Omonrice 16: 81-87 (2008)

EFFECT OF SEEDING RATE AND NITROGEN MANAGEMENT UNDER TWO DIFFERENT WATER REGIMES ON GRAIN YIELD, WATER PRODUCTIVITY AND PROFITABILITY OF RICE PRODUCTION

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ABSTRACT

The objective of this study is to quantify the impact of new irrigation method (alternate wetting and drying: AWD) on grain yield, water productivity and economic efficiency under different seeding rates and nitrogen application methods in comparison with the conventional water management, continuous flooding (CF). The experiment was laid out in 2006 wet season and 2007 dry season at CLRRI, following a randomized completed block design with four replications and six treatments in combination of three seeding rates and methods (row seeding at 70 kg ha^{-1} (P_1), broadcast at 70 kg ha^{-1} (P_2) and broadcast at 120 kg ha^{-1} (P_3) and two nitrogen management methods [Current SSNM recommendation (N_1) and Alternative nitrogen management (N_2)]. The two water regimes were physically separated in the plots to ensure that seepage of water did not interfere together.

Grain yields were varied from 2.68 to 2.76 tons ha^{-1} in 2006 wet season (WS) and from 5.81 to 5.98 tons ha^{-1} in 2007 dry season (DS) at AWD, while higher grain yields attained at CF. It got the grain yields from 2.75 to 2.90 tons ha^{-1}and from 6.03 to 6.10 tons ha^{-1}, respectively. The differences in grain yield were statistically significant only in 2007 DS. Although the higher grain yields of CF, the AWD reduced the irrigation water inputs compared to those. It reduced 33.3% of irrigation water input in 2006 WS and 28.6% in 2007 DS. Water productivity of AWD was also increased compared to CF. It got 1.4 kg m^{-3} and 0.9 kg m^{-3} in 06 WS and 1.6 kg m^{-3} and 1.2 kg m^{-3} in 07 DS, respectively. The net benefit of AWD water use attained higher value than CF of 154 thousand VND ha^{-1} in 06 WS and 1.02 million VND ha^{-1} in 07 DS. The difference of profit between two seeding rates 70 and 120 kg ha^{-1} was 208 thousand VND ha^{-1} in 06 WS and 285 thousand VND ha^{-1} in 07 DS. The difference of net benefit between two nitrogen management methods was 118 thousand VND ha^{-1} and 248 thousand VND ha^{-1} in 06 WS and 07 DS, respectively.

Keywords: Alternate wetting and drying (AWD), Continuous flooding (CF), grain yield, irrigation water input, profit, water productivity (WP)

INTRODUCTION

The water crisis is threatening the sustainability of the irrigated rice system and food security in Asia. Tuong and Bouman (2003) indicated that 2 million ha of irrigated dry-season rice and 13 million ha of irrigated wet-season rice in Asia will experience "physical water scarcity" by 2025. Most of the 22 million ha of irrigated dry-season rice in South and Southeast Asia will suffer "economic water scarcity". There was also much evidence that water scarcity already prevails in rice growing areas (Bouman et al. 2002), where farmers need technologies to cope with water shortage and ways must be sought to grow rice with less water. The saving water techniques for rice production have applied in Asian countries like China, Philippines, India, etc. while the intensive rice production in Mekong Delta of Vietnam still followed with conventional water management, continuous flooding. This paper shows the results of the

research on the combination of seeding rate, nitrogen application method under two different water regimes on rice growth and grain yield. The research also determines the irrigation water input saving and water productivity. It will evaluate the impact of these management practices on grain yield and net benefit of intensive rice production.

MATERIALS AND METHODS

The experiment was done on twice rice cropping system in 2006 wet season and 2007 dry season. The experiment included three factors in which the two water regimes (Continuous flooding (CF) and Alternate wetting and drying (AWD)) were physically separated in the plots to ensure that seepage of water did not interfere together. The treatment was the combination of seeding rate and nitrogen management (Table 1). It was laid out in a randomized complete block design with four replications.

