Impact of Alternate Wetting and Drying Irrigation (AWDI) on water saving and yield of transplanted rice

Original Research Article

ABSTRACT:

A large-scale demonstrations was conducted on Alternate Wetting and Drying Irrigation (AWDI) on water saving and yield of Transplanted Rice in Mettur-Noyyal confluence sub basin areas of Tamil Nadu, India, by the Tapioca and castor Research station, Yethapurfrom the year 2019 to 2023. For adopting the safe AWDI, the depth of ponded water on the field is monitored using a 'Field Water Tube' which is made of 40-cm long plastic pipe having a diameter of 15 cm which is perforated with holes on all sides. The AWDI technology consumed ranges between 871 mm to 950 mm of irrigation water, higher water use efficiency (6.22 to 7.53 $kgha^{-1}mm^{-1}$) and number of irrigations were recorded between 22 to 30. Adopting AWDI in rice resulted in the highest yield of 7045 kg ha^{-1} compared to the conventional method, which produced 5927 kg ha^{-1} across all experiments. The highest gross returns (Rs. 131927 ha^{-1}), net return (Rs. 77438 ha^{-1}) and BCR (2.99) were observed in adoption of AWDI. The AWDI will be an appropriate technology for water saving in rice. This technology saves up to 49 per cent of irrigation water without reducing yield, and it reduces the number of irrigations by 12 compared to farmers.

Keywords: Rice, Alternate Wetting and Drying Irrigation, Field Water Tube, Water Use Efficiency

1. INTRODUCTION

The water crisis is a major concern as the water demand in growing areas is gradually increasing. The main water sources can no longer meet the increasing demand for the domestic, industrial and agricultural sectors. In agricultural areas, water is a prime factor and important resource needed for proper crop growth, particularly for water-intensive crops such as rice (Jury and Vaux, 2007). Farmers usually adopt conventional practices where paddy is grown under continuously flooded conditions. This traditional practice typically requires 700 to 1,500 mm of standing water per season (Oliver et al., 2010).Nonetheless, this practice has a long-term issue concerning the environmental effect of unnecessary irrigation water consumption. The International Rice Research Institute (IRRI) introduced an advanced technological approach focused on water-saving management practices, known as the "Alternate Wetting and Drying (AWD) technique" (Nelson *et al.,* 2015). The enforcement of AWD is farmer-friendly. Water conservation technology only needs a proper field water tube made from a low-cost material, such as bamboo and polyvinyl chloride (PVC) (Jajere*et al.,*2025). A field water tube is used to monitor the standing water level. The paddy field is flooded with water and is allowed to dry out to a certain ground depth before the irrigation water is reapplied again. In AWD practices, less water for irrigationis required. Past researchers (Carrijo*et al.,* 2017; Mote *et al*., 2021;Chapagain *et al*., 2011; Howell *et al*., 2015; Sriphirom*et al*., 2019) have reported and acknowledged this technique and found that by using AWD practice, there is no significant decrease in yield compared to continuous flooded practice. In AWD irrigation, not only does a reduction of up to 15-30 per cent of total irrigation water input, but the total water productivity is also increased, and the same goes for the nutrient uptake (Wichaidist*et al*., 2023). AWD irrigation has been widely used worldwide and is one of the popular methods in paddy cultivation. AWD has promoted water productivity in rice irrigation relative to conventional irrigation (Arai *et al*., 2021; Pascual and Wang, 2017; Bwire *et al*., 2024; Gao *et al*., 2024; Ishfaq *et al*., 2020). In addition, Norton *et al.* (2017) ascertained in their report that AWD increased the total grain mass due to the high number of productive tillers. Sekhar *et al.* (2022), who mentioned that the AWD practice positively affects the tiller, panicle numbers, and grain yield. During *kharif* season in Tiruvannamalai district, more than 40,000 hectares of land is under paddy cultivation. The indiscriminately use of water to the paddy crop by continues flooding and farmers were lack of awareness about AWD through Pani Pipe were identified as major problem. By considering the above problems, present demonstration was conducted to create an awareness to transplanted paddy farmers of Tamil Nadu Irrigated Agriculture Modernization Project Phase-II, Aliyar sub basin of Tiruvannamalai district about judicious use of irrigation water by using Pani Pipe. In order to address climate change in rice production, a climate-smart strategy that presents both adaptation and mitigation benefits is essential. Numerous water-saving techniques have been introduced and documented since time immemorial, for example, intermittent irrigation, drip irrigation, deficit water regime, a system of rice intensification (SRI) and alternate wetting and drying (AWD). AWD is the most popular water-saving technology adopted to improve water use efficiency (Haonan*et al.* 2023).The objective of this study is to comprehensively assess the effects of AWDI on water conservation and the yield of transplanted rice. This will be achieved through a large-scale demonstration, aiming to provide valuable insights into the potential of AWDI as a sustainable irrigation technique for improving water use efficiency and enhancing rice productivity. The study will specifically focus on evaluating the effectiveness of AWDI in reducing water consumption while maintaining or improving the yield of transplanted rice in practical field conditions.

