**Impact of Different Soil Moisture Regimes Under Alternate Wetting and Drying (AWD) on the Growth and Yield of Wetland Paddy**

**ABSTRACT**

Water management plays a crucial role in optimizing rice production while ensuring sustainability. This study conducted in the School of Agricultural Sciences, KITS, Coimbatore, evaluates the impacts of different soil moisture regimes underalternate wetting and drying on the growth and yield of wetland paddy. The study was performed following a Randomized Block Design (RBD) with eight different treatments, each replicated three times. Among the treatments, T3 (Irrigation immediately after the development of hairline cracks) demonstrated the highest effectiveness, followed by T4 (Irrigation at 5.0 cm fall of water table below the soil surface). The enhanced performance of T3 attributed to improved soil aeration which promotes root growth and nutrient uptake, leading to increased crop growth and yield.

***Keywords:*** *Rice, Alternate wetting and drying, hairline cracks, irrigation, growth and yield.*

**1. INTRODUCTION**

Rice is a vital and widely consumed staple food, especially in Asia, where it is a central part of the diet for a large portion of the population. The primary cereal crop in the Poaceae family, *Oryza sativa* L. is mainly grown in warm, tropical regions, in contrast to cooler temperate areas. It plays a crucial role in providing essential calories, carbohydrates, vitamins and minerals to millions of people worldwide. In the 2022-2023 crop year, rice was cultivated over approximately 165 million hectares globally, producing 502 million metric tons (Statista, 2024).

Agriculture is the dominant global freshwater consumer, utilizing approximately 70% of all water withdrawals, with some developing nations reaching 95% (FAO, 2019). As global populations rise and water competition intensifies, the need for water-efficient agricultural practices becomes critical to ensure food security. Rice cultivation, requiring 3,000 to 5,000 liters of water per kilogram produced (based on water footprint and virtual water concepts), significantly strains water resources. To mitigate this, various water-saving rice farming methods have been developed, including direct seeded rice (DSR), aerobic rice cultivation, system of rice intensification (SRI), saturated soil culture (SSC), alternate wetting and drying (AWD) and evapotranspiration (ETc) based irrigation scheduling (Mallareddy *et al*., 2023). Among these, alternate wetting and drying (AWD) is the most widely adopted (Li and Barker, 2004). Given the increasing pressure on freshwater resources from urbanization, industrialization, and population growth, AWD’s water-conserving approach is vital for maintaining rice production and ensuring food security, particularly in the face of climate change induced erratic rainfall and droughts.

The alternate wetting and drying (AWD) irrigation method was developed by the International Rice Research Institute (IRRI) and is considered a technically effective, water-saving and economically viable approach that is also environmentally sustainable. AWD involves alternating between soil saturation and drying, which helps conserve irrigation water. Water is applied when the soil reaches a certain moisture threshold, with flooding occurring after a predetermined number of days following the previous drying cycle. AWD is essential for the sustainable cultivation of rice, helping to tackle the growing challenges of water scarcity, climate change and environmental sustainability. It has a potential to cut water usage in paddy crops by 35-50% (Zhang *et al*., 2009; Nayak *et al*., 2021). By allowing the soil to partially dry before being reflooded, AWD improves water absorption efficiency and minimizes wastage. Additionally, AWD lowers input costs by reducing the need for water, fertilizer and pesticides providing economic benefits to farmers.

The soil moisture regimes in paddy fields under AWD, employing techniques like depletion to varying depths, the formation of hairline cracks, and different IW/CPE ratios, need to be explored across different soil types and climate conditions. Effectively managing water within these safe limits is key to maximizing crop yield while minimizing water use. A substantial amount of research is still needed to thoroughly assess the benefits and promote the broader implementation of these practices.

**2. MATERIALS AND METHODS**

**2.1 Experimental Site**

The field experiment related to this research was conducted during the *Kharif* season of 2024-2025 in field number L3, located in the Instructional farm (South) of the School of Agricultural Sciences, Karunya Institute of Technology and Sciences, Coimbatore. The site is situated at an elevation of approximately 427 meters above sea level, with coordinates at 10.9362 ̊ N latitude and 76.744 ̊ E longitude. This area is part of the Western Tamil Nadu Agro-climatic zone and falls under the Southern Plateau and Hills Region within India’s agro-climatic zones. The soil texture was classified as silty clay loam and prior to the trail, the nutrient levels were as follows; high in organic carbon, medium in available nitrogen, high in available phosphorus and high in available potassium. The soil had an alkaline reaction, with a pH of 8.8.

