

Effect of irrigation scheduling and different levels of zinc and boron on yield, economics, water productivity and nutrient uptake in aerobic rice (*Oryza sativa*)

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Received : April 2019; Revised accepted : September 2019

ABSTRACT

A field study was conducted during the rainy (*khari*) seasons of 2015 and 2016 at Chiplima, Sambalpur, under west central tableland zone of Odisha, to evaluate 6 different micronutrient combinations under 4 different irrigation schedules in aerobic rice (*Oryza sativa* L.). Application of irrigation after 3 rainless days resulted in significantly highest grain yield (4.05 t/ha) over all other treatments owing to optimum soil moisture and nutrient availability. The highest number of panicle bearing tillers/m² (375.1), panicle length, filled grains/panicle (108.5) and 1,000-grain weight (26.23 g) attributed to the higher yield under this treatment. It also resulted in the highest net returns (₹30,316/ha), benefit: cost (B:C) ratio of 1.88 and nutrient uptake. Among different levels of micronutrient, an application of recommended dose of fertilizer (RDF, 80-40-40) kg/ha N, P₂O₅ – K₂O + 5 kg Zn/ha + 0.2% B as foliar spray (2 sprays) registered significantly highest grain yield of 4.24 t/ha along with higher values of yield attributes such as panicle-bearing tillers/m² (391.1), panicle length (25.52 cm), filled grains/panicle (117.9) and 1,000-grain weight (26.17 g). It also resulted in higher net return (₹30,362/ha), benefit: cost ratio of 1.89 and nutrient uptake than all the other treatments. Water use was highest in case of irrigation scheduling after 3 rainless days (91.33 cm) with lowest water productivity (0.43 kg/m³). Out of 6 micronutrient levels, application of RDF (80-40-40 N, P₂O₅ and K₂O Kg/ ha) + 5 kg Zn/ ha + 0.2 % B as foliar spray (2 sprays) resulted in the highest water productivity (0.57 kg/m³) owing to higher yield and low water use. However, the interaction effect was statistically non-significant.

Key words: Aerobic Rice, Irrigation schedule, Micronutrient, Rainless days, Water productivity

In India, Rice is the staple food crop grown in an area of 44.6 million ha with a production of 104.4 million tonnes and average productivity of 2.4 t/ha (DACFW, 2017–18). Transplanting is the most common method of establishment for rice followed in India, which requires a lot of water to maintain flooding condition throughout the entire crop-growth period. Most of Asian countries are facing severe water scarcity, which may pose problem for sustainability of traditional rice production. Hence, it is necessary to opt water-saving technologies to make crop production more sustainable. Among various water-saving techniques for rice production, aerobic rice is one of the agro-techniques to cope with increasing shortage of water

supply to agriculture. In this method, rice is grown like other cereals in non-flooded and unsaturated soil. Rice cultivation under aerobic condition requires less water than conventional irrigation system (Ghosh and Singh, 2010). Each nutrient affects specific function in growth and development of crop plants, and their inadequacy leads to reduction in growth and yield. Almost 30% of soil is zinc deficient, which covers 49 developed and developing countries of the world (Alloway, 2004). Crop production and quality of produce is seriously affected by emerging deficiency of micronutrients (boron and zinc) all over the world. Numerous studies have indicated that zinc deficiency is a serious nutritional problem for upland crops. There is a decrease in rice productivity due to high analysis fertilizer and reduced micronutrient application (Bhandari *et al.*, 2003). Zinc and boron are 2 important micronutrients required by rice crop. Zinc is a major component and activates several enzymes involved in metabolic activities. In rice plant, zinc is essential for several

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biochemical processes such as cytochrome and nucleotide synthesis, auxin metabolism, chlorophyll content, enzyme activation and membrane integrity. Boron stimulates enzymatic activity, availability of sugar, and respiration, which leads towards improved pollen growth. Boron is responsible for better pollination, seed setting and grain formation in rice. Deficiency of boron in rice plant results in thinner stems, shorter and fewer tillers and failure to produce viable seeds. In view of enhancing water productivity for rice and mitigating micronutrient deficiency, the present study was carried out to investigate the effect of irrigation and micronutrient on yield, yield-attributing characters and water productivity of aerobic rice.