2. MATERIAL AND METHODS

A large-scale on-farm demonstration was conducted in irrigated lowlands using the Alternate Wetting and Drying Irrigation (AWDI) method over five consecutive years (2019–2024) as part of the Tamil Nadu Irrigated Agriculture Modernization Project (TNIAMP) Phase-II in the Mettur-Noyyal sub-basin, implemented by the Tapioca and Castor Research Station, Yethapur, Salem, Tamil Nadu.The demonstration on AWDI with field water tube in transplanted rice was carried out in Salem, Namakkal and Dharmapuri districts including four villages with 277 farmers holdings covering the areas of 326 ha. These demonstrations took place at the fields of farmers in the village of K.N.Puthur, Alamarathupatti, Lakkampatti, Neethipuram, Perumbalai, Avadathur, Periyasoragai, Vanavasi, Arasiramani, Koneripatti and Thevur in the Salem, Namakkal and Dharmapuri district of Tamil Nadu, India. The districts of Salem, Namakkal, and Dharmapuri in Tamil Nadu share similar soil and climatic characteristics. The predominant soil types in these areas are red soils, which are well-drained and suitable for dryland crops like groundnut and cotton, and black soils, found in the lowland regions, which are more fertile and ideal for crops such as sugarcane and cotton. The climate in these districts is typically semi-arid tropical, with hot summers and moderate winters. The average temperature ranges from 25°C to 38°C, and rainfall is mainly received during the northeast monsoon, ranging from 700 to 1000 mm annually, depending on the region. These conditions make the areas suitable for crops like groundnut, cotton, pulses, and paddy, although water management practices are crucial due to the semi-arid climate.Two treatments such as: T1-Conventional method like farmer practice, T2- AWDI method (Field Water tube) was imposed in larger way. Non-adoption of improved water management practices during critical stages of crop growth especially tillering stage, milky stage and dough stage resulted in a greaternumber of unproductive tiller and chaffy grains. For adopting the safe AWDI, the depth of ponded water on the field is monitored using a Field Water Tube, made of a 40-cm long perforated plastic pipe with a 15-cm diameter, was installed with 15 cm protruding above the soil surface. The tube allows monitoring of water levels, ensuring the water table inside matches the outside.The water table inside the tube is to be same as outside the tube. The results of network experiments on safe AWDI conducted by the Centre for Water and Geospatial Studies (CWGS) of Tamil Nadu Agricultural University for the past five years, revealed that safe AWDI of 10 cm depletion in light soils and 15 cm in heavy soils may be adopted in Mettur Noyal sub basin areas as safe AWDI for improving the water use efficiency in transplanted rice. The ponding depth was 5cm after reaching the threshold level.The present study revealed that the grain yield, extension gap, technology gap, economic analysis and water saving technology through the AWDI method using pani pipe were demonstrated in farmer's holdings.

