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Evaluating the Performance of Alternate Wetting and Drying Irrigation Technology: An On-farm Rice Case Study in An Giang Province, the Mekong Delta of Vietnam

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ABSTRACT

Alternate wetting and drying irrigation (AWD) is a promising technique that has been tried across Southeast Asia to reduce water consumption and methane emissions in irrigated rice cultivation. The study conducted in the upper Vietnamese Mekong Delta compared the effectiveness of plant growth, yield components, and yield under three different water application regimes: the treatments of community AWD (AWD_C), household individually (AWD_H), and continuous flooding (CF) with the expectation to explore the ability to use water effectively in rice cultivation. The results showed no significant difference in water use between the three treatments. However, there was a considerable difference in coefficient of variation value (CV); the CV value of the water column in the AWD_C (1.32%) was a significant difference from that of AWD_H (0.87%) and CF (0.89%). The mean chlorophyll content, the yield, and the weight of 1,000 grains of the AWD_H treatment were significantly higher than that of the other two treatments. In another aspect, the water productivity of the AWD_H treatment was the highest (0.66 kg/m^3), a statistically significant difference compared to the AWD_C and CF (0.37; 0.33 kg/m^3). In conclusion, the AWD_H shows efficiency in leaf chlorophyll content, 1,000-grain weight, yield, and water productivity. The

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AWD_C is inferior to the AWD_H due to the large variation of field elevation. It is noted that field elevation is critical to the technique's success in being applied on a large scale.

Keywords: Alternate wetting and drying technology, continuous flooding, rice yield, the Mekong Delta, Vietnam, water productivity

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INTRODUCTION

With the awareness of accelerating global climate change and ecological degradation, Southeast Asian states are grappling with worsening water insecurity, particularly in river delta regions, which form critical agricultural production and food security centres. The Mekong Delta of Vietnam provides more than 50% of the country's rice production and more than 90% of rice exports, making it crucial to the nation's economy. However, the delta faces multiple problems related to water resources insecurity, including worsening incidents of flooding, drought, and riverbank erosion driven by external/cross-border and local causes and processes (Boretti, 2020; World Bank [WB], 2022). One of the growing concerns is the increasing severity of water scarcity in the Delta, as surface water becomes more constrained and demand from agriculture and other sectors spirals basin-wide. In short, periods of drought are becoming more common in the Mekong region. Public irrigation providers and individual farmers find it harder to guarantee enough water for rice crop provision, especially in the dry season.

In this context, agencies responsible for water provision to rice farmers are increasingly keen to introduce techniques that might reduce irrigation water consumption and improve efficiency without hurting yields or farmer income. In theory, such water conservation efforts would free up more water supply for other downstream users and provide beneficial environmental flows (recognising the needs of the wider ecosystem and biodiversity in a river system, from both a water quantity and quality perspective) in the river system. Thus, water and agricultural research institutes across Asia have been testing a novel water-saving technique, AWD, which has shown some promise in lowering on-farm water use in irrigated rice cultivation, while reducing emissions of greenhouse gases (GHG) and not negatively affecting crop yields. Agriculture is the second largest contributor to global GHG emissions, accounting for 24% of total emissions (Adounkpe et al., 2021). In the agricultural sector, paddy rice cultivation is one of the most important sources of anthropogenic emissions of GHGs, thus making it a high priority to introduce methods to mitigate its significant impact (Arunrat et al., 2018).

A review of adoption trials across eight Asian countries (Lampayan et al., 2015) found that irrigation water usage had been reduced by up to 38% under AWD with no reduction in crop yield. Another study has suggested that AWD techniques helped to reduce freshwater use by 15–30%, methane emissions by about 30% compared to traditional flood irrigation techniques (Tivet & Boulakia, 2017) and, in some cases, increased rice yields by 0.1–0.5 ton/ha (Nhẫn et al., 2013), and 0.7 ton/ha (Tin et al., 2015). AWD has been considered a "climate-smart" method, one of several potential tools to help rice farmers adapt to water shortages under more uncertain and extreme weather conditions (Allen & Sander, 2019). The benefits of AWD are reported to have been widely recognised by farmers in the Philippines: Palis et al. (2005) have claimed AWD saves water, time, and labour due to lesser expenditure, produces heavier 1,000-grain weight due to larger grains with good shape, and less pest problems. In An Giang Province, Vietnam, one study stated that AWD reduced water usage by 15–40% (Yamaguchi et al., 2016). As far as economic benefits go, based on a "with" or "without" AWD trial in the Mekong Delta, Lampayan et al. (2015) reported that farmers' incomes had increased by 17%, with decreased costs of water pumping. They concluded that, in general, and when applied correctly, AWD provided a high rate of return on investment both at the farm level and for research organisations experimenting with the technology, with an average benefit-to-cost ratio of 7:1.

