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Original Article

Alternate Wetting and Drying (AWD): Pioneering Water Management in Rice Farming

Hridesh Harsha Sarma[1*] and Anasuya Boruah[2]

[1]MSc. (Agriculture), Department of Agronomy, Assam Agricultural University, Jorhat, Assam
[2]Ph.D. Scholar, Department of Agronomy, Punjab Agricultural University, Ludhiana, Punjab

**Corresponding author: hrideshsarma.official@gmail.com*

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INTRODUCTION

The sustainability of rice farming and global food security are under threat due to global warming and diminishing water resources. The rising global population is driving greater demand for food, posing a monumental challenge to food security amidst diminishing natural resources such as land and water (Alauddin *et al*., 2020). Rice is traditionally cultivated in lowland areas under continuously flooded conditions because it is typically considered a high-yielding crop. However, this conventional method, which involves transplanting seedlings aged 30–35 days from nurseries to fields, faces challenges due to diminishing water resources. While the continuously flooded system ensures high productivity, effective weed control, and optimal plant growth, it also demands significant water quantities and involves practices like puddling that can degrade soil health by forming plow pans and disintegrating soil particles. Moreover, this method requires more labour, emits higher levels of methane, contributes to global warming, and increases the accumulation of mercury and arsenic in grains. To mitigate these impacts and preserve ecosystem health, there is a growing need to transition from the continuously flooded system to resource-conserving alternatives. The deterioration of soil quality, rising deficiencies in micronutrients, and decreasing organic matter are additional challenges to the ongoing sustainability of conventional rice farming. Also, rice cultivation covers a vast expanse of 167 million hectares (mha), with the majority being cultivated under continuously flooded conditions (FAO, 2018). In response, the alternate wetting and drying (AWD) irrigation system emerges as a promising solution that conserves water, is economically feasible, and promotes environmental sustainability as an alternative to continuous flooding (CF).

Overview of Alternate wetting and drying (AWD)

In the AWD method, fields undergo cycles of flooding and drying rather than maintaining continuous flooding throughout the entire crop season. Fields are re-flooded once the soil surface reaches an aerobic state, allowing water to recede through percolation and evapotranspiration. This approach shifts from the traditional practice of keeping paddy fields continuously flooded to implementing alternating wet and dry conditions.

Generally, AWD method is implemented through the following steps:

1. Initial Water Management after Transplanting

Approximately two weeks following transplanting, the rice field undergoes a drying phase until the water level reaches 15 cm below the soil surface. It is then reflooded to a depth of 3–5 cm before being drained again. This cycle of irrigation continues, with adjustments made during flowering to maintain a shallow water depth of 3–5 cm. The frequency of drainage and the duration of non-flooded periods vary depending on crop stage and local conditions.

2. Monitoring and Assurance of Water Levels

To monitor water levels effectively, farmers utilize a field water tube—a 30-cm section of 15-cm diameter plastic pipe or bamboo with drilled holes. This tube is submerged into the rice field until 10 cm protrudes above the soil surface, providing a reliable indicator of water accessibility for rice plants. Once the alternate wetting and drying (AWD) method is established, reliance on soil monitoring often replaces the need for continuous use of the water tube.

3. Importance of Proper Field Levelling

Achieving uniform field levelling is crucial to prevent areas from becoming excessively dry or waterlogged, which can negatively impact crop yields. In some agricultural systems, laser land levelling may be employed to ensure optimal field conditions.

4. Weed Control Strategies

Effective weed management is essential during periods of soil drying, as these conditions can promote weed growth. Maintaining flooded conditions for approximately two weeks post-transplanting helps suppress weed growth while facilitating rice plant establishment.

