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Rice growth, yield composition and water efficiency in different soil series using alternate wetting and drying water management

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ABSTRACT

Optimized fertilizer and irrigated water use efficiency are two of the most crucial factors that significantly increase the productivity of rice growing. The objective of the present study was to investigate the beneficial effects of implementing a precision fertilizer management practice in combination with an alternate wetting and drying (AWD) water management practice on agricultural characteristics and water use efficiency (WUE) index of *Oryza sativa* L. var. *indica* cv. Pathum Thani 1, grown on Samut Prakan, Phetchaburi, and Rangsit soil series, and compared them with those received continuous flooding (CF) water management practice. Results showed that the response of the agronomic and yield components of the rice to the two water practices was similar, except for the heights of the rice grown on the Phetchaburi soil series, where the rice that received the CF was significantly taller than those that received the AWD. The water savings and WUE index of the rice that received the AWD were relatively better than those of the rice that received the CF by 20.44, 19.79, and 18.96%, and 21.21, 18.15, and 20.48% in the Samut Prakan, Phetchaburi, and Rangsit soil series, respectively. In conclusion, the AWD water management practice did not diminish rice production but did improve water savings and WUE.

Keywords: precision fertilization; water management; rice; soil series

1. INTRODUCTION

Thailand is one of the world's top ten largest rice producers and the top five of the world's largest rice exporters (FAOSTAT, 2021). Traditionally, farmers are accustomed to administering chemical fertilizers at a level that exceeds the rice demands and is incompatible with the existing soil's nutrient contents (Isuwan, 2014; Cheun-im et al., 2010). Excessive use of chemical fertilizers irrespective of the requirements is wasteful and leads to environmental damage (Osotsapar et al., 2008; Nunes et al., 2016; Brodt et al., 2014). Apart from excessive use of fertilizers, most farmers implement a continuous flooding (CF) water management system to grow rice throughout the entire cultivating season, resulting in the overconsumption of irrigated water.

Alternatively, precision fertilizer (PF) management practices have been promoted to optimize the use of chemical fertilizers. There are many practices and tools to assist farmers in performing PF practices. One of the most efficient tools recently developed in Thailand by a research team at Silpakorn University, which can be downloaded at the App Store and Play Store or used through the website at www.soil.asat.su.ac.th, is the All-rice1 application (Isuwan et al., 2021). Recent studies revealed that fertilizer use based on the recommendations of the All-rice1 application to cultivate Pathum Thani 1 rice (*Oryza sativa* L. var. *indica* cv. Pathum Thani 1) resulted in improved rice productivity and economic returns, when compared with those from conventional fertilization practice (Isuwan and Keawaram, 2021; Isuwan et al., 2018).

An alternative wetting and drying (AWD) water management practice is now being promoted to improve the water productivity of rice farming. It has been reported that the AWD practice has not negatively affected rice production, but resulted in increased water savings of about 24% (Carrijo et al., 2017).

Unfortunately, the beneficial effects of combining these two advanced technologies (PF and AWD) on rice farming performance have never been explored. Therefore, the present study was carried out to investigate the effects of combining the PF practice based on the recommendations of the All-rice1 application and the AWD practice on agronomic performance and water use efficiency (WUE) of Pathum Thani 1 rice (*Oryza sativa* L. var. *indica* cv. Pathum Thani 1) grown on the three major soil series in Phetchaburi province.

2. MATERIALS AND METHODS

2.1 Site and soil properties

The experiment was carried out at the Agricultural Technology Training and Transfer Center located at Silpakorn University, Phetchaburi Information Campus, Phetchaburi, Thailand, from December 2020 to May 2021.

Rice was grown on three different soil series, comprising 1) Samut Prakan soil series (fine, mixed, nonacid, isohyperthermic Fluvaquentic Endoaquepts), 2) Phetchaburi soil series (fine-silty, mixed, active, isohyperthermic Aquic Haplustalfs), and 3) Rangsit soil series (very-fine, mixed, semiactive, acid, isohyperthermic Sulfic Endoaquepts) (Department of Land Development, 2018). It should be noted that these are the major soil series for growing rice in Phetchaburi province, accounting for approximately 80% of the total cultivated area of rice.

Initially, the topsoil at a depth of 0-30 cm was collected, dried in the shade, then crushed and sifted to pass through a 2-mm sieve. Representative samples of each soil series were taken to analyze the chemical properties before commencing the experiment. The results of the analysis are shown in Table 1, and they were used as inputs to calculate NPK fertilizer recommendations in the All-rice1 application. Generally, the N contents of these soil series are low, although the P and K contents are high, except for the K content in the Rangsit soil series, which is low. The All-rice1 used these data into account to compute the fertilizer recommendations.

