Field Crops Research 222 (2018) 111–120

Contents lists available at ScienceDirect

Field Crops Research

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

Conservation agriculture and precision nutrient management practices in maize-wheat system: Effects on crop and water productivity and economic profitability

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ARTICLE INFO

Keywords:
Tillage
Crop establishment
Residue management
Nutrient management
Maize-wheat rotation
Sustainable intensification

ABSTRACT

Excessive pumping of groundwater over the years to meet the high irrigation water requirement of rice-wheat system has resulted in over exploitation of groundwater in the Indo-Gangetic plains (IGP) of India. Replacement of traditional rice with less water crops such as maize under conservation agriculture (CA) based management (tillage, crop establishment and residue management) practices are required to promote sustainable intensification. Furthermore, inefficient nutrient management practices are responsible for low crop yields and nutrient use efficiencies in MW system. A 3-year field experiment was conducted in farmer's participatory strategic research mode at Taraori, Karnal, India to evaluate the effects of tillage and crop establishment (TCE) methods, residue management, mungbean integration, and nutrient management practices on crop yields, water productivity and profitability of MW system. The main plot treatments included four combinations of TCE, residue and mungbean integration [conventional tillage (CT), conventional tillage with mungbean (CT + MB), permanent bed (PB) and permanent bed with MB (PB + MB] with three nutrient management practices [farmer's fertilizer practice (FFP), recommended dose of fertilize (RDF) and site specific nutrient management (SSNM)] using Nutrient Expert® as sub plot treatments. System productivity, water use efficiency (WUE) and net returns under PB + MB were significantly increased by 28.2–30.7%, 27.8–31.0% and 36.8–40.5% compared to CT respectively, during three years of experimentation. Integration of MB in MW system contributed 24.9 and 27.6% increases in system productivity and net returns compared with no MB, respectively. SSNM based nutrient management increased the mean (averaged across 3 yrs) system productivity, WUE and net returns of MW system by 13.4%, 13.3% and 15.3% compared with FFP, respectively. Study showed that conservation agriculture based sustainable intensification (PB + MB) and SSNM approach provided opportunities for enhancing crop and water use efficiency, and profitability of MW system in North-West IGP of India.

1. Introduction

Rice (*Oryza sativa* L.) – wheat (*Triticum aestivum* L.) is the highly productive and dominant cereal based system in South Asia. However, its high productivity is at the cost of over-exploitations of natural resources (water and soil) with increasing air pollution (Ladha et al., 2003). Continuous pumping of groundwater over the years to meet the high demand for water by transplanted rice has resulted in a drastic decline in groundwater tables in North-West India (Humphreys et al., 2010; Yadvinder-Singh et al., 2014) leading to potential reduction in water availability for future cultivation. The detrimental effects of exploitative agriculture have given impetus to pursue alternative crops and cropping systems, which are more environmentally friendly and efficient in utilizing natural resources (Yadvinder-Singh et al., 2014). In the recent past the acreage under maize has shown increasing trends in north-western (NW) India mainly because of decreasing water table and electric supply as well as increasing cost of pumping water for rice (Sharma et al., 2015). Given the increasing economy and changing dietary pattern towards consumption of fast food, and growing piggery and poultry industry, the demand for maize in South Asia will surpass

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https://doi.org/10.1016/j.fcr.2018.03.025
Received 20 July 2017; Received in revised form 10 October 2017; Accepted 30 March 2018

