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## 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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### ABSTRACT

During the 2015 and 2016 kharif seasons, researchers in Chiplima, Sambalpur, Odisha, tested six distinct combinations of micronutrients in aerobic rice (*Oryza sativa* L.) grown under four distinct irrigation regimes. Due to optimal soil moisture and nutrient availability, applying irrigation after three rainless days produced the best grain production (4.05 t/ha) compared to all other treatments. Because of this treatment, the crop produced more grain per square meter (375.1), longer panicles, more full grains per panicle (108.5), and 26.23 g per 1,000 grains. Nutrient uptake, a benefit-to-cost ratio of 1.88, and net returns of 30,316/ha were all best achieved by this method. Applying the recommended dose of fertilizer (RDF, 80-40-40) kg/ha N, P<sub>2</sub>O<sub>5</sub> - K<sub>2</sub>O + 5 kg Zn/ha + 0.2% B as a foliar spray in two applications resulted in the highest grain yield (4.24 t/ha) and other yield attributes, including tillers bearing panicles per square meter (391.1), panicle length (25.52 cm), filled grains per panicle (117.9), and 1,000-grain weight (26.17 g). Not only that, compared to the other treatments, it had the best net return (30,362/ha), benefit-cost ratio (1.89), and nutrient uptake. In the scenario of irrigation scheduling after three days without rain, the maximum water usage was 91.33 cm, while the lowest water productivity was 0.43 kg/m<sup>3</sup>. The maximum water productivity was seen in a foliar spray application of RDF (80-40-40 N, P<sub>2</sub>O<sub>5</sub>, and K<sub>2</sub>O Kg/ha) + 5 kg Zn/ha + 0.2% B, out of six different micronutrient levels. This spray was applied twice. Increased production with little water use results in ductivity of 0.57 kg/m<sup>3</sup>. Statistical analysis did not reveal a significant interaction impact, nevertheless.

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

With an average yield of 2.4 t/ha and a total area under cultivation of 44.6 million ha, rice is the most important crop in India's diet (DACFW, 2017–18). A lot of water is needed to keep the flooding state going during the full crop-growth period when transplanting is the most popular way of establishing rice in India. Traditional rice cultivation may become unsustainable in most Asian nations due to their extreme water shortages. In order to make crop production more sustainable, it is vital to select for water-saving methods. One agro-technique that might help farmers deal with the growing water scarcity is aerobic rice, one of many water-saving methods for rice cultivation.

other crops. Ghosh and Singh (2010) found that growing rice in aerobic conditions used less water compared to traditional irrigation methods. Inadequate levels of nutrients reduce crop growth and output because each nutrient influences a different process in plant development and growth. Zinc deficiency affects over 30% of the world's soil, spanning 49 industrialized and developing nations (Alloway, 2004). A global shortage of two micronutrients, boron and zinc, is having a devastating effect on crop production and food quality. Research shows that upland crops are particularly vulnerable to zinc deficiency, which may have devastating nutritional effects. Reduced micronutrient application and increased analytical fertilizer use lead to lower rice yields (Bhandari et al., 2003). The rice crop is unable to grow without the minerals zinc and boron. Crucial to metabolic processes, zinc stimulates a number of enzymes. Zinc has a crucial role in rice plants for several

feed the agricultural sector. This technique involves growing rice on soil that is neither inundated nor saturated, much like



biological activities, including the production of cytochromes and nucleotides, the metabolism of auxin, the concentration of chlorophyll, the activation of enzymes, and the maintenance of cell membranes. Boron promotes enhanced pollen production by increasing enzymatic activity, sugar availability, and respiration. Rice benefits from boron because it improves pollination, seed establishment, and grain development. When rice plants don't have enough boron, they develop weaker stems, fewer tillers, and can't set seed. The current research was to examine the impact of irrigation and micronutrients on aerobic rice water productivity, yield-attributing characteristics, and yield in order to improve rice water productivity and reduce micronutrient shortage.