Table 1. Selected soil properties before commencing the experiment

Soil properties	Values			References
	Samut Prakan	Phetchaburi	Rangsit	
pH (soil: water 1:1)	6.67	7.66	4.12	McLean (1982)
Electrical conductivity (ds/m)	1.49	0.17	0.88	Jackson (1958); Walkley (1947)
Organic matter (%)	1.26	0.32	1.69	FAO (1947)
Total N (%)	0.06	0.02	0.07	Bremner and Mulvaney (1982)
Available P (mg/kg)	112.26	92.10	11.48	Bray and Kurtz (1945)
Exchangeable K (mg/kg)	173.32	59.00	116.49	Peech et al. (1947)
Exchangeable Ca (mg/kg)	5560	578	731	Peech et al. (1947)
Exchangeable Mg (mg/kg)	1841	711	400	Peech et al. (1947)

2.2 Experimental design and treatments

The experiment was divided into 3 trials with respect to individual soil series. For each trial, a group comparison t-test design with 15 replications was used. Treatments were based on two water management models as follows.

Model 1: AWD. In this model, the water level was maintained at a level of 5 cm above the soil surface until the first fertilization event (20 days after transplanting). Then, the water was allowed to evaporate naturally to a depth of 10 cm below the soil surface. After that, water was added to a height of 5 cm above the soil surface. This process was rotated until the rice reached the inflorescence stage, when the second fertilization event was performed (55 days after transplanting). Thereafter, the water level was kept at 5 cm above the soil surface until 10 days before harvesting rice. The harvesting date was 120 days after transplanting. It should be noted that water levels were measured through the 2.5-cm diameter and 25-cm length holed PVC tubes. The tubes were penetrated 15 cm below the soil surface.

Model 2: CF. In this model, the water level was maintained at 5 cm above the soil surface from the beginning of the experiment until 10 days before harvesting the rice, when the water was drained out. The first and second fertilization events were performed at 20 days and 55 days after transplanting, respectively.

2.3 Plant growing and management

Rice was grown at 50 cm diameter and 40 cm height of glazed clay pots. Initially, the pot was filled with 50 kg of sifted soil individually. Then, water was filled at a level of 5 cm above the soil surface. Subsequently, 20-day-old Pathum Thani 1 rice seedlings were transplanted with 3 seedlings per clump and 4 clumps per pot, each clump was 25 cm apart. Pots were placed at a space of 1 m apart from each other to avoid the effects of shading. Other details associated with general management practices, such as weeding and pest control, have been reported in Isuwan (2015).

By using the chemical components of soil as inputs, the All-rice1 application recommended total amounts of NPK fertilizers and application timing were as follows;

For the Samut Prakan soil series, 0.40 g per pot of diammonium phosphate (DAP) fertilizer (18-46-0), 1.70 g per pot of urea (U) fertilizer (46-0-0), and 0.40 g per pot of potassium (K) fertilizer (0-0-60) were applied. This was equivalent to a fertilizer rate of 6.99-1.52-1.98 kg N-P_2O_5-K_2O/rai (6.25 rai = 1 hectare).

For the Phetchaburi soil series, 0.80 g per pot of DAP fertilizer, 2.08 g per pot of U fertilizer, and 1.23 g per pot of K fertilizer were applied. This was equivalent to the fertilizer rate of 8.99-2.99-6.00 kg N-P_2O_5-K_2O/rai.

For the Rangsit soil series, 0.66 g per pot of DAP fertilizer, 1.60 g per pot of U fertilizer, and 0.40 g per pot of K fertilizer were applied. This was equivalent to the fertilizer rate of 6.99-2.48-1.98 kg N-P_2O_5-K_2O/rai.

2.4 Data collection

At 30, 45, 60, 75, and 90 days after transplanting, the height of plants and the tiller numbers per clump were recorded. At 120 days after transplanting, grain yield was measured. Other agronomic characteristics associated with grain yield, i.e., the number of grains per panicle, 100-grain weight, and filled grain percentage were measured.

The accumulated amount of water use was recorded. The data were used to compute water use, water saving index, and the WUE index of rice.

2.5 Calculation and statistical analysis

The percentage of water savings (water saving, %) was calculated as follows: water saving (%) = [(total amount of water used in the CF treatment (liters) - total amount of water used in the AWD treatment (liters) / total amount of water used in the F treatment (liters)] × 100.

The WUE index was calculated as follows: WUE = total amount of water used for growing rice (liters)/standard grain yield production (kg), where standard grain yield means paddy without impurities and adjusted moisture content to 14%.