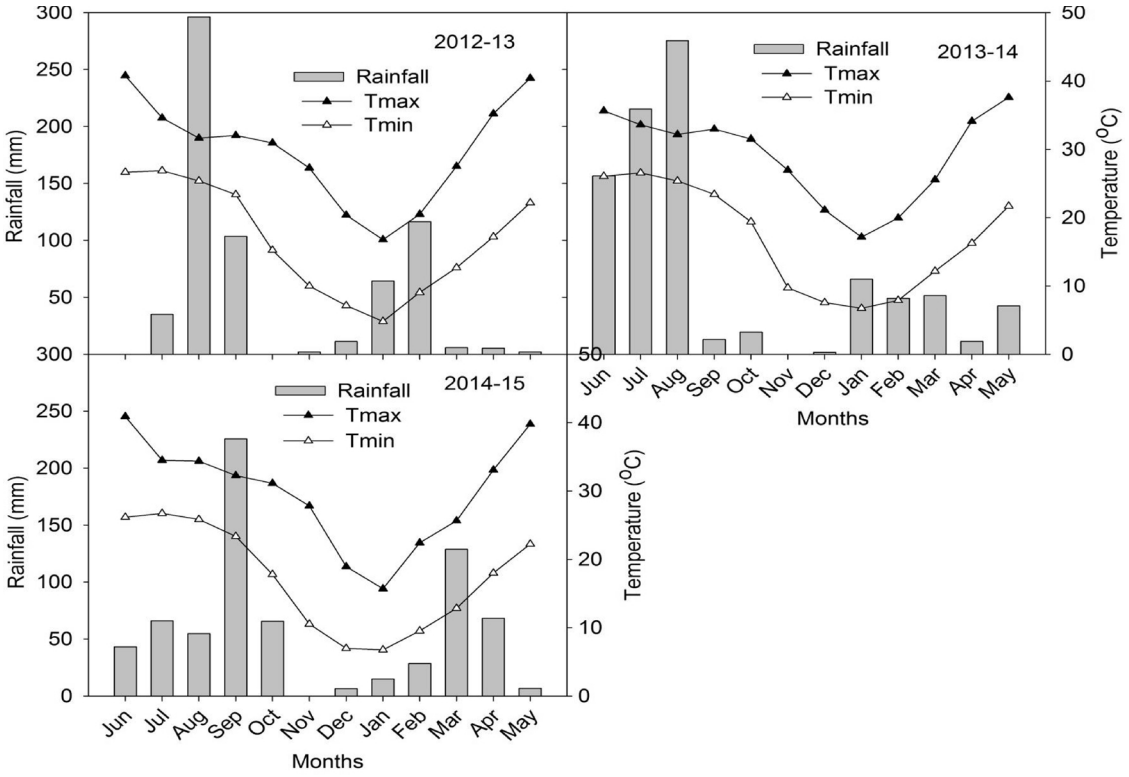

Fig. 1. The monthly minimum temperature (mean), maximum temperature (mean) and rainfall (total) from crop year 2012-13 to 2014-15.

the demand of rice and wheat (Srinivasan et al., 2004).

Traditionally, maize and wheat are grown by broadcast seeding on flat surface in the field after 6–7 tillage operations and using flood method of irrigation. The traditional practices with growing these crops contribute greatly to the high energy and labour costs resulting in lower economic returns (Aryal et al., 2015). Intensive tillage accelerate the oxidation of organic matter by opening the plough layer which causes decrease in soil organic carbon and ultimately resulted in degradation of soil properties (Gathala et al., 2011). To overcome some of the aforementioned problems, crop management technologies based on the principle of conservation agriculture (CA) hold potential to enhance soil organic carbon and soil health sustainably in North-West IGP (Jat et al., 2013, 2015; Parihar et al., 2016a). Zero-tillage (ZT) with residue retention opens avenues for optimum crop establishment using bed planting of maize which help in increasing input-use-efficiency and crop yields (Hassan et al., 2005). Maize planted on permanent raised beds (PB) with retention of residues of wheat and maize resulted in 16% higher water use efficiency (WUE) and 11% saving in irrigation water compared to conventional till (CT) system (Jat et al., 2013). Ram et al. (2010) reported similar crop productivity but with higher WUE and economic returns from MW system under PB and ZT compared with CT system on coarse-textured loamy sand soil in NW India. Adoption of ZT without surface residue mulch usually results in lower yields (Verhulst et al., 2011; Baudron et al., 2012; Yadvinder-Singh et al., 2014) compared with CT. Inclusion of a short duration pulse crop (e.g. mungbean/sesbania) will be beneficial to break the monotony of cereal based systems and to improve the soil quality (Parihar et al., 2016a).

Although conservation agriculture (CA) is gradually taking momentum in South Asia, nutrient management is still largely based on blanket recommendation made similar to that for CT system. This may lead to, in many cases, sub-optimal crop yields, low nutrient use efficiency, lower economic profitability and greater environmental footprints. Site-specific nutrient management (SSNM) is a set of nutrient management principles, which aims to supply a crop's nutrient requirements tailored to a specific field or growing environment (Majumdar et al., 2012; Jat et al., 2016). Results of Parihar et al. (2017a,b) showed that SSNM based nutrient application coupled with CA-based tillage practices in maize-wheat-mungbean (MWMb) system has complementarity to attain higher system productivity, energy and WUE. On 3-yrs basis, grain yield and WUE was increased by 38.3–80.5 and 30.6–59.9%, respectively in SSNM plots compared to the unfertilized plots in MWMb system (Parihar et al., 2017a). SSNM plots improved the WUE by 30.1–35.2% and net returns by 31.4–37.8% on 7′ yrs average basis compared with farmers' fertilizer practice (Parihar et al., 2017b). In maize, SSNM increased mean yield by 1.2 Mg ha^{-1} and economic return by US$ 184 ha^{-1} compared with farmer fertilizer practices in Indonesia, Philippines, and Vietnam (Pasuquin et al., 2010).

The soils of NW India are generally low in organic carbon content and the conventional CT based MW system is less profitable and low input (water, energy and nutrient) use efficient. Presently, limited information is available on the evaluation of integrating short duration pulse crop and SSNM using Nutrient Expert © system on crop productivity and net returns in MW system. Therefore, an attempt has been made to evaluate CA practices (tillage, crop establishment, residue management, integration of pulse crop) and site specific nutrient management (SSNM) on performance, water productivity and profitability of MW system in the IGP of India. We hypothesized that adopting the CA-based management practices together with precise nutrient management would improve system productivity, profitability and water use efficiency for accelerating the crop diversification in NW India.

2. Materials and methods

2.1. Experimental site

On-farm participatory research trial was conducted for three years from 2012 to 13 to 2014-15 in Taraori village (N 29°48′30; E 76°55′16), district Karnal, Haryana, India. The climate of the area is semi-arid