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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 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 2008 dry and wet 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 separate in the plots to ensure that seepage of water did not interfere together.

Grain yields varied from 6.19 to 6.46 tons ha^{-1} in 2008 DS and from 4.21 to 4.41 tons ha^{-1} in 2008WS at AWD, while lower grain yields attained at CF in which it got the grain yields from 6.06 to 6.37 tons ha^{-1} and from 4.10 to 4.26 tons ha^{-1}, respectively. The AWD did not only get higher grain yield (increased of 3.6% in 2008 DS and 2.6% in 2008 WS) but also reduce the irrigation water inputs compared to those of CF. It reduced 26.7% of irrigation water input in DS and 32% in WS. It also got high value of water productivity and economic efficiency. It got 1.87 kg m^{-3} and 1.34 kg m^{-3} in DS and 1.81 kg m^{-3} and 1.25 kg m^{-3} in WS, respectively. The net benefit of AWD water use attained higher value than CF of VND 1.52 million ha^{-1} in DS and VND 918 thousand ha^{-1} in WS. The difference of profit between two seeding rates RS70 and B120 kg ha^{-1} was VND 354 thousand ha^{-1} in DS and VND 207 thousand ha^{-1} in WS. The difference of net benefit between two nitrogen management methods was VND 269 thousand ha^{-1} and VND 174 thousand ha^{-1} in 2008 dry and wet seasons, 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 2008 dry and wet seasons. The experiment included three factors in which the two water regimes (Continuous flooding (CF) and Alternate wetting and drying (AWD)) were set physically separate 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	15	15 - 35 (LCC)	0 – 35 (LCC)
WS	N_1	20-25	0 - 30 (LCC)	0 – 30 (LCC)
	N_2	10	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 50 kg K_2O ha^{-1} in a two splits at 7-10 DAS and PI stage in 2008 DS and applied at 30 kg K_2O ha^{-1} at 7-10 DAS in 2008 WS.

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 2008 DS, the nitrogen management followed with current SSNM recommendation (N_1) did not save N fertilizer compared to N_2 with N rate of 80 kg N ha^{-1}. It was higher N rate of 90 kg N ha^{-1} with split applied at 30-30-30 but proved to meet the plant nutrient requirement at each growth stage in this season. So the grain yield of N_1 was higher than those of N_2 at all 3 seeding rate and methods and two water regimes (Table 4 and 5). Grain yields were varied from 6.19 to 6.46 tons ha^{-1} at AWD while lower grain yields attained at CF (6.06 to 6.37 tons ha^{-1}). 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; Huan et al, 2008).

In 2008 WS, the alternative N management N_2 with 1st split application was a half dose of SSNM and followed LCC at tillering and panicle initiation stages for both two N application methods, so the N applied as the same (75 kg N ha^{-1}) but the grain yields got some difference at 5% level. Grain yields were varied from 4.21 to 4.41 tons ha^{-1} at AWD, while lower grain yields attained at CF in which it got the grain yields from 4.10 to 4.26 tons ha^{-1} (Table 4 and 5).

Table 4: Nitrogen rate (kg N/ha) and timing application in 2008 DS and WS.

N application method	7-10 DAS	22-25 DAS	40-45 DAS	N rates/season
2008 DS				
N_1 (SSNM)	30	30 (LCC >3-4)	30 (LCC >3-4)	**90**
N_2 (Alternative N)	15	35 (LCC <3)	30 (LCC >3-4)	**80**
2008 WS				
N1 (SSNM)	25	20 (LCC >3-4)	30 (LCC <3)	**75**
N_2 (Alternative N)	15	30 (LCC <3)	30 (LCC <3)	**75**

Table 5: Effect of water management, nitrogen application methods and seeding rates on grain yield (t/ha) of OMCS2000 in 2008 DS and 2008 WS.

