Characterization of Water Availability, Management Practices and Grain Yield for Deepwater Rice in Northwest Cambodia

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Abstract

This study aimed to characterize rice area from the shallower (lower toposequence of) rainfed lowlands side to the deeper floating rice side in Northwest Cambodia during wet season rice (WSR) production in 2009 and 2010 for the yearly and spatial differences in field water conditions, management practices and grain yield. This area considered as deepwater rice (DWR) area was divided into three groups with (1) upper fields located near the National Road Number 5 (referred as ULR); (2) middle fields (referred as MLR and MFR where lowland rice (LR) and floating rice (FR) were planted, respectively); and (3) lower fields located near to the Lake (referred as LFR). Water came to the paddy fields from both the inundation from Tonle Sap Lake and rainfall in WSR 2009, but only from rainfall in WSR 2010. Water depths increased from upper to lower fields in 2009, while they were shallower and relatively similar between the field locations in 2010. Broadcasting time started earlier and harvesting time finished later in FR fields than in LR fields. The overall average grain yield for both years of 2009 and 2010 was low. The lowest yields were observed in MLR and MFR in 2009 as well as they were in MFR and LFR in 2010. Lower yield in WSR 2009 was mainly due to the water shortage at heading stage for both FR and LR, improper application of N fertilizer and insufficient weed management for LR, and late sowing for FR. Lower yield in WSR 2010 was mainly due to low water level for FR, low N fertilizer rate and insufficient weed management. This study identified important spatial and yearly variation in rice management and grain yield for farmers to cope with unpredictable flooding environments in DWR area.

Keywords: Cambodia, deepwater rice, flooding pattern, rice type

Introduction

In Cambodia, deepwater rice (DWR) areas are located in the provinces near to the Tonle Sap Lake, the Mekong River, and Tonle Bassac River. In 1960s, the DWR area occupied up to 16% of Cambodia's rice land (about 400,000 ha) (Javier, 1997; Seng *et al,* 1988). However, as the discouragement of growing DWR during Pol Pot regime, DWR area decreased sharply and it was only 120,000 ha in 1988 (Seng *et al.,* 1988). DWR presented 3.9% of the cultivated area in 2006 (MAFF, 2006). Cambodian's Tonle Sap Lake (TSL) floodplain is well known for its unique dynamic flooding pattern between dry and rainy season. Volume of the Lake ranges from about 1.3 to 75 km^3, its surface area varies from 2,500 to about 15,000 km^2, and its water level increases from 1.4 to 10.3 m above sea level, between dry and rainy season (MRC, 2010a). DWR is important source of livelihood to many poor villages in the TSL floodplain that do not have access to better agricultural land higher up. There is a need to further increase the productivity of DWR in order to improve the local farmers' livelihood and to conserve the DWR area. However, necessary information for yield improvement in DWR area such as flooding pattern, land use pattern, management practices in Cambodia are not sufficient. We conducted a study to quantify the yearly and spatially difference in field water condition in DWR area in Northwest Cambodia, and to assess rice management practices and grain yield in the area.

Materials and Methods

The study was carried out at a DWR area inside a flood plain area of TSL located in Kampong Preah village, Kampong Preah commune, Sangke district, Battambang province, Northwest Cambodia in 2009 and 2010. Eighty five fields (91.2 ha in planting area) were selected which were located continuously along a transect line from a toposequentially upper zone nearby National Road Number 5 toward TSL. These 85 fields were divided into three groups according to their field locations : (1) upper fields located closer to the National Road Number 5 where only LR was grown (19 fields; 11.4 ha) and referred as ULR; (2) middle fields where both LR and FR were grown (19 fields; 31.6 ha) and referred as either MLR or MFR; and (3) lower fields located near to the Lake where only FR was grown (37 fields; 48.2 ha) and referred as LFR. Variety, field size and type of rice were determined for the 85 fields in WSR 2009 and 2010. Thirty fields within the 85 fields were selected from each field group; sowing time, mid-season tillage practice, fertilizer input, pest control and grain yield were determined by the interviews to the owners in ending time of each WSR.

Results and Discussion

Field water environment

Field water regime of the studied area in WSR 2009 was completely different from that in WSR 2010 (Figure 1). In WSR 2009, water came to the fields from both the inundation from the Tonle Sap Lake and rainfall. Flood started earliest in lower fields in September, then middle and upper fields afterward. Flood started receding to the Lake in late October and rice fields became non-flooded conditions in middle fields and upper fields in late November and in lower fields in early to mid December. There was large difference in water depth between the 3 field locations in 2009. Rice ecosystems of the three locations could be classified as DWR for middle and lower fields and medium-deep rainfed lowland rice for upper fields (Mackill *et al*., 1996). In WSR 2010, water came to the fields only from the rainfall; field water regime was relatively similar to all the 3 field locations with the average maximum water depths less than 30 cm in mid October. These water conditions in 2010 were more favorable for rainfed lowland rice than floating rice. Low water level in Tonle Sap Lake leading to shrink floodplain area in 2010 was probably due to extremely low water level in Mekong River (IRIN news, 2010) which was caused likely by a combination of an early end to the 2009 wet season, low monsoon rainfall and very low rainfall in the dry season in upper Mekong Basin (MRC, 2010b).

