Effect of Alternate Wetting and Drying on Crop Performance, Water Input and Water Productivity of Direct Wet-seeded Inbred and Hybrid Rice

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Abstract

The experiments were conducted to evaluate the yield performance of the inbred and hybrid rice varieties under alternate wetting and drying (AWD), to compare the water productivity of rice varieties under AWD condition and to investigate the water saving percent in different rice varieties under AWD. Two water regimes (alternate wetting and drying, AWD and continuous flooding, CF) in main plot and four varieties including two hybrid varieties (Long-9, Yezin Pale Thwe-3) and two inbred varieties (Yaenelo-4 , Yaenelo-1) in sub plot were laid out as split plot design with four replications. During the study period, loam soil in DaikU Township and silty clay loam soil in Maubin Township were observed. The maximum grain yield and yield components of tested varieties were 2.99 t ha^{-1} in DaikU and 5.76 t ha^{-1} in Maubin. The water productivities of AWD were not statistically different with CF but water saving were resulted under AWD in both DaikU and Maubin townships. Hybrid rice produced higher grain yield, yield components, morphological traits and water productivity than those of inbred rice in both townships. Grain yield and water productivity were not significantly different between AWD and CF. However, more water can save under AWD than CF and subsequently found that above 20 % of water saving for hybrid and above 30% for inbred during summer rice growing season in the study areas. Therefore, this study indicated that applied AWD irrigation maintained current yield and reduction of water input for Hybrid and Inbred rice varieties under the tested areas, DaikU and Maubin Townships.

Key words: Grain yield, Continuous Flooding, Alternate Wetting and Drying, Water productivity.

Introduction

Globally, over 478 million tons of milled rice were produced in 2014/15 of which over 90% was used directly for human consumption (USDA, 2016). Myanmar has a total land area of 676578 km^2. Myanmar is the country based on agriculture and mainly growing paddy rice. The rice-cultivated areas increased by more than 20 percent between 1994 and 2014 (from 5.9 to 7.2 million hectares), and production increased by 37 percent, reaching 28.2 million tonnes in 2014. Mostly paddy rice is growing in central Myanmar (e.g. Mandalay, Sagaing) and in lower part (e.g. Ayarweddy, Bago). Total growing area is about 8 million hectares, about 39.52 million hectares is monsoon paddy growing area and about 7.41 million hectares is summer paddy growing area (Swithun et al., 2016).

In Myanmar, presently there are 11.38 million hectares of net sown area. Myanmar has a long tradition of rice production, started search on hybrid rice in 1997 and released its hybrid rice to fulfill the needs of consumption for the country (IRRI 2002). Hybrid seed production is still carried out by the private sector and the Department of Agriculture (DOA). Alternate wetting and drying (AWD) has been reported to reduce water inputs by 23% (Bouman and Tuong, 2001) compared to continu-

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ously flooded rice systems. AWD also has the potential of reducing greenhouse gas (GHG) emissions, especially methane (Wassmann et al.2010). Alternative water saving irrigation techniques have been developed and increasingly adopted in rice growing countries during recent decades.

In Myanmar, there are many areas which cannot be sown because of no water during the dry season. By using AWD method, it can control water wasting, continuous flooding, and efficient water management. Therefore, AWD method is being practicing more and more than using continuous flooding method. Thus, this study was carried out with the following objectives:

- to evaluate yield performance of the inbred and hybrid rice varieties under AWD,
- to compare water productivity of rice varieties under AWD condition, and
- to investigate the water saving percent in different rice varieties under AWD.

Materials and Methods

The experiments were conducted in the field of Ka Dote Phayar Gyi village in DaikU Township,Bago Region and, A Lann village in Maubin Township, Ayarweddy Region during summer rice growing season from December 2015 to April 2016. These experiments were laid out in split-plot design with four replications. Two water regimes(alternate wetting and drying, AWD and continuous flooding, CF) were applied in main plot and two hybrid varieties (Long-9, Yezin Pale Thwe-3) and two inbred varieties (Yaenelo-4 and Yaenelo-1) were applied in sub plot.

For inbred varieties, 56.81 kg N ha^{-1} was applied as urea in three equal splits at 20, 40 and 55 days after seeding. Triple super phosphate was applied as basal application at the rate of 27.79 kg P ha^{-1}. A rate of potassium fertilizer (37.05 kg K ha^{-1}) was applied in twice at 40 and 55 days after seeding. For hybrid varieties, compound fertilizer (15-15 -15) was used as basal application with the rate of 123.5 kg ha^{-1}. Phosphorous and potassium fertilizers were used as described in inbred varieties. As top dressing, urea (85.21 kg ha^{-1}) was used at active tillering, maximum tillering and panicle initiation. In addition, potash (56.81 kg ha^{-1}) was applied at panicle initiation.