Much research remains to be done to reliably measure the benefits of AWD and encourage adopting these practices at the scale needed, as at present, they have only been applied at a relatively small and localised scale, and not all risks or downsides have been identified. Previous studies have pointed to some potential drawbacks to applying AWD. The case in the paddy field of Padang Raja Kelantan, Malaysia, showed that it may be due to a lack of information, awareness, expertise, and successful experimental evidence (Ilahi et al., 2022). Farmers in the Philippines and Vietnam reported problems with rats when they used AWD (Quynh & Sander, 2015; Smedley, 2017) and weeds (Tirol-Padre et al., 2018). Furthermore, applying AWD on a relatively small scale to a few paddy fields within a larger irrigated block can make precise water management difficult, as there may be seepage from surrounding fields and coordination of water flows for the AWD practising farmers may be problematic.

These observed problems may be a limiting factor to the wider adoption of AWD in the Mekong Delta. Thus, to test the purported benefits of AWD for small-scale farmers within the Mekong Delta, a trial to measure the rice yield and water productivity of the technique over one dry season crop with two different treatments of AWD's applicability and control was arranged to understand how practical and productive this water saving technique would prove under actual farm-based conditions, and what were the limitations or obstacles to its application.

MATERIALS AND METHODS

Research Site and Experimental Design

The trial was carried out in Vinh Trung Commune, Tinh Bien district of An Giang province in the Upper Mekong Delta (Figure 1). This predominantly rural area is populated with Kinh and Khmer villagers. They practice farming as their main livelihood; the average farm size is approximately 1.3 ha/household.

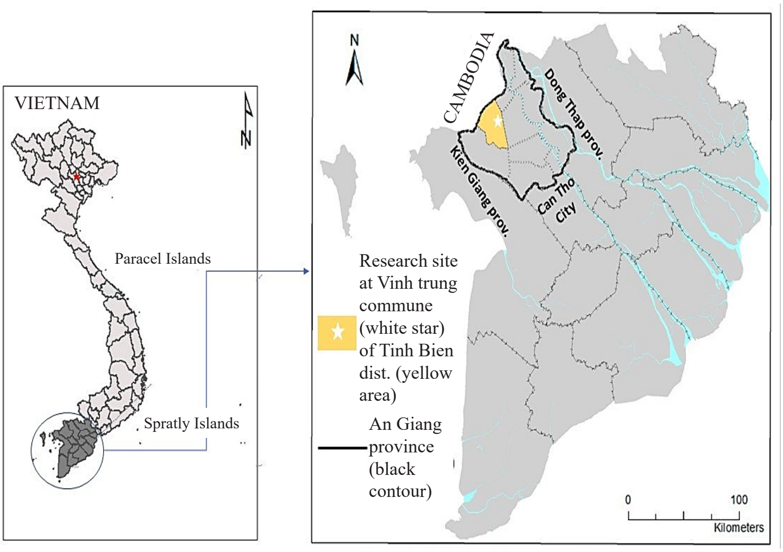

Figure 1. The map of Vietnam and the study area in Tinh Bien district, An Giang province