**2.2 Treatment Details**

The experiment was conducted using a Randomized Block Design (RBD) with eight treatments each replicated three times. The rice variety “Bhavani”, with a growth duration of 130-135 days, was used in this study. The treatments were: T1 - Continuous submergence with 5 cm of standing water as per farmer’s practice, T2 - Irrigation immediately after the disappearance of ponded water, T3 - Irrigation immediately after the development of hairline cracks in the soil, T4 - Irrigation at 5.0 cm fall of water table below the soil surface, T5 - Irrigation at 10.0 cm fall of water table below the soil surface,T6 - Irrigation at 15.0 cm fall of water table below the soil surface,T7 - Irrigation at IW/CPE (Irrigation water/Cumulative Pan Evaporation) ratio of 1.0 at vegetative phase and 1.2 at reproductive phase, T8 - Irrigation at IW/CPE ratio 1.2 at vegetative phase and 1.5 at reproductive phase. A water depth of 2 cm was maintained in all experimental plots until 14 days after transplanting to ensure seedling establishment. The irrigation depth was 5.0 cm. To provide irrigation at 5.0, 10.0, 15.0 cm below the soil surface the water level was monitored using a field water tube.

**2.3 Observations Recorded**

Biometric traits such as plant height, leaf count and dry matter accumulation were recorded at 45 and 90 days after transplanting (DAT) and at harvest, while tiller count was observed at 60 DAT. Yield attributes, including the number of panicles, grains per panicle, grain filling percentage, 1000-grain weight, grain yield and straw yield were assessed at harvest.

**2.4 Statistical Analysis**

The variance for each growth stage was analyzed separately using the randomized block design (RBD) with two-factor combinations, and significance was determined through the F-test. (Gomez and Gomez, 2010) Duncan’s Multiple Range Test (DMRT) was employed to distinguish treatments that exhibited no significant differences.

**3. RESULTS AND DISCUSSION**

**3.1 Impact of Soil Moisture Regimes under AWD on Growth of wetland paddy**

**3.1.1 Plant Height (cm)**

The data regarding the plant height at 45 DAT, 90DAT and at harvest are given in Table.1 and Fig.1. A notably greater plant height was recorded with T3 (Irrigation immediately after the development of hairline cracks in the soil) which was statistically on par with T1 (Continuous submergence with 5cm of standing water as per farmer’s practice) during 45 DAT. Similarly, T3 registered maximum plant height of 123.1 cm and 126.7 cm during 90 DAT and at harvest respectively. This was statistically on par with T4, T1, T3, and T8. T5 and T6 recorded lower plant height at all the 3 stages of observation. Similar results were recorded by Baby *et al*., (2021) were irrigation at 5 cm depletion resulted in higher plant height. The rise in meristematic cell activity and elongation accelerated stem growth, ultimately increasing the height of rice plants (Chowdhury *et al*., 2014). As moisture stress increased, plant height decreased significantly (Sariam and Anuar, 2010).

**3.1.2 Number of leaves (hill-1)**

The mean data recorded on number of leaves at 45 DAT, 90 DAT and at harvest are given in Table.1 and Fig. 2. At 45 DAT there was no significant difference in number of leaves among the treatments. Irrigation immediately after the development of hairline cracks (T3) registered the maximum number of leaves of 56.7 and 12.5 at 90 DAT and at harvest. This was statistically on par with T1, T2 and T4 at 45 DAT and with T1, T2, T4 and T8 at harvest respectively. T5 recorded the minimum number of leaves at 90 DAT. T7 recorded minimum number of leaves at harvest. The higher number of leaves might be due to higher number of tillers putting forth more leaves (Singh *et al*., 2015).

**3.1.3 Number of tillers (plant-1)**

Among the different soil moisture regimes under AWD, Irrigation immediately after the formation of hairline cracks (T3) registered higher number of tillers of 21 plant-1 which was statistically at par with T1 and T4 (Table. 1). Similar findings on higher number of tillers were noted by Kunnathandi *et al*., (2015) and Selvakumar *et al.*, (2020). This could be attributed to improved aeration, which stimulated root growth and nutrient absorption, leading to greater growth and increased tiller production.