As weed management, pre-emergence herbicide (Bensulfuron + Quinclorac) was applied with a dose of (247 g ha^{-1}) at 10 days after seeding. Manual weeding was also done at 34, 50 and 63 days after seeding. In the AWD treatment timing of irrigation was based on the water depth in the field water tube installed in each plot. When there was no visible water in the tube, irrigation was applied until the depth was reached 5 cm above the soil surface. The amount of water that was applied to each treatment was recorded. At around flowering, all AWD treatments were suspended and water depth was maintained from 3 to 5 cm depth. In CF plots, wooden stick gages were installed to monitor daily ponded water depths. Water Productivity, WP (kg m^{-3}) and water saving (%) were calculated according to Bouman et.al 2007. Grain yield (kg ha^{-1}) is divided by total water input from irrigation and rainfall (m^3 ha^{-1}) for the crop during the growing season.

(Bouman et al., 2007)

$$\text{Water productivity (I + R)} = \frac{\text{Grain yield}}{\text{Total water input (Irrigation + Rainfall)}}$$

$$\text{Water saving (\%)} = \frac{\text{Water used in CF plot} - \text{Water used in AWD plot}}{\text{Water used in CF plot}}$$

The yield components such as number of panicles m^{-2}, number of spikelets $panicle^{-1}$, filled grain percent and 1000- grain weight were separately analyzed from one square meter of each sample area per plot. Grain yield was also measured from harvest area ($5m^2$). The data were subjected to analysis of variance by using and Statistix (Version 8.0) and means comparison were done by Least Significant Different (LSD) at 5% level.

Results and Discussion

Yield and yield components

According to the soil analysis results, loam soil in DaikU Township and silty clay loam soil in Maubin Township were observed (Table 1). At DaikU Township (loam soil), the differences of mean effects of applied AWD were observed in grain yield

Table 1. Some physicochemical properties of experimental soils

Characteristis	Unit	DaikU		Maubin	
		Content	Rating	Content	Rating
Sand	(%)	45.0	Loam	1.9	Silty clay loam
Silt	(%)	35.0		68.1	
Clay	(%)	20.0		30.0	
pH	-	5.2	Moderately acid	5.5	Moderately acid
Available N	mg kg^{-1}	168.0	Medium	155.0	Medium
Available P	mg kg^{-1}	1.0	Low	7.0	Low
Available K	mg kg^{-1}	98.0	Low	524.0	High
Organic Matter	(%)	0.47	Low	1.48	Low

and yield components of tested varieties (Long-9, Yezin Pale Thwe-3,Yaenelo-4 and Yaenelo-1) (Table 2). The results showed that mean yield of AWD irrigation was not significantly different with CF. This result could be due to AWD irrigation which enhanced root and panicle dry matter accumulation and partitioning, and yield components of effective panicles per m^2, spikelets per m^2 and grain filling percentage. This result is similar to the finding of (Shao et al. 2014). At Maubin Township (silty clay loam soil), the differences of mean effects of applied AWD were observed in grain yield and yield components of tested varieties (Long-9, Yezin Pale Thwe-3,Yaenelo-4 and Yaenelo-1) (Table 3).

The maximum grain yield and yield components were observed from the AWD irrigation. However, yield and yield components were not much different from those of CF irrigation. The mean values of grain yield and yield components were differently observed between the tested varieties (Table 3). Hybrid rice varieties gave the higher grain yield, yield components and harvest index than those of inbred rice varieties in both study areas. Murayama et al. (1987) considered that hybrid rice had a higher photosynthetic rate due to heterosis. Lafarge et al. (2004) reported that grain yield was significantly higher for hybrid rice as hybrid increased assimilates allocation towards productive tillers.

There was no significant different interaction between applied water regime and variety on grain yield and yield components in both experiments. In general, the grain yield and yield components that resulted from loam soil were relatively higher than that of silty clay loam soil because of different soil conditions.