Note. Prov. = Province; Dist. = District

After consultation with the head of the Tinh Bien Agriculture and Rural Development office, the trial sites located in the complete dike area were agreed upon. It was in a deltaic floodplain area enclosed by full dikes that protect the land from seasonal floods and allow for triple rice cropping. The field experiment was implemented with the cooperation of three groups of households: Group 1 (the control) consisted of three farmers who use the standard local irrigation application regime of continuously flooded fields throughout the crop cycle (the control treatment), with their land occupying a total area of 3,240 m^2, hereafter called continuous flooding (CF, coordinates 10.556632°N, 105.024844° E); Group 2 consisted of three farmers applying AWD individually (the fields separately were irrigated by standard methods) with their land occupying a total area of 6,480 m^2, hereafter called AWD_H (coordinates 10.557766° N, 105.027514° E); and Group 3 was made up of four households with adjacent fields all cooperatively applying AWD, with a total area of 12,960 m^2, hereafter called AWD_C (coordinates 10.556018° N, 105.026574° E). All households grew rice variety OM18 (a high yield variety with a growth period of about 95–100 days, a hybrid combination of the variant OM 8017 and OM 5166), sowed on the same date, January 14, 2022, at a density of 150 kg of paddy seed/ha. It is a short-cycle rice variety from the Cuu Long Rice Research Institute of Vietnam. At this time of year, there is a low probability of rainfall. During the experimental period, it rained 13 times with an average rainfall of 10.08 mm, so crops almost entirely depend on the state-managed irrigation system.

Water Management In-field Trial Treatments

Irrigation water is provided by electric pumping stations that lift water from large secondary canals into a field network of tertiary and quaternary canals. The pumping station operates once every seven days to provide water for the whole area. Separate bunds and the farmers' surrounding rice fields decide the water height within each block of fields. In the trial, there were three types of water management as follows:

For the CF group, the field was flooded continuously from 7 to 76 days after sowing (DAS), according to local farmers' standard irrigation application regime.

Treatments AWD_H and AWD_C: The fields were flooded continuously from 7 to 17 DAS, then an irrigation regime of the alternate flood (three times at 40, 50, and 73 DAS) and drying periods were applied to harvest by blocking the inflow channel and diverting water to other fields. The water level in the field was monitored for these two treatments using a polyvinylchloride (PVC) pipe with a diameter of 20 cm, a height of 30 cm, and a perforated wall with multiple holes of 3 mm diameter to ensure that water was able to move freely through the pipes. Each participating household installed three plastic pipes in their field at different locations to monitor the water level and let farmers know when to reapply irrigation water. The pipes were installed into the ground at a depth of 20 cm from the ground level so the sub-surface water level could be easily observed and recorded, with details of the irrigation regime outlined in the section below.

Data Collection and Analysis

The following parameters were measured:

Soil Sample Analysis. The experimental area is on a soil type of Orthi Haplic Arenosols. Three soil samples were taken to represent each treatment and explore its capacity to store water related to the soil structure. Five sub-samples were collected within each treatment by travelling in a zig-zag pattern across the fields. Sub-samples were taken at a depth of 20 cm and then mixed well to make a combined 1 kg sample. The soil was analysed following these methods: Robinson method for soil texture (analysed at Can Tho University, Vietnam); total nitrogen (N), phosphate (P), and organic matter (OM) analysed at An Giang University, Vietnam by different methods, including the Kjeldahl method, colourimetric method, and atomic absorption spectroscopy (AAS).

Water Column Depth. A plastic ruler of 50 cm was used to measure the water column depth. It was measured once every three days while water was in the field. The water depth was measured from the ground level for the CF treatment. Treatments AWD_C and AWD_H were measured similarly to CF when standing water was in the fields, but when the water level was below ground level, the water column depth was measured inside the installed plastic pipes.

Growth, Yield, and Yield Components. Each treatment was tested using a square metre bamboo frame with three replicates held together by string. Five rice clusters were selected for growth and biological characteristics data collection in each frame. The height of rice plants was measured weekly with a plastic ruler from the ground to the top of the tallest leaf. Chlorophyll content was determined by a soil plant analysis development (SPAD-502) meter, measuring the highest fully developed leaf at 3 points of its blade. From this, an average of the data taken at the top, middle, and bottom positions was calculated. At harvest time, all the shoots in the frame were measured for height and yield component parameters, including number of shoots, spikelet number/panicle, filled grain/panicle, and unfilled grain/panicle. The yield was calculated based on farmers' data at harvest time (checked the grain humidity from the provided samples).

SPSS 20 software was used to analyse one-way analysis of variance (ANOVA) treatment, and a Duncan's multiple range test at a 5% significance level was used to compare water management treatments.

