**Yield, Nutrient Uptake and Economics of Aerobic Rice Under Different Irrigation Regimes and Cultivars**

**Abstract:**

Transplanted rice is the traditional rice cultivation consumes more water, which threatens the sustainability of rice production. Thus, there is a need to find out the alternate means of rice cultivation to save water and other inputs. A field experiment was conducted during the summer seasons of 2019 and 2020 in the West Central Table Zone of Odisha to evaluate the efficacy of medium-duration rice varieties under varying irrigation regimes in aerobic conditions. The experiment followed a split-plot design with four irrigation regimes ( IW**/CPE ratios of 1.0, 1.5, 2.0, and 2.5)** as main plots and four rice varieties (**Naveen, MTU-1010, CR Dhan-201, and CR Dhan-204)** as subplots. The irrigation regime at **IW/CPE = 2.5** recorded the **maximum grain yield of 4.07 t/ha,** which was **significantly superior** to the other irrigation regimes, but statistically at par with **IW/CPE = 2.0 (3.90 t/ha).** Among the cultivars, the variety **CR Dhan-201** produced the higher grain yield (3.54 t/ha), which was significantly higher than the other varieties, but at par with Naveen (3.30 t/ha). Maximum nutrient uptake was observed at the IW/CPE = 2.5 irrigation level, with uptake values of 80.07 kg N/ha, 36.70 kg P/ha, and 124.4 kg K/ha, all of which were significantly superior to other irrigation regimes. Similarly, the variety CR Dhan-201 exhibited the higher nutrient uptake, recording 65.41 kg N/ha, 30.49 kg P/ha, and 104.8 kg K/ha, significantly superior than the other cultivars/varieties. The maximum FWUE was observed under **IW/CPE = 1.5,** with a value of **40.71 kg/ha-cm,** which was at par with other irrigation regimes except IW/CPE 2.5 whereas, B: C ratio (1.74) was observed with irrigation at IW/CPE 2.0 which was at par with IW/CPE 2.5 (1.73)and significantly superior to other irrigation regimes. Among the varieties, **CR Dhan-201** recorded the higher **B:C ratio of 1.62 &** higher FWUE of **41.60 kg/ha-cm** which was significantly superior to the rest other cultivars.

 ***Key words:*** Aerobic rice, Water use efficiency, IW/CPE ratio, Yield attributes, Growth parameter, BC ratio

**Introduction**

Rice (*Oryza sativa L*.) is the most important food for billions of people all over the world. In order to produce one kg rice, traditional rice cultivation requires 3000 - 5000 litres of water depending on the variety and cultivation methods. Increasing scarcity of water has threatened practices all over the world” (Tuong & Bouman, 2003). It also causes environmental degradation and reduces the fertilizer use efficiency (Venkatesha et al., 2015). Transplanted rice is the traditional rice cultivation consumes more water, which threatens the sustainability of rice production. Thus, there is a need to find out the alternate means of rice cultivation to save water and other inputs (Murthy & Reddy, 2013). Aerobic rice culture is an alternative way of growing rice where, the direct seeded rice varieties with aerobic environment are grown in well drained un puddled and non-saturated soil in order to increase the water use efficiency”. This concept is mainly target for irrigated low lands where, water is not sufficient for rice cultivation and suitable uplands, where facility for supplemental irrigation was available (Yadav et al., 2011). This method is unique in its characteristics to withstand both flooding and dry soil conditions. Therefore, present field experiment was taken in order to know the efficacy of medium duration selected rice varieties with varying irrigation regimes that will be suitable for aerobic cultivation