Table 1: The treatments of the experiment

No.	Treatment	Seeding rate and method	N Management
1	P_1N_1	Row seeding 70 kg ha^{-1}	Current SSNM recommendation
2	P_2N_1	Broadcast 70 kg ha^{-1}	Current SSNM recommendation
3	P_3N_1	Broadcast 120 kg ha^{-1}	Current SSNM recommendation
4	P_1N_2	Row seeding 70 kg ha^{-1}	Alternative N management
5	P_2N_2	Broadcast 70 kg ha^{-1}	Alternative N management
6	P_3N_2	Broadcast 120 kg ha^{-1}	Alternative N management

The timing and rate of N application vary on season and based on LCC (4 scales- Leaf color Chart) (Table 2 and 3).

Table 2: Nitrogen rate (kg N/ha) and timing application for rice-rice cropping systems.

Season	N Management	7-10 DAS	22-25 DAS	40 –42 DAS
DS	N_1	30	15 - 35 (LCC)	0 – 35 (LCC)
	N_2	50	15 - 35 (LCC)	0 – 35 (LCC)
WS	N_1	20-25	0 - 30 (LCC)	0 – 30 (LCC)
	N_2	40	0 - 30 (LCC)	0 – 30 (LCC)

Table 3: The N rate (kg/ha) for each split application based on LCC

LCC	Dry season		Wet season	
	22-25 DAS	PI (40 –42 DAS)	22-25 DAS	PI (40-42 DAS)
> 4	15-20	0	0	0
> 3 to 4	30	30	20	20
<3	35	35	30	30

Phosphorus was applied at 40 kg P_2O_5 ha^{-1} at 7-10 DAS for both seasons. Potassium was applied at 30 kg K_2O ha^{-1} at 7-10 DAS in 06 WS and applied at 50 kg K_2O ha^{-1} in a two splits at 7-10 DAS and PI stage in 07 DS.

Other management practices: Organic fertilizer would not be applied. All rice stubble would be removed after each crop.

The collected data comprised of measuring of Perched-water depth, groundwater depth, and percolation rate everyday from 21 days after sowing (DAS) to 15 days before harvesting. Tiller number and plant dry matter were collected at tillering stage (25-27 DAS), panicle initiation stage (40-42 DAS) and flowering stage (60-65 DAS). The rice yield components and grain yield,

water productivity, and water input saving were also collected and analyzed with IRRI's standard method.

RESULTS AND DISCUSSION

Effect of water management, nitrogen application method and seeding rate on grain yield

In 2006 wet season, there was no difference in grain yields among treatments although the difference in nitrogen rates between nitrogen application methods. The alternative N management (N_2) with higher nitrogen dose than the current SSNM recommendation (N_1) as followed the method in Table 2, 3 and 4. Among seeding rates, row seeding 70 kg seed ha^{-1} and broadcast 70 kg seed ha^{-1} got the same grain yields with broadcast 120 kg ha^{-1}. The averaged grain yield of OM2517 varied from 2.69 to 2.84 tons ha^{-1} (Table 5). The grain yield of continuous flooding (CF) treatment was little higher than that of alternate wetting and drying (AWD) treatment but it was not significantly different.

In 2007 dry season, there were no differences in grain yields among treatments on seeding rates and nitrogen application methods in each irrigation method, but between two water regimes, the grain yields of CF were significantly higher than those of AWD from 0.08 to 0.28 tons ha^{-1} (1.5-4.6%). At the same seeding rate, there was no difference in grain yields between two N application methods although the difference in nitrogen rates, N_2 with 110 kg N ha^{-1} higher nitrogen dose than N_1 with 90 kg N ha^{-1}. Among seeding rates, row seeding 70 kg seed ha^{-1} and broadcast 70 kg seed ha^{-1} got the same grain yields with broadcast 120 kg ha^{1}. The averaged grain yield of OMCS2000 varied from 5.81 to 6.10 tons ha^{-1} (Table 5).

Table 4: Nitrogen rate (kg N/ha) and timing application in 06 WS and 07 DS.