RESULTS AND DISCUSSION

Soil Characteristics of the Study Area

The soil of the study area had a medium OM content of 6.36%. Total nitrogen, phosphorus, and exchangeable potassium were 0.20, 0.02, and 0.10%, respectively (Table 1). In terms of soil texture, it averaged 45.54% sand, 34.40% silt, and 20.06% clay. The soil type of the study area is classified as sandy loam due to an almost equal proportion of sand, silt, and/or clay in the samples. Soil texture composition determines the degree of water absorption and permeability, thus affecting the potential degree of control of water levels in clay soil, causing poor infiltration resulting in water logging, soil salinity, and reduced biological activity. On the other hand, sandy soil gives high infiltration, leading to low water-holding capacity and poor nutrient retention (Dhindsa et al., 2016). It implies that the soil of the study can absorb less water and easily lose water. That means that if AWD is applied in the research area, more irrigation water is expected; however, it depends on the quality of the bunds. In this study, the farmers took care of the bunds well, and the problem of water leaking was avoided.

Changes in Field Water Column Depth in Response to Irrigation Water Application

After initial sowing, all three comparative treatments were irrigated similarly,

Table 1
Soil characteristics of the study area

Sample no.	OM (%)	Soil chemicals			Soil texture			
		N_{total} (%)	P_{total} (%)	$K_{Exchangable}$ (meq/100 g)	Sand (%)	Silt (%)	Clay (%)	Type
1	6.00	0.19	0.03	0.08	48.90	38.44	12.66	-
2	7.21	0.24	0.02	0.16	32.09	34.16	33.75	-
3	5.86	0.17	0.02	0.07	55.64	30.60	13.76	-
Average	6.36 ± 0.30	0.20± 0.08	0.02± 0.03	0.10± 0.17	45.54± 1.73	34.40± 0.63	20.06± 3.34	Sandy loam

Note. OM = Organic matter; N = Total nitrogen; P = Total phosphate; $K_{Exchangable}$ = Exchangeable potassium specifically at 10 and 17 days after sowing, as shown in Figure 2. From 22 days DAS to harvest, there were three irrigation applications for AWD_C and AWD_H (at 37, 52, and 70 DAS), while the CF treatment received six irrigation applications. In terms of water column height, all three treatments were identical during 17 DAS with a value of 9-10 cm water column height but varied considerably after that. From 22 DAS, the CF treatment ranged from 3 cm minimum to 15 cm maximum water depth. The AWD_C and AWD_H treatments followed similar water column depth value trends, with the maximum at about 5 cm and the minimum measured at about 20 cm below surface level. Controlling water depth depended on prevailing weather conditions, surrounding irrigation applications and soil properties (Tirol-Padre et al., 2018). The results of this study are quite different from the study of Tin et al. (2015), with seven watering times. The number of irrigation applications/crops for AWD depends on factors such as temperature (related to evapotranspiration), quantity of rainfall, and soil texture (determining the infiltration rate) (Huệ et al., 2016). Unfortunately, neither this study (Tin et al., 2015) recorded air temperature or humidity during the research period.

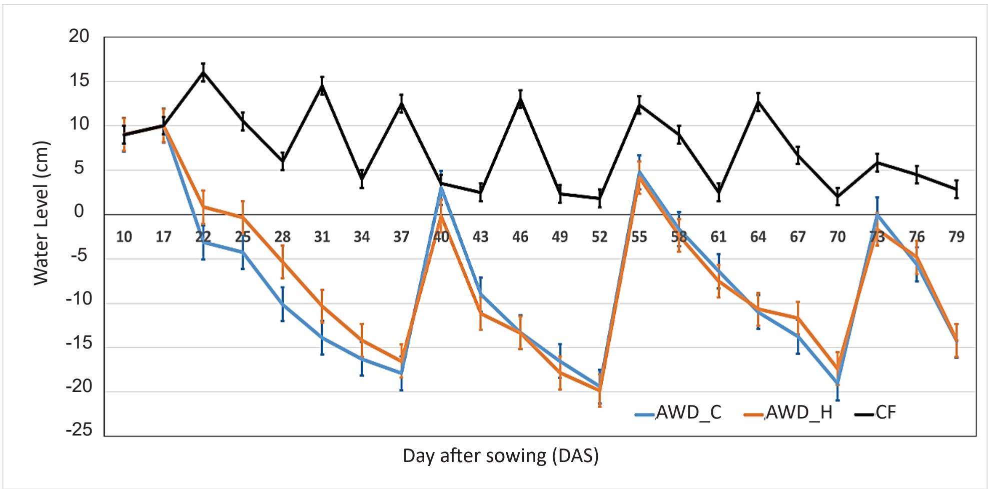

Figure 2. Changes in field water level over time to harvest

Note. AWD_C = Treatments of community; AWD_H = Household individually; CF = Continuous flooding

