Mitigating water scarcity through an aerobic system of rice production

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Abstract

Rice grows and produces best under flooded condition but large amount of water is needed to satisfy puddling during land preparation and maintenance of standing paddy water depths throughout its growth period. Hence, reducing water use through an aerobic system of rice production that eliminates puddling and maintenance of ponded water in paddies is necessary to mitigate the potential occurrence of water scarcity. In 2001-02, a field experiment on aerobic rice was conducted at the International Rice Research Institute (IRRI) to evaluate the potential of aerobic rice in the tropics to mitigate a looming water crisis. Under aerobic conditions, the soil was dry-plowed and flush-irrigated when the soil moisture tensions reached –30 to –50 kPa during the crop growth stage. Compared to flooded conditions, the soil was puddled during the land preparation and a paddy water depths of 2-10 cm were maintained during the crop growth stage. Aerobic rice saved 73% of irrigation water for land preparation and 56% during the crop growth stage. Moreover, it effectively used rainfall during the wet season. Aerobic rice yields were lower by an average of 28% in the dry season and 20% lower in wet season. Magat (a tropical lowland hybrid) and Apo (a traditional upland inbred) showed the highest yield potential between 5-6 t/ha under aerobic conditions. Further experiments in medium textured soil and breeding of varieties better suited to aerobic conditions are needed.

Media summary

Aerobic shystem of rice production saved irrigation water by more than half compared to flooded system and can possibly mitigate water scarcity in the future.

Key Words

Rice production, water scarcity, mitigation, aerobic system, flooded, water saving.

Introduction

Water is a looming crisis (IRRI 1995) due to competition among agricultural, industrial, environmental and domestic users. By 2025, 30% of the human population would be threatened by water scarcity (CGIAR News April 2003) because worldwide, 70% of water withdrawals is used in irrigated agriculture (Rosegrant 1998). In Asia, more than 50% of irrigation water is used to irrigate rice (Barker et al 1999). A growing scarcity of fresh water will pose problems for rice production in future years. Hence, shifting gradually from traditional rice production system to growing rice aerobically, especially in water scarce irrigated lowlands, can mitigate occurrence of water related problems.

In 2001, IRRI started experimenting on aerobic rice for the Asian tropics (IRRI 2001) to quantify the water savings potential of aerobic cultivation of rice and to evaluate the performance, yield stability, and water productivity of tropical varieties under a continuous aerobic conditions.

Methods

Experimental design and layout

The experiment was laid out in a split-plot design with four replicates (Table 1). Three water treatments were implemented as main plots: (1) aerobic conditions in the DS and the WS (AA), (2) aerobic in the DS but flooded in the WS (AF), and (3) flooded in both the DS and the WS (FF). The flooded plots were puddled and kept continuously flooded after transplanting until 2 weeks before harvest. The water depth was initially 2 cm and gradually increased to 10 cm at full crop development. The aerobic plots were dry-plowed and harrowed. The soil was soaked a day before transplanting and then flooded for about a week with 2-3 cm water layer to ease the establishment of the crop. After that, flash irrigation was applied when the soil moisture tension at 15 cm depth reached –30 kPa. No standing water except for the day of irrigation and during severe rainfall.

Table 1. Experimental Design: Split-plot with four replicates

Treatment	Soil	Crop year/season			
	condition	2001 DS	2001 WS	2002 DS	2002 WS
Main plot :	A-A *	Aerobic rice in both seasons			
Water management	A-F	Aerobic in dry season and flooded in wet season			
	F-F**	Flooded rice in both seasons			
Sub-plot:	V1	IR43	IR43	IR43	IR43
Variety	V2	B6144F	IR73868H	IR64	Magat
	V3+N	Apo (with N)	Apo (with N)	Apo (with N)	Apo (with N)
	V3-N	Apo (zero N)	Apo (zero N)	Apo (zero N)	Apo (zero N)
	V4	none	none	Magat	none

*Aerobic rice (A) - tensiometer reading from -30-50 kPa
**Flooded rice (F) - 2-10 cm water depth

Water parameter measurements

Irrigation water was supplied at the center of each main plot through a 6-inch PVC pipes that were connected to the station's underground pressurized irrigation system. The water spilled from the pipes into a 90-degree boxed weirs (V-notch type)after which it got equally distributed among the four subpplots. The amount of water applied was monitored at each irrigation by measuring the depth h *(cm)* of water over the V-notch. The dischage Q (lps) was computed using the equation by Hansen et al (1980): $Q=0.0138 \times h^{2.5}$

Results

Water savings were realized under aerobic rice compared to flooded rice in both the land preparation and crop growth period (Table 2).