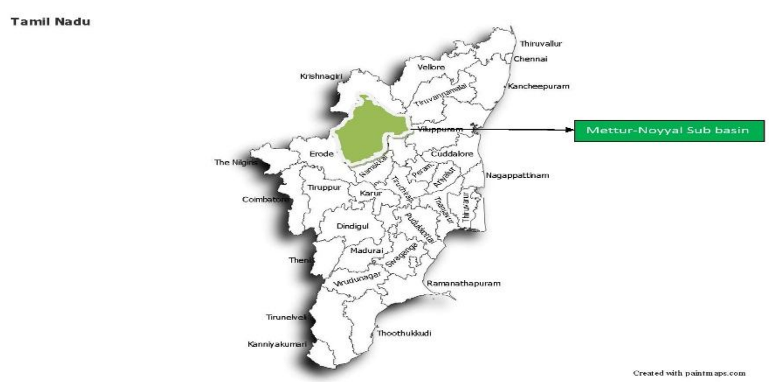
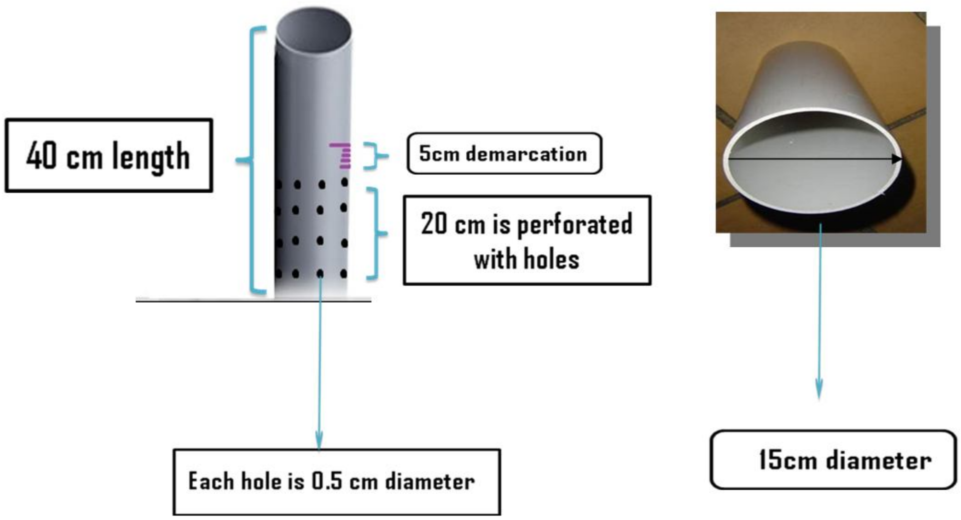


Figure 1: Map ofMettur-Noyyal sub basin

How to implement AWD?

AWD is only one of several techniques which offer opportunities to increase rice production using less water (Pascual et al., 2017).A practical way to implement AWD safely is by using a 'Field Water Tube' (Pani Pipe) to monitor the water depth on the field. The Field water tube will be placed @ 3 per hectare since most of the paddy field in this Ayacut are fragmented. Field Water Tube (Fig. 2) made up of PVC. A few weeks after transplanting, AWD was initiated. When there are a lot of weeds, AWD is delayed for two to three weeks in order to help the ponded water suppress the weeds and increase the effectiveness of the herbicides.A large-scale demonstration was conducted to assess the technology gap between the potential yield and the demonstrated yield.The study aimed to evaluate the

Water Use Efficiency (WUE) between the demonstration method and conventional irrigation practices.It sought to examine the feasibility and effectiveness of the field water tube in managing the Alternate Wetting and Drying (AWD) irrigation regime for transplanted rice.The research aimed to determine the optimal reduction in water level to optimize water use for improved yield.Additionally, the study worked to evaluate water productivity under the different irrigation methods.



*Note the holes on all sides up to 15 cm height.

Figure 2: Field water tube

Data Analysis

The data was obtained from both the demonstration and conventional (farmer practice) method using the random crop cutting method. The "random crop cutting method" refers to a technique used to estimate crop yield by randomly selecting plots within the study area. In this method, a specified number of samples (e.g., 10-15 random plots) are chosen across the field to ensure unbiased representation. Each sample consists of a plot of a defined size, typically $1m^2$ or $2m^2$, depending on the crop type. The crops within each plot are harvested and weighed to estimate the yield per unit area. The selection of these plots is random to minimize any bias, and the criteria for selection include ensuring that the samples are distributed uniformly across the entire field to account for potential variability in soil and growth conditions. This approach provides a reliable estimate of the overall yield for the field under study.Qualitative data was converted to quantitative form and expressed as percentage increase in yield. The data was further analyzed by using statistical tools(ANOVA).

3. RESULTS AND DISCUSSION

The results and discussion examine the impact of AWDI on both water conservation and the yield of transplanted rice. This analysis explores how AWDI contributes to significant water savings compared to traditional irrigation methods, while also evaluating its effectiveness in sustaining or improving rice yields. The findings provide insights into the practical benefits of implementing AWDI, particularly in regions facing water scarcity, and discuss its potential for optimizing irrigation practices without compromising agricultural productivity.