Treatment	**2008 DS**			**2008 WS**		
	CF	AWD	Difference (AWD-CF)	CF	AWD	Difference (AWD-CF)
P_1N_1	6.37	6.46	0.09	4.25	4.39	0.14
P_2N_1	6.10	6.20	0.10	4.26	4.22	-0.04
P_3N_1	6.18	6.36	0.18	4.19	4.41	0.22
P_1N_2	6.18	6.21	0.03	4.24	4.29	0.05
P_2N_2	6.06	6.19	0.13	4.10	4.21	0.11
P_3N_2	6.13	6.33	0.20	4.18	4.36	0.18
F	**	**	-	*	*	-
CV%	10.2	10.6	-	10.5	10.2	-
LSD5%	0.11	0.16	-	0.10	0.13	-

Water productivity and irrigation water input saving between two water regimes

The parameters of 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 (1-2 mm day^{-1}), the number of days without pond water in AWD regime could be prolonged 4-7 days (Table 6).

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 26.7% and 32% in 2008 DS and 2008 WS, respectively. The water productivity of AWD was higher than that of CF. In 2008 DS, it got 1.87 kg m^{-3} at AWD compared to 1.34 kg m^{-3} at CF. In 2008 WS, the water productivity was 1.25 kg m^{-3} at CF and 1.81 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 2008 DS and 2008 WS.

Parameter	2008 DS			2008 WS		
	CF	AWD	Diff. (AWD-CF)	CF	AWD	Diff. (AWD-CF)
1. Field water table (cm)	[2.5-12.5] **7.2**	[(-7)-11] **5.3**	**- 1.9**	[2.5-7.5] **5.3**	[(-4)-8.5] **3.6**	**- 1.7**
2. Percolation (mm/day)	1.46	0.96	-0.5	1.00	0.82	-0.18
3. Groundwater depth (cm)	-21.7	-29.5	5.8	-19.7	-22.8	3.1
4. Irrigation water input (m^3/ha/season)	4,597	3,368	1,229	3,368	2,291	1,077
5. Grain yield (kg/ha)	6,170	6,293	123	4,200	4,310	110
6. Irrigation water input (%)[a]	-	-	26.7	-	-	32.0
7.Water productivity (kg grain/m^3 water)[b]	1.34	1.87	0.53	1.25	1.81	0.56

[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 2008 DS (268-269 thousand VND, respectively). In 2008 WS, N_1 got the higher difference of net benefit than that of N_2. Its value was 273 thousand VND compared to 75 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	2008 DS		2008 WS	
	CF	AWD	CF	AWD
RS70 kg/ha	674.4	900.6	38.1	188.1
B70 kg/ha	55.3	-84.7	721.9	-178.6
B120 kg/ha	75.1	-9.5	60.2	215.9
Mean (N_1-N_2)	***268.3***	***268.8***	**273.4**	**75.2**

Among seeding rates, the lower seeding rate with RS70 kg ha^{-1} helped to save seed cost and got higher grain yields than B120 kg ha^{-1}, so their profits were high. The averaged differences varied from VND 153 thousand ha^{-} to VND 1.1 million ha^{-1} in 2008 DS and from VND 297 to 512 thousand ha^{-1} in WS 2008. The mean of profit among seeding rates and seeding methods in DS 2007-08 and WS 2008 was VND 354 and 207 thousand ha^{-1}, respectively (Table 8).

Table 8: The difference of profit among **seeding rates** under different nitrogen application methods and water regimes.

Unit: VND 1000 /ha

Water regimes	N_1		N_2		**Mean**
	P_1-P_2	**P_1-P_3**	**P_1-P_2**	**P_1-P_3**	
2008 DS					
CF	1110.1	1108.0	491.1	508.8	***538.9***
AWD	1091.6	707.4	106.3	-202.7	***168.2***
Mean	***1100.9***	***907.7***	***298.7***	***153.0***	***353.6***
2008 WS					
CF	-46.9	598.5	637.0	620.6	***406.3***
AWD	754.3	-4.1	387.6	23.8	***6.6***
Mean	***353.7***	***297.2***	***512.3***	***322.2***	**206.5**

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 VND 1.52 million ha^{-1} in 2008 DS and VND 918 thousand ha^{-1} in 2008 WS.