The statistical analysis and comparison of the means were performed by a group comparison t-test design using the R program.

3. RESULTS AND DISCUSSION

3.1 Growth characteristics

Figure 1 illustrates the growth characteristics (plant heights and tillage numbers) of the rice that received the two water management models and was grown on Samut Prakan (Figure 1A), Phetchaburi (Figure 1B), and Rangsit (Figure 1C) soil series. The heights and tillage numbers of the rice in the two water models were somewhat similar across soil series, except for the heights of the rice grown on the Rangsit soil series where, the rice that received the AWD model were higher than those that received the CF model over the cultivated season (Figure 1C).

It was reported by Harakotr and Thong-oon (2016) that AWD and CF water management practices had a non-significant effect on the heights of rice. However, the CF model may result in higher rice stalks, especially during the reproductive stage, because when the water level is high, the rice plants extend their joints to maintain the shoots and leaves above the water level (Chaengpui et al., 2016).

It could not be clearly described why the heights of rice grown in the Phetchaburi soil series responded differently, when compared with those grown in Samut Prakan and Rangsit soil series. It may be because there were other effects stemming from soil series rather than fertilizers added and water management practices. However, the present study confirmed that tillage numbers of rice were not significantly affected when the AWD model was applied. This was consistent with the findings reported by Karim et al. (2014), Chaengpui et al. (2016), and Netsing et al. (2016).

3.2 Yield and yield components

Rice received the PF practice based on the recommendations of the All-rice1 application combined with either AWD and CF water models presented insignificant effect (p>0.05) on grain yields and yield components (Table 2).

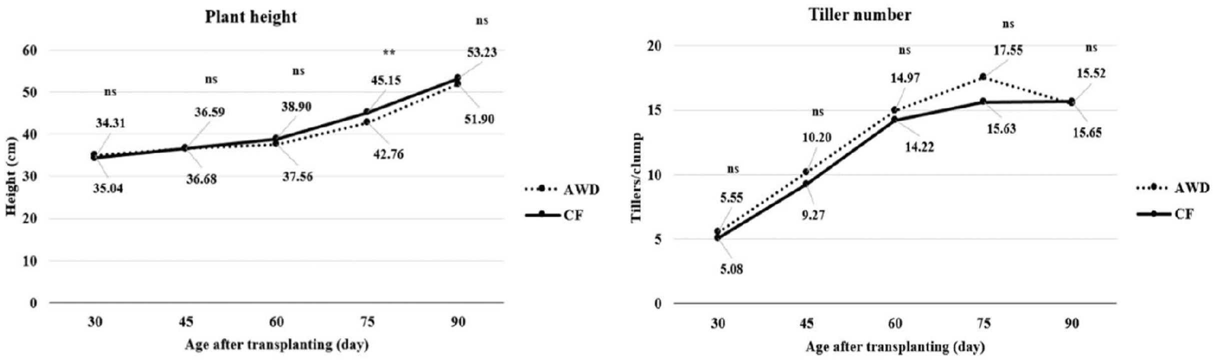
3.3 Water use and water efficiency

Rice with the AWD model consumed a lower amount of irrigated water than those with the CF model by 20.44, 19.79, and 18.96% in Samut Prakan, Phetchaburi, and Rangsit soil series, respectively (Table 2). Similarly, the WUE index of rice that received the AWD model was higher than those of the rice that received the CF model by 21.21, 18.15, and 20.48% on Samut Prakan, Phetchaburi, and Rangsit soil series, respectively.

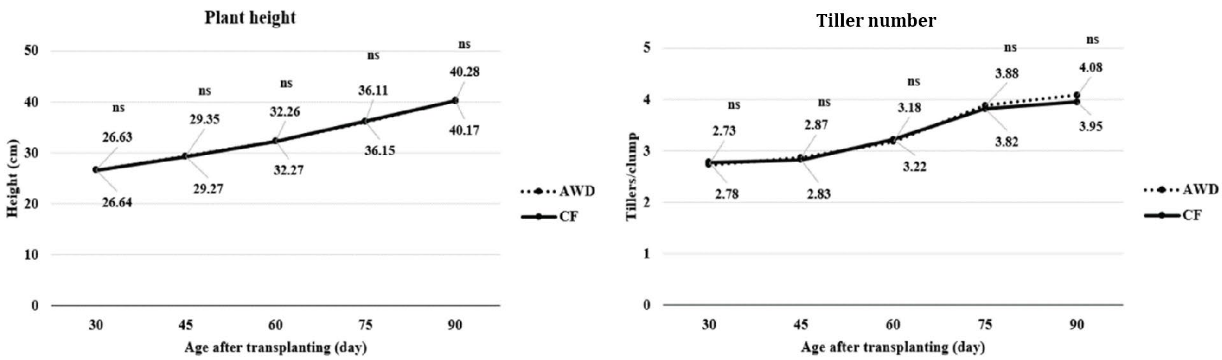
The results of the present study confirmed that AWD water management practice could not only lead to saved irrigated water but also elevated WUE index of rice growing. These have been evidenced by Chaengpui et al. (2016), Chumjom et al. (2017), Lampayan et al. (2015), Sibayan et al. (2018), Tran and Nguyen (2006), Carrijo et al. (2017), and Chidthaisong et al. (2018). These publications reported that implementing the AWD water management practice resulted in reduced water consumption by 14.8-47.5% without negatively affecting the total gain yields of rice.