Yield Analysis

The average grain yield under demonstrated plots was 7045, 5812, 5915, 6028 and 5074 kgha^{-1} with an average of 5975 kg ha^{-1}from the years 2019-2020 to 2023-2024 respectively when compared with farmers practices of 5927, 5304, 5271, 5373 and 4149 kg ha^{-1}with an average of 5205 kg ha^{-1}(Tab.1). The comparison between the grain yield of demonstrated plots and farmers practice revealed that the average yield of demonstrated plots was 14.2 percent (Fig.3) higher than that of farmer practice. The higher yield observed in the demonstration plots could be a result of improved root system development caused by alternate wetting and drying irrigation, leading to a greater number of tillers per square meter and subsequently higher yields. Similarly, Ayyadurai et al. (2024) states that the yield increase was 24.3 per cent. The extension gap, technology gap and technology index were 12.6 q ha^{-1} , 5.8 q ha^{-1} and 8.29 per cent, respectively.

Table 1. Influence of Yield (kgha^{-1}) on AWDI in transplanted rice

Year	Area (ha)	Yield (kgha^{-1})	
		AWDI	Conv.
2019	50	7045	5927
2020	80	5812	5304
2022	80	5915	5271
2022	80	6028	5373
2023	36	5074	4149
Average		5975	5205

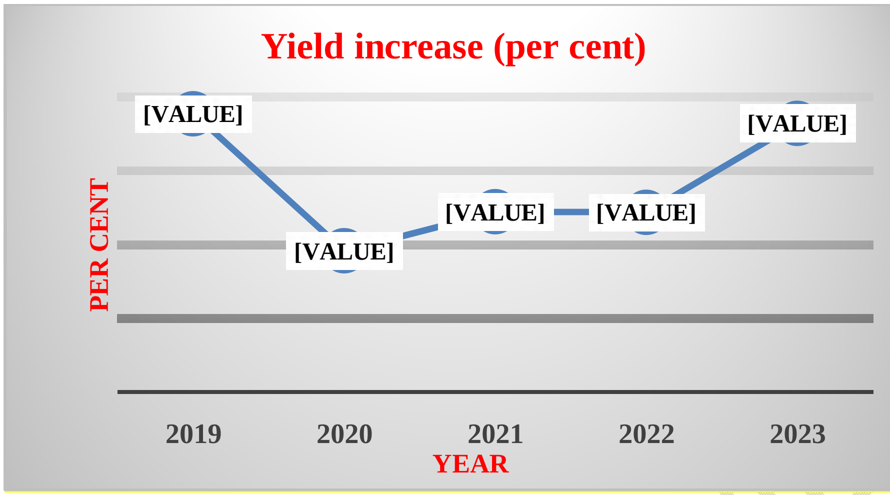


Figure 3. Impact of adapting AWDI practice on yield increase (per cent)

Economic analysis

The demonstration plots using alternate wetting and drying irrigation have demonstrated a higher economic return compared to traditional methods. This is primarily due to the increased yield achieved through improved root development and a higher number of tillers per square meter. Additionally, the reduced water consumption associated with alternate wetting and drying irrigation can lead to lower operational costs and potentially higher profits (Leon and Izumi, 2022).The higher gross return of Rs.1,27,991 ha-1 , higher net return of Rs.73,980 ha-1 , and Benefit-Cost ratio of 1.37 were observed in the AWDI plot compared to farmers' practices of continuous flooding method (Mariyappan, 2024).

The average net return over the past five years for the demonstration plots was Rs.72,784 ha^{-1} and the farmer practice revealed that the average net return over the past five years was Rs.56,625ha^{-1}. The average net return over the past five years for the demonstration plots using alternate wetting and drying irrigation was significantly higher than that of traditional methods. The benefit-cost ratio (BCR) of the alternate wetting and drying irrigation method (2.45) was greater than that of the traditional method (1.94) (Table 2)

Table 2. Effect of AWDI on Economics in transplanted rice

Year	Area (ha)	Cost of cultivation ($Rsha^{-1}$)		Gross Return ($Rsha^{-1}$)		Net Return ($Rsha^{-1}$)		BCR	
		AWDI	Conv.	AWDI	Conv.	AWDI	Conv.	AWDI	Conv
2019	50	38809	36349	116247	97796	77438	61447	2.99	1.88
2020	80	41789	45502	62305	52975	60516	44473	2.34	1.97
2021	80	45241	48401	106484	94880	61243	46479	2.35	1.96
2022	80	48104	50286	71395	59419	73291	59133	2.26	1.89
2023	36	40482	36539	131914	108133	91432	71594	2.32	2.00
Average		42885	43415	97669	82640	72784	56625	2.45	1.94

Effect of AWDI on irrigation frequency, water use rate (mm) and Water Use Efficiency (kgha^{-1}mm^{-1}) in Transplanted rice