According to Kumar and Rajitha (2019), irrigation requirements vary from place to place, depending on local conditions, but are reported to be usually in the range of 900–2,250 mm per rice crop (equivalent to 9,000–22,500 m^3/ha). The volume of water applied in this trial varied from about 7,200 m^3/ha for AWD_C and AWD_H up to 7,500 m^3/ha for CF (Figure 3), which appears considerably lower than previous research

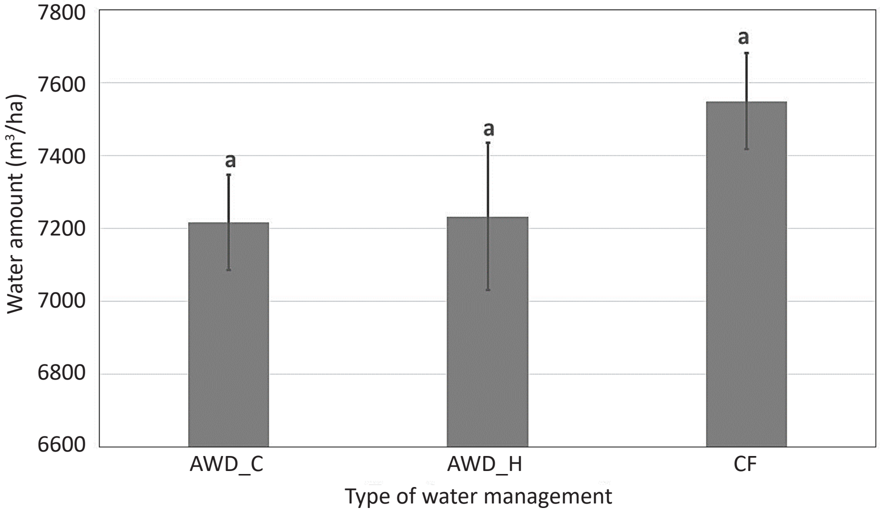

Figure 3. The water irrigation amount in each treatment

Note. AWD_C = Treatments of the community; AWD_H = Household individually; CF = Continuous flooding; The same letters indicate a similar between the treatments at a 5% confidence limit

results reported in the above research. Our research did not consider the initial water volume required for soil preparation, which Kumar and Rajitha (2019) report about 1,500 to 2,000 m^3/ha. No significant water use difference was found between the treatments in this study. However, there was a considerable difference in variation of water column between treatments, e.g., the AWD_C treatment showed a coefficient of variation (CV %) of water column height was up to 1.32%, which was significantly higher than that of the CF and AWD_H treatments with a CV% of 0.89 and 0.87%, respectively (Figure 4). According to actual observations, the water column height of the AWD_C treatment was not equal across the survey points.

This discrepancy is due to different field elevations between the survey sites, which may have affected the growth and yield of rice. A previous study demonstrated that decreased starch content in matured grains was explained that the shortening of grain filling stage under drought stress resulted in early plant senescence and decreased yield of rice under drought was more serious in susceptible variety (IR64) than tolerant genotype (N22) (Prathap et al., 2019). Elevation of the field level is an essential factor in applying AWD, particularly at the community level, to avoid a lack of water in the needed stages of growth.

Effects of Water Management on Growth, Yield Composition, and Yield of Rice

From 22 to 50 DAS, the rice plant height was similar across all three treatments (Table 2). However, at the flowering stage, the average height of rice plants in the CF treatment reached 78.61 cm, significantly

