Field Crops Research 144 (2013) 62–68

Contents lists available at SciVerse ScienceDirect

Field Crops Research

journal homepage: www.elsevier.com/locate/fcr

Integrating best management practices for rice with farmers' crop management techniques: A potential option for minimizing rice yield gap

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ARTICLE INFO

Article history:
Received 5 October 2012
Received in revised form 16 January 2013
Accepted 16 January 2013

Keywords:
Rice–rice cropping system
Yield gap
Productivity
Net profit
Leaf color chart

ABSTRACT

The major cereal cropping system in Bangladesh is rice (*Oryza sativa* L.) in the dry season (Boro) – rice in the wet season (Aman). The average productivity (7 t ha^{-1}) of this system is far below attainable yields (14 t ha^{-1}) in farmers' fields, resulting in a large yield gap mainly due to farmers' traditional management practices. We evaluated a set of selected best management practices (BMP) along with two N management options in the farmers' crop management practices for rice in numerous farmers' fields across 24 villages over 5 contiguous seasons during 2006–2008. Across years, BMP and two N management options increased grain yields compared with the farmers' practice (FP) by 0.73 t ha^{-1} in both Aman and Boro seasons. The higher yield response (24.6% in Aman and 8.6% in Boro season) occurred with BMP in combination with leaf color chart (LCC) aided N management (BMP–LCC) than BMP with Urea Super Granule as N source (BMP–USG). Best management practices and two N management options reduced the yield gap of FP by 45%, with an average of 1.5 Mg ha^{-1}. The average added net returns with BMP were US$22 to US$120 ha^{-1} in the wet season and US$93 to US$115 ha^{-1} in the dry season. Our study shows that the integration of BMP and either LCC-aided N management or USG as an N source with the farmers' management techniques and its adoption has the potential to boost rice yield and profit and total rice production in Bangladesh.

1. Introduction

Rice is a staple food and accounts for more than 40% of the calorie supply of most Asians (IRRI, 2008). About 90% of the world's rice is grown and produced (142 million ha area with production of 622 million tons) in Asia (FAO, 2010). Economically disadvantaged people spend as much as 30–40% of their income just to buy rice (IRRI, 2008). Increasing the amount of rice production and keeping the rice price low and affordable to them are crucial for poverty reduction. Rice yield must continue to increase at an annual rate of 1.5% compared with the current rate of 0.8% to keep pace with the expected demand (Aureus, 2011). Like in many other Asian countries, rice is the staple food in Bangladesh and it contributes one-half of the agricultural GDP and 55% of the total labor employment (Bangladesh Economic Review, 2009). During the last 20 years, Bangladesh has increased rice production 1.8 times with almost no increase in its land area of about 11.7 million ha (FAO, 2012). However, because of the continuous increase in population growth, rice demand in 2050 is projected to be 56% higher than in 2001 (Mukherjee et al., 2011). This is going to be doubly challenging in light of the diversion of better quality land, water, and labor to other sectors of the national economy. Evidence is now appearing that the productivity of rice–rice and rice–wheat systems is plateauing because of a fatigued natural resource base (Ladha et al., 2003; Pathak et al., 2003). The productivity and sustainability of rice-based cropping systems are threatened because of (i) the inefficient use of fertilizer, water, and labor; (ii) increasing scarcity of water and labor; (iii) changing climate; (iv) emerging energy crisis and rising fuel prices; and (v) emerging socioeconomic changes such as urbanization, migration of labor, and preference for nonagricultural work (Ladha et al., 2009). In addition, recent increases in the prices of farm inputs in relation to outputs, fewer off-farm work opportunities for supplementing farm income, reduced remittances from relatives working outside villages, and declining income and purchasing power of poor consumers have threatened the existence of rice producers and consumers (Ladha et al., 2009).

Bangladesh produced about 50.1 million tons of rough rice from 11.7 m ha of land in 2010 with a productivity of 4.3 t ha^{-1} (FAO, 2012). The present productivity is far below the attainable yield of 8–10 t ha^{-1} in the dry season (Boro) and 5–6 t ha^{-1} in the wet season (Transplanted Aman) in farmers' field experiments (BRRI, 2007, 2008, 2009, 2010). This difference in yield in farmers' fields between farmer-managed and researcher-managed trials is

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http://dx.doi.org/10.1016/j.fcr.2013.01.010

mainly due to the differences in management practices adapted by researchers and farmers. The causes of such a yield gap are classified into two broad categories: (i) biotic factors such as poor-quality seeds and seedlings, insects, diseases, weeds, and rodents; and (ii) abiotic factors such as soil, nutrients, and water. However, a large portion of this yield gap remains unexplained.