**3.1.4 Dry matter production (DMP) (kg ha-1)**

Among the irrigation management practices, dry matter production at 45 DAT did not show significant difference, whereas high dry matter production of 16291.1 kg ha-1 at 90 DAT and dry matter production of 22115.8 kg ha-1 at harvest was recorded with Irrigation immediately after the formation of hairline cracks (T3) were significantly superior to other treatments. Irrigation at 5 cm fall of water table below the surface (T4) was next in the order and T6 recorded the lowest dry matter production at 90 DAT and at harvest (Table.1). Similar results were observed by Selvakumar *et al*., (2020) and the rise in DMP with these treatments could be attributed to the improved aeration and better soil properties which enhanced water availability and transport of nutrients (Gurovich and Oyarce, 2015).

**3.2 Impact of Soil Moisture Regimes under AWD on Yield of Wetland Paddy**

**3.2.1 Yield attributes**

A higher count of panicles (333 m-2) was observed with irrigation immediately after the formation of hairline cracks (T3) which was statistically on par with irrigation at 5.0 cm fall of water table below the surface (T4) and T8 (Irrigation at IW/CPE ratio of 1.2 at vegetative phase and 1.5 at reproductive phase). A higher count of grains (108 panicle-1) was observed with irrigation immediately after the formation of hairline cracks (T3) which was on par with T3, T4, T2, and T8. Filling percentage of grains did not show significant difference between the treatments (Table. 2). A well-developed root system, improved soil aeration and increased nutrient uptake contributed to favorable growth conditions leading to higher yield attributes. These results align with the findings of previous studies by Veeraputhiran *et al.,* (2010) and Selvakumar *et al.,* (2020). The development of more tillers due to enhanced nutrient absorption was promoted by irrigation after the formation of hairline cracks facilitating the efficient transfer and storage of photosynthates under optimal soil-plant water conditions (Satyanarayana *et al.,*2007).

**3.2.2 Grain yield, Straw yield and Harvest Index**

Highest grain yield of (7438 kg ha-1) and straw yield of (17486 kg ha-1) were observed with irrigation immediately after the formation of hairline cracks (T3) and this was statistically on par with irrigation at 5.0 cm fall of water table below the soil surface (T4) (Table. 2). Irrigating immediately after the development of hairline cracks (T3) resulted in a 11.2% increase in grain yield and a 25.3% increase in

**Table 1. Impact of Soil Moisture Regimes under AWD on Growth of Wetland Paddy**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Treatments** | **Plant height (cm)** | | | **No. of leaves (hill-1)** | | | **No. of tillers (plant-1)** | **Dry matter production (kg ha-1)** | | |
| **45 DAT** | **90 DAT** | **At harvest** | **45 DAT** | **90 DAT** | **At harvest** | **60 DAT** | **45 DAT** | **90 DAT** | **At harvest** |
| T1 | 74.9 | 120.7 | 123.7 | 23.4 | 54.1 | 11.4 | 19.7 | 2753.0 | 13889.2 | 17912.8 |
| T2 | 68.3 | 119.0 | 122.6 | 23.0 | 53.7 | 10.8 | 18.3 | 2735.6 | 13855.8 | 17502.4 |
| T3 | 76.5 | 123.1 | 126.7 | 26.2 | 56.7 | 12.5 | 21.0 | 3006.7 | 16291.1 | 22115.8 |
| T4 | 74.4 | 121.8 | 124.9 | 25.0 | 55.7 | 10.7 | 19.5 | 2907.6 | 14471.4 | 19378.2 |
| T5 | 63.9 | 108.2 | 111.8 | 17.6 | 46.5 | 8.3 | 13.5 | 2592.0 | 12634.6 | 16597.7 |
| T6 | 64.3 | 108.9 | 112.6 | 17.2 | 47.1 | 9.7 | 14.1 | 2575.9 | 12133.0 | 16206.2 |
| T7 | 66.1 | 113.2 | 118.2 | 18.7 | 49.6 | 8.0 | 16.1 | 2662.8 | 13680.7 | 17081.9 |
| T8 | 68.4 | 117.3 | 120.9 | 22.8 | 50.2 | 10.3 | 18.0 | 2856.0 | 13990.2 | 18163.9 |
| Mean | 69.3 | 116.5 | 120.2 | 21.72 | 51.71 | 10.19 | 17.53 | 2760.37 | 13868.26 | 18119.88 |
| SE (d) | 2.85 | 3.38 | 3.4 | 3.31 | 2.68 | 1.04 | 1.83 | 139.07 | 322.61 | 534.66 |
| CD (p=0.05) | 6.12 | 7.26 | 7.29 | NS | 5.74 | 2.22 | 3.93 | NS | 691.94 | 1146.73 |