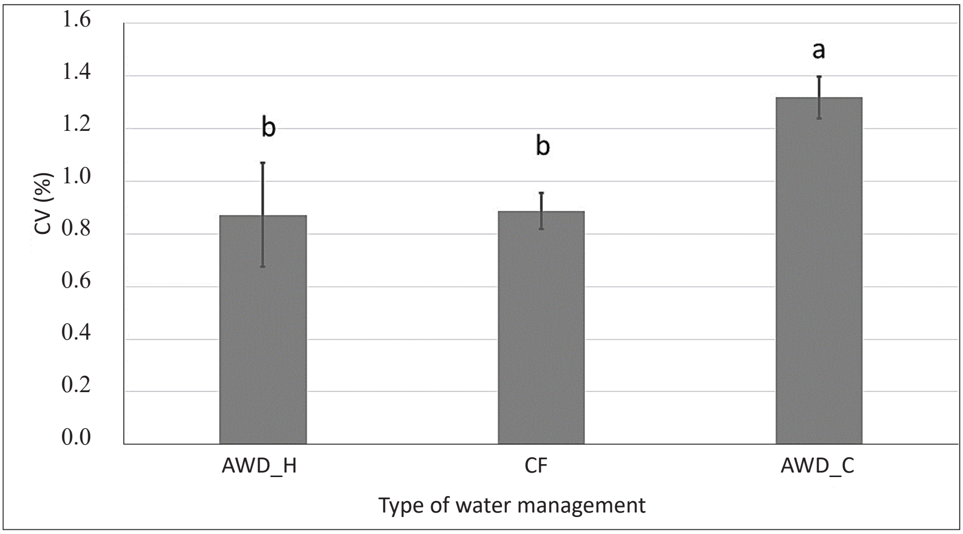

Figure 4. Variation of the water column in each treatment during measurement times

Note. AWD_C = Treatments of community; AWD_H = Household individually; CF = Continuous flooding; CV (%) = Coefficient of variation; Different letters indicate a significant difference between the treatments at a 5% confidence limit

taller than AWD_H at 5% confidence limit, but not significantly different from the AWD_C treatment. In the CF treatment, the water column in the field was always higher than that of the other two treatments (Figure 2), which could explain the greater height of rice plants at the panicle initiation stage.

The SPAD index is used as an indicator of the nitrogen concentration in the leaves of plants, including rice. Nitrogen in leaves is obtained by absorption from the soil. Previous research has shown that SPAD Value increased with increasing N level and growth stages to the flowering stage (Singh et al., 2020). Other research showed that there was a strong correlation between the nitrogen content of rice leaves and SPAD values at 45, 55, and 65 days after

Table 2
Effect of water management regime on plant height (cm)

Irrigation treatment	Day after sowing					
	22	29	36	43	50	57
AWD_C	31.83	47.44	51.06	52.06	58.50	72.06ab
AWD_H	36.33	44.50	52.11	55.06	58.94	69.44b
CF	36.67	44.56	56.44	61.78	64.50	78.61a
CV (%)	7.10	7.21	5.41	7.06	7.37	4.89
Sig.	ns	ns	ns	ns	ns	*

Note. AWD_C = Treatments of community; AWD_H = Household individually; CF = Continuous flooding; Sig. = Significance; ns = Non-significant; In the last column, different letters indicate a significant difference between treatments at 5% (*)

transplanting (Suresh et al., 2017), and rice leaves with a higher SPAD index (>35) indicated higher chlorophyll and nitrogen content (Islam et al., 2009).

In this study, when comparing the two AWD treatments, it was found that the AWD_H treatment had a considerably higher SPAD index than that of AWD_C at 22, 43, and 57 DAS. For the average SPAD index, the results showed that AWD_H gave the highest value (33.85±0.63), which was significantly higher than both AWD_C (31.84±0.25) and CF (31.63±0.73), although the amount of fertiliser applied was the same with each treatment. A difference in the SPAD index of rice between CF, AWD_C, and AWD_H treatments was measured, meaning that rice absorbed different nitrogen levels from the soil under different water regime conditions due to differences in uniformity between AWD_H and AWD_C (Figure 4). The results of previous studies claimed that the soil in AWD condition creates favourable conditions for the release of more nitrogen compared to the CF state, specifically in the period from sowing to 14 days for ammonium (NH_4^+) and 14–28 days DAS for nitrate (NO_3^-) being made available to plants during the drier periods (Đông et al., 2018).

Unfortunately, in our experiment, the total nitrogen of the investigated soil (Table 1) as baseline nitrogen was studied; nitrogen available during the experimental period should have been analysed to observe the relationship between nitrogen available and the SPAD index. It is the weakness of our study. The results from our study indicated that the SPAD value changed over time for each treatment, and the differences were found to be statistically significant between the treatments at 22, 29, 43, and 57 DAS (Table 3). The AWD_H treatment reached a SPAD index of 37.91 (at 22 DAS), 34.74 (at 29 DAS), and 34.63 (at 57 DAS), which were significantly higher values than that of CF.