MATERIALS AND METHODS

The field study was conducted during the rainy seasons (*kharif*) of 2015 and 2016 at research farm of Regional Research and Technology Transfer Station, Chiplima, Sambalpur (20°11' N-20°20' N and 82°15' E-85°39' E) under All India Coordinated Research Project on Irrigation Water Management. The rice crop received precipitation of 598 mm in 19 rainy days and 1493.8 mm in 48 rainy days, maximum temperature 34.3°C to 32°C and minimum temperature varied between 20.5°C and 20.7°C during the *kharif* 2015 and 2016, respectively. The soil was sandy loam, slightly acidic in reaction (*pH* 5.5) with electrical conductivity of 0.70 dS/m (1 : 2 soil to water). The soil was medium in organic carbon (wet-digestion method), available nitrogen (alkaline permanganate-oxidizable) and zinc (DTPA-extractable) (0.71%, 270 kg/ha and 1.116 ppm, respectively), fairly rich in available P₂O₅ (Brays'P), and K₂O (NH₄OAc-extractable) (31 kg/ha and 260 kg/ha respectively), and low (0.09 ppm) in available boron (DTPA-extractable).

The experiment was laid out in a split-plot design with 3 replications, comprising scheduling of irrigation in main plot and different combinations of micronutrients in subplots. There were 24 treatments comprising of 4 irrigation scheduling (irrigation at 3 rainless days interval, irrigation at 5 rainless days interval, irrigation at 7 rainless days interval and rainfed condition) in main plot and 6 levels of micronutrient combinations such as recommended dose of fertilizer (RDF) [(80-40-40 N,P₂O₅ and K₂O kg/ha)], RDF (80-40-40) + 5 kg Zn/ha + 0.2% B as foliar spray (2 sprays), RDF (80-40-40) + 5 kg Zn/ha, RDF (80-40-40) + 2.5 kg Zn/ha + 0.2% B as foliar spray (2 sprays), RDF (80-40-40) + 2.5 kg Zn/ha and RDF (80-40-40) + 0.2% B as foliar spray (2 sprays) in the subplots. Farmyard manure @ 5 t/ha was applied to the field. The N,P₂O₅ and K₂O were applied at the rate of 80-40-40 kg/ha. The whole quantity of P₂O₅ and K₂O and half of N along with zinc as per treatments were applied basal dose to rice crop and the

remaining amount of N was top-dressed in 2 equal splits, i.e. at tillering and panicle-initiation stage. Boron was applied twice, i.e. at pre-flowering and flowering stage @ 0.2%. The seedlings of 14 days old aerobic rice variety 'Pyari' ('CR Dhan 200') of mid-early duration (115–120 days) was transplanted at 20 cm × 20 cm spacing. All improved packages of practices were followed to raise the crop. Ten random plants were selected from each plot, excluding border row, for taking observation on growth and yield attributes of aerobic rice. The gross returns (₹/ha) for each treatment combination was calculated taking into consideration the yield and market price of produce. The net returns (₹/ha) and benefit: cost ratio were calculated for each treatment combination separately. The total uptake of N, P, K, Zn and B by aerobic rice at harvesting for each treatment was computed by N, P, K, Zn and B content in grain and straw with the respective dry weight and expressed as kg/ha using the following formulae:

$$\text{Primary nutrient uptake (kg/ha)} = [\text{Nutrient content (\%)} \times \text{Dry-matter yield (kg/ha)}] / 100$$

$$\text{Micronutrient uptake (g /ha)} = [\text{Nutrient content (ppm)} \times \text{Dry-matter yield (kg /ha)}] / 100$$

All the data with regards to plant-growth characters, yield-attributing characters, grain yield and straw yield were recorded and statistically analysed using the analysis of variance technique.

