative turgidity technique for estimating water deficit in leaves. *Aust. J.Biol.Sci.,* **15:** 413-428.

Balamani, K., Ramulu, V., Reddy, M.D. and Devi, M.U. 2012. Effect of irrigation methods and irrigation schedules on aerobic rice (*Oryza sativa* L.). *Journal of Research ANGRAU*. **40 (4):** 84-86.

Belder, P., Bouman, B.AM., Spiertz, J.H.J., Peng, S., Castan, A. R. and Visperas, R. M. 2005. Crop performance, nitrogen and water use in flooded and aerobic rice. *Plant and Soil.* **273(1/2):** 167-182.

Borrell, A.K., Garside, A.L. and Fukai, S. 1997. Improving efficiency of water use for irrigated rice in a semi-arid tropical environment. *Field Crops Res.,* **52:** 231-248.

Ghosh, A. and Singh, O.N. 2010. Determination of threshold regime of soil moisture tension for scheduling irrigation in tropical aerobic rice for optimum crop and water productivity. *Exp. Agric.* **46(4):** 489-499.

Gomez, K.A. and Gomez, A. A. 1984. Statistical procedures for agricultural research. Second Edn. John Wiley and Sons**,** New York. 680 p.

Gupta, R.K, Naresh, R. K, Hobbs, P.R and Ladha, J.K. 2002. Adopting conservation agriculture in the rice-wheat system of the Indo-Gangetic Plains: new opportunities for saving water. **In:** 'Water-wise rice production'. (Eds. BAM Bouman, H., Hengsdijk, B., Hardy, P.S., Bindraban, T.P., Tuong, JK, Ladha) Los Baños (Philippines): International Rice Research Institute, 207-222 p.

Hasamuzzaman, M., Fujita, M., Islam, M.N., Ahamed, K.U. and Nahar, K. 2009. Performance of four irrigated rice varieties under differentlevels of salinity stress. *Int. J. Integr. Biol.,* **6:** 85.

Kamoshita, A. and Abe, J. 2007. Growth of rice plants (Oryza sativa L.) under non-flooded water-saving paddy fields. *Agriculture Journal.* **2:** 375-383.

Maheswari. J., Maragatham, N. and Martin, G. J. 2007. Relatively simple irrigation scheduling and N application enhances the productivity of aerobic rice (Oryza sativa L.). *Am. J. Plant Physiol.,* **2(4):** 261-268.

Muthukumar, V.B., Norsworthy, J.K. and Scott, R.C. 2011. Comparison of Weed Management Programs for Furrow-Irrigated and Flooded Hybrid Rice Production in Arkansas. Weed Technol., **25(4):**556-562.

Naresh, R.K., Gupta, R.K., Kumar, A, Singh, B, Prakash, S., Kumar, S. and Rathi, R.C. 2011. Direct-seeding and reduced-tillage options in the rice-wheat system of the Western Indo-Gangetic Plains*. Int. J. Agric. Sci.*, **7(1):** 197–208.

Naresh, R.K., Tomar, S.S., Dipender Kumar., Samsher., Purushottam., Singh, S.P., Ashish Dwivedi. and Vineet Kumar. 2014. Experiences with Rice Grown on Permanent Raised Beds: Effect of Crop Establishment Techniques on Water Use, Productivity, Profitability and Soil Physical Properties *Rice Sci.,* **21(3):**170–180.

Reddy, M.D., Reddy, S.N. and Ramulu, V. 2010. Evaluation of rice cultivars for aerobic and transplanted conditions. *Agric. Sci. Dig.,* **30(2):**129-132.

Sharma, P..K, Bhushan, L., Ladha, J.K., Naresh, R..K, Gupta, R.K., Balasubramanian, B.V. and Bouman, B.A.M. 2002. Crop-water relations in rice-wheat cropping under different tillage systems and water-management practices in a marginally sodic, medium-textured soil. **In:**"Water-Wise Rice Production". (Eds. Bouman BAM, Hengsdijk H, Hardy B, Bindraban PS, Tuong TP, Ladha JK). Proceedings of the International Workshop on Water-Wise Rice Production, 8-11 April 2002, Los Baños, Philippines. Los Baños (Philippines): International Rice Research Institute, 223-236 p.

Shekara, B.G. and Sharanappa, K.N. 2010.Effect of irrigation schedules on growth and yield of aerobic rice (Oryza sativa L.) under varied levels of farmyard manure in Cauvery command area. Indian J. Agron., **55(1):** 35-39.

Singh, A.K., Choudury, B.U and Bouman, B.A.M. 2002. The effect of rice establishment techniques and water management on crop-water relations. **In:** "Water-Wise Rice Production". (Eds. Bouman BAM, Hengsdijk H, Hardy B, Bindraban PS, Tuong TP, Ladha JK). Proceedings of the International Workshop on Water-Wise Rice Production, 8-11 April 2002, Los Baños, Philippines. Los Baños (Philippines): International Rice Research Institute, 237-246 pp.

Tabbal, D.F., Bouman, B.A.M., Bhuiyan, S.I, Sibayan, E.B. and Sattar, M.A. 2002. On-farm strategies for reducing water input in irrigated rice: case studies in the Philippines. *Agric. Water Manag.,* **56:**93-112.