**Materials and Methods**

 The field experiment was conducted during the summer seasons of 2019 and 2020 at the Regional Research Technology and Transfer Station (RRTTS), Chiplima, Odisha, in order to study the effect of medium-duration rice varieties under varying irrigation regimes in aerobic conditions. The soil of the experimental field was **acidic** (pH 5.45), **sandy loam** in texture , **low organic carbon content** (0.38 )and available N, P, K content are 187, 15.4and 172 kg/ha, respectively. The experiment was laid out in a **split-plot design** with **four irrigation regimes** in the main plots (Irrigation at IW/CPE ratios of 1.0, 1.5, 2.0, and 2.5) and **four rice varieties** (Naveen, MTU-1010, CR Dhan-201, and CR Dhan-204) in the subplots .Seeds of cultivars were sown (hand dibbled) in well ploughed leveled field in 2-3 cm depth@ 45 kg/ha in furrows made by trench hoe at 20 cm ×10cm spacing. Fertilizers were applied uniformly in all treatments at the recommended dose of **80:40:40 kg N:P₂O₅:K₂O per hectare.** Standard cultural practices were followed as per the recommendations. In each plot, the volume of irrigation water was calculated by multiplying the depth of irrigation and area of the plot. In every plot, time of irrigation was computed by using given depth of irrigation, area of the plot and discharge rate. Grain and straw yields were recorded from the net plot area. The water requirement was computed by adding the effective rainfall received during the crop growth period & irrigation water applied to the field. The ratio of grain yield and the amount of water applied to the field plots was used to calculate field water use-efficiency (kg/ha-cm).Economic analysis was carried out based on prevailing market prices for inputs and produce. The experimental data collected on various parameters were statistically analyzed using the Analysis of Variance (ANOVA) technique to draw valid conclusions.

**Results and Discussion**

***Yield attributes:***

The pooled data presented in Table 2 indicate that irrigation at an IW/CPE ratio of 2.5 resulted in the maximum number of effective panicles (287 panicles/m²), followed by IW/CPE = 2.0 (279 panicles/m²). Both the above irrigation regimes produced significantly superior to rest of other irrigation regimes. The maximum number of filled grains panicle (80.98) was recorded with irrigation regime at IW/CPE = 2.5, which was significantly higher than rest other irrigations. The test weight was recorded maximum with irrigation regime at IW/CPE = 2.5 (22.27 g) ,which was significantly superior to rest of the irrigation regimes except at IW/CPE = 2.0 (21.51 g).It might be due to promoted higher number of tillers m-2 , dry matter production and nutrient uptake and also enhanced the supply of photosynthates from source to sink. This was in accordance with findings of Shekara *et al., (*2010) and Duary (2017). As regards to cultivars, CR Dhan 201 recorded the maximum number of effective panicles (286 panicles/m²) and filled grains per panicle (74.47), significantly higher than the other variety. The test weight (21.60 g) was also observed maximum in CR Dhan 201, which was significantly superior to other varieities except Naveen (20.97 g). This was in accordance with the findings of Duary et al. (2017)

***Yield:***

The result showed that grain yield was significantly increase up to IW/CPE 2.0 and further increase IW/CPE did not prove beneficial (Table-1). The highest grain yield of 4.09, 4.06 and 4.07 t /ha were observed with irrigation regime at IW/CPE =2.5 in first year, second year and pooled mean, respectively. The pooled increase in grain yield owing to irrigation at IW/CPE = 2.5 over at IW/CPE=2.0,IW/CPE= 1.5 and IW/CPE=1.0 were 4.4, 42.3 and 82.5 %, respectively. The increased in straw yield was significantly with increase in IW/CPE up to 2.5.It might be due to supply of more photosynthates towards the reproductive sink. This result was in corroborates with the findings of Maheswari et al. (2008) and Shekara et al. (2010).Among the cultivars, the rice variety CR Dhan 201 gave better grain yield than the other varieties during individual years and its pooled mean .In first year as well as pooled mean, the rice variety CR Dhan 201 recorded the highest grain yield of 3.60 and 3.54t/ha, respectively and significantly superior to rest of the varieties. Whereas in second year, the grain yield of rice variety CR Dhan201 was at par with Naveen variety and significantly superior to rest of the varieties. The pooled increase in grain yield owing to rice variety CR Dhan 201 over Naveen, CR Dhan 204 and MTU-1010 were 7.3, 12.7 and 14.9 %, respectively. But incase of straw yield, the variety like CR Dhan 201 produced significantly higher grain yield than all other varieties except Naveen. It might be due to enhanced stature of growth and yield attribute. This was in accordance with the findings of Duary et al. (2017). The interaction between irrigation regimes and cultivars was significant for grain yield in the pooled analysis (Table 2).The interaction of irrigation at IW/CPE 2.0 with variety CR Dhan 201 gave the highest grain yield (4.39t/ha) which was at par with irrigation at IW/CPE 2.5 with variety CR Dhan 201 (4.30 t/ha) and significantly superior to other interaction of irrigation regimes with cultivars. Hence, interaction between irrigation at IW/CPE 2.0 with variety CR Dhan 201 might be economic optimum to realize maximum yield under aerobic rice cultivation. The results are in conformity with the findings of Maheswari *et al.,* (2008)