## DATA AND PROCEDURE

The field study was carried out at the research farm of the Regional Research and Technology Transfer Station, Chiplima, Sambalpur (20°11' N-20°20' N and 82°15' E-85°39' E) under the auspices of the All India Coordinated Research Project on Irrigation Water Management during the 2015 and 2016 thematic periods. During the kharif seasons of 2015 and 2016, the rice crop was watered with 598 mm of precipitation over 19 rainy days and 1493.8 mm over 48 rainy days, respectively. Temperatures ranged from 34.3°C to 32°C during the day, with lows of 20.5°C and 20.7°C. The sandy loam soil had an electrical conductivity of 0.70 dS/m (1:2) and a mildly acidic reaction pH of 5.5. Based on the results of the wet-digest technique, the soil had a medium level of organic carbon, a moderate amount of available nitrogen (0.71%), a decent amount of zinc (DTPA-extractable), and a reasonably high level of accessible phosphorus (Brays'P) and potassium (K<sub>2</sub>O) (NH<sub>4</sub>OAc-extractable) (31 kg/ha and 260 kg/ha, respectively).

in the DTPA-extractable boron concentration, which is low at 0.09 ppm.

The experimental design was a split-plot with three replications. The main plot was used for irrigation scheduling, while the sub-plots were used to test various combinations of micronutrients. 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,P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O 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. The field was amended with farmyard manure at a rate of 5 t/ha. A rate of 80-40-40 kg/ha was used for the application of N, P<sub>2</sub>O<sub>5</sub>, and K<sub>2</sub>O. The baseline dosage of P<sub>2</sub>O<sub>5</sub>, K<sub>2</sub>O, half of the

nitrogen, and zinc were administered to the rice crop according to the treatments, and the

At the tillering and panicle-initiation stages, the remaining quantity of nitrogen was applied as a top dressing in equal portions. At both the pre- and post-flowering stages, boron was applied at a concentration of 0.2%. The aerobic rice variety 'Pyari' ('CR Dhan 200'), which is 14 days old and has a mid-early lifespan of 115-120 days, was transplanted at a spacing of 20 cm x 20 cm. The crop was raised in accordance with all proven sets of methods. In order to observe the development and yield properties of aerobic rice, ten plants were randomly chosen from each plot (not including the boundary row). While calculating the gross returns (/ha) for each treatment combination, the yield and market price of product were taken into account. Each treatment combination was evaluated independently for its net returns (/ha) and benefit:cost ratio. With the following equations, we were able to calculate the total absorption of N, P, K, Zn, and B by aerobic rice at harvest for each treatment. We did this by combining the N, P, K, and Zn content in grain and straw with their respective dry weights, and then we expressed the result as kg/ha:

Total nutrient absorption (kg/ha) is equal to the product of the nutrient content (%) and the dry-matter yield (kg/ha).one hundred

You may calculate micronutrient absorption (g/ha) by dividing the nutrient concentration (ppm) by the dry-matter yield (kg/ha).one hundred

Using the analysis of variance approach, all data pertaining to plant-growth characteristics, yield-attributing characters, grain yield, and straw yield were recorded and statistically analyzed.

## RESULT AND DISCUSSION

The yield of grain and straw Applying irrigation water resulted in a considerable improvement in grain output compared to the control. Of all the treatments applied to the main plot, irrigation at 3-day intervals without rain produced the greatest grain production (4.20 t/ha), a 32.19% increase over the control (Table 1). Applying various micronutrients resulted in a significant increase in grain production compared to the control in one of the subplots. With a yield of 100 L-R, 40.92% more than the control, the RDF (80-40-40) + 5 kg Zn/ha + 0.2% B as foliar spray (2 Sprays) outperformed the other treatments. Irrigation scheduling under rainfed conditions resulted in a higher straw production compared to irrigation scheduling at three days intervals without rain.