RESULT AND DISCUSSION

Grain yield and straw yield

There was significant increase in grain yield with application of irrigation water over the control. Among main plot treatments, irrigation at 3 rainless days interval resulted in the highest grain yield (4.20 t/ha) over all other treatments, being 32.19% higher over the control (Table 1). Among the subplots, grain yield increased significantly over the control with application of different micronutrients. The RDF (80-40-40) + 5 kg Zn/ha + 0.2% B as foliar spray (2 Sprays) recorded the highest yield (100 L-R) over the other treatment, which was 40.92% higher than the control. Higher straw yield was noted with irrigation scheduling under rainfed condition, followed by irrigation scheduling at 3 rainless days interval.

Among micro-nutrient treatments, RDF (80-40-40) + 5 kg Zn/ha + 0.2% B as foliar spray (2 sprays) resulted in significantly higher straw yield (7.07 t/ha) over all the other treatments. Malamasuri *et al.* (2014) reported that, soil application of ZnSO₄ at 12.5 kg/ha along with RDF to aerobic rice showed higher grain yield and other yield-attributing characters. It could be because of synergetic effect of zinc along with recommended dose of fertilizer and improved soil physical properties and higher translocation of carbohydrates to grains, which ultimately resulted in

higher grain yield under foliar application of micronutrients. Rashid *et al.* (2004) observed that, there was a substantial increase in grain yield of rice due to reduced panicle sterility after boron application. However, the interaction effect was non-significant.

Yield-attributing characters

Different scheduling of irrigation management resulted in significant effect on yield attributes, viz. effective tillers/m², panicle length, filled grains/panicle and 1,000-grain weight (g). Irrigation after 3 rainless days resulted in significantly higher number of effective tiller (375.1) than all the other treatments. It also recorded higher number of grains/panicle, (108.5) panicle length (24.9 cm) and 1,000-grain weight (26.2 kg) (Table 2). The higher number of panicle-bearing tillers and grains/panicle might be owing to availability of water and micronutrients at panicle-differentiation stage and good aerated condition at root zone, which in turn helped to retain more number of panicle-bearing tillers at harvesting. These results confirm the findings of Barik *et al.* (2006). Number of panicles/m² and 1,000-grain weight increased consistently with increased water input (Bouman *et al.*, 2006). Aerobic rice variety 'HD 502' recorded grain yield of 5.3–5.7 t/ha with 640–920 mm of total water input and 3–3.6 t/ha with 470–550 mm water (Bouman *et al.*, 2006).

Among different micronutrient combinations, RDF (80-40-40) + 5 kg Zn/ha + 0.2% B as foliar spray (2 sprays)

resulted in higher number of panicle-bearing (391.1) tillers over all the other treatments, being at par with RDF (80-40-40) + 2.5 kg Zn/ha + 0.2 % B as foliar spray (2 sprays) (314.5). It also recorded the highest number of grains/panicle, (117.9) panicle length (25.5 cm) and 1,000-grain weight (26.29 g). More number of grains/panicle and higher grain weight by boron application might be owing to involvement of boron in reproductive growth, as boron improves the panicle fertility in rice (Rehman *et al.*, 2012). Maximum number of grains/panicle against the control plots might be owing to the reduction in pollen sterility of rice and proper grain filling (Rashid *et al.*, 2004). Rashid *et al.* (2009) observed increasing trend in number of tillers, 1,000-grain weight and yield with boron application in rice crop. This might be owing to improved availability of nitrogen and phosphorus because of their synergistic effect with boron and zinc. Our results confirm the findings of Patel *et al.* (2010) and Veeresh *et al.* (2011). However, the interaction effect was non-significant.