***Nutrient Uptake:***

The result showed that nutrient uptake of rice increased significantly with increase in IW/CPE up to 2.5 (Table-3).The highest uptake of nutrient(80.07kg /ha), P(36.70kg /ha) and K(124.4kg /ha ) were produced with irrigation regime at IW/CPE =2.5 but it was significantly superior to rest other irrigation regimes. Similar findings have also been reported by Shekara et al. (2010).Among the cultivars, the result indicated that highest uptake of N (65.41kg /ha), P(30.49kg /ha) and K(104.8kg /ha ) were produced with variety CR Dhan 201 but it was significantly superior to rest other varieties. This was in accordance with the findings of Duary et al. (2017)

***Water Use Efficiency:***

The results (Table 3) indicated that the maximum field water use efficiency (40.71 kg/ha-cm) was recorded at IW/CPE ratio of 1.5 which was statistically at par with IW/CPE ratios of 2.0 and 1.0, and significantly higher than the irrigation at 2.5 IW/CPE . Similar findings have also been reported by Shekara et al. (2010).Among the cultivars, the variety CR Dhan 201 recorded the maximum water use efficiency (41.60 kg/ha-cm), which was statistically comparable to Naveen (39.25 kg/ha-cm), and significantly superior to the other varieties. This supports the findings of Duary et al. (2017).

***Economics:***

 The result showed that the maximum net return (Rs35781/ha) and benefit: cost ratio (1.74) were obtained (Table 3) at IW/CPE 2.5 which was significantly superior to other irrigation regimes and at par with at IW/CPE 2.0. It might be due to higher grain yield with higher irrigation levels. Similar findings obtained Shekara et al., (2010). The maximum net return (Rs28367/ha)and benefit: cost ratio (1.62) was obtained with variety CR Dhan 201. It was significantly superior to that of other cultivars. It might be due to higher grain yield. Similar findings obtained Reddy et al., (2012) and Pradhan et al., (2014).

 ***Conclusion:***

From the present investigations, it may be concluded that CR Dhan 201 variety produced economically optimum yield and field water use efficiency at irrigation regimes at IW/CPE 2.0 in West Central Table Land Zone of Odisha under aerobic condition.