Land preparation

The amount of irrigation applied in 2001WS in flooded conditions was 358 mm and in aerobic only 53 mm, a 75% savings in irrigation water. In 2002 DS, flooded rice used 303 mm of irrigation water and 89 mm in aerobic, a 70% saving. In 2002WS, irrigation use was 222 mm in flooded and only 85 mm in aerobic rice, again a saving of 62%. An average irrigation water savings of 70% was realized in aerobic rice that is attributed to the reduction in evaporation, seepage and percolation losses.

Crop growth stage

In the 2001 DS, irrigation water use in the flooded condition was 1148 mm and only 431 mm in the aerobic condition, a 62% savings in irrigation water. In 2001WS, 574 mm was used in flooded conditions and only 89 mm in aerobic, a high savings of 84%. In 2002DS, irrigation water use in flooded was 911 mm compared to 702 mm in aerobic, a 23% savings. In 2002WS, an irrigation water of 508 mm was used in flooded and 225 mm in aerobic conditions, an irrigation water savings of 56%. On the average, 60% water savings was attained because of significant contribution from rainfall, which was more than 80% of total, and effectively utilized through irrigation suspension. Limited irrigation was needed in aerobic conditions because the soil was generally at saturation throughout the growing season. Irrigation water was delivered only during the first 10 days for crop establishment and to dissolve applied chemical fertilizers for immediate uptake of rice crop. On the other hand, irrigation water was always needed in the flooded conditions to maintain the designed standing paddy water depth causing high water losses through seepage and percolation. In the dry seasons, irrigation water was directly saved through limited irrigation applications. The soil was allowed to reach a minimum soil moisture tension of –30 kPa before irrigation. With this tension, the soil is dry but within the range of –30 to –50 kPa, which is considered a threshold value for crop damage.

Table 2. Water balance components in aerobic and flooded treatments.

Farming activity/ seasons	**Irrigation applied** (mm)	**Rainfall depth** (mm)	**Total water input** (mm)	**Evapo-transpiration** (mm)	**Percolation loss** (mm)	**Seepage loss** (mm)
Flooded 2001 DS						
Land preparation	nm	2	2	nm	nm	nm
Crop growth period	1148	222	1370	547	128	695
Flooded 2001 WS						
Land preparation	358	76	434	92	nm	nm
Crop growth period	574	751	1325	554	62	709
Aerobic 2001 DS						
Land preparation	nm	2	2	-	-	-

Crop growth period	431	222	653	-	-	-
Aerobic 2001 WS						
Land preparation	89	29	118	-	-	-
Crop growth period	53	751	804	-	-	-
Flooded 2002 DS						
Land preparation	303	4	307	91	nm	nm
Crop growth period	911	58	969	609	59	301
Flooded 2002 WS						
Land preparation	222	38	260	84	nm	nm
Crop growth period	508	991	1499	572	60	867
Aerobic 2002 DS						
Land preparation	89	0	89	-	-	-
Crop growth period	702	58	760	-	-	-
Aerobic 2002 WS						
Land preparation	85	0	85	-	-	-
Crop growth period	225	991	1216	-	-	-

nm - not measured

Yield and yield decline

There was a yield reduction of 27-29% during the DS when shifting from a flooded to aerobic environment and 20% during the WS (Table 3). The smaller reduction in the WS was due to comparable soil moisture conditions because of uniform rainfall contributions.

Table 3. Yields in aerobic rice compared to flooded rice.

Variety	Dry season			Wet season		
	Flooded (t/ha)	Aerobic (t/ha)	Yield loss (%)	Flooded (t/ha)	Aerobic (t/ha)	Yield loss (%)
2001						
Apo	5.06	4.36	14	5.19	4.19	19
IR43	5.9	3.56	40	4.78	4.1	14
B6144F	3.85	2.55	34	-	-	-
IR73868H	-	-	-	5.22	3.88	26
IR64	-	-	-	-	-	-
Magat	-	-	-	-	-	-
Mean	**4.94**	**3.49**	**29**	**5.06**	**4.06**	**20**
2002						
Apo	7.33	5.66	23	4.99	3.49	30
IR43	6.59	5.19	21	3.12	2.92	6
B6144F	-	-	-	-	-	-
IR73868H	-	-	-	-	-	-
IR64	7.08	4.69	34	-	-	-
Magat	8.66	6.03	30	6.02	4.61	23
Mean	**7.42**	**5.39**	**27**	**4.71**	**3.67**	**20**

Conclusion

Flooded rice used three times more irrigation water than aerobic rice for land preparation and twice during the crop growth period. These savings in irrigation water in aerobic rice can be translated into a larger rice area served during the DS. Grain yields under aerobic conditions were lower compared with flooded conditions, which is a clear trade-off. Development of aerobic rice that suits aerobic conditions is, therefore, needed to contribute in mitigating water scarcity and increase water productivity.

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