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Review

Improvement of cereal-based cropping systems following the principles of conservation agriculture under changing agricultural scenarios in Bangladesh

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ABSTRACT

In the Eastern Gangetic Plains of Bangladesh, the cropping systems are predominantly rice based, having large yield gaps in farmers' fields because of poor management practices adopted by farmers. The increasing scarcity of resources (water, labor and energy) and production costs further make the rice-based cropping system less sustainable and less profitable. We hypothesized that integrating the best compatible cropping patterns accompanied by best management practices into the portfolio of farmers' own technologies would improve system productivity, resource use efficiency and economic profitability. To test this hypothesis, we evaluated four cropping system scenarios (S1–S4) designed to be adapted to current and future drivers of agricultural changes and varying from each other in best management practices (BMPs) and conservation agriculture (CA) principles (tillage and crop establishment, residue management, and crop rotation). Four cropping system scenarios were (i) current farmers' practice (S1), (ii) BMPs with conventional tillage and farmers' crop rotation (S2), (iii) BMPs with reduced tillage and farmers' crop rotation (S3), and (iv) BMPs with reduce or zero tillage and crop diversification (S4). Scenario 2 alone compared with S1 increased system productivity (24–33%), total water productivity (16–50%) and net economic returns (85–169%), and decreased specific energy (11–17%). The combination of BMPs in S2 with reduced tillage and manual or mechanical transplanting (S3) did not further increase yield and save water. Crop diversification with potato in place of Boro rice and intensification with maize or mung-bean in between Boro and Aman rice (S4) yielded 1.9–3.7 times higher net economic returns than S1. Results of a three-year study indicated that farmers' productivity and economic returns can be improved by BMPs, which not only increase crop yields but also improve the efficiencies of resources such as water and energy.

Contents

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1. Introduction

In South Asia, rice, wheat and maize are the major cereal crops grown often in rotation with non-cereal crops such as potato, mustard and legumes (Balasubramanian et al., 2012). Among them, rice and wheat provide the staple food for hundreds of millions of people. Maize is mainly a feed crop but it is also a food crop in many poverty-stricken areas, especially in the hilly areas. These crops greatly influence the livelihoods and health of the urban and rural poor in these regions. Cereal production needs to increase by about 2% per annum over the next four decades to ensure food security in South Asia (Ray et al., 2013). National mean yields of these cereals in South Asia are below global averages except for maize in Bangladesh, and large yield gaps of about 50% or more exist (Balasubramanian et al., 2012). Since there is little or no scope for expanding the area under cultivation in South Asia, further intensification of land use together with increases in crop productivity and production are the options to meet the growing demand.

In Bangladesh, rice is the major staple food crop grown on 80% of the cultivated land area sometimes in rotation with other crops, contributes 19.6% to the gross domestic product (GDP) and provides employment for 63% of the country's population (Gumma et al., 2012). Bangladesh has increased rice production 1.8 times during the last 20 years with almost no increase in rice area (FAO, 2012). However, because of the continuous increase in population, rice demand is projected to be 56% higher in 2050 than in 2001 and demand for other dominant cereals such as maize and wheat is projected to be more than 10 times and twice, respectively, in 2050 (Mukherjee et al., 2011).

Cropping patterns in Bangladesh are largely rice-based, comprising rice–non-rice crops (34% of rice area), rice–rice–non-rice crops (37% of rice area), rice–rice (21% of rice area), rice–rice–rice (6% of rice area) and rice alone (2% of rice area) (Gumma et al., 2012). The major non-rice crops in these cropping systems are wheat, potato, maize, pulses, oilseeds and jute. Rice is mostly established by transplanting seedlings into puddled soil, and the field is kept continuously flooded for much of the growing season. Non-rice crops are established into dry soil prepared by intensive dry tillage. These conventional practices of land management and crop establishment are labor and water intensive which are becoming scarce and expensive resulting in sharp increases in cost of cultivation (Kumar and Ladha, 2011). In addition, the national average rice yield is much lower than what has been achieved by researchers and progressive farmers. In 2010, national average was 4.3 Mg ha^{-1} (FAO, 2012) which is far below the reported yields of 8–10 Mg ha^{-1} in the dry season (Boro) and 5–6 Mg ha^{-1} in the wet season (Aman) (BRRI, 2010). This yield gap in farmers' fields is mainly due to the differences in management practices adopted by farmers and researchers. The causes of large rice 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 poor management of nutrients and water. However, a large portion of this yield gap remains unexplained.

The development and understanding of appropriate practical technologies to bridge the yield gap are critical for meeting the future rice demand with less inputs (i.e. water, labor, agrochemicals). There is a need of highly productive, resource efficient and sustainable crop rotations and management practices that are adapted to the changes in agricultural, socioeconomic and climatic environment. Integrating the appropriate crop rotation accompanied by BMPs and CA into the portfolio of farmers' own technologies is crucial for maximizing productivity and economic benefits to the farmers (Ladha et al., 2009).

Systematic studies integrating BMPs with CA in the key cropping systems adapted to the changes within and outside of agricultural environment are lacking in the region. Such studies are important for extrapolation to broader geographical levels. Therefore, a production-scale field trial guided by key scenarios of agricultural environment was designed and established in four locations in the key agro-ecosystems of South Asia. Recently, the responses of various management practices in the rice–wheat system, which is predominant in two major agro-ecosystems (western and central) of the Indo-Gangetic Plains (IGP) were reported (Gathala et al., 2013; Laik et al., 2014). However no systematic studies have been carried out in the Eastern IGP which is home to the world's highest rural population density. Cropping patterns are largely rice-based with large potential of intensification and diversification and therefore is envisioned to supply future demand of food grains. As part of this comprehensive study, here we report the performance of rice–rice rotation during the three years, at Gazipur, Bangladesh, a part of the Eastern IGP. Using a range of indicators related to yield, economics, and input (water, labor, energy) usages and their