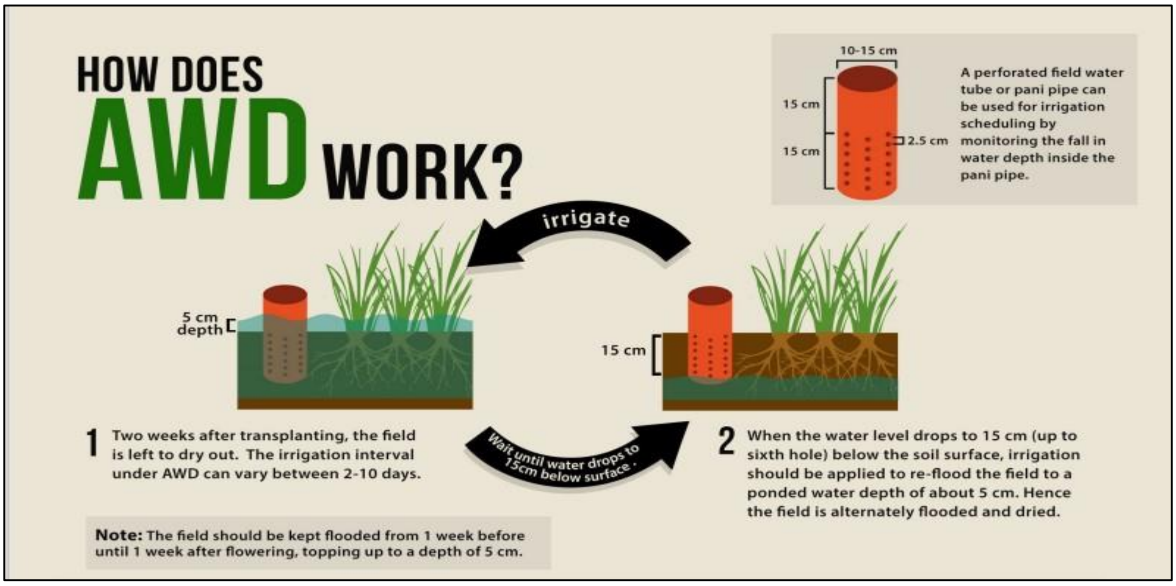

Fig. 1: Working principle of AWD technique

(Source: https://ghgmitigation.irri.org/mitigation-technologies/alternate-wetting-and-drying **)**

AWD is classified into safe-AWD, mild/moderate-AWD, and severe-AWD based on soil water potential or field water level. Among these, "safe AWD" is currently recommended and gaining popularity among farmers across several Asian countries such as India, Vietnam, Philippines, and Bangladesh. The AWD method is employed in both direct seed rice (DSR) and transplanted rice systems. Water-saving techniques such as AWD or mid-drainage, whether applied to traditional flooded puddled transplanted rice systems (CF-TRP) or water-saving systems like Direct Seeded Rice (DSR), aim to decrease water usage and mitigate potential adverse effects on rice growth, physiology, and yield.

Fig.2&3: Implementation of AWD technique in the field
(**Source**: https://ghgmitigation.irri.org/mitigation-technologies/alternate-wetting-and-drying)

Significance of AWD on soil

The effectiveness of alternate wetting and drying cycles on crop performance and final yields depends on soil texture, pH levels, organic carbon content, soil microbes, and prevailing climatic conditions. Transitioning from continuously flooded (CF) to aerobic soil conditions (AWD) alters soil aeration, moisture levels, and nutrient availability through processes like mineralization. Improved air exchange between the atmosphere and soil under AWD practices enhances soil organic matter mineralization and reduces nitrogen immobilization due to sufficient oxygen supply. This contributes to enhanced soil fertility and availability of essential nutrients crucial for rice plant growth. Implementing AWD cycles impacts soil microbial activity and water uptake, influencing nutrient cycling and nutrient availability to plants (Dodd *et al*., 2015). During dry periods under AWD, aerobic conditions promote soil microbial activity, enhancing mineralization and the subsequent release of nutrients in the rhizosphere. AWD irrigation is particularly beneficial in soils with organic carbon content exceeding 1% (SOC > 1%), as higher SOC levels correlate with improved aggregate stability, reduced bulk density, enhanced soil structure, and increased porosity. These improvements collectively enhance water availability for plants and contribute to improved water-holding capacity (Murphy, 2014).

Significance of AWD on rice crop

The AWD system contributes significantly to enhancing both root and shoot growth and development. Under mild-AWD conditions combined with regular nitrogen fertilizer application, there is observed improvement in root and shoot growth, as well as increased root density and biomass (Pascual and Wang, 2017). The periodic drying cycles in AWD promote root proliferation, facilitating higher nutrient and water uptake, increased leaf area index, and enhanced leaf elongation rate. Deep roots with higher hydraulic conductivity play a crucial role in extracting water and nutrients from the rhizosphere, ensuring optimal conditions for plant growth. Upon re-irrigation, plants respond rapidly, exhibiting an increased net assimilation rate. Re-wetting may elevate root water potential, leading to higher cytokinin levels in the xylem, which contribute to plant growth regulation. AWD irrigation patterns also enhance rice performance by influencing leaf angle, increasing leaf area duration, reducing unproductive tillers, and promoting productive tillers. Additionally, enhanced vegetative growth improves canopy structure.

During the drying phase of AWD, elevated levels of abscisic acid (ABA) in roots stimulate the translocation of photosynthates towards developing grains by enhancing enzyme activities in the stem and rice kernel (SuS, StS, ADPG, and SBE enzymes). Increased ABA biosynthesis in roots during drying further enhances its concentration. Re-wetting increases cytokinin levels in lower-quality spikelets, boosting their sink strength through enhanced endosperm cell division and grain filling rate, and upregulating genes encoding enzymes in the sucrose-to-starch pathway.

AWD and reduction in GHG emissions

In wet or "paddy" rice fields, methane (CH_4) is generated through anaerobic decomposition of organic matter once the fields are flooded. Allowing the fields to drain interrupts the anaerobic conditions temporarily, halting CH_4 production and thereby reducing overall emissions during the growing season.

Nitrous oxide (N_2O) production is also affected by oxygen availability. Unlike CH_4, the alternating shifts between aerobic and anaerobic conditions promote bacterial conversion of nitrogen compounds into N_2O, leading to its release from the soil. The amount of nitrogen fertilizer applied to rice paddies strongly influences N_2O emissions, as higher nitrogen availability in the soil increases N_2O production. AWD decreases methane emissions by 48% while maintaining the same level of yield (Richards & Sander, 2014).