*T1 - Continuous submergence with 5 cm of standing water as per farmer’s practice, T2 – Irrigation immediately after disappearance of ponded water, T3 – Irrigation immediately after the development of hairline cracks in the soil, T4 – Irrigation at 5.0 cm fall of water table below the soil surface, T5 – Irrigation at 10.0 cm fall of water table below the soil surface, T6 – Irrigation at 15.0 cm fall of water table below the soil surface, T7- Irrigation at IW/CPE ratio of 1.0 at vegetative phase at 1.2 at reproductive phase, T8 – Irrigation at IW/CPE ratio of 1.2 at vegetative phase and 1.5 at reproductive phase*

**Fig.1** Impact of soil moisture regimes under AWD on plant height

**Fig.2** Impact of soil moisture regimes under AWD on number of leaves

**Fig.3** Impact of soil moisture regimes under AWD on grain and straw yield

**Table 2. Impact of Soil Moisture Regimes under AWD on Yield of Wetland Paddy**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Treatment** | **Panicles m-2** | **Grains panicle-1** | **Filling Percentage** | **Grain yield (kg ha-1)** | **Straw yield (kg ha-1)** | **Harvest Index** |
| T1 | 312 | 101 | 97.7 | 6690 | 13950 | 32.4 |
| T2 | 308 | 105 | 96.8 | 6673 | 13540 | 33 |
| T3 | 333 | 108 | 97.2 | 7438 | 17486 | 29.8 |
| T4 | 323 | 107 | 97 | 7275 | 15415 | 32.1 |
| T5 | 300 | 97 | 97.3 | 6224 | 12634 | 33.3 |
| T6 | 300 | 96 | 97 | 6181 | 12243 | 33.7 |
| T7 | 303 | 99 | 97.07 | 6302 | 13119 | 32.5 |
| T8 | 315 | 101 | 97.5 | 6812 | 14201 | 32.4 |
| Mean | 311.75 | 101.75 | 97.21 | 6699.46 | 14073.29 | 32.43 |
| SE (d) | 8.5 | 3.51 | 0.46 | 261.42 | 542.89 | 0.61 |
| CD (p=0.05) | 18.23 | 7.53 | NS | 560.69 | 1164.38 | 1.32 |

*T1 - Continuous submergence with 5 cm of standing water as per farmer’s practice, T2 – Irrigation immediately after disappearance of ponded water, T3 – Irrigation immediately after the development of hairline cracks in the soil, T4 – Irrigation at 5.0 cm fall of water table below the soil surface, T5 – Irrigation at 10.0 cm fall of water table below the soil surface, T6 – Irrigation at 15.0 cm fall of water table below the soil surface, T7- Irrigation at IW/CPE ratio of 1.0 at vegetative phase at 1.2 at reproductive phase, T8 – Irrigation at IW/CPE ratio of 1.2 at vegetative phase and 1.5 at reproductive phase*

straw yield compared to continuous submergence with 5 cm of standing water as per farmer’s practice (T1). Selvakumar *et al*., (2020) also verified that grain yield and straw yield were high under irrigation after formation of hairline cracks and was on par with irrigation when water level reached 5 cm below soil surface. They also stated that this could be attributed to the increased number of tillers and higher number of panicles with high filling percentage. Safe AWD enhanced soil aeration, promoted root growth and development, and improved nutrient availability throughout the crop cycle, enhancing yield attributes and ultimately increasing rice yield. In terms of Harvest Index, T6 showed the highest harvest index and was comparable with T1, T2, T5, T7, T8 and T3 recorded the lowest Harvest Index.

**4. CONCLUSION**

Based on the experimental findings it can be inferred that irrigation immediately after the formation of hairline cracks emerged as the most effective treatment followed closely by irrigation at 5.0 cm fall of water table below the soil surface, in terms of growth and yield parameters under different irrigation depths in alternate wetting and drying method. The superior performance under irrigation immediately after the development of hairline cracks can be attributed to improved soil aeration, enhanced root and tiller development and optimal nutrient availability which collectively contributed to higher yield attributes. The results highlight the significance of selecting the appropriate irrigation depth to maximize rice productivity while ensuring water use efficiency. Future research should focus on optimizing irrigation depths under alternate wetting and drying across different soil types and climatic conditions to enhance water-use efficiency and yield sustainability.

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**AUTHORS’ CONTRIBUTIONS**

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

**DISCLAIMER**

Authors hereby declare that no generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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