Economics

Pooled data (2 years) revealed that net returns (₹30,316/ha) were the highest when irrigation was given at 3 rainless days interval. Among subplot treatments, RDF (80-40-40) + 5 kg Zn/ha + 0.2% B as foliar spray (2 sprays) resulted in the maximum net return of ₹30,362/ha over all the other treatments. Irrigation at 5 rainless days interval recorded the maximum benefit: cost ratio (1.88)

Table 1. Effect of irrigation and micronutrient on yield and yield-attributing characters of aerobic rice (pooled data of 2 years)

Treatment	Grain yield (t/ha)	Straw yield (t/ha)	Panicles/m ² (Nos.)	Panicle length (cm)	Filled grains/panicle (Nos.)	Test weight (g)
<i>Irrigation scheduling</i>						
I ₁ , Irrigation after 3 rainless days	4.20	6.51	375.1	24.9	108.5	26.2
I ₂ , Irrigation after 5 rainless days	4.09	6.42	364.5	24.4	103.4	26.2
I ₃ , Irrigation after 7 rainless days	3.81	6.49	343.5	24.2	99.9	26.1
I ₄ , Rainfed condition	3.26	6.67	305.6	23.9	94.8	26.2
SEm±	0.06	0.08	5.73	0.15	1.58	0.06
CD (P=0.05)	0.19	0.26	17.88	0.46	4.76	0.18
<i>Micronutrient level</i>						
N ₁ , RDF (80-40-40)	3.12	6.23	279.8	23.6	94.1	26.1
N ₂ , RDF (80-40-40) + 5 kg Zn/ha + 0.2% B as foliar spray (2 sprays)	4.24	7.05	391.1	25.5	117.9	26.2
N ₃ , RDF (80-40-40) + 5 kg Zn/ha	3.83	6.40	338.4	24.0	94.3	26.1
N ₄ , RDF (80-40-40) + 2.5 kg Zn/ha + 0.2% B as foliar spray (2 sprays)	4.20	6.43	384.2	24.8	113.4	26.2
N ₅ , RDF (80-40-40) + 2.5 kg Zn/ha	3.91	6.41	351.5	24.4	93.3	26.2
N ₆ , RDF (80-40-40) + 0.2% B as foliar spray (2 sprays)	3.73	6.60	338.0	23.9	97.1	26.3
SEm±	0.04	0.09	5.22	0.15	1.66	0.06
CD (P = 0.05)	0.11	0.26	15.75	0.45	4.97	0.18

RDF, Recommended dose of fertilizer

among the main plot treatments. Maximum benefit: cost ratio (1.89) was recorded with combined application of boron and zinc i.e. RDF (80-40-40) + 5 kg Zn/ha+ 0.2% B as foliar spray (2 sprays) over other treatments because of higher yield obtained in that treatment. Application of micronutrients resulted in improved performances in all the treatments, while the effect was more pronounced in case of more water availability. The application of zinc and boron was highly cost effective because of low cost so positive yield and quality impacts were observed. Hussain and Yasin (2004) also reported that, boron use in rice is highly economical with value cost ratios of 45 : 1 to 26 : 1 in different rice varieties. This result confirms the findings of Sarwar *et al.* (2013).

Water requirement and water productivity

Water requirement showed the amount of water used in individual irrigation scheduling. Pooled data of 2 years showed that maximum water was used in irrigation scheduling at 3 rainless days interval (91.33 cm) and the average water use for subplot treatments was 77.53 cm. Bouman *et al.* (2002) reported that, use of 476–612 mm total water resulted in grain yield of 4.6–6.6 t/ha on loamy soils.

The results revealed that irrigation at 7 rainless days interval recorded the maximum water productivity (0.54 kg/m³) over all other treatments owing to less water use and high yield. Among the subplot treatments, RDF (80-40-40) + 5 kg Zn/ha+ 0.2% B as foliar spray (2 sprays) achieved the maximum water productivity (0.57 kg/m³). Geethalakshmi

et al. (2009) reported that, water productivity of 0.37 kg/m³ and 4.2 kg/m³ in 2 consecutive years in rice hybrid 'CORH' under aerobic condition. Similar results were also reported by Malamasuri *et al.* (2014), Martin *et al.* (2007) and Maragatham *et al.* (2010). This shows that aerobic rice cultivation with proper water and micronutrient management results in higher yield than traditionally anticipated.