N application method	7-10 DAS	22-25 DAS	40-45 DAS	N rates/season
2006 WS				
N_1 (SSNM)	25	20 (LCC >3-4)	20 (LCC >3-4)	**65**
N_2 (Alternative N)	40	20 (LCC >3-4)	20 (LCC >3-4)	**80**
2007 DS				
N1 (SSNM)	30	30 (LCC >3-4)	30 (LCC >3-4)	**90**
N_2 (Alternative N)	50	30 (LCC >3-4)	30 (LCC >3-4)	**110**

Table 5: Effect of water management, nitrogen application methods and seeding rates on grain yield (t/ha) in 06 WS and 07 DS

Treatment	**2006 WS (OM2517)**			**2007 DS (OMCS2000)**		
	CF	AWD	Difference (AWD-CF)	CF	AWD	Difference (AWD-CF)
P_1N_1	2.79	2.90	0.11	6.07	5.98	- 0.09
P_2N_1	2.83	2.80	- 0.03	6.10	5.93	- 0.17
P_3N_1	2.79	2.75	- 0.04	6.03	5.83	- 0.20
P_1N_2	2.68	2.76	0.08	6.06	5.92	- 0.15
P_2N_2	2.70	2.68	- 0.02	6.04	5.91	- 0.13
P_3N_2	2.73	2.72	- 0.01	6.09	5.81	- 0.28
F	Ns	Ns	Ns	Ns	Ns	*
CV%	6.9	6.1	7.3	10.4	9.8	10.6
LSD5%	0.17	0.13	0.16	0.13	0.16	0.10

For both seasons, the nitrogen management followed with current SSNM recommendation (N_1) which were lower N rate of 65 kg N ha^{-1} in 2006 WS and 90 kg N ha^{-1} in 2007 DS proved to meet the plant nutrient requirement and assisted to save 15-20 kg N ha^{-1} compared to N_2 with 80 and 110 kg N ha^{-1} in 06 WS and 07 DS, respectively. These results had the similar records of the researches on optimum fertilizer nitrogen rate for high-yielding rice under different seeding rates (Huan et al. 1998; 2000; Khuong et al. 2002).

Water productivity and irrigation water input saving between two water regimes

The parameters of Perched-water table (field water depth), groundwater depth and Percolation losses (Table 6) showed that the experimental soil type with clay texture, shallow groundwater depth (20-30 cm) and low percolation rate (1-5 mm day^{-1}), the number of days without pond water in AWD regime could be prolonged 10 days (Fig. 1).

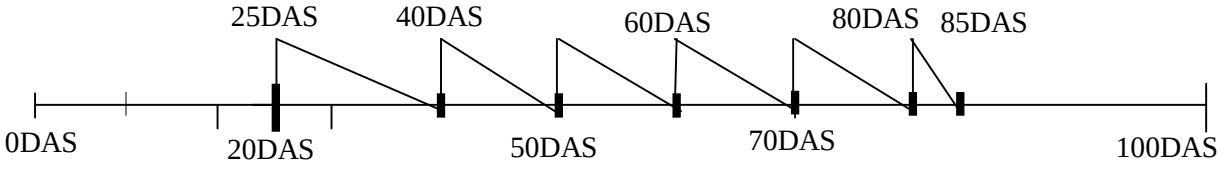

Fig. 1: The dried field periods and irrigation intervals of AWD in 2007 DS

The conventional continuous flooding regime required to keep field water depth at 5±3 cm, so it must be put more irrigation input than AWD regime. Consequently, the water input saving of AWD was 33.3% in 2006 WS and 28.6% in 2007 DS. The water productivity of AWD was higher than that of CF. In 06 WS, it got 1.4 kg m^{-3} at AWD compared to 0.9 kg m^{-3} at CF. In 07 DS, the water productivity was 1.2 kg m^{-3} at CF and 1.6 kg m^{-3} at AWD. These values were the same tendencies of the researches on application of water- saving techniques in rice growing of Asia countries such as China, Philippines, India (Tuong et al. 2005).

Table 6: Comparison of irrigation water input, water input saving and water productivity between two water regimes in 06 WS and 07 DS.