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| **Table1: Effect of Irrigation Regimes and Cultivars on Yield,Attributes and Yield Economics UnderAerobic Condition (Pooled data)** |
| **Treatments** | **Effective Panicles (Nos/m2)** | **Filled Grains/Panicle (Nos)** | **Test Weight****(g)** | **Grain Yield (t/ha)** | **Straw** **Yield (t/ha)** | **Harvest** **Index (%)** |
| **2019** | **2020** | **Pooled** |
| **Irrigation Regimes** |
| IW/CPE =1.0 | 244 | 59.05 | 19.16 | 2.20 | 2.25 | 2.23 | 2.85 | 43.82 |
| IW/CPE =1.5 | 264 | 67.14 | 20.30 | 2.96 | 2.77 | 2.86 | 3.60 | 44.21 |
| IW/CPE =2.0 | 279 | 75.83 | 21.51 | 3.93 | 3.86 | 3.90 | 4.85 | 44.36 |
|  IW/CPE =2.5 | 287 | 80.98 | 22.27 | 4.09 | 4.06 | 4.07 | 5.17 | 44.03 |
| SEm(±) | 4.9 | 1.05 | 0.28 | 0.08 | 0.08 | 0.06 | 0.07 | 0.45 |
| CD(0.05) | 15.2 | 3.23 | 0.88 | 0.29 | 0.27 | 0.18 | 0.21 | NS |
| **Cultivars** |
|  Naveen | 272 | 71.27 | 20.97 | 3.33 | 3.27 | 3.30 | 4.11 | 44.47 |
|  MTU-1010 | 255 | 68.13 | 20.00 | 3.06 | 3.09 | 3.08 | 3.98 | 44.06 |
| CR Dhan 201 | 286 | 74.47 | 21.60 | 3.60 | 3.47 | 3.54 | 4.36 | 44.68 |
| CR Dhan 204 | 260 | 69.13 | 20.66 | 3.18 | 3.11 | 3.14 | 4.03 | 43.21 |
| SEm(±) | 4.9 | 1.01 | 0.31 | 0.07 | 0.08 | 0.06 | 0.07 | 0.40 |
| CD(0.05) | 13.9 | 2.88 | 0.88 | 0.21 | 0.24 | 0.16 | 0.20 | NS |

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| **Table -2 Interaction effect of irrigation regimes and cultivars on grain yield of rice under aerobic condition** |
| **Irrigation regimes** | **Grain yield (t/ ha)** |
| **Pooled** |
| **Cultivars** |
| Naveen | MTU-1010 | CR Dhan 201 | CR Dhan 204 |
| I1 : IW/CPE = 1.0 | 2.32 | 2.04 | 2.37 | 2.18 |
| I2 : IW/CPE =1.5 | 3.09 | 2.72 | 3.08 | 2.53 |
| I3 : IW/CPE = 2.0 | 3.72 | 3.44 | 4.39 | 4.03 |
| I4 : IW/CPE = 2.5 | 4.07 | 4.11 | 4.30 | 3.82 |
|  | I within V | V within I |
| **SEm (±)** | 0.110 | 0.109 |
| **CD (P=0.05)** | 0.34 | 0.31 |

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| **Table-3: Effect of Irrigation Regimes and Cultivars on Nutrient Uptake,Water Use Efficiency and Economics Under Aerobic Condition (Pooled data)** |
| **Treatments** | **Nutrient Uptake(grain+straw)(kg/ha)** | **WUE(kg/ha-cm)** | **Net Return(Rs/ha)** | **B:C ratio** |
| N | P | K |
| **Irrigation Regimes** |
| IW/CPE =1.0 | 28.58 | 14.77 | 51.22 | 2.20 | 2.25 | 2.23 |
| IW/CPE =1.5 | 46.73 | 21.67 | 76.47 | 2.96 | 2.77 | 2.86 |
| IW/CPE =2.0 | 65.00 | 27.99 | 102.32 | 3.93 | 3.86 | 3.90 |
|  IW/CPE =2.5 | 80.07 | 36.70 | 124.39 | 4.09 | 4.06 | 4.07 |
| SEm(±) | 1.00 | 0.49 | 1.81 | 0.08 | 0.08 | 0.06 |
| CD(0.05) | 2.90 | 1.41 | 5.25 | 0.29 | 0.27 | 0.18 |
| **Cultivars** |
|  Naveen | 59.48 | 26.53 | 98.97 | 3.33 | 3.27 | 3.30 |
|  MTU-1010 | 46.00 | 21.09 | 69.25 | 3.06 | 3.09 | 3.08 |
| CR Dhan 201 | 65.41 | 30.49 | 104.79 | 3.60 | 3.47 | 3.54 |
| CR Dhan 204 | 49.50 | 23.02 | 81.39 | 3.18 | 3.11 | 3.14 |
| SEm(±) | 0.81 | 0.45 | 1.42 | 0.07 | 0.08 | 0.06 |
| CD(0.05) | 2.27 | 1.26 | 3.97 | 0.21 | 0.24 | 0.16 |