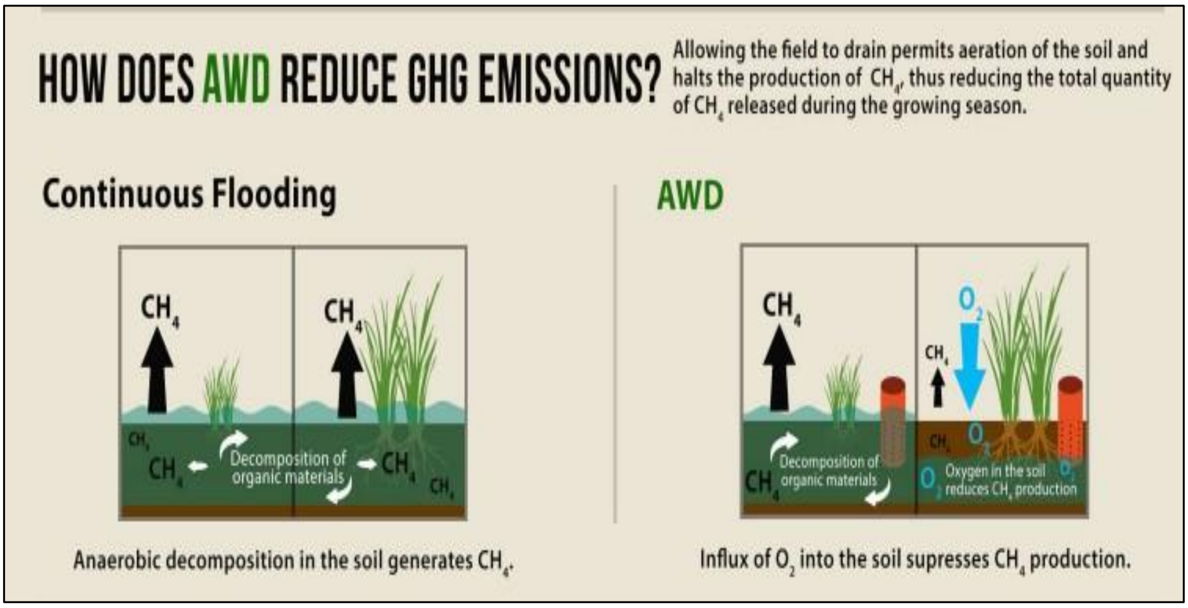

Fig.4: Continuous flooding vs AWD
(Source: https://ghgmitigation.irri.org/mitigation-technologies/alternate-wetting-and-drying **)**

Benefits of AWD

1. Implementing AWD can decrease water usage by as much as 30% by reducing the frequency of irrigation events. This approach supports farmers in managing water scarcity and enhances the dependability of irrigation water supply downstream.
2. Effective management of rice straw and fertilizers can significantly decrease methane (CH_4) emissions. Optimizing nitrogen use can also mitigate the rise in nitrous oxide (N_2O) emissions associated with AWD, simultaneously enhancing yields and reducing costs for farmers.
3. AWD, when compared to continuous flooding, maintains yields and potentially enhances them by fostering better tillering and stronger root development in rice plants. Farmers employing pump irrigation can save on irrigation expenses and achieve greater profitability by adopting AWD.
4. Moreover, AWD has the potential to decrease labour costs by improving field conditions, particularly soil stability during harvest, which facilitates mechanical harvesting.

Enhancing the benefits of AWD

Soil additives like phosphogypsum, silicate fertilizer, ammonium sulfate, and calcium carbide can further reduce greenhouse gas emissions in rice fields that are periodically irrigated. Silicate fertilizers and phosphogypsum, when used alongside nitrogen fertilizer, not only enhance rice yields but also decrease methane emissions by over 30% during intermittent irrigation. Calcium carbide serves as a nitrification inhibitor, reducing nitrous oxide emissions by about one-third under Alternate Wetting and Drying (AWD) conditions. The availability and use of these amendments have the potential to amplify the environmental benefits of AWD practices.

Organic materials like rice straw, manure, and compost should be applied to dry soil during the off-season to minimize methane emissions. The feasibility of this approach varies depending on the agricultural calendar, as some regions irrigate fields even in the dry season, limiting the time available for aerobic decomposition of organic inputs. Both straw and manure, which can also undergo composting, emit less methane once integrated into rice soils compared to fresh organic matter. Effective management of organic residues should incorporate biogas technology, where methane produced from rice straw reduces reliance on fossil fuels. The resulting biogas slurry serves as a beneficial fertilizer with lower methane emission potential than applying fresh organic material directly to the soil (Richards & Sander, 2014).

CONCLUSION

Alternate Wetting and Drying (AWD) presents a holistic solution for modern rice farming practices. By strategically managing water levels in paddy fields, AWD not only reduces methane emissions significantly but also conserves water resources by minimizing unnecessary irrigation. This approach supports sustainable water management, crucial in regions facing water scarcity. It also promotes healthier soil conditions and enhances crop yields through improved nutrient management and root development. Farmers adopting AWD can potentially reduce costs associated with irrigation and labour, thereby increasing profitability and economic resilience in agricultural operations.

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