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Review

A review of resource conserving technologies for sustainable management of the rice–wheat cropping systems of the Indo-Gangetic plains (IGP)

Raj Gupta[a], Ashok Seth[b,*]

[a]*Rice–Wheat Consortium for the Indo-Gangetic Plains, CIMMYT India, NASC Complex, Pusa, New Delhi, India*
[b]*ARD Consultants Ltd., Whitedown Lane, Alton, Hampshire, UK*

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Abstract

Rice and wheat are the staple food crops occupying nearly 13.5 million hectares of the Indo-Gangetic plains (IGP) of South Asia covering Pakistan, India, Bangladesh and Nepal. These crops contribute more than 80% of the total cereal production and are critically important to employment and food security for hundreds of millions of rural families. The demand for these two cereals is expected to grow between 2% and 2.5% per annum until 2020, requiring continued efforts to increase productivity while ensuring sustainability. Starting from the 1960s, expansion of area and intensification of rice–wheat productions system based on the adoption of Green Revolution (GR) technologies, incorporating the use of high-yielding varieties, fertilizers and irrigation, led to increased production and productivity of both these crops. However, continued intensive use of GR technologies in recent years has resulted in lower marginal returns and, in some locations to salinization, overexploitation of groundwater, physical and chemical deterioration of the soil, and pest problems. This paper presents findings from recent research on resource conservation technologies involving tillage and crop establishment options that are enabling farmers to sustain productivity of intensive rice–wheat systems. Field results show that the resource conserving technologies, an exponent of conservation agriculture, improve yields, reduce water consumption, and reduce negative impacts on the environmental quality. The paper considers contributions of innovative inter-institutional collaboration in international agricultural research and socio-economic changes in the IGP countries that led to rapid development and adoption of these technologies by farmers.

Keywords: Crop establishment; RCT; Rice; Tillage; Water; Wheat

1. Introduction

In South Asia, Bangladesh, India, Nepal, and Pakistan, have devoted nearly half of their total land area of 401.72 million hectare (m ha) to feed and provide livelihoods for 1.8 billion people. Rice and wheat are the staple food crops and contribute more than 80% of the total cereal production. Over about 13.5 m ha of the Indo-Gangetic plains (IGP), spread over the four countries, these two crops are grown in rotation, with other crops such as maize, pigeon pea, sugarcane, and lentil substituting either the rice or wheat crop in some years (Ladha et al., 2000; Gupta et al., 2003; Hobbs and Morris, 1996; Woodhead et al., 1993, 1994; Timsina and Connor, 2001; Abrol et al., 2000; Razzaque et al., 1995; Huke et al., 1993a–c). The rice–wheat production systems are fundamental to employment, income, and livelihoods for hundreds of millions of rural and urban poor of South Asia (Paroda et al., 1994).

Despite priority given to rice and wheat research by the national institutions during the 1940s, 1950s and early 1960s, only limited advances were made in productivity. This, combined with unpredictable climatic conditions, meant that South Asia increasingly relied on imported food grains to feed its growing population. The 1960s also witnessed establishment of an international agricultural research system, known as the Consultative Group for

*Corresponding author.
E-mail addresses: r.gupta@cgiar.org (R. Gupta), aksth1@aol.com (A. Seth).

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International Agricultural Research (CGIAR). The institutions established by the CGIAR included the International Rice Research Institute (IRRI) and Centro Internacional de Mejoramiento de Maize and Trigo (CIMMYT) which gave major boost to international research on rice and wheat, respectively in close partnerships with the national institution, including those in South Asia. The major objective set for this innovative network of national and international working in close collaboration with each other was to develop new varieties of rice and wheat to improve productivity. Availability of new varieties, responsive to much higher rates of fertilizer use, and expansion of irrigation systems, led to dramatic increases in productivity and total production of rice and wheat in Asia during late 1960s, which continued through the 1970s, 1980s and early 1990s. Other contributing factors to increased production included: suitable thermal regimes for rice and wheat cultivation; expansion of land under rice–wheat cropping systems; and an increasing demand for staple cereals from the rising population with higher incomes. Although since the 1960s, the growth rate in the South Asian cereal production (on an average wheat 3.0%, rice 2.3% per annum) has kept pace with population growth (Pingali and Heisey, 1996), evidence is now emerging that continuous cultivation of rice and wheat is lowering soil fertility and organic matter content (Yadav et al., 1998), depleting ground water resources in tube-well irrigated areas (Gulati, 1999), exacerbating weed problem, including resistance to herbicide, (Malik and Singh, 1995; Malik, 1996; Malik et al., 1998), and pest problems (Pingali and Gerpacio, 1997). In addition, micro-nutrient deficiencies, e.g. zinc, boron, sulfur, have also started appearing as a serious concern (Nayyar et al., 2001). In view of the increasing threat to sustained incremental food production in the IGP, in 1994, the national and the international partners of the CGIAR established the Rice–Wheat Consortium (RWC) as an eco-regional initiative of the CGIAR. The main mandate of the RWC was address concerns related to sustainability of the rice–wheat production systems and to promote technologies that help farmers to reduce cost of production. This paper reviews the outcome of the work supported by RWC to develop resource conserving technologies (RCTs) and their benefits in terms of improved productivity, farm-gate incomes and potential for mitigation of adverse environmental impacts. The paper also examines the role played by different stakeholders in the rapid dissemination of RCTs.

