*Original Research Article*

# Effect of varying irrigation regimes and cultivars on growth, yield, water use efficiency, and economics of rice (*Oryzasativa*) under aerobic condition


## Abstract

The present study was undertaken for standardization of irrigation interval and performances of medium duration selected rice varieties under the aerobic conditions in the westen Odisha. The field experiment was conducted at the Regional Research Technology and Transfer Station (RRTTS), Chiplima, Sambalpur, Odisha, during the *summer* season of2019 and 2020 to see the performance of medium-duration rice varieties with varying irrigation regimes under aerobic conditions. The experiment was laid out in split plot design with three replications and consisted of four irrigation regimes ($I_1$ = Irrigation at IW/CPE = 1.0, $I_2$ = Irrigation at IW/CPE = 1.5, $I_3$ = Irrigation at IW/CPE = 2.0, and $I_4$ = Irrigation at IW/CPE = 2.5) in main plot treatments and four varieties ($V_1$ = Naveen, $V_2$ = MTU-1010, $V_3$= CR Dhan-201 and $V_4$ = CR Dhan-204 in subplot treatments. The result of the pooled mean of both years showed that growth and yield attributes significantly affect in regards to different irrigation regimes and cultivars. The maximum plant height (69.0 cm) and filled grains per panicle (80.98)leaf area index (LAI ) at 75DAS(3.940, dry matter accumulation of the shoot at 90 DAS ( 927 g $m^{-2}$), number of effective panicles $m^{-2}$ (287) and test weight (22.27 g) was maximum at irrigation regime IW/CPE = 2.5. In contrast, it was at par with the irrigation regime at IW/CPE = 2.0.The maximum plant height(67.1cm), filled grains per panicle(74.47), leaf area index (LAI ) at 75DAS(3.52),dry matter accumulation of the shoot at 90 DAS (901 g $m^{-2}$ ), and a number of effective panicles $m^{-2}$(286) were recorded with CR Dhan 201 which was significantly higher as compared to other cultivars. The result of the pooled mean of both years showed that the highest grain yield was recorded at IW/CPE = 2.5, i.e., 4.07 t/ha, which was at par with IW/CPE = 2.0 (3.90 t/ha) and significantly superior to rest of other irrigation regimes. But in the case of cultivars, the highest grain yield was obtained with variety CR-Dhan 201(3.54 t/ha), which was at par with variety Naveen (3.30t/ha) and significantly superior to the rest of other cultivars. The highest mean FWUE of 40.71kg/ ha-cm was observed with irrigation at IW/CPE 1.5, which was at par with other irrigation regimes except IW/CPE 2.5, whereas the highest B: C ratio (1.74) was observed with irrigation at IW,/CPE 2.0which was at par with IW/CPE 2.5 (1.73) and significantly superior to other irrigation regimes.But in the case of cultivars, the highest mean FWUE of 41.60kg/ ha-cm and B: C ratio (1.62) was observed with variety CR Dhan 201and significantly superior to the rest of the other cultivars.Hence, a variety like CR Dhan 201 needs to be irrigated at IW/CPE 2.0 to produce economically optimum yield and field water use efficiency on sandy loam soils of the western region of Odisha under aerobic conditions.



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

## Introduction

The staple food for nearly 50% of the world's population is rice (Oryzasativa L.). The topic "Rice is life" is quite fitting for India because this crop is vital to our country's food security and provides a living for millions of rural communities. Due to a decline in water levels on the one hand and the demand for water from industries and other sectors on the other, there has recently been an increasing shortage of fresh water for agriculture, especially for the cultivation of rice. This threatens the sustainability of the irrigated rice ecosystem. By 2025, it was predicted that 22 million areas in Asia may experience "economic water scarcity," while 17 million hectares of irrigated land may experience "physical water scarcity."and 22 million areas may have "economic water scarcity" (Tuong&Bouman, 2005). Traditional rice farming methods are in danger worldwide due to the growing water shortage (Tuong&Bouman, 2003). Therefore, the occurrence of water-related issues can be reduced by progressively switching from a traditional rice production system to an aerobic rice production system. In an aerobic environment, direct-seeded rice varieties are cultivated in well-drained, non-puddled, and non-saturated soils (aerobic soils) using a new technology and innovative method called aerobic rice culture. In regions with limited water resources and rising rice demand, aerobic rice becomes more significant.