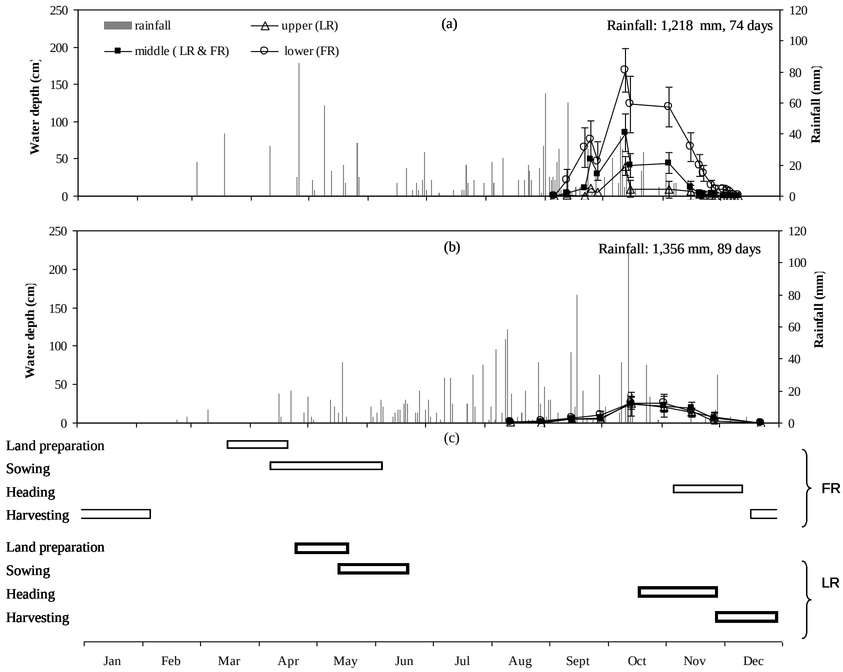
Management practices

Crop calendar

Planting season for FR fields is earlier than that for LR fields. For FR fields, farmers start land preparation from early March to late April (Figure 1). Dry seeds with rate of about 100 kg ha^{-1} are broadcasted mainly from early April to early May. Farmers sometimes have to broadcast seeds for the second time in late May or early June if rice establishment failed due to drought. For LR fields, land preparation is often from mid April to mid May. Dry seeds with higher rate in comparison with FR (150 kg ha^{-1}) are broadcasted from mid May to mid June. Rice is harvested from early December to early February in FR fields and from late November to early January in LR fields, both depending on maturity type of rice varieties.

Distribution of rice type and varieties

LR and FR were both grown in the studied area in the both WSR 2009 and 2010. In general, early medium varieties of LR were only planted in upper fields while medium varieties of LR were planted in both upper and middle fields. Early varieties of FR were only planted in middle fields while medium and late varieties of FR were planted in both middle and lower fields. In comparison between WSR 2009 and 2010, there was a small change in the area ratio of LR and FR in middle area. Area of LR decreased from 38% in WSR 2009 to 30% in WSR 2010 but area of FR increased from 62% in WSR 2009 to 70% in WSR 2010. Among the varieties planted in the studied area, early varieties of FR in the middle area had the largest increase in area percentage, from 22% in WSR 2009 to 47% in WSR 2010.



(a) and WSR 2010 (b), and cropping calendar for FR and LR (c) in the studied area. The error bars indicate standard deviations.

Figure 1. Rainfall distribution and water depth in the 3 field locations (upper, middle and lower) in WSR 2009.

Relationship between grain yield, environmental and management factors

In WSR 2009, grain yields of ULR and LFR (120 and 164 g m^{-2}, respectively) were significantly higher than those of MLR and MFR (50 and 56 g m^{-2}, respectively). However, grain yields of ULR and MLR (both 262 g m^{-2}) were significantly higher than those of MFR and LFR (87 and 111 g m^{-2}, respectively) in WSR 2010.

Average grain yield of both WSR 2009 and 2010 was low with only 180 g m^{-2} for LR and 110 g m^{-2} for FR. The lowest yields were observed in MLR and MFR in WSR 2009 which was due to risky water environments in middle fields. With maximum water depth of 85 cm and absence of standing water after late November (Figure 1), the water condition in this area was too deep for LR for a possible submergence damages and insufficient for medium and late maturing FR to maintain good grain filling. This was also supported by the positive correlation between maximum water depth and grain yield for FR and negative correlation between those for LR (Table 1). Farmers responded to this risky water condition by changing rice type/varieties from year to year based on yield obtained from previous year. The increase in area of early variety of FR in WSR 2010 was due to that farmers observed that yields of early variety of FR in middle fields were higher than other varieties of LR and FR in this area (data not shown).