According to an earlier study, rice yield under AWD conditions was significantly lower than CF (Chapagain & Yamaji, 2010) because drought stress at the flowering stage is recognised to have a strong influence on

Table 3
Effect of water management on soil plant analysis development index in rice leaves

Irrigation treatment	Day after sowing						Average
	22	29	36	43	50	57	
AWD_C	32.22±0.36b	35.56±1.39a	29.32±1.46	28.20±066b	33.36±1.49	32.35±1.06ab	31.84±0.25b
AWD_H	37.91±1.09a	34.74±0.10a	33.69±1.23	31.66±0.70a	30.44±1.78	34.63± 1.22a	33.85±0.63a
CF	33.93±1.35b	28.46±0.85b	31.15±1.62	31.94±1.09a	34.63±4.14	29.65±0.88b	31.63±0.73b
CV (%)	5.09	4.95	7.97	4.75	14.47	5.71	3.07
Sig.	*	**	ns	*	ns	*	*

Note. AWD_C = Treatments of community; AWD_H = Household individually; CF = Continuous flooding; CV (%) = Coefficient of variation; Sig. = Significance; ns = Non-significance; In the same column, different letters indicate significant difference between treatments at 5% (*) and 1% (**) confidence limits, respectively rice physiological traits and yield (Yang et al., 2019). Another study showed a negative relationship between soil moisture and unfilled grains, with the lowest unfilled grains detected when soil moisture was at -30 kPa (Ullah & Datta, 2018). As noted earlier, using AWD under field conditions causes water levels to fall below surface level, which can provide favourable conditions for weeds to grow, which compete for soil nutrients and for rodents to eat the rice plants more easily. Researchers have tried to overcome these potential challenges, so more recent studies have shown some significantly positive results regarding rice yield under AWD compared to using CF (Yamaguchi et al., 2017).

The results of our study, shown in Table 4, indicate that the yield of the AWD_H treatment (4.72 tons/ha) was significantly higher than that of the AWD_C treatment (2.66 tons/ha) and CF (2.51 tons/ha). Most yield components, such as the number of panicles/m^2, number of grains per panicle, percentage of filled grain and percentage of unfilled grain, were not significantly different across the three treatments. However, Allen and Sander (2019) reported that rice under AWD conditions produces more tillers and has enhanced root depth and density compared with CF. It is thought to lead to better drought, disease and lodging resistance, plus increased nutrient and water uptake. One notable result from our research was the 1,000-grain weight measurements, which found a significant difference between the treatments. The AWD_H treatment produced the highest weight (24.60 g/1,000 grains), which was significantly higher than that of the other treatments, namely AWD_C (21.83 g/1,000 grains) and CF (21.82 g/ 1,000 grains). The yield of AWD_H treatment was significantly higher than others, which could be due to significant differences in 1,000-grain weight (Table 4).

Water Productivity of Water Management Methods

Two main objectives of AWD technology have been to save water and contribute towards climate change mitigation by

Table 4

Effects of the trial's treatment regime on rice yield and yield components

Irrigation treatment	Yield (ton/ha)	Panicle (s/m^2)	Spikelet number/ panicle	Filled grain/ panicle	Unfilled grain/ panicle	1,000-grain weight (g)	Filled grain rate (%)	Unfilled grain rate (%)
AWD_C	2.66b	367.67	51.57	41.10	10.47	21.83b	78.56	13.29
AWD_H	4.72a	457.33	55.23	48.70	6.53	24.60a	87.83	7.48
CF	2.51b	378.33	52.77	43.90	8.87	21.82b	83.49	10.81
CV (%)	16.24	18.50	20.90	23.33	25.75	2.54	5.56	28.77
Sig.	**	ns	ns	ns	ns	**	ns	Ns