AWD irrigation is a water-saving technique that involves allowing the soil to dry out periodically between irrigation events. This practice mimics natural rainfall patterns and encourages deeper root development, enabling plants to access water stored in the lower soil profile. By reducing the frequency of irrigation, AWD can significantly reduce water consumption. Additionally, this method can help improve soil health by promoting beneficial microbial activity and reducing the risk of water logging (Soliman *et al.* 2024). As a result, AWD can lead to higher water use efficiency, lower irrigation frequency, and reduced water use rates compared to conventional irrigation methods, such as flooded irrigation. AWDI offers several advantages over conventional methods like flooded irrigation, particularly in terms of water conservation and soil health. By allowing the soil to dry out periodically between irrigation events, AWDI significantly reduces water consumption compared to continuous flooding. This practice encourages deeper root development, enabling plants to access water stored in the lower soil profile and reducing reliance on surface irrigation. Additionally, AWDI can help improve soil structure by promoting beneficial microbial activity and reducing the risk of water logging. This can lead to enhanced nutrient cycling and increased crop yields. Furthermore, AWDI can help mitigate greenhouse gas emissions, such as methane, that are often associated with flooded irrigation (Wijesundara, 2024). Overall, AWDI is a more sustainable and efficient irrigation method that can contribute to improved agricultural productivity while conserving water resources. The AWDI method required only 27 irrigations, significantly fewer than the 39 irrigations needed in conventional methods. The AWDI method demonstrated a significant reduction in average water use rate, requiring only 910 mm of water per unit area compared to the 1394 mm needed in conventional methods. This substantial decrease in water consumption highlights the efficiency of AWDI in optimizing water usage for agricultural production. The demonstrated method exhibited a significantly higher average water use efficiency of 6.78 kg ha^{-1}mm^{-1} (Table 3) compared to the conventional method, which averaged 3.92 kg ha^{-1}mm^{-1}. This substantial improvement of 72.7 per cent indicates that the demonstrated method was more effective in converting water into crop yield, ultimately reducing water consumption and improving agricultural productivity.Compared to famers‘ practice of continuous flooding (CF), safe AWD saves as much as 30 percent irrigation water without reducing rice yield, and increases farmers‘ income by 30 percent (Lampayan, 2013). By maintaining a thin water layer at saturated soil conditions, or Alternate Wetting and Drying (AWD), can reduce water usage by approximately 40-70 per cent compared to the traditional practice of continuous submergence, without causing significant yield loss (Tabba*et al.,* 2002)

Table 3. Effect of AWDI in no of irrigation, water use (mm) and WUE (kg ha^{-1}mm^{-1})in Transplanted rice

Year	Area (ha)	AWDI			Conventional		
		No. of Irrigation	Water use (mm)	Water Use efficiency (kg ha^{-1}mm^{-1})	No. of Irrigation	Water use (mm)	Water Use efficiency (kg ha^{-1}mm^{-1})
2019	50	30	935	7.53	39	1368	4.30

2020	80	29	871	6.67	40	1300	4.08
2021	80	22	950	6.22	38	1540	3.42
2022	80	26	891	6.70	42	1369	3.90
2023	36	28	901	6.73	40	1394	3.92
Average		27	910	6.78	39	1394	3.92

4. CONCLUSION

Farmers have reported significant benefits from adopting AWDI, including reduced water consumption, improved crop health and resilience, enhanced soil quality, increased yields, and overall economic and environmental advantages. Despite initial hesitation, many farmers have found AWDI to be a valuable and effective irrigation technique that has positively impacted their agricultural practices. A five-year study evaluating AWDI's effectiveness in water-saving rice cultivation showed significant reductions in water consumption (up to 49 PER CENT), fewer irrigations (12 less than traditional methods), and increased yields (7045 $kgha^{-1}$ compared to 5927 $kgha^{-1}$). AWDI also improved water use efficiency and generated higher economic returns. However, there are challenges in implementing AWDI, such as the need for proper monitoring tools to manage irrigation schedules effectively and potential difficulties in scaling the technology across larger areas or diverse farming systems. These factors highlight the practical considerations that must be addressed for broader adoption. Nevertheless, these findings suggest that AWDI has significant potential as a scalable solution for sustainable rice production, not only in Tamil Nadu but also in other regions with similar agricultural conditions. Its application could help address water scarcity in areas beyond Tamil Nadu, providing both economic and environmental benefits.

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