Rice cultivation and soil properties as affected by Alternative Wetting and Drying irrigation in Chau Thanh, An Giang province

Nguyen Van Chuong[1*], Nguyen Anh Tu[2]
[1]Crop science department, Agricultural faculty, An Giang University, Vietnam 880000
[2]Master student of crop science, An Giang University, Vietnam 880000
*Corresponding author, Email address: nvchuong@agu.edu.vn

Abstract

The study that was carried out in winter-spring 2018 in Thoai Son, An Giang province, include experiments: Effects of (AWDI) to (i) Characters in soil; (ii) rice yield and (iii) water use and water use efficiency of Jasmine rice. The experiment was carried out with 4 treatments, 4 replications. The treatments ranged from continuous submergence (NT1) of the field to a number of delayed irrigations (NT2, NT3, NT4) denoting application of 4 cm irrigation water when water level in the perforated PVC pipe fell 18, 14 and 10 cm below ground level. The study revealed that NT1 attributed by the highest total water use (118 cm) and the lowest WUE (60.3 kg/ha/cm) produced the highest grain yield (8,10 t/ha). On the contrary, the yields in NT3 (6.80 t/ha) and NT2 (5.80 t/ha) were significantly lower at 0,5 times level of significance compared to that of NT1 and NT4 (7.83 t/ha).

Keywords: *Alternate wetting and drying irrigation, Jasmine rice, soil properties, Water use efficiency, yield*

1. Introduction

For nearly half of the world's population (2.7 billion people), rice (*Oryza sativa* L.) is the staple food providing 35–60 percent of the calories consumed (Guerra, Bhuiyan, Tuong, & Barker, 1998). More than 75 percent of the world's rice is produced in irrigated rice lands, which are predominantly found in Asia. Rice is a major staple crop with more than 50 kg of rice being consumed per capita per year worldwide (FAOSTAT, 2016). Globally, over 478 million tons of milled rice was produced in 2014/15 of which over 90% was used directly for human consumption (USDA, 2016). Due to increasing scarcity of freshwater resources available for irrigated agriculture and escalating demand of food around the world, in the future, it will be necessary to produce more food with less water. Since, more irrigated land is devoted to rice than to any other crops in the world, wastage of the resource in the rice field should be minimized (IRRI, 2003). The abundant water environment in which rice grows best differentiates it from all other important crops. But, water is becoming increasingly scarce. By 2025, the per capita available water resources in Asia are expected to decline by 15–54 percent compared with 1990 (Moya, Hong, Dawe, & Chen, 2001).

With the increasing threat of water scarcity currently affecting 4 billion people around the globe (Mekonnen & Hoekstra, 2016), it is crucial to develop agronomic practices with the potential to reduce water use while maintaining or increasing yields to support a growing population. One practice that has been shown to reduce water use inrice systems is an irrigation management practice referred to as AWDI (Linquist, Anders, Adviento-Borbe, Chaney, Nalley, Da Roda, & Van Kessel, 2014; Lampayan, Samoy-Pascual, Sibayan, Ella, Jayag, Cabangon, & Bouman, 2014). AWDI is one method of managing the water so that water will not be wasted but it will aid the root growth, facilitate higher nutrient uptake and increase land and water productivity (Sarkar, 2001). Improvisation of the water management techniques adopted by the farmers for the production of rice was the core objective of this study. More specifically, the objective could be outlined as to find out, from a number of AWDI irrigation treatments, the best one with the highest water use efficiency that would result in an insignificant yield loss and ensure the best use of the available water resources.