Nutrient uptake

Among different irrigation scheduling methods, the uptake of different nutrients such as N, P₂O₅, K₂O, Zn and B except K₂O was significantly higher in irrigation scheduling at 3 rainless days over all other treatment. The uptake by grain and straw was 64.4 and 47.2 kg/ha N, 14.8 and 4.3 kg/ha P₂O₅, 38.2 and 142.0 kg/ha Zn and 4.9 and 4.3 kg/ha B, respectively, in irrigation scheduling at 3 rainless days. The uptake of K₂O by grain and straw (97.3 and 113.1 kg/ha) was higher under rainfed condition. Among different levels of micronutrient application, RDF (80-40-40) + 5 kg Zn/ha+ 0.2% B as foliar spray (2 sprays) resulted in higher nutrient uptake (98.4 and 86.1 kg/ha N by grain and straw; 15.2 and 4.2 kg/ha P₂O₅ by grain and straw, 21.3, 75.1 kg/ha K₂O by grain and straw followed by RDF (80-40-40) + 2.5 kg Zn/ha + 0.2% B as foliar spray (2 sprays) (Table 3). This might be owing to positive interaction of micronutrients with other nutrients. Absorption of zinc by roots also plays an important role in uptake of the nutrients.

It was concluded that aerobic rice variety 'Pyari' re-

Table 2. Effect of irrigation and micronutrient on economics, water requirement and water productivity of aerobic rice (pooled data of 2 years)

Treatment	Net returns (× 10 ³ ₹/ha)	Benefit: cost ratio	Water requirement (cm)	Water productivity (kg/m ³)
<i>Irrigation scheduling</i>				
I ₁ , Irrigation after 3 rainless days	30.32	1.88	91.33	0.48
I ₂ , Irrigation after 5 rainless days	28.65	1.86	81.28	0.52
I ₃ , Irrigation after 7 rainless days	24.50	1.75	71.45	0.54
I ₄ , Rainfed condition	23.08	1.73	66.45	0.53
SEm±	–	–	–	–
CD (P=0.05)	–	–	–	–
<i>Micronutrient level</i>				
N ₁ , RDF (80-40-40)	18.32	1.56	77.53	0.45
N ₂ , RDF (80-40-40) + 5 kg Zn/ha + 0.2% B as foliar spray (2 sprays)	30.36	1.89	77.53	0.57
N ₃ , RDF (80-40-40) + 5 kg Zn/ha	26.16	1.77	77.53	0.53
N ₄ , RDF (80-40-40) + 2.5 kg Zn/ha + 0.2% B as foliar spray (2 sprays)	29.39	1.87	77.53	0.56
N ₅ , RDF (80-40-40) + 2.5 kg Zn/ha	26.94	1.80	77.53	0.53
N ₆ , RDF (80-40-40) + 0.2% B as foliar spray (2 sprays)	24.58	1.73	77.53	0.51
SEm±	–	–	–	–
CD (P=0.05)	–	–	–	–

RDF, Recommended dose of fertilizer

Table 3. Effect of irrigation and micronutrient on nutrient uptake by aerobic rice (pooled data of 2 years)