Among the micro-nutrient treatments, the one that produced the highest straw yield (7.07 t/ha) was the combination of RDF (80-40-40) + 5 kg Zn/ha + 0.2% B applied as a foliar spray in two applications. Improved grain production and other yield-attributing traits were seen when aerobic rice was treated with soil applied ZnSO<sub>4</sub> at a rate of 12.5 kg/ha in conjunction with RDF, according to Malamasuri et al. (2014). That might be



because the soil's physical attributes increased, the amount of fertilizer used had a synergistic effect, and more carbohydrates were translocated to the grains, leading to a

increased grain production when micronutrients are applied to the leaves. After applying boron to rice, Rashid et al. (2004) found that the panicle sterility was decreased, leading to a significant increase in grain production. The interaction effect, however, did not reach statistical significance.

**Yield-related traits**  
Variations in irrigation schedule had a notable impact on yield variables such as effective tillers/m<sup>2</sup>, panicle length, full grains/panicle, and 1,000-grain weight (g). A much larger number of effective tillers (375.1) were obtained by irrigation after three days without rain, surpassing all other treatments. In addition, its panicle length was 24.9 cm, number of grains per panicle was 108.5, and 1,000-grain weight was 26.2 kg, as shown in Table 2. It is possible that the plenty of water and micronutrients throughout the panicle-differentiation stage, as well as the well-aerated root zone, contributed to the retention of a greater number of panicle-bearing tillers at harvest. This would explain the higher number of grains/panicle. Barik et al. (2006) found the same thing, and these data prove it. More water was consistently associated with a higher number of panicles per square meter and a 1,000-grain weight (Bouman et al., 2006). According to

Bouman et al. (2006), the aerobic rice variety 'HD 502' produced a grain yield of 5.3-5.7 t/ha when water input ranged from 640-920 mm and 3-3.6 t/ha when water input ranged from 470-550 mm.

Combinations of micronutrients include RDF (80-40-40) + 5 kg Zn/ha + 0.2% B applied as a foliar spray twice

outperformed all other treatments in terms of the number of panicle-bearing tillers (391.1), on par with RDF (80-40-40) + 2.5 kg Zn/ha + 0.2% B as a foliar spray (2 sprays) (314.5). Additionally, it had the greatest 1,000-grain weight (26.29 g), panicle length (25.5 cm), and number of grains per panicle (117.9). Since boron enhances panicle fertility in rice, its use may lead to an increase in grain weight and the quantity of grains per panicle (Rehman et al., 2012). Reduced pollen sterility and adequate grain filling may explain why the experimental plots produced more grains per panicle than the control plots (Rashid et al., 2004). Applying boron to rice crops increased the number of tillers, 1,000-grain weight, and yield, according to Rashid et al. (2009). This could occur because of the synergistic impact of phosphorus and nitrogen with zinc and boron, which increases their availability. Our findings are in agreement with those of Veeresh et al. (2011) and Patel et al. (2010). Nevertheless, there was no statistically significant interaction impact.

**Business and finance**  
Net returns (30,316/ha) were greatest when irrigation was applied at three days intervals without rain, according to pooled data from two years. With a highest net yield of 30,362/ha, among the subplot treatments, the one that stood out was RDF (80-40-40) + 5 kg Zn/ha + 0.2% B as foliar spray applied twice. The best benefit-to-cost ratio (1.88) was achieved by irrigation spaced five days apart when there was no rain.