2. Materials and methods

The farm of Chau Thanh was selected as the experimental site. Topography of the land being plain was suitable for check basin irrigation. Individual plots were located inside a close growing rice field so that actual growing condition (reception of the direct and diffused fluxes) prevails in the site. Soil texture of the experimental site was found to be silty loam. The upper root zone of the experimental field was tilled with high puddling intensity. The experimental plots (4 m x 2.5 m) were laid out with split-plot design (SPD) combining one modern varieties of Jasmine rice and four irrigation treatments that were replicated 4 times. This resulted in a total of 16 plots in the field with 6 plots in a row. Each of the plots was separated by 1 m of transition zone while each of the replications was demarcated by a buffer zone of 1.5 m in between. To prevent seepage, polythene sheets were pushed into the edges of the levees along the inner perimeter of all plots. PVC pipes of 4 cm in diameter and 40 cm in length were installed in the field keeping 7 cm above the soil and the remaining 33 cm which was perforated underneath to measure the depletion of soil water in the field. Irrigation water was applied when depleting water table inside the pipe reached a certain level. The first treatment (NT1) was continuous submergence (1 to 7 cm standing water) and the remaining three (NT2, NT3 and NT4) stood for an application of 5 cm irrigation water when water level in the pipe fell 18, 14 and 10 cm below the G.L., respectively. Continuous standing water (5 cm) was maintained in all the plots up to 28 days after transplantation (DAT) to avoid pre-apprehended weed infestation that could be awesome during crop establishment stage. A bowl of 1.5 litres was used to irrigate the plots from the buffer zones by throwing water in. The seedlings were transplanted maintaining hill to hill distance of 15 cm and row to row distance of 25 cm. The first and the last hills were kept at 7,5 cm away from their nearest levees resulting in 25 hills along the length and 10 hills along the width. Since the grains of jasmine rice got ripened, the former was harvested (01 May 2019) two weeks earlier than the harvesting date (14 May, 2019) of the latter. Matured plants inside 1 m square of land were harvested for subsequent analysis. Moisture content of the grains, however, was adjusted to 14% equivalent moisture content after measuring through digital grain moisture meter for subsequent analysis. Quantitative information related to yield and all the yield contributing characters viz. plant height, effective tillers, length of the panicle, no. of spikelets per panicle, no. of filled and unfilled grains per panicle, 1,000 grain weight, grain yield, straw yield, harvest index and water use efficiency of the variety (Jasmine rice) were analysed to obtain the effect for AWDI on rice.

3. Results and discussion

Soil pH: the results at the end of the experiment did show significant difference among all treatments, for soil pH (Table 2). This could be due to the fact that the soil of the experimental site had a relatively high buffering capacity based on its high delayed irrigations from 10 cm to 18 cm below ground level and can fix any change in its pH during organic matter decomposition thank to oxygen content in soil.

Table 1 Soil characteristics of the experimental site at the first of the experiment

Characteristics			
Mechanical analysis		Available nutrients	
Sand (%)	5.50	Total N (%)	0.259
Clay (%)	64.1	Available P(ppm)	35.9
Silt (%)	30.4	Available K (ppm)	124
pH	4.95	OM(%)	4.69

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Total Nitrogen (N): Table 2 indicates that total nitrogen percent in the all AWDI treatments were significantly higher than all other treatments (16%), whereas no significant effects of control treatments on the lowest soil total nitrogen was noticed, when compared to AWDI treatments.

Available Phosphorous (P): Highly significant available phosphorus was obtained by using continouus irrigation (NT1). Table 2 shows that the effect of irrigation treatments on available phosphorus was significant at 5 percent level of probability. The highest content of available phosphorus (35.9) in CF treatment was found in treatment NT1 and the number consistently decreased in treatments NT2 (28.6), NT3 (29.1), and T4 (30.2) as shown in Table 2. The results showed that the number of available phosphorus in the AWDI treatments (NT2, NT3 and NT4) increased significantly compared to the NT1 treatment (Table 2).

Available Potassium (K): The NT4 treatment had the highest available potassium (152 ppm), which was significantly higher than all other treatments (Table 2). The highest available potassium (152 ppm) was obtained in treatment NT4 followed by treatments NT3 (108 ppm), NT2 (71.3 ppm), while the lowest content (58.0 ppm) was obtained by the control treatment (Table 2). On the other hand, higher amounts were recorded by using treatments with a highly significant difference when compared to other treatments. the available potassium of all treaments was significantly different according to LSD at 1%.

Total Organic Matter (O.M.): The highest soil organic matter content (4.98 %) was obtained by the CF treatment, a significant differences with all other treatments, while the lowest content (2.68 %) was obtained by the NT3 treatment (Table 2).

Table 2 Results of Soil chemical analysis at the end of the experiment

Treatments	pH	Total N (%)	Available P (ppm)	Available K (ppm)	Total O.M. (%)
- NT1 (CF)	5.38^{c}	0.336^{b}	35.9^{a}	58.0^{d}	4.98^{a}
- NT2 (AWDI) (18cm below the G.L.,)	5.58^{b}	0.385^{a}	28.6^{b}	71.3^{c}	2.79^{c}
- NT3 (AWDI) (14cm below the G.L.,)	5.87^{a}	0.392^{a}	29.1^{b}	108^{b}	2.68^{d}
- NT4 (AWDI) (10 cm below the G.L.,)	5.35^{c}	0.389^{a}	30.2^{b}	152^{a}	4.18^{b}
F	*	*	*	*	*
CV(%)	5.78	15.3	13.2	23.7	23.3