According to Prasad (2011), rice varieties ideal for aerobic must systems combine drought resistance with high yielding traits. The development of rice varieties suited for aerobic cultivation would benefit from the identification of medium-duration varieties that lead to superior yield performances under aerobic conditions. In all rice-growing nations, research is being done to create unique aerobic and nutrient-responsive cultivars. The evaluation of the various kinds that are sustainable for particular sites and management techniques under shortage conditions is necessary since aerobic rice production is a new method. Odisha has a sizable region of dry, rainfed/semi-dry rice cultivation as well as a sizable area for producing rice in an aerobic environment.However, reliable information on vital agro techniques for successful aerobic rice cultivation in this region is absolutely lacking. Against this backdrop, the present study was undertaken for standardization of irrigation interval and performances of medium duration selected rice varieties under aerobic conditions in the west central table land zone of Odisha.

## Materials and Methods

The field experiment was conducted at the Regional Research Technology and Transfer Station (RRTTS), Chiplima, Sambalpur, Odisha, during the*Summer*seasons of2019 and 2020 to see the performance of medium-duration rice varieties with varying irrigation regimes under aerobic conditions. The acidic (pH 5.45) soil of the experimental field was sandy loam soil, low in organic carbon (0.38%), and available N, P, and K content is 187, 15.4and 172 kg/ha, respectively. The moisture content at field capacity and permanent wilting point was 19.6 and 8.6 percent, respectively. The experiment was laid out in a split plot design with three replications. It consisted of four irrigation regimes ($I_1$ = Irrigation at IW/CPE = 1.0, $I_2$ = Irrigation at IW/CPE = 1.5, $I_3$ = Irrigation at IW/CPE = 2.0, and $I_4$ = Irrigation at IW/CPE = 2.5) in main plot treatments and four varieties ($V_1$ = Naveen, $V_2$ = MTU-1010, $V_3$= CR Dhan-201 and $V_4$ = CR Dhan-204 in subplot treatments.The experimental field was plowed three times in dry unpuddled conditions. The first plowing was done in order to remove all weeds and other plant residues of the previous crops from the field. The second plowing was done 15 days after the first plowing, and light irrigation was applied to the field to enhance the germination of weed seeds and seeds of the previous crops in the field. The third plowing was done three days before sowing to destroy the weed and previous crops in the field. Then, field wasleveled witha leveler in order to prepare a good seedbed for the smooth germination of rice seeds. Seeds of cultivars were manually sown (hand dibbled) in 2-3 cm depth@ 45 kg/ha in furrows made by trench hoe at 20 cm ×10cm spacing. Thinning and gap filling were done at seedling 20 days after sowing so as to maintain optimum and uniform plant population in all the plots.

Recommended dose fertilizers (80kgN, 40kg $P_2O_5$and 40kg$K_2O$)applied in the field. A full dose of phosphorus in the form of DAP and half dose of potash in the form of MOP were applied as basal in the rows about 4-5 cm deep before seeding, and the remaining half dose of potash was top dressed at 60days after sowing(DAS). The nitrogen in the form of urea was top dressed in three splits, i.e., half dose of nitrogen at 20 DAS, and the remaining half dose of nitrogen was applied in two equal splits, each at 40DAS and 60DAS. All the other cultural operations were carried out as per recommendation. The volume of irrigation water in each plot was calculated by multiplying the depth of irrigation and the area of the plot. Then, irrigation water was measured on the basis discharge rate (l/s) of water entering the experimental field. The time of irrigation for every plot was computed by using the given depth of irrigation, area of the plot, and discharge rate. The initial two common irrigations were applied to all the treatments after sowing for the proper establishment of the plants till 20DAS, and thereafter, irrigation was applied as per treatment details.

The observations on grain and straw yield were recorded on a net plot basis. Water requirement was calculated by adding effective rainfall during the crop growth period and irrigation applied to the field. Field water use efficiency (kg/ha-cm) was calculated as the ratio of grain yield and the amount of water applied to the field plots. Economics was worked out on the basis of the prevailing market price of the produce and inputs used in the experiment. The experimental data recorded for various parameters under study were subjected to statistically analyzed ANOVA given by Gomez and Gomez (1984) to draw a valid conclusion. The variation in the treatment mean was tested by using critical difference (CD) values at a 5% level of significance.