**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 <sup>2</sup> (Nos.)	Panicle length (cm)	Filled grains/panicle (Nos.)	Test weight (g)
<i>Irrigation scheduling</i>						
I <sub>1</sub> , Irrigation after 3 rainless days	4.20	6.51	375.1	24.9	108.5	26.2
I <sub>2</sub> , Irrigation after 5 rainless days	4.09	6.42	364.5	24.4	103.4	26.2
I <sub>3</sub> , Irrigation after 7 rainless days	3.81	6.49	343.5	24.2	99.9	26.1
I <sub>4</sub> , 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 <sub>1</sub> , RDF (80-40-40)	3.12	6.23	279.8	23.6	94.1	26.1
N <sub>2</sub> , 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 <sub>3</sub> , RDF (80-40-40) + 5 kg Zn/ha	3.83	6.40	338.4	24.0	94.3	26.1
N <sub>4</sub> , 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 <sub>5</sub> , RDF (80-40-40) + 2.5 kg Zn/ha	3.91	6.41	351.5	24.4	93.3	26.2
N <sub>6</sub> , 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



while dealing with the primary story points. In comparison to other treatments, the one that resulted in the highest benefit-to-cost ratio (1.89 in this case) was the foliar spray application of a combination of boron and zinc, namely RDF (80-40-40) + 5 kg Zn/ha + 0.2% B, which required two sprays. The use of micronutrients enhanced performance across the board, with the impact being most noticeable in situations where there was an abundance of water. The cheap cost of zinc and boron made their use very cost efficient, leading to beneficial affects on production and quality. Additionally, Hussain and Yasin (2004) found that boron is quite cost-effective when used in rice, with value-cost ratios ranging from 45:1 to 26:1 across various types of rice. Sarwar et al. (2013) found the same thing, and this finding checks it out.

Need for water and efficiency in water use  
The quantity of water consumed in each irrigation schedule was shown by water need. Two years' worth of data indicated that irrigation scheduling used the most water at 91.33 cm intervals between rainy days, and that subplot treatments used an average of 77.53 cm. Grain yields of 4.6-6.6 t/ha on loamy soils were seen when 476-612 mm total water was used, according to Bouman et al. (2002).

Because it used the least amount of water while producing the most crop, irrigation with a 7-day rainless interval had the highest water productivity (0.54 kg/m<sup>3</sup>) compared to the other treatments. With a maximum water productivity of 0.57 kg/m<sup>3</sup>, the subplot treatment consisting of RDF (80-40-40) + 5 kg Zn/ha + 0.2% B applied as a foliar spray twice was the

most effective. The goddess Geethalakshmi:

Under aerobic conditions, et al.(2009) found that the water productivity of the rice hybrid "CORH" ranged from 0.37 kg/m<sup>3</sup> to 4.2 kg/m<sup>3</sup> over the course of two years. Other studies that found the same thing include Malamasuri et al. (2014), Martin et al. (2007), and Maragatham et al. (2010). This demonstrates that, in comparison to conventional methods, aerobic rice production with adequate water and micronutrient management yields greater yields.

Uptake of nutrients  
Irrigation schedule at three rainless days resulted in a much increased absorption of nutrients (N, P<sub>2</sub>O<sub>5</sub>, K<sub>2</sub>O, Zn, and B) compared to all other treatments, with the exception of K<sub>2</sub>O. In irrigation scheduling during three rainless days, grain and straw up-taked 64.4 and 47.2 kg/ha N, 14.8 and 4.3 kg/ha P<sub>2</sub>O<sub>5</sub>, 38.2 and 142.0 kg/ha Zn, and 4.9 and 4.3 kg/ha B, respectively. Grain and straw had a greater K<sub>2</sub>O absorption in rainfed conditions, at 97.3 and 113.1 kg/ha, respectively. According to Table 3, the foliar spray application of RDF (80-40-40) + 2.5 kg Zn/ha + 0.2% B resulted in the highest nutrient uptake (98.4 and 86.1 kg/ha N by grain and straw, 15.2 and 4.2 kg/ha P<sub>2</sub>O<sub>5</sub> by grain and straw, and 21.3 and 75.1 kg/ha K<sub>2</sub>O by grain and straw, respectively), among the different levels of micronutrients. The beneficial interplay between micronutrients and other nutrients might be the reason for this. Zinc absorption by roots is a key component of nutrient intake.