Note:Common letters within the column do not differ statistically either at 5% level of probability; = *Statistically significant at 5% level of probability*

Panicle length: Regarding, the panicle length, an application of 14 cm delayed irrigations water (NT3) showed the maximum panicle length. On the other hand, the other 18 cm delayed irrigations water (NT4) showed the shortest panicle (Table 3). Significant consequences of AWDI on the production of Jasmine rice were observed as given in Tables 1, and 3. The highest plant height (90.6 cm) was obtained in treatment NT1 (continuous submergence) and the lowest (81.7 cm) in NT2 (applying irrigation after 18 cm depletion of W.L. below G.L). It was found that increasing water stress significantly resulted in a decrease of plant height. Insignificant varietal and interaction effects were recorded on the number of effective, non effective and number of tillers and 1,000 Grain weight (gm) as did the treatments except for the number of effective tillers (Table 4). Delayed irrigation also caused reduced number of filled grains in the panicles counting to be the highest (90.2) in treatment NT4 and the lowest (66.2) in treatment NT2 (Table 3). Significant effects of variety, treatment, and their interaction on the number of filled grains per panicle were also obtained where a

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decreasing number of filled grains were found as the water stress increased (Table 3 & 4). Thousand grain weight (1,000 grain weight), as it is called the test weight of the desired crop, was significantly affected by the interaction between varieties and treatments though the effect of treatment alone on this parameter remained insignificant at 5% level of probability (Table 3).

Number of panicles: Number of panicles per hill, was markedly influenced by different treatments and various irrigation levels application as well as their interaction (Table 3). The delayed irrigations differed significantly in their abilities in producing panicles per hill. Among the treaments, NT1 and NT4 gave the highest values of number of panicles per hill while NT2 recorded the lowest values in treatments. This might be due to the differences in the reduced irrigation background among were found as the water stress increased. The high rate of irrigations recorded maximum counts of panicles per hill in continuous submergence treatment and NT4 (applying irrigation after 10 cm depletion of W.L. below G.L), while the NT2 (applying irrigation after 18 cm depletion of W.L. below G.L) showed minimum counts of panicles per hill.

Number of filled grains: The NT4 recorded maximum number of filled grains per panicle, while, NT2 recorded the lowest number of filled grains in other treatments. Regarding irrigation levels effect, decreased rate of water from after 10 cm to 18 cm depletion of W.L. below G.L significantly reduced the number of filled grains per panicle for the jasmine rice. The application rate of continuous submergence and water from after 10 cm depletion of W.L. below G.L, recorded the maximum number of filled grains per panicle followed by 14 depletion of W.L. below G.L treatment and the NT2 the lowest value.

Number of unfilled grains: The NT3 and NT4 recorded the maximum number of unfilled grains per panicle; on the other hand, the NT2, water from after 18 cm depletion of W.L. below G.L exhibited the lowest number (Table 3). With increased rate of the reduced irrigation background, a significant decrease in number of unfilled grains per panicle for all treatments were observed. This increase in number of unfilled grains might be associated with production of more spikelets per plant and photoassimilation

Table 3 Mean effect of interaction between varieties and irrigation treatments on the Plant height, panicle length and number of filled grains and unfilled grains per panicle

Treatments	Plant height (cm)	Panicle length (cm)	Number of panicles.hill^{-1}	No. of filled grains Panicle^{-1}	No. of unfilled grains panicle^{-1}
- NT1 (CF)	90.6^{a}	21.3^{c}	16.2^{a}	84.1^{c}	7.22^{b}
- NT2 (AWDI) (18cm below the G.L.,)	86.1^{b}	22.2^{b}	14.7^{c}	66.2^{d}	5.13^{c}
- NT3 (AWDI) (14cm below the G.L.,)	83.3^{c}	27.1^{a}	15.3^{b}	85.4^{b}	8.11^{a}
- NT4 (AWDI) (10 cm below the G.L.,)	81.7^{d}	20.9^{d}	16.5^{a}	90.2^{a}	8.13^{a}
F	*	*	*	*	*
CV (%)	13.4	23.3	10.4	17.3	23.5

*Note: Common letters within the column do not differ statistically either at 5% level of probability; * = Statistically significant at 5% level of probability;*

The grain yield, on the other hand, was found to be significantly influenced by different degrees of AWDI irrigation treatments at 5% level of probability (Table 4). The highest and the lowest grain yield was obtained, in treatment NT1 (8.10 t/ha) and NT2 (5.80 t/ha), respectively. Longer water stresses resulted in a loss of grain yield of about 2.3 t/ha compared to the grain yield obtained from continuous saturation (NT1). The second highest yield (7.83 t/ha) was marked in treatment NT4 (applying irrigation when W.L. depletes 10 cm below G.L.) which do differ statistically either at 5% level of the highest yield (8.10 t/ha). Grain yield for the