Treatment	N (kg/ha)		P (kg/ha)		K (kg/ha)		Zn (g/ha)		B (g/ha)				
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw			
<i>Irrigation scheduling</i>													
I ₁ , Irrigation after 3 rainless days	64.4	47.2	111.6	14.8	4.3	19.1	19.1	38.2	142.0	180.2	4.9	4.3	9.2
I ₂ , Irrigation after 5 rainless days	62.1	43.1	105.2	10.4	4.0	14.4	12.2	32.4	135.1	167.5	4.7	4.2	8.9
I ₃ , Irrigation after 7 rainless days	57.1	37.6	94.7	6.2	2.1	8.3	14.4	24.1	126.2	150.3	4.1	3.8	7.9
I ₄ , Rainfed condition	49.2	32.3	81.5	4.2	1.3	5.5	15.8	19.2	103.2	122.4	3.6	2.9	6.5
SEM±	5.23	4.93	5.55	1.12	0.43	2.13	4.32	4.10	17.10	18.04	0.12	0.45	0.62
CD (P=0.05)	15.62	14.73	16.53	3.47	1.33	6.35	13.05	12.31	51.17	54.34	0.37	1.40	1.853
<i>Micronutrient level</i>													
N ₁ , RDF (80-40-40)	68.4	41.7	110.1	15.2	4.2	19.4	8.8	28.4	74.7	103.1	2.5	1.9	4.4
N ₂ , RDF (80-40-40) + 5 kg Zn/ha + 0.2% B as foliar spray (2 sprays)	98.4	86.1	184.5	8.1	3.1	11.2	21.3	40.2	171.3	211.5	4.8	4.2	9.0
N ₃ , RDF (80-40-40) + 5 kg Zn/ha	87.6	51.4	139.0	11.4	4.0	15.4	15.5	41.3	180.4	221.7	3.2	2.8	6.0
N ₄ , RDF (80-40-40) + 2.5 kg Zn/ha + 0.2% B as foliar spray (2 sprays)	95.4	82.4	177.8	10.2	3.8	14.0	19.8	38.2	176.0	214.2	4.8	4.4	9.2
N ₅ , RDF (80-40-40) + 2.5 kg Zn/ha	90.2	77.5	167.7	8.3	3.1	11.4	16.2	37.6	173.1	210.7	3.1	2.7	5.8
N ₆ , RDF (80-40-40) + 0.2% B as foliar spray (2 sprays)	73.5	66.1	139.6	12.2	4.1	16.3	19.5	30.5	155.2	185.7	4.8	4.3	9.1
SEM±	6.11	6.74	21.67	0.67	0.28	3.23	0.57	1.65	24.3	25.7	0.23	0.41	0.64
CD (P=0.05)	18.26	20.15	67.22	2.00	0.84	9.65	1.70	4.93	72.66	76.82	0.69	1.24	1.93

RDF, Recommended dose of fertilizer

sponded positively to different scheduling of irrigation. Irrigation scheduling at 3 rainless days interval performed best amongst the different irrigation scheduling. Application of zinc and boron had a positive effect on nutrient uptake and productivity. Application of RDF (80-40-40) + 5 kg Zn/ha + 0.2% B as foliar spray (2 sprays) proved promising in optimizing aerobic rice productivity in sandy-loam soils of western central table land zone of Odisha.