2. IGP: agro-ecological conditions

The IGP comprises the Indus and the Gangetic plains covering Pakistan, India, Nepal and Bangladesh. In term of vegetation, IGP is a relatively homogeneous ecological region. The IGP has a continental monsoonal climate. In the northwest Indus and Gangetic plains, average annual precipitation ranges from 400 to 750 mm/yr and increases towards the Bay of Bengal. In the warm and humid easterly Gangetic plains, annual rainfall is as high as 1800 mm/yr. Nearly 85% of the total precipitation is received during the monsoon season from June to September. In the cooler (winter) months between November and February, only a few showers, which is the wheat-growing season (November–March). Rice is grown during the warm humid/sub-humid monsoon season (June–October). The calcareous alluvial soils of the semiarid northwest are micaceous and alkaline in reaction, whereas they are slightly acidic in the sub-humid/humid eastern region. Based on physiographic, bioclimatic, and social factors, the region can be subdivided into five broad transects as shown in Fig. 1 (RWC-CIMMYT, 2003; Rice–Wheat Consortium (RWC), 2005). A brief overview of these transects is given below:

- *Transect* 1 lies in the Pakistan Punjab, with a semi-arid climate, alluvial soils with gentle slopes and good drainage (with some pockets of alkali soils and low-quality groundwater).
- *Transect* 2 lies in the Indian States of Punjab, Himachal Pradesh and Haryana, with climate and soils similar to Transect 1, except for the topography, which is saucer-shaped, and the diversity of agro-ecosystems is greater. In parts of this transect, irrigated rice (in rotation with wheat) is grown on relatively light sandy loam/loam soils, and is established before the onset of the monsoon. This results in huge demands for irrigation water and correspondingly heavy exploitation of groundwater reserves to support high irrigation intensity. As a result, in the central areas of Punjab, for example, the groundwater table shows a decline of 20 cm/yr, with some places reaching a decline of 100 cm/yr.
- *Transect* 3 lies in parts of Haryana, western and central Uttar Pradesh, and the Terai regions of India and Nepal. It is characterized by a hot sub-humid climate, a saucer-shaped topography, and substantially more diverse agro-ecosystems. In parts of this transect, e.g., in areas surrounding Karnal in Haryana, irrigated

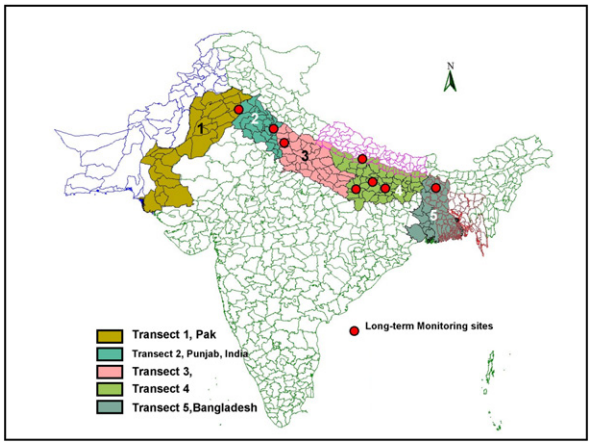

Fig. 1. Map showing the Indo-Gangetic Plains transects according to Rice–Wheat Consortium (source: RWC, New Delhi).