Note. AWD_C = Treatments of community; AWD_H = Household individually; CF = Continuous flooding; CV (%) = Coefficient of variation; Sig. = Significance; ns = Non-significance; In the same column, different letters indicate significant differences between treatments at 1% (**) confidence limits lowering water demand and emissions of greenhouse gases, most notably methane. Thus, many studies have focused on assessing water use efficiency or productivity, which measures how much water is required to produce 1 kg or a ton of rice. Bouman (2009) maintains that producing 1 kg of paddy rice requires from 800 to 5,000 L of fresh water, with 2,500 L needed on average. According to another calculation that considers the yield of rice per unit of water used, an average of 1.74 kg of rice/m^3 may be produced under AWD conditions (Chapagain & Yamaji, 2010). Under continuous flooding conditions, water productivity fluctuated in the range of 0.2–0.3 kg of paddy rice/m^3 of water, according to Kumar and Rajit (2019). In this study, it was found that the water productivity figures were not consistent with previous studies, where water productivity under the AWD_H treatment was the highest (0.66 kg/m^3), which was significantly higher than other treatments, namely AWD_C and CF with values of 0.37 and 0.33 kg/m^3, respectively (Figure 5). This difference is attributed to higher yields of the AWD_H treatment (Table 4), while there was no considerable difference in water consumed between treatments (Figure 3).

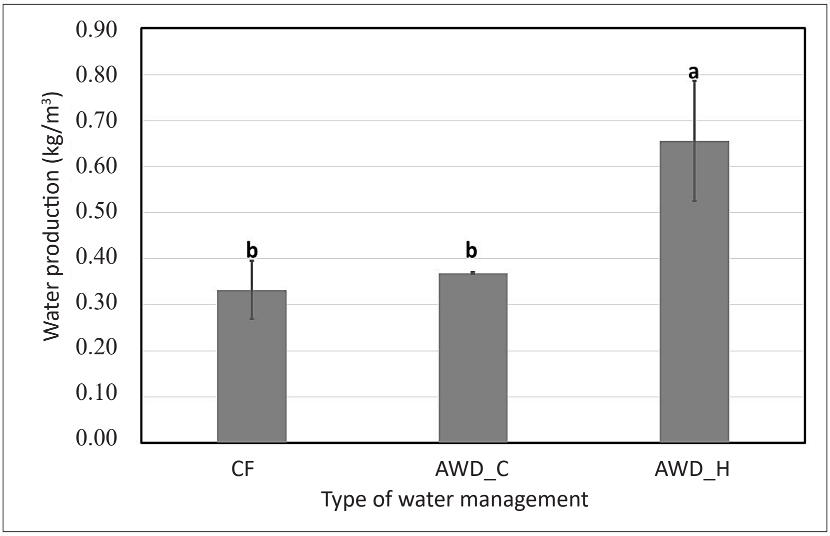

Figure 5. Evaluating water productivity in each treatment

Note. AWD_C = Treatments of community; AWD_H = Household individually; CF = Continuous flooding; Different letters indicate a significant difference between the treatments at a 5% confidence limit

The treatment that was expected to bring the highest rice yield and water productivity was the AWD_C treatment. After all, a larger area cultivated might have two advantages: (1) better water management due to the limitation of water loss, and (2) possibly less damage from weeds or pets because the rat population or weeds may be more dispersed. However, the results showed that AWD_H gave the highest water productivity and higher rice yield, above that of AWD_H and CF. This result is consistent with previous research results, which indicated that AWD resulted in heavier and larger rice grains (Ilahi et al., 2022; Mboyerwa et al., 2021). The critical question is, why should AWD-H be more productive? Because AWD_C covered a relatively large area (from many households working together), where there were differences in land elevation levels between one field to another, leading to significant differences in water column depth across the field. The difference between the high and low fields is about 5–15 cm. The study also tested and compared the water column's coefficient of variation (CV %) between the three water management treatments over 22 measurement periods. The result shows that the CV % value of the water column under the AWD_C treatment was significantly higher than the other two treatments (Figure 4). Considering the SPAD index under AWD_H, it was significantly higher than both AWD_C and CF, which points to greater levels of photosynthesis, resulting in a greater yield.

CONCLUSION

The AWD_H treatment is more efficient than the AWD_C and CF treatments in terms of rice yield and water productivity due to the high 1,000-grain weight. The unequal field surface of the AWD_C treatment and lower SPAD index led to a lower grain weight than AWD_H. To improve benefits of AWD_C, checking the flat of field ground is necessary.

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