REFERENCES

- Alloway, B.J. (Eds). 2004. *Zinc in Soils and Crop Nutrition*. 130 pp. IZA and IFA publishers, Brussels and Paris.
- Barik, A.K., Das, A., Giri, A.K. and Chattopadhyay, G.N. 2006. Effect of integrated nutrient management on growth, yield and production economics of wet season rice. *Indian Journal of Agronomy* 76(11): 657-660
- Bhandari, A.L., Ladha, J.K., Pathat, H. and Gupta, R.K. 2003. Yield and soil nutrient changes in rice-wheat. *American Journal* 66: 162-170.
- Bouman, B.A.M., Xiaoguang, Y., Huaqui, W., Zhiming, W., Junfang, Z., Changgui, W. and Bin, C. 2002. Aerobic rice (Han Dao): A new way growing rice in water short areas. (In) *Proceedings of the 12th International Soil Conservation Organization Conference*, 26-31 May 2002, Tsinghua University, Beijing, pp. 175-181.
- Bouman, B.A.M., Yang, X.G., Wang, H.Q., Wang, Z.M., Zhao, J.F. and Chen, B. 2006. Performance of aerobic rice varieties under irrigated conditions in North China. *Field Crops Research* 97: 53-65.
- DAC FW. 2017-18. Annual Report 2017-18, Department of Agriculture, Cooperation & Farmers Welfare, Ministry of Agriculture and Farmers Welfare. Government of India, New Delhi, p.3.
- Geethalakshmi, V., Ramesh, T., Palamuthirsolai, A. and Lakshmanan, A. 2009. Productivity and water usages of rice as influenced by different cultivation systems. *Madras Agricultural Journal* 96(7): 349-352.
- Ghosh, A., Singh, O.N. and Rao, K.S. 2010. Improving irrigation management in dry season rice cultivation for optimum crop and water productivity in non-traditional rice ecologies. *Irrigation and Drainage* 60(2): 174-178.
- Hossain, M.B., Kumar, T.N. and Ahmed, S. 2001. Effect of zinc, boron and molybdenum application on the yield and nutrient uptake by BRRI Dhan 30. *Journal of Biological Science* 1: 698-700.
- Hussain, F. and Yasin, M. 2004. Soil fertility monitoring and management in rice wheat system. (In) *Annual Report, 2004-05. National Agricultural Research Centre, Islamabad*, pp. 1-33.
- Malamsuri, K., Reddy, Y.K., Rao, P.V., Tirupataiah, K., Sandhyarani, K. And Duttarganvi, S. 2014. Effect of irrigation scheduling and nutrition (Fe and Zn) on growth, yield and water productivity of aerobic rice. (In) *Proceedings of the International Symposium on*

- Integrated Water Resources Management (IWRM-2014)*, 19–21 February, 2014, CWRDM, Kozhikode, pp. 924–931.
- Maragatham, N., Martin, G.J. and Poongodi, T. 2010. Effect of nitrogen sources on aerobic rice production under various rice soil eco system. (In) *Proceedings of the 19 World Congress of Soil Sciences for a Changing World*, 1–6 August 2010, Brisbane, pp. 15–16.
- Martin, J.G., Padmanathan, P.K. and Subramanian, E. 2007. Identification of suitable rice variety adaptability to aerobic irrigation. *Journal of Agricultural and Biological Sciences* **2**(2): 1–3.
- Patel, D.P., Das, A., Munda, G.C., Ghosh, P.K., Borodoloi, J.S. and Kumar, M. 2010. Evaluation of yield and physiological attributes of high yielding rice varieties under aerobic and flood-irrigated management practices in mid-hills ecosystem. *Agricultural Water Management* **97**(9): 1,269–1,276.
- Rashid, A. and Ryan, J. 2004. Micronutrient constraints to crop production in soils with Mediterranean type characteristics: A Review. *Journal of Plant Nutrition* **27**: 959–975.
- Rashid, A., Yaseen, M., Ashraf, M. and Mann R. A. 2004. Boron deficiency in calcareous soils reduces rice yield and impairs grain quality. *International Rice Research Notes* **29**: 58–60.
- Rashid, A., Yasin, M., Ali, M.A., Ahmad, Z. and Ullah, R. 2009. Boron deficiency in rice in Pakistan: A serious constraint to productivity and grain quality. *Salinity and Water Stress: Improving Crop Efficiency*, pp. 213–219, Springer-Verlag, Publishers, Netherland.
- Rehman, A., Farooq, M., Cheema, Z. A. and Wahid, A. 2012. Seed priming with boron improves growth and yield of fine grain aromatic rice. *Plant Growth Regulation* **68**(2): 189–201.
- Sarwar, N., Ali, H., Ahmad, A., Ullah, E., Ahmad, S., Mubeen, K. and Hill, J.E. 2013. Water-wise rice cultivation on calcareous soil with the addition of essential micronutrients. *The Journal of Animal and Plant Sciences* **23**(1): 244–250.
- Veeresh, Desai, B.K., Viswanatha, S., Anilkumar, S.N., Rao, S. and Halepyati, A.S. 2011. Growth and yield of rice (*Oryza sativa* L.) varieties as influenced by different methods of planting under aerobic method of cultivation. *Research Journal of Agricultural Sciences* **2**(2): 298–300.