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RESEARCH ARTICLE

Response of Wheat to Tillage Plus Rice Residue and Nitrogen Management in Rice-Wheat System

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Abstract

Zero tillage with residues retention and optimizing nitrogen fertilization are important strategies to improve soil quality and wheat (*Triticum aestivum* L.) yield in rice (*Oryza sativa* L.)-wheat system. Field experiments were conducted on silty clay soil (Hyperthermic, and Typic Torrifluvents) in D. I. Khan, Pakistan, to explore the impact of six tillage methods (zero tillage straw retained (ZTsr), ZT straw burnt (ZTsb), reduced tillage straw incorporated (RTsi, including tiller and rotavator), RT straw burnt (RTsb), conventional tillage straw incorporated (CTsi, including disc plow, tiller, rotavator, and leveling operations), CT straw burnt (CTsb)) and five nitrogen rates, i.e., 0, 100, 150, 200, and 250 kg ha^{-1} on wheat yield. Mean values for N revealed that spikes m^{-2}, grains/spike, 1 000-grain weight (g), and grain yield (kg ha^{-1}) were significantly higher at 200 kg N ha^{-1} in both the years as well as mean over years than all other treatments. Mean values for tillage revealed that ZTsr produced highest number of spikes m^{-2} among tillage methods. However, grains/spike, 1 000-grain weight, and grain yield were higher in tillage methods with either straw retained/incorporated than tillage methods with straw burnt. Interaction effects were significant in year 1 and in mean over years regarding spikes m^{-2}, 1 000-grain weight, total soil organic matter (SOM), and total soil N (TSN). ZTsr produced the most spikes m^{-2} and 1 000-grain weight at 200 kg N ha^{-1}. ZTsr also produced higher SOM and TSN at 200-250 kg N ha^{-1} at the end of 2 yr cropping. Thus ZTsr with 200 kg N ha^{-1} may be an optimum and sustainable approach to enhance wheat yield and soil quality in rice-wheat system.

Key words: wheat yield, tillage, nitrogen, TSN, SOM

INTRODUCTION

Rice-wheat rotation constitutes a major production system of Pakistan (Farooq *et al*. 2007; Abedi *et al*. 2011; Krishna *et al*. 2012). Farmers normally use wheat straw as animal feed but rice straw is either burnt or used as fuel source in rural areas or incorporated in the field to avoid clogging of seeding equipment and to facilitate subsequent sowing of crop (Ahmed and Ahmad 2013). However, burning produces greenhouse gases, which are hazardous to our environment and also affect human health (Mandal *et al*. 2004; Brar *et al*. 2010). It destroys our precious natural resource (the organic matter) that may adversely affect soil physical, chemical and biological properties (Taa *et al*. 2004; Gangwar *et al*. 2006; Brar *et al*. 2010). Besides these harmful effects, burning results in nutrients losses (up to 80% of N, 25% of P 21% of K, and 4-60% of S) and decreases soil microbial

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activities (Raison 1979; Ponnamperuma 1984; Lefroy *et al*. 1994; Mandal *et al*. 2004; Singh *et al*. 2005). Burning of huge amount of rice residue is not only a waste of organic manure source but also negatively affects soil ecosystem (Liu and Ji 2003). Residues accumulation in the soil acts as a mulch which protects the soil from soil aggregate destruction, enhances infiltration of water and reduces loss of soil by erosion (Freebairn and Boughton 1985; McGregor *et al*. 1990; Dormaar and Carefoot 1996). It is an important organic source for retaining and improving soil fertility (Wang *et al*. 2002). Residue retention/incorporation into soil is an essential management practice to handle crop residue (Jiang *et al*. 2001). The retention/incorporation of rice residues may affect soil fertility, soil physico-chemical properties and yield of the crop (Ocio *et al*. 1991; Kludze and Delaune 1995; Eagle *et al*. 2000; Witt *et al*. 2000; Wang *et al*. 2001). Nutrients in crop residues and soil amendments are more available to crops if they are retained/incorporated into the soil rather than burnt.

Keeping in view importance of residues retention/incorporation into soil one should adopt appropriate tillage method. One of the environmentally acceptable alternative methods of residue disposal is residue incorporation with conventional tillage (CT), which can increase soil organic matter, improve physical and biological conditions of the soil, and prevent soil degradation (Aulakh *et al*. 2001). However, CT that involves numerous plowings and disturbs the entire soil surface (CTIC 1998; Endale *et al*. 2002) for incorporation of rice residues is neither feasible nor economical in case of rice-wheat system. Because the time between harvesting of rice and sowing of wheat is short for land preparation and decomposition of incorporated rice residues, which may delay sowing of wheat beyond favorable sowing time (mid November). This delay may reduce wheat yield by 1-1.5% per day delay in optimum sowing time (Hobbs *et al*. 1988). Application of N fertilizer is considered as an important strategy to enhance wheat yield. In Pakistan, farmers tend to increase the application of N fertilizer to achieve higher wheat yield. Both rice and wheat are exhaustive crops and there is continuous mining of nutrients from the soil (Mandal *et al*. 2004). On the other hand, much use of N in CT may not be productive and economical besides environmental hazards (Li 1997; Hussain *et al*. 2000; Kumar and Goh 2000). Therefore, alternative tillage in combination with optimum N rate may be explored for optimizing wheat yield and soil quality.

To deal with the aforementioned problems particularly late sowing of wheat, zero tillage (ZT) is a possible alternative which simultaneously cuts cultivation costs and advances wheat sowing about 2-3 wk by drilling directly into the previous crop residues (Sidhu *et al*. 2007). Rice and wheat are grown in sequence with CT on heavy textured soils that are relatively less fertile, poorly drained, low in organic matter, and compacted by machine traffic (Carreker *et al*. 1977; Lal 1993). These soils need management practices that improve soil organic matter and soil nutritional status. ZT with residue retention increases soil organic matter and total soil N and therefore induces major changes in N management. ZT may perform better than other tillage methods if N management is optimized (Sah *et al*. 2013). ZT is more safe practice compared to CT regarding its impact on soil, water and environment (Edwards and Daniel 1992). ZT with straw retained may reduce surface soil crusting, increase water infiltration, reduce run-off and give higher yield than tilled soils (Cassel *et al*. 1995; Thierfelder *et al*. 2005; Mohammad *et al*. 2012). Rice residues in combination with ZT may result in better soil surface aggregation (Karlen *et al*. 1994). Research revealed that ZT with residue cover had higher aggregate stability, higher aggregate size and total organic carbon in soil aggregates than CT (Madari *et al*. 2005). ZT in the long run may sustainably produce more food from less land through more efficient use of natural resources and with least impact on the environment (Lal 2005). Agronomic and crop management practices are aimed to reduce greenhouse gas emissions by reducing tillage and residue burning and improving nitrogen use efficiency. Since there are contrasting results in literature that whether higher N (Gangawar *et al*. 2006), or lower N rates are required (Rahman *et al*. 2005) to crops sown in previous crop residues, the aim of the present study was to determine the best method of tillage and to explore optimum N rate in wheat sown after rice.

RESULTS

Spikes m^{-2}

Numbers of spikes m^{-2} were significantly affected by