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treatment NT3 (6.80 t/ha) was 19.1% less than the highest yield obtained (Table 4). The interaction between the varieties and the treatments, as shown in Table 4, also affected grain yield significantly.
The highest yield of Jasmine rice was obtained for the NT1 treatment (8.10 t/ ha) and the lowest (5.8 t/ha) for NT2 treatment (Table 4). For jasmine rice, maximum amount of water (118 cm) was required for NT1, while, second maximum (92.2 cm) for NT4 was followed by the other two treatments, NT3 (87.2 cm) and NT2 (82.2 cm), respectively (Table 5).

Table 4 Yield and yield contributing characters of Jasmine rice under different irrigation treatments

Treatments	No.of effective tillers $(m^2)^{-1}$	No.of non effective tillers $(m^2)^{-1}$	No.of tillers $(m^2)^{-1}$	1,000 Grain weight (gm)	Grain yield (t/ha)
- NT1 (CF)	118^{a}	11.1	129	25.1	8.10^{a}
- NT2 (AWDI) (18cm below the G.L.,)	110^{ab}	11.0	121	23.2	5.80^{d}
- NT3 (AWDI) (14cm below the G.L.,)	112^{ab}	10.4	122	28.3	6.80^{c}
- NT4 (AWDI) (10 cm below the G.L.,)	103^{b}	10.3	113	26.2	7.83^{b}
F	*	*ns*	*ns*	*ns*	*
CV (%)	21.0	12.1	20.7	13.9	6.96

Note:Common letters within the column do not differ statistically either at 5% level of probability; = Statistically significant at 5% level of probability; ns = Non significant at either 1% or 5% level of probability*

Water use efficiency (WUE) is the most important criterion to rationalize AWDI practice. The features of total water use and water use efficiency (WUE) came out vivid in the study showing the highest WUE of 69.9 kg/ha/cm of water in treatment NT2 and the lowest (60.3 kg/ha/cm) in treatment NT1. The second highest WUE (68.9 kg/ha/cm) was found in treatment NT4 which was much closer to the highest one (Table 5).
The highest average total water (117 cm) used by the plant was found in treatment NT1 which was also attributed by the highest yield (8.1 t/ha). The treatment NT4 (applying irrigation after 10 cm depletion of W.L. below G.L, gave a yield of 7.83 t/ha. This clearly demonstrates that submerged paddy field is not necessarily the only solution for optimum production. This practice was found to be the most suitable because of the highest water use efficiency (69.9 kg/ha/cm), insignificant reduction in grain yields (4.08%) and water saving (25.8 cm). The value of the water saved by this technique would itself be sufficient to arrest the economic justification of the insignificant yield loss in AWDI technique.

Table 5 Water use efficiency for different treatments

Treatments	Total water use (cm)	Average total water used (cm)	Water use efficiency (kg/ha/cm)
- NT1 (CF)	118.0^{a}	117.0^{a}	60.3^{d}
- NT2 (AWDI) (18cm below the G.L.,)	82.2^{d}	84.7^{d}	69.9^{a}

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- NT3 (AWDI) (14cm below the G.L.,)	87.2^{c}	89.7^{c}	69.2^{b}
- NT4 (AWDI) (10 cm below the G.L.,)	92.2^{b}	94.7^{b}	68.9^{c}
F	*	*	*
CV (%)	13.9	14.8	8.3

Note:Common letters within the column do not differ statistically either at 5% level of probability; = Statistically significant at 5% level of probability; ns = Non significant at either 1% or 5% level of probability*

4. Conclusion

Numerous studies have shown that AWD irrigation management can reduce water use which are both valuable benefits in terms of achieving sustainable intensification goals. However, it is also known that AWD can reduce rice yields if not implemented correctly. One of our objectives in this analysis was to identify management and soil conditions under which AWD can be practiced without sacrificing yields. We found that the AWD threshold had a major effect on yields and that yields could be maintained in most soils under Mild AWD. Using AWD also provided a reduction in water use. Importantly, we also found that soil properties can affect AWD performance; highlighting the need for regional research to fine-tune recommendations for farmers. Finally, these outcomes demonstrate that AWD is a promising management practice, but increased efforts need to be made to scale out results to the field and irrigation district scales where additional constraints may be encountered.

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