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 <sup>3</sup> ₹/ha)	Benefit: cost ratio	Water requirement (cm)	Water productivity (kg/m <sup>3</sup> )
<i>Irrigation scheduling</i>				
I <sub>1</sub> , Irrigation after 3 rainless days	30.32	1.88	91.33	0.48
I <sub>2</sub> , Irrigation after 5 rainless days	28.65	1.86	81.28	0.52
I <sub>3</sub> , Irrigation after 7 rainless days	24.50	1.75	71.45	0.54
I <sub>4</sub> , Rainfed condition	23.08	1.73	66.45	0.53
SEm±	—	—	—	—
CD (P=0.05)	—	—	—	—
<i>Micronutrient level</i>				
N <sub>1</sub> , RDF (80-40-40)	18.32	1.56	77.53	0.45
N <sub>2</sub> , 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 <sub>3</sub> , RDF (80-40-40) + 5 kg Zn/ha	26.16	1.77	77.53	0.53
N <sub>4</sub> , 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 <sub>5</sub> , RDF (80-40-40) + 2.5 kg Zn/ha	26.94	1.80	77.53	0.53
N <sub>6</sub> , 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		
<b>Irrigation scheduling</b>												
I <sub>1</sub> , Irrigation after 3 rainless days	64.4	47.2	111.6	4.3	19.1	70.2	89.3	38.2	142.080.2	4.9	4.3	9.2
I <sub>2</sub> , Irrigation after 5 rainless days	62.1	43.1	105.2	4.0	14.4	81.5	93.7	32.4	135.1167.5	4.7	4.2	8.9
I <sub>3</sub> , Irrigation after 7 rainless days	57.1	37.6	94.7	2.1	8.3	89.2	103.6	24.1	126.1250.3	4.1	3.8	7.9
I <sub>4</sub> , Rainfed condition	49.2	32.3	81.5	1.3	5.5	97.3	113.1	19.2	103.122.4	3.6	2.9	6.5
SEm±	5.23	4.93	5.55	0.43	2.13	5.10	5.22	4.10	17.108.04	0.12	0.45	0.62
CD (P=0.05)	15.62	14.73	16.53	1.33	6.35	15.41	15.53	12.31	51.154.34	0.37	1.40	1.853
<b>Micronutrient level</b>												
N <sub>1</sub> , RDF (80-40-40)	68.4	41.7	110.1	4.2	19.4	68.4	77.2	28.4	74.703.1	2.5	1.9	4.4
N <sub>2</sub> , RDF (80-40-40) + 5 kg Zn/ha + 0.2% B as foliar spray (2 sprays)	98.4	86.1	184.5	3.1	11.2	75.1	96.4	40.2	171.311.5	4.8	4.2	9.0
N <sub>3</sub> , RDF (80-40-40) + 5 kg Zn/ha	87.6	51.4	139.0	4.0	15.4	60.2	75.7	41.3	180.221.7	3.2	2.8	6.0
N <sub>4</sub> , RDF (80-40-40) + 2.5 kg Zn/ha + 0.2% B as foliar spray (2 sprays)	95.4	82.4	177.8	3.8	14.0	72.3	92.1	38.2	176.2014.2	4.8	4.4	9.2
N <sub>5</sub> , RDF (80-40-40) + 2.5 kg Zn/ha	90.2	77.5	167.7	3.1	11.4	68.3	84.5	37.6	173.110.7	3.1	2.7	5.8
N <sub>6</sub> , RDF (80-40-40) + 0.2% B as foliar spray (2 sprays)	73.5	66.1	139.6	4.1	16.3	73.1	92.6	30.5	155.185.7	4.8	4.3	9.1
SEm±	6.11	6.74	21.67	0.28	3.23	3.16	5.42	1.65	24.325.7	0.23	0.41	0.64
CD (P=0.05)	18.26	20.15	67.22	0.84	9.65	9.45	16.20	4.93	72.666.82	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.

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