Given the continuously increasing population, coupled with scarcity of land, water, labor, and energy, Bangladesh is under tremendous pressure to increase, by all possible means, rice production. Since the possibility of expanding rice area is limited, the extra rice production must come from productivity increases. The major challenge is to minimize or bridge the yield gap in farmers' fields and increase productivity with less water, less agro-chemicals, and less labor, thereby making rice farming more profitable and sustainable in the long term. An adequate understanding and the development of appropriate practical technologies to minimize the causes of the yield gap are critical for meeting the challenges of continued gains in rice production, without degrading the natural resource base.

Minimizing the yield gap and increasing profit and product quality are becoming increasingly difficult to achieve by using a single-technology-centric approach. The use of a component technology in isolation also has limited widespread adoption. Combining and simultaneously applying a number of the best compatible individual or component technologies is crucial for maximizing overall benefits to farmers. Depending on the need and profitability of new technologies, farmers generally integrate new technology with the cultural practices being practiced by them on their farms. This process of integrating new technologies with existing farmers' practice has been referred to as integrated crop and resource management (ICRM) or best management practices (Ladha et al., 2009). The choice or selection of the best individual or component technologies in an integrated manner is crucial for achieving the full benefit. The integration of best component technologies should (i) ensure timely crop establishment and uniform crop stands, resulting in higher crop yields; (ii) enhance resource- or input-use efficiency; (iii) provide immediate, identifiable, and demonstrable economic benefits; and (iv) reduce adverse effects on the environment and build up soil fertility over the long term. This study therefore evaluated a set of selected best management practices integrated with the farmers' management techniques in rice for productivity and profitability in many farmers' fields over five seasons during three years.

2. Materials and methods

2.1. Experimental sites and seasons

On-farm trials were conducted in a continuous rice–rice cropping system for five consecutive seasons during 2006–2008 at 24 villages located within a radius of 50 km in central Bangladesh. Number of selected villages were 14 in Kapasia Upazila ($23^{\circ}55'$ to $24^{\circ}12'$N and $90^{\circ}29'$ to $90^{\circ}43'$E) of Gazipur District, 4 in Pakundia Upazila ($24^{\circ}16'$ to $24^{\circ}0'$N and $90^{\circ}46'$E) of Kishoreganj District, and 6 in Monohardi Upazila ($24^{\circ}03'$ to $24^{\circ}16'$N and $90^{\circ}38'$ to $90^{\circ}49'$E) of Narshingdi District (Table 1). The villages which represent common cropping systems, farmers' management practices, land types, and soil types were selected. Each village had 800–1500 farm families. All the villages in Gazipur District belong to Agro-Ecological Zone (AEZ) 28 (Madhupur Tract), AEZ 8 (Young Brahmaputra and Jamuna Floodplains), and AEZ 9 (Old Brahmaputra Floodplain), whereas the villages in Kishoreganj District belong to AEZ 8 and AEZ 9 and those in Narshingdi District belong to AEZ 9. The soils are (a) well drained friable clay loam to clay or heavy clay, strongly acidic, mainly phosphate fixing, low in P, K, S, and B in AEZ – 28, (b) permeable silt loam to silty clay loam, neutral to slightly acidic, deficient in N, P and S but medium in K and Zn status in AEZ – 8, and (c) silt loam to silty clay loam, moderately acidic to neutral, with low K and medium P status in AEZ – 9 (FRG, 2005).

Table 1
Locations and number of farmers' fields where the trials were conducted in central Bangladesh in Aman and Boro seasons during 2006–2008.

Location			Number of farmers' fields				
District	Upazila	Village	Aman 2006	Boro 2007	Aman 2007	Boro 2008	Aman 2008
Agro-ecological zone (AEZ) – 28, AEZ – 8 and AEZ – 9							
Gazipur	Kapasia	Saluateki	9	14	33	19	15
		Sultanpur	29	32	28	49	48
		Tokenagar		29	20	34	42
		Borjapur		31	15	17	
		Shahartoke		23	12	13	
		Bagua				7	
		Baraigao				7	
		Barapusia				7	
		Pabur				7	
		Roynanda				7	
		Sonaroa				7	
		Uttarkhamer				7	
		Gosherkandi					31
		Aralia					25
AEZ – 9							
Narshingdi	Monohardi	Harordia				20	10
		Kachikata				20	6
		Kathalia					16
		Hatirdia					10
		Kocherchar					10
		Dosdona					10
AEZ – 8 and AEZ – 9							
Kishoreganj	Pakundia	Kodalia					10
		Egarasindur					10
		Motkhola					15
		Meratala					5
Total			38	129	108	221	263