Parameter	06 WS			07 DS		
	CF	AWD	Difference (AWD-CF)	CF	AWD	Difference (AWD-CF)
1. Perched-water table (cm)	7.3	1.0	- 6.3	5.2	1.6	-3.6
2. Percolation (mm/day)	0.42	0.47	0.05	0.97	0.63	-0.34
3. Groundwater depth (cm)	20.0	23.9	3.9	24.7	29.9	5.2
4. Irrigation water input (m^3/ha/season)	3000	2000	1000	5250	3750	1500
5. Grain yield (kg/ha)	2750	2770	20	6070	5945	-125
6. Irrigation water input (%)[a]	-	-	33.3	-	-	28.6
7.Water productivity (kg grain/m^3 water)[b]	0.92	1.39	0.47	1.16	1.59	0.43

[a] *Water Input Saving (%) =100 - [(Irrigation water input of AWD x 100)/Irrigation water input of CF)]*
[b] *Water productivity (WP) (kg grain/m^3 water) = Grain yield (kg)/Irrigation water input (m^3)*

Effect of water management, nitrogen application method and seeding rate on profit of rice production

The economic efficiency of the current SSNM recommendation (N_1) was higher than that of the alternative N management (N_2) for both two water regimes. The mean difference of profit between two nitrogen application methods got the same value at CF and AWD in 06 WS (122 and 113 thousand VND, respectively). In 07 DS, N_1 got the higher difference of net benefit than that of N_2. Its value was 290 thousand VND compared to 205 thousand VND (Table 7).

Table 7. The difference of profit between two **nitrogen application methods** at the same seeding rate under different water regimes. (*Unit: 1000 VND/ha)*

Seeding rate and method	2006 WS		2007 DS	
	CF	AWD	CF	AWD
RS70 kg/ha	-119.9	-44.9	223.8	366.3
B70 kg/ha	230.1	205.1	366.3	252.3
B120 kg/ha	255.1	180.1	24.8	252.3
Mean (N_1-N_2)	**121.8**	**113.3**	**204.8**	**290.3**

Among seeding rates, the lower seeding rates (RS70 and B70 kg ha^{-1}) helped to save seed cost and got the same grain yields with the higher seeding rate (B120 kg ha^{-1}), so their profits were high. The averaged differences varied from 162.5 to 462.5 thousand VND ha^{-1} in 2006 WS and from 306.3 to 505.8 thousand VND ha^{-1} in 2007 DS (Table 8).

Table 8: The difference of profit among **seeding rates** under different nitrogen app. methods and water regimes. (*Unit: 1000 VND/ha)*

Water Regime	**N_1**			**N_2**		
	P_1-P_2	**P_1-P_3**	**P_2-P_3**	**P_1-P_2**	**P_1-P_3**	**P_2-P_3**
2006 WS						
CF	-100	225	325	250	600	350
AWD	-50	100	150	200	325	125
Mean	**-75**	**162.5**	**237.5**	**225**	**462.5**	**237.5**
2007 DS						
CF	-85.5	349.0	434.5	57.0	149.5	92.5
AWD	142.5	662.5	520.0	28.5	548.5	520.0
Mean	**28.5**	**505.8**	**477.3**	**42.8**	**349.0**	**306.3**

The result in Table 9 showed the economic efficiency between two water regimes. The net benefit of AWD was higher than that of CF. The mean difference was 154 thousand VND ha^{-1} in 2006 WS and 1.02 million VND ha^{-1} in 2007 DS.

Table 9: The difference of profit **between AWD with CF** under different seeding rates and nitrogen app. methods. (*Unit: 1000 VND/ha)*

Seeding rates	RS70	B70	B120	**Mean**
		2006 WS		
N_1(65 kg N/ha)	125.0	75.0	250.0	***150.0***
N_2 (80 kg N/ha)	50.0	100.0	325.0	***158.3***
Mean (AWD-CF)	**87.5**	**87.5**	**287.5**	***154.2***
		2007 DS		
N_1 (90 kg N/ha)	1,243.5	1,015.5	930.0	***1,063.0***
N_2 (110 kg N/ha)	1,101.0	1,129.5	702.0	***977.5***
Mean (AWD-CF)	**1,172.3**	**1,072.5**	**816.0**	***1,020.3***

The water management also affected to nitrogen application method and seeding rate. Both CF and AWD treatments got the similar profit differences at the current SSNM recommendation N_1 and the alternative N management N_2 in 2006 WS, but N_1 got higher net benefit than that of N_2 in 2007 DS. For seeding rate, their profit differences of low seeding rates (RS70 and B70 kg ha^{-1}) were higher than those of B120 kg ha^{-1}.