Table 9: The difference of profit **between AWD with CF** under different seeding rates and nitrogen app. methods.

Unit: VND 1000 /ha

Seeding rates	RS70	B70	B120	**Mean**
		2008 DS		
N_1(30-30-30 kg N/ha)	1378	1396	1778	**1517.4**
N_2 (15-35-30 kg N/ha)	1151	1536	1863	**1516.8**
Mean (AWD-CF)	**1264.5**	**1466.0**	**1820.5**	***1517***
		2008 WS		
N_1 (25-20-30 kg N/ha)	885	84	1488	**819.0**
N_2 (15-30-30 kg N/ha)	735	985	1332	**1017.3**
Mean (AWD-CF)	**810**	**534.5**	**1410**	***918***

CONCLUSION

The AWD did not only get higher grain yield (increased of 3.6% in 2008 DS and 2.6% in 2008 WS) but also reduce the irrigation water inputs compared to those of CF. It reduced 26.7% of irrigation water input in 2008 DS and 32% in 2008 WS. Water productivity of AWD was also increased compared to CF. It got 1.87 kg m^{-3} and 1.34 kg m^{-3} in 2008 DS and 1.81 kg m^{-3} and 1.25 kg m^{-3} in 2008 WS, respectively. The net benefit of AWD water use attained higher value than CF of VND 1.52 million ha^{-1} in 2008 DS and VND 918 thousand ha^{-1} in 2008 WS. The difference of profit between two seeding rates RS70 and B120 kg ha^{-1} was VND 354 thousand ha^{-1} in DS 2007-08 and VND 207 thousand ha^{-1} in 2008 WS. The difference of net benefit between two nitrogen management methods was VND 269 thousand ha^{-1} in DS 2007-08 and VND 174 thousand ha^{-1} in 2008 WS.

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Ảnh hưởng của mật độ sạ, phương pháp bón đạm và chế độ 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, phuơng pháp sạ và phương pháp bón đạm, các thí nghiệm đồng ruộng thực hiện trong hai vụ ĐX 2007-08 và HT 2008 tại Viện Lúa với hai chế độ tưới 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 6,19-6,46 t/ha trong vụ ĐX2007-08 và từ 4,21-4,41 t/ha trong vụ HT2008 ở chế độ nước ngập khô xen kẽ trong khi ở chế độ ngập nước thuờng xuyên nhận được năng suất thấp hơn, đạt 6,06-6,37 t/ha và 4,1-4,26 t/ha, tương ứng. Tưới nước ngập khô xen kẽ đạt hiệu quả sử dụng nước cao hơn so với ngập thường xuyên là 1,87 kg m^{-3} và 1,81 kg m^{-3} so với 1,34 kg m^{-3} và 1,25 kg m^{-3} tương ứng cho hai vụ ĐX2007-08 và HT2008. Lượng nước tưới tiết kiệm được của chế độ ngập khô xen kẽ là 26,7% và 32% trong hai vụ ĐX2007-08 và HT2008. Về hiệu quả kinh tế, tưới nước ngập khô xen kẽ đạt lợi nhuận cao hơn: 1,52 triệu đồng/ha trong vụ mùa khô và 918 ngàn đồng/ha trong mùa mưa so với chế độ nước ngập thường xuyên. Giữa hai mật độ sạ hàng 70 kg/ha và sạ lan 120 kg/ha tiết kiệm được 354 ngàn đồng/ha và 207 ngàn đồng/ha. Bón phân theo nhu cầu cây (SSNM) đạt hiệu quả cao hơn so với bón đạm thay đổi là 269 ngàn đồng/ha và 174 ngàn đồng/ha cho hai vụ tương ứng.