Water input and water productivity

In DaikU and Maubin townships, the differences of mean effects of applied AWD were observed in water input and water productivity of tested varieties (Table 4 and 5). Alternate wetting and drying gave the lower water input and higher water productivity. Earlier studies of B. A. M. Bouman (2001) showed that even a 2%–70% water irrigation reduction would not lead to rice yield decrease.The increase in WP was either associated with a reduction in grain yield, as irrigated rice yield declined when field water content dropped below soil saturation (Bouman and Tuong, 2001; Tabbal et al., 2002), or with a maintenance or even an increase in grain yield (Li, 2001; Zhang et al., 2009; Belder et al., 2004; Yang et al., 2007).

These inconsistencies could be explained by the threshold soil water potential, the soil type, the climate conditions, and the genotype characteristics. The frequency of irrigations in DaikU were Yezin

Table 2. Mean effects of water regime and variety on yield and yield components in DaikU during summer rice growing season, 2016

Items	Grain yield ($t\ ha^{-1}$)	Panicles ($no.\ m^{-2}$)	Spikelets ($no.\ panicle^{-1}$)	Filled grain (%)	1000 - grain wt. (g)	Harvest index
Water regime (W)						
AWD	2.51 a	75.56 a	87.18 a	81.86 a	25.11 a	0.34 a
CF	2.44 a	69.06 b	86.31 a	81.71 a	24.54 a	0.34 a
$LSD_{0.05}$	0.26	1.03	9.47	3.21	1.08	0.03
Variety (V)						
Long-9	2.77 a	79.00 a	105.13 a	85.02 a	26.01 a	0.37 a
Yezin Pale Thwe -3	2.99 a	76.75 b	112.00 a	80.31 ab	24.82 b	0.36 ab
Yaenelo - 4	2.13 b	68.75 c	62.63 b	81.96 ab	24.44 b	0.33 bc
Yaenelo - 1	1.99 b	64.75 d	67.25 b	79.86 b	24.03 b	0.29 c
$LSD_{0.05}$	0.39	6.08	13.12	5.11	0.81	0.03
Pr>F						
W	0.4837	0.0003	0.7879	0.8963	0.1970	0.8196
V	0.0001	<0.0001	<0.0001	0.1746	0.0005	0.0017
W×V	0.0375	0.0023	0.2468	0.2846	0.5224	0.4677
CV a (%)	9.60	1.26	9.70	3.49	3.87	8.42
CV b (%)	15.04	2.82	14.40	5.95	3.11	10.49

In each column, means having a common letter are not significantly different at 5 % LSD.
AWD = Alternate Wetting and Drying; CF = Continuous Flooding

Table 3. Mean effects of water regime and variety on yield and yield components in Maubin during summer rice growing season, 2016

Items	Grain yield ($t\ ha^{-1}$)	Panicle ($no.\ m^{-2}$)	Spikelets ($no.\ panicle^{-1}$)	Filled grain (%)	1000-grain wt. (g)	Harvest Index
Water regime (W)						
AWD	5.08 a	69.75 a	169.88 a	80.69 a	22.45 a	0.55 a
CF	4.66 a	68.19 a	162.50 a	80.99 a	21.73 b	0.48 a
$LSD_{0.05}$	0.75	5.54	11.52	1.56	0.54	0.07
Variety (V)						
Long-9	5.76 a	79.00 a	201.50 a	84.34 a	23.06 a	0.61 a
Yezin Palae-thwe -3	4.95 b	70.00 b	181.63 b	82.63 a	22.75 ab	0.53 b
Yaenelo -4	4.29 b	63.38 b	136.63 c	77.68 b	21.37 bc	0.45 b
Yaenelo -1	4.46 b	63.50 b	145.00 c	78.73 b	21.19 c	0.47 b
$LSD_{0.05}$	0.72	6.79	17.17	2.65	1.44	0.08
Pr>F						
W	0.1749	0.4352	0.1343	0.5745	0.0240	0.0563
V	0.0019	0.0003	0.0001	0.0001	0.0266	0.0017
W × V	0.9168	0.7803	0.3049	0.2643	0.5830	0.9347
CV a (%)	13.75	7.13	6.16	1.71	2.16	11.24
CV b (%)	14.07	9.38	9.84	3.12	6.19	13.86

In each column, means having a common letter are not significantly different at 5% LSD.
AWD = Alternate Wetting and Drying; CF= Continuous Flooding

Table 4. Mean effects of water regime and variety on water input and water productivity in DaikU township during summer rice growing season, 2016