CONCLUSION

Although the higher grain yields of CF, the AWD reduced the irrigation water inputs as compared to those. It reduced 33.3% of irrigation water input in 2006 WS and 28.6% in 2007 DS. Water productivity of AWD was also increased compared to CF. It got 1.4 kg m^{-3} and 0.9 kg m^{-3} in 2006 WS and 1.6 kg m^{-3} and 1.2 kg m^{-3} in 2007 DS, respectively. The net benefit of AWD water use attained higher value than CF of 154 thousand VND ha^{-1} in 2006 WS and 1.02 million VND ha^{-1} in 2007 DS. The difference of profit between two seeding rates 70 and 120 kg ha^{-1} was 208 thousand VND ha^{-1} in 2006 WS and 285 thousand VND ha^{-1} in 2007 DS. The difference of net benefit between two nitrogen management methods was 118 thousand VND ha^{-1} in 2006 WS and 248 thousand VND ha^{-1} in 2007 DS.

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Ảnh hưởng của mật độ sạ, phương pháp bón đạm và chế độ nước tưới đến năng suất, hiệu quả sử dụng nước và lợi nhuận trong sản xuất lúa cao sản

Nhằm đánh giá tác động của biện pháp quản lý nước ngập khô xen kẽ trên năng suất lúa, hiệu quả sử dụng nước và hiệu quả kinh tế dưới ảnh hưởng của các mật độ, phương pháp sạ và phương pháp bón đạm, các thí nghiệm đồng ruộng thực hiện trong hai vụ HT 2006 và ĐX 2006-07 tại Viện Lúa với hai chế độ tưới nước riêng biệt: ngập nước thường xuyên (CF) và ngập khô xen kẽ (AWD). Các nghiệm thức thí nghiệm là sự kết hợp giữa 3 mật độ sạ và phương pháp sạ: SH 70 kg/ha, SL 70 kg/ha và SL 120 kg/ha với hai phương pháp bón đạm là bón đạm theo SSNM (N_1) và quản lý đạm thay đổi (N_2) được bố trí theo khối hoàn toàn ngẫu nhiên, bốn lần lặp lại. Năng suất lúa ghi nhận được biến động từ 2,68-2,76 t/ha trong vụ HT 2006 và từ 5,81-5,98 t/ha trong vụ ĐX 2006-07 ở chế độ nước ngập khô xen kẽ; trong khi ở chế độ ngập nước thuờng xuyên nhận được năng suất cao hơn, đạt 2,75-2,90 t/ha và 6,03-6,10 t/ha, tương ứng. Tưới nước ngập khô xen kẽ đạt hiệu quả sử dụng nước cao hơn so với ngập thường xuyên là 1,4 kg m^{-3} và 1,6 kg m^{-3} so với 0,9 kg m^{-3} và 1,2 kg m^{-3} tương ứng cho hai vụ HT2006 và ĐX2006-07. Lượng nước tưới tiết kiệm được của chế độ ngập khô xen kẽ là 33,3% và 28,6% trong hai vụ HT 2006 và Đ X2006-07. Về hiệu quả kinh tế, tưới nước ngập khô xen kẽ đạt lợi nhuận cao hơn: 154 ngàn đồng/ha trong vụ mùa mưa và 1,02 triệu đồng/ha trong mùa khô so với chế độ nước ngập thường xuyên. Giữa hai mật độ sạ 70 và 120 kg/ha tiết kiệm được 208 ngàn đồng/ha và 285 ngàn đồng/ha. Bón phân theo nhu cầu cây (SSNM) tiết kiệm hơn so với bón đạm thay đổi là 118 ngàn đồng/ha và 248 ngàn đồng/ha cho hai vụ tương ứng.