Low yield in WSR 2009 was mainly due to (1) the water shortage at heading stage for both FR and LR, (2) non- or late application of N fertilizer for LR, (3) insufficient weed management for

LR and (4) late sowing for FR (Table 1). (1) Due to low rainfall occurring at pre-flood period (June to August; Figure 1a) in WSR 2009, rice plants suffered drought stress leading to delayed heading, mainly from late November to mid December while there was also low rainfall in the late season. This caused the shortage of water at heading stage of 10 out of total 29 fields. Those fields where rice plants did not suffer drought at late stage were mainly located in lower part, or bunded with high levees, or pumped water from the water source nearby. This indicated that well-water management, especially at heading stage, is crucial to improve yield in DWR area, particularly in middle and upper fields. (2) In WSR 2009, LR plants were likely submerged during high flood (40 cm in upper fields and 85 cm in middle fields), growing situation of rice plants before flood commence was very crucial for gaining high grain yield. Taller and more vigorous rice plants, which could be improved by basal application of N fertilizer (before flood commence), were able to withstand submergence and hence gave higher yield and this was also indicated in Puckridge (1991). It was suggested that rice plant should be able to uptake more than 20 kg N ha^{-1} before onset of flooding in order to reduce yield loss due to submergence (Puckridge, 1991) while Sharma and Gosh (1998) reported that optimum basal fertilizer rate for semi-deep water environment was 30 kg N ha^{-1}. The average N fertilizer applied in LR field in WSR 2009 was less than half of this recommendation rate (4-15 kg N ha^{-1}; data not shown). (3) Our study showed that conducting midseason tillage practice, a weed control method, helped to improve yield of LR in WSR 2009. All of LR fields were conducted the practice in WSR 2010 while about half of LR field number were not conducted in WSR 2009, which was perhaps due to water constraint (drought or flood at the time farmers wanted to do the practice). (4) Late sowing significantly decreased yield of LFR. High rainfall occurred mainly from late April to mid May while only few rains with small amount occurred in June and July (Figure 1a). This might be the reason leading the poor establishment of crop with late sowing. When the flood arrived, this late sowing rice was likely more susceptible to the rapidly rising water in September. The importance of sowing in time was also mentioned by Catling (1983), Javier (1997) and Sing *et al*. (2004).

Table 1. Correlation between rice yield and water condition, management factors of LR and FR in WSR 2009 and WSR 2010

Items	WSR 2009		WSR 2010	
	LR (n=13)	FR (n=16)	LR (n=13)	FR (n=17)
Water condition				
max WD (cm)	-0.784***	0.679***	0.374	0.326
flooded at heading stage (n=29) [a]	0.715***			
Sowing time (DOY)	0.145	-0.345*	-0.269	0.157
Fertilizer management				
fertilizing before flood commence [b]	0.581**		0.386	
N fertilizer (kg ha^{-1})	0.331		0.504*	
Weed management				
conducting mid-season tillage [c]	0.492*			
plowing for mid-season tillage [d]			0.653**	
herbicide (g a.i. ha^{-1})	0.253	-0.400*	-0.193	0.628***

*P<0.1; **P<0.05; ***P<0.01

[a] values for flooded at heading stage and those for other water conditions at heading were 1 and 0, respectively, as a dummy variable

[b] values for inorganic fertilizer applied before flood commence and those for not applied or after flood commence were 1 and 0, respectively, as a dummy variable

[c] values for conducting mid-season tillage and those without the practice were 1 and 0, respectively, as a dummy variable

[d] values for conducting mid-season tillage by plowing and those for conducting the practice by harrowing were 1 and 0, respectively, as a dummy variable

Low yield of FR in WSR 2010 was mainly due to low water level as the discussion at beginning of this section. Beside that insufficient weed control was also another reason. Higher application rate of herbicide was applied in WSR 2010 in comparison with that in WSR 2009 and low application rate of herbicide significantly reduced yield of FR in WSR 2010 (Table 1). This was because that weed infestation was more severe throughout the crop season due to the low water level in WSR 2010 while FR fields were not conducted midseason tillage for controlling weed like LR. Different from WSR 2009, water condition in WSR 2010 was more favorable for growing LR like in rainfed lowland environment. Therefore, yield of LR in WSR 2010 could be further improved by conducting midseason tillage with plowing for controlling weed (Table 1) and increase application rate of N fertilizer. The N fertilizer rate applied this WSR was only about one third of the recommendation rate for rainfed lowland rice in drought or submerged prone area with rate of 60 kg ha^{-1} (Balasubramnian and Hill, 2002). However, it should be noticed that field water environment in WSR 2010 was not representative for most years in the studied area.

In short, it is risky for farmers to attempt to increase planting higher yielding lowland rice in the middle part of the floodplain of TSL, due to the occurrence of deep flood incidence, but farmers could miss chances of higher yield if planting traditional floating rice varieties just to escape from submergence damage. It is desirable if information on water situation in the area is informed to farmers by a long-term weather forecast before the cropping season (February or March). So that farmers will be able to make a right decision of selecting rice type/variety to grow in the area. Beside that early maturity varieties with higher yield potential and tolerance to submergence (suitable for medium-deep water area) can be introduced in to the area in order to improve grain yield in a sustainable manner.

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