Items		Water Input (mm)	Water productivity (kg m^{-3})
Water regime (W)	CF	1269.10 a	0.34 a
	AWD	934.10 b	0.35 a
	LSD$_{0.05}$	11.83	0.02
Variety (V)	Long - 9	1220.00 a	0.39 a
	Yezin Palae Thwe - 3	1229.00 a	0.41 a
	Yaenelo - 4	984.00 b	0.30 b
	Yaenelo - 1	973.40 b	0.29 b
	LSD$_{0.05}$	12.92	0.04
Pr > F	W	<0.0001	0.4950
	V	<0.0001	<0.0001
	W x V	<0.0001	0.0352
	CV a (%)	0.95	6.60
	CV b (%)	1.12	10.93

In each column, means having a common letter are not significantly different at 5 % LSD.
AWD = Alternate Wetting and Drying; CF = Continuous Flooding

Table 5. Mean effects of water and variety on water input and water productivity in Maubin township during summer rice growing season, 2016

Items		Water Input (mm)	Water productivity (I+R)(kg m^{-3})
Water regime (W)	CF	1235.0 a	0.59 a
	AWD	896.4 b	0.61 a
	LSD$_{0.05}$	8.18	0.09
Variety (V)	Long - 9	1199.1 a	0.68 a
	Yezin Palae Thwe - 3	1173.3 b	0.59 b
	Yaenelo - 4	950.6 c	0.54 b
	Yaenelo - 1	939.9 c	0.58 b
	LSD$_{0.05}$	12.93	0.08
Pr>F	W	<0.0001	0.4950
	V	<0.0001	<0.0001
	W x V	<0.0001	0.0352
	CV a (%)	0.68	13.36
	CV b (%)	1.16	12.9

In each column, means having a common letter are not significantly different at 5 % LSD.
AWD = Alternate Wetting and Drying; CF = Continuous Flooding

Pale Thwe-3 (27), Long-9 (27), Yaenelo-4 (23) and Yaenelo-1 (23) respectively in AWD, consequently, under AWD plot water saving percent were 20-30% for hybrid rice and 30-32% for inbred rice (Table 6).

In Maubin township, the differences of mean effects of applied AWD were observed in water input and water productivity of tested varieties. The minimum water input was found in AWD and the maximum water productivity was also observed under AWD irrigation. The frequencies of irrigation were Yezin Pale Thwe-3 (27), Long-9 (27), Yaenelo -4 (23) and Yaenelo-1 (23) respectively in AWD. Moreover, under AWD plot water saving percents were 20-30% for hybrid rice and 30-32% for inbred rice (Table 7). Under both study areas, Hybrid variety gave the minimum water input and maximum water productivity than that of inbred variety (Table 6 and 7).

Conclusion

Based on the findings of this study, it can be highlighted that for Hybrid variety AWD irrigation should be used under loam soil. It can reduce more water saving percent up to 20 % than continuous flooding. Regarding inbred rice variety, alternate wetting and drying irrigation should be also used because it can save water up to 30%.Under sality clay loam soil condition, both tested varieties produced similar yields when AWD was applied. Therefore, it can be suggested that AWD should be

Table 6. Comparison of amount of water use and saving in DaikU township during summer rice growing season, 2016

	CF				AWD			
Variety	**V_1**	**V_2**	**V_3**	**V_4**	**V_1**	**V_2**	**V_3**	**V_4**
Water input (mm)	1359.9	1371.9	1175.3	1165.3	1080.2	1086.1	792.4	781.5
Frequency of irrigation	66	67	62	60	27	27	23	23
Water saving (%)	-	-	-	-	20.6	20.8	32.6	32.9

AWD=Alternate Wetting and Drying; CF = Continuous Flooding
V_1= Long-9, V_2= Yezin Pale Thwe-3,V_3 = Yaenelo-4,V_4= Yaenelo-1

Table 7. Comparison of amount of water use and saving in Maubin township during summer rice growing season,2016

	CF				AWD			
Variety	**V_1**	**V_2**	**V_3**	**V_4**	**V_1**	**V_2**	**V_3**	**V_4**
Water input (mm)	1351.9	1313.4	1144.4	1130.3	1046.3	1033.1	756.8	749.5
Frequency of irrigation	65	64	62	62	276	26	22	22
Water saving (%)	-	-	-	-	22.6	21.4	33.9	33.7

AWD – Alternate Wetting and Drying; CF = Continuous Flooding
V_1 = Long-9, V_2 = Yezin Pale Thwe-3, V_3 = Yaenelo-4 and V_4 = Yaenelo-1

used for rice varieties to obtain good yield and reduce of water input under tested areas, DaikU and Maubin Townships.

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