## Results and Discussion

### Growth parameters

The result showed that growth and yield attributes of rice increased significantly with an increase in IW/CPE up to 2.0, and a further increase in IW/CPE did not prove beneficial during a pooled mean of both the years (Table-1) except plant height and filled grains per panicle. The maximum plant height (69.0 cm) and filled grains per panicle (80.98) were recorded with the irrigation regime at IW/CPE = 2.5, which was significantly higher as compared to other irrigation regimes. Whereas leaf area index (LAI ) at 75DAS(3.940, dry matter accumulation of the shoot at 90 DAS ( 927 g $m^{-2}$ ), number of effective panicles $m^{-2}$ (287), and test weight (22.27 g) was maximum at irrigation regime IW/CPE = 2.5 which was at par with irrigation regime at IW/CPE = 2.0 and significantly higher as compared to other irrigation regimes. The reduction of growth and yield attributes due to water scarcity resulted in low leaf water potentials and reductions in photosynthesis; photosynthetic activity declines because of decreased stomata opening and the inhibition of chloroplast activity; this reduced the length of the internodes, decreased functional leaf area and enhanced leaf senescence, reduced the number of tillers $m^{-2}$, dry matter production and nutrient uptake. The results are in conformity with the findings of Shekara*et al*. (2011), Nayak (2015), and Diary (2017).

The result showed that growth and yield attributes of rice significantly affect cultivars. The maximum plant height(67.1cm), filled grains per panicle(74.47), leaf area index (LAI ) at 75DAS(3.52), dry matter accumulation of the shoot at 90 DAS ((901 g $m^{-2}$ ), and a number of effective panicles $m^{-2}$ ((286)) were recorded with CR Dhan 201 which was significantly higher as compared to other cultivars. At the same time, the maximum test weight was recorded with variety CR Dhan 201 (21.60 g), which was at par with Naveen (20.97g) and significantly superior to other verities.This result was in corroborates the findings of Maheswari*et al*. (2008), Sekhara*et al.* (2010), Mandal*et al*. (2013), Diary (2017)andMukherjee *et al*. (2017).



**Grain yield**

The result showed that the grain yield of rice increased significantly with an increase in IW/CPE up to 2.0, and a further increase in IW/CPE did not prove beneficial during both individual years and its pooled mean (Table-1). The highest grain yield of 4.09, 4.06, and 4.07 t /ha were produced with irrigation regime at IW/CPE =2.5 in the first year, second year, and pooled mean, respectively. The 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 4.1, 38.2, and 85.9 % in the first year, 5.2, 46.6 and 80.4 % in the second year and 4.4, 42.3 and 82.5 % in pooled mean, respectively. The highest grain yield produced with an increase in irrigation frequency might be due to higher growth and yield attributes as well as a conducive situation for efficient water and nutrient uptake, which boost their growth and yield attributes through the supply of more photosynthates towards the reproductive sink. This result corroborated the findings of Maheswari*et al*. (2008) and Shekara*et al.* (2010).

Among the cultivars, the rice variety CR Dhan 201 performed better in grain yield than the other varieties during individual years and its pooled mean. In the 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 the rest of the varieties. Whereas in the second year, the grain yield of rice variety CR Dhan201 was at par with the Naveen variety and significantly superior to the rest of the varieties. The increase in grain yield owing to rice variety CR Dhan 201 over Naveen, CR Dhan 204, and MTU-1010 were 8.1, 13.2 and 17.6 % in the first year, 6.11, 11.57 and 12.3 % in the second year and 7.3, 12.7 and 14.9 % in pooled mean, respectively. The probable reasons assigned for rice variety CR Dhan 201 produced significantly higher grain yield than all other varieties due to enhanced stature of growth and yield attribute and finally increased grain yield. This was in accordance with the findings of Duary*et al.* (2017).

**Field water use efficiency (FWUE)**

Water requirement (average of two years) of different irrigation intervals varied from 55.23 to 120.23cm. The highest water requirement of 120.23cm was observed with irrigation at IW/CPE 2.5, whereas the lowest value of 55.23cm was observed with irrigation at IW/CPE 1.0 among different irrigation regimes.

The pooled mean result of both the years under study(Table2), the highest mean FWUE of 40.71kg/ ha-cm was observed with treatment that received irrigation at IW/CPE 1.5, which was at par with irrigation at IW/CPE 2.0 and IW/CPE 1 and significantly superior to irrigation regime at IW/CPE 2.5. Similar findings have also been reported by Shekara*et al.* (2010).

Among the cultivars, the result of the pooled mean of both the years under study showed that the highest mean FWUE of 41.60kg/ ha-cm was observed with variety CR Dhan 201, which was at par with variety Naveen (39.25kg/ ha-cm ) and significantly superior to rest of the other varieties.

**Economics:**

The maximum net return (Rs35781/ha) and benefit: cost ratio (1.74) were obtained (Table 2)from the crop irrigated at IW/CPE 2.5, which was at par with irrigation at IW/CPE 2.0 and significantly superior to those of other irrigation regimes. It might be due to higher grain yield with higher irrigation levels. Similar findings were obtained by Shekara*et al.* (2010). The maximum net return (Rs 28367/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 were obtained by Reddy *et al.* (2012) and Pradhan*et al.* (2014).