4. CONCLUSION

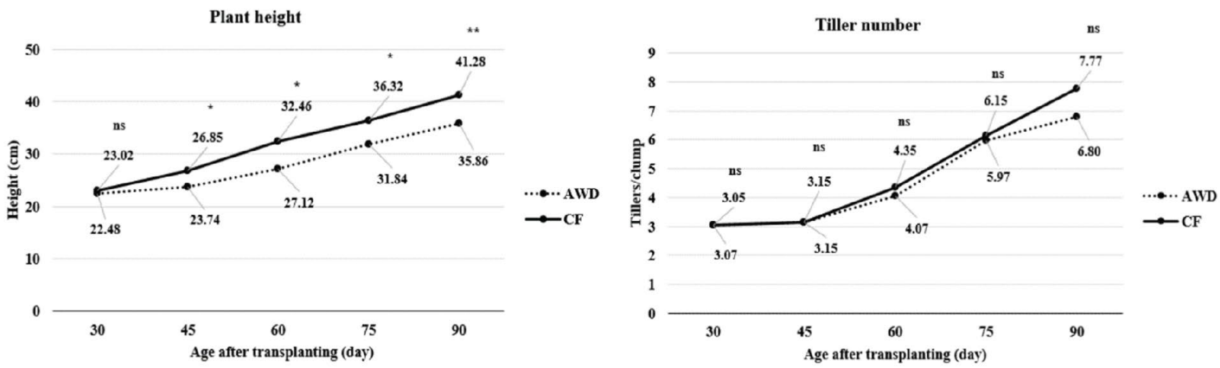
Based on the results of the present study, it could be concluded that a combination of the PF and AWD practices revealed a non-negative effect on agronomic and production characteristics of Pathum Thani 1 rice grown on Samut Prakan, Phetchaburi, and Rangsit soil series. In turn, it resulted in improved relative water saving of approximately 20% and relative WUE index by approximately 20%, when compared with those that received a combination of the PF and CF practices.



(A) Samut Prakan soil series



(B) Phetchaburi soil series



(C) Rangsit soil series

Figure 1. Plant heights and tillage numbers of rice grown in (A) Samut Prakan, (B) Phetchaburi, and (C) Rangsit soil series and received either AWD or CF water management practices

Table 2. Effect of wetting and drying (AWD) and continuous flooding (CF) water management practices on the yield components of rice grown in different soil series (mean±standard error)

Treatment	Number of panicles per clump	Number of seeds per panicle	Filled grain (%)	100-Grain Weight (g)	Yield (g/pot)	water usage (L/pot)	Relative water saving (%)	Water efficiency (L/kg)	Relative water efficiency (%)
Samut Prakan soil series									
AWD	24.23±1.42	95.70±1.67	85.24±1.02	2.05±0.02	89.71±3.18	8.72	+20.44	98.73	+21.21
CF	21.63±1.59	93.56±1.77	84.63±1.20	2.07±0.02	88.83±3.15	10.96	-	125.30	-
p-value	ns	ns	ns	ns	ns				
Phetchaburi soil series									
AWD	18.10±0.38	87.63±1.39	80.02±0.73	2.04±0.04	79.87±1.98	7.50	+19.79	95.37	+18.15
CF	17.97±0.47	87.29±1.70	79.81±0.75	2.00±0.03	79.94±1.75	9.35	-	116.52	-
p-value	ns	ns	ns	ns	ns				
Rangsit soil series									
AWD	19.57±0.41	91.57±1.18	82.02±0.88	2.03±0.04	87.26±2.58	7.78	+18.96	90.55	+20.48
CF	19.43±0.98	90.96±1.36	81.27±0.52	2.01±0.03	85.62±2.29	9.60	-	113.88	-
p-value	ns	ns	ns	ns	ns				

Note: ns = non significant, $p>0.05$

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