**Conclusion:**

From the present investigations, a variety like CR Dhan 201 needs to be irrigated at IW/CPE 2.0 to produce economically optimum yield and field water use efficiency on sandy loam soils of the western region of Odisha under aerobic conditions.

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| Table-1: Effect of irrigation regimes and cultivars on growth and yield attributes under aerobic condition (Pooled data) | | | | | | |
|---|---|---|---|---|---|---|
| **Treatments** | **Plant height** | **Leaf area index(LAI) at 75DAS** | **Dry matter accumulation (DMA)(g/m$^2$) 90DAS** | **Effective panicles (Nos/m$^2$)** | **Filled grains (Nos/Panicle)** | **Test weight(g)** |
| **Irrigation Regimes** | | | | | | |
| $I_1$: IW/CPE =1.0 | 59.6 | 2.33 | 805 | 244 | 59.05 | 19.16 |
| $I_2$: IW/CPE =1.5 | 63.6 | 3.07 | 859 | 264 | 67.14 | 20.30 |
| $I_3$: IW/CPE =2.0 | 65.0 | 3.82 | 901 | 279 | 75.83 | 21.51 |
| $I_4$: IW/CPE =2.5 | 69.0 | 3.94 | 927 | 287 | 80.98 | 22.27 |
| $SE_m(\pm)$ | 0.7 | 0.05 | 6.6 | 4.9 | 1.05 | 0.28 |
| CD(0.05) | 2.1 | 0.17 | 29.7 | 15.2 | 3.23 | 0.88 |
| **Cultivars** | | | | | | |
| $V_1$: Naveen | 64.6 | 3.30 | 885 | 272 | 71.27 | 20.97 |
| $V_2$: MTU-1010 | 62.0 | 3.14 | 845 | 255 | 68.13 | 20.00 |
| $V_3$: CR Dhan 201 | 67.1 | 3.52 | 901 | 286 | 74.47 | 21.60 |
| $V_4$: CR Dhan 204 | 63.4 | 3.21 | 864 | 260 | 69.13 | 20.66 |
| $SE_m(\pm)$ | 0.6 | 0.06 | 9.0 | 4.9 | 1.01 | 0.31 |
| CD(0.05) | 1.6 | 0.17 | 25.8 | 13.9 | 2.88 | 0.88 |

| **Table-2: Effect of irrigation regimes and cultivars on yield ,water use efficiency and economics under aerobic condition (Pooled data)** | | | | | | |
|---|---|---|---|---|---|---|
| **Treatments** | **Grain yield (t/ha)** | | | **WUE(kg/ha-cm)** | **Net Return(Rs/ha)** | **B:C ratio** |
| | **2019** | **2020** | **Pooled** | | | |
| **Irrigation Regimes** | | | | | | |
| $I_1$: IW/CPE =1.0 | 2.20 | 2.25 | 2.23 | 40.35 | 5337 | 1.13 |
| $I_2$: IW/CPE =1.5 | 2.96 | 2.77 | 2.86 | 40.71 | 16496 | 1.39 |
| $I_3$ : IW/CPE =2.0 | 3.93 | 3.86 | 3.90 | 38.87 | 34274 | 1.74 |
| $I_4$ : IW/CPE =2.5 | 4.09 | 4.06 | 4.07 | 33.89 | 35781 | 1.73 |
| $SE_m(\pm)$ | 0.08 | 0.08 | 0.06 | 0.73 | 1103 | 0.02 |
| CD(0.05) | 0.29 | 0.27 | 0.18 | 2.26 | 3400 | 0.08 |
| **Cultivars** | | | | | | |
| $V_1$: Naveen | 3.33 | 3.27 | 3.30 | 39.25 | 23602 | 1.52 |
| $V_2$: MTU-1010 | 3.06 | 3.09 | 3.08 | 36.06 | 19426 | 1.42 |
| $V_3$ : CR Dhan 201 | 3.60 | 3.47 | 3.54 | 41.60 | 28367 | 1.62 |
| $V_4$ : CR Dhan 204 | 3.18 | 3.11 | 3.14 | 36.91 | 20492 | 1.44 |
| $SE_m(\pm)$ | 0.07 | 0.08 | 0.06 | 0.68 | 1073 | 0.02 |
| CD(0.05) | 0.21 | 0.24 | 0.16 | 1.94 | 3051 | 0.07 |