Soil & Tillage Research 141 (2014) 1–9

Contents lists available at ScienceDirect

Soil & Tillage Research

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

Weed dynamics and productivity of wheat in conventional and conservation rice-based cropping systems

Muhammad Farooq [a,b,c,*], Ahmad Nawaz [a]

[a] Department of Agronomy, University of Agriculture, Faisalabad, Pakistan
[b] The UWA Institute of Agriculture, The University of Western Australia, Crawley, WA 6009, Australia
[c] College of Food and Agricultural Sciences, King Saud University, Riyadh 11451, Saudi Arabia

ARTICLE INFO

Article history:
Received 30 December 2013
Received in revised form 8 March 2014
Accepted 23 March 2014

Keywords:
Resource conservation
Rice production system
Seed priming
Tillage

ABSTRACT

There exist edaphic and time conflicts between rice and following wheat crop in the conventional rice–wheat system. Conservation agriculture offers a pragmatic option to resolve these conflicts in the conventional rice–wheat system in the Indo-Gangetic Plains. In this two-year field study; wheat was raised through zero tillage, deep tillage, conventional tillage and on raised beds after harvesting rice grown in aerobic, alternate wetting and drying (AWD) and flooded systems. Various wheat tillage systems after different rice production systems significantly affected weed dynamics, stand establishment, morphological and yield-related traits of wheat during both year of study. Soil physical environment was better in the field occupied by aerobic rice followed by AWD-sown rice while it was poor after flooded rice. Density of lambsquarters (*Chenopodium album* L.) was lowest after flooded rice while densities of toothed dock (*Rumex dentatus* L.) and littleseed canarygrass (*Phalaris minor* Retz.) were lowest after aerobic rice. Broad leaf weeds like lambsquarters and toothed dock dominated in deep tillage, conventional tillage and bed sowing; whereas narrow leaf weeds like littleseed canarygrass dominated in zero tillage. Better stand establishment, water use efficiency, resource use efficiency and grain yield were recorded from wheat following aerobic rice culture, which was followed by AWD. Amongst the wheat tillage systems, stand establishment, morphological and yield related traits and water use efficiency were better in deep tillage; whereas resource use efficiency was the maximum in zero tillage wheat. Performance of bed-sown wheat was poor in term of yield related traits and grain yield. However, bed-sown wheat completed the phenological stages more rapidly than other wheat tillage systems. Maximum net income was observed in zero tillage wheat following aerobic rice culture. In crux, zero tilled wheat after aerobic rice culture is the best resource conservation technology; whereas deep tillage in rice–wheat cropping system may ameliorate the puddling-induced edaphic problems.

1. Introduction

Rice–wheat cropping system occupies an area of 24 Mha in Asia with 13.5 Mha in South Asia (Anonymous, 2007). Although, rice–wheat crop rotation is dominant in irrigated areas but there are rainfed pockets as well with this system (Surendra et al., 2001; Hussain et al., 2012a,b).

Conventionally puddling is done in rice fields; while after rice harvest, wheat is sown in well-pulverized soil. This shows an edaphic conflict in conventional soil management practice for rice and its subsequent wheat crop (Farooq et al., 2008a). Although, puddling helps in weed management and reducing water loss through percolation (Surendra et al., 2001; Farooq et al., 2011a); nonetheless it deteriorates the soil environment for post-rice crops (Sharma and DeDatta, 1985; Farooq et al., 2008a; Farooq and Basra, 2008). This results in erratic stand establishment of post-rice crops owing to poor contact of seed with soil (Ringrose-Voase et al., 2000; Farooq et al., 2008a; Farooq and Basra, 2008). Subsurface compaction of soil, caused by puddling, may induce the drought to post-rice crops by restricting the root development (Kirchhof et al., 2000; Kukal and Aggarwal, 2003). Moreover, conventional rice production system requires 3000–5000 l of water to produce one kg of rice (Belder et al., 2004; Geethalakshmi et al., 2011), which is 2–3 times more than other cereals like maize, barley, wheat and sorghum (Barker et al., 1998; Bouman et al., 2007). However, declining water resources and increasing labor cost has threatened the sustainability of

* Corresponding author at: Department of Agronomy, University of Agriculture, Faisalabad, Pakistan. Tel.: +92 41 9201098; fax: +92 41 9200605.
E-mail address: farooqcp@gmail.com (M. Farooq).

http://dx.doi.org/10.1016/j.still.2014.03.012
0167-1987/

conventional rice production system (Pandey and Velasco, 1999; Farooq et al., 2009).

In conventional rice production areas, wheat plantation is delayed mostly due to late maturation of Basmati varieties (Byerlee et al., 1984; Farooq et al., 2008b, 2011b), and any rainfall during this time accompanied with low temperature further delays the wheat planting (Farooq et al., 2008b; Farooq and Basra, 2008). This late plantation of wheat is one of the major factors responsible for low wheat yield (Hussain et al., 2012a,b). Moreover, flooded paddy fields are the major source of methane emission (Neue et al., 1990). This methane escapes into the atmosphere through roots, stems and leaves of rice and contributes to global warming (Maclean et al., 2002).

Conservation agriculture offers a pragmatic option to resolve the edaphic conflict in the conventional rice–wheat system (Hobbs et al., 2007; Farooq and Basra, 2008; Farooq et al., 2011b). For Instance, just by eliminating the puddling operation for rice, the yield of succeeding wheat crop may be substantially improved along with decrease in production cost (Timsina and Connor, 2001; Farooq et al., 2008a). Conservation rice production systems, like aerobic culture and alternate wetting and drying, may help in resolving the edaphic conflict in the rice and proceeding crop (Farooq and Basra, 2008; Farooq et al., 2008a, 2009) in addition to substantial cut on the water and labor requirement, and the greenhouse gas emission (Sarkar, 2001; Bouman and Tuong, 2001; Farooq et al., 2009, 2011a).

Conservation tillage may help in timely planting of wheat with significant decrease in production cost (Erenstein and Laxmi, 2008). However, deep tillage before wheat planting may help to break the hardpan created during puddling. Deep tillage reduces soil strength, promotes deep rooting (Kundu et al., 1996), reduces penetration resistance (Busscher et al., 2000), resulting in better acquisition of water (Holloway, 1991). Deep tillage in post-rice fields can improve wheat yields (Hobbs et al., 2002), by improving the soil physical properties (Mahajan and Bhagat, 2006), through reduction in bulk density and soil strength. Wheat planting with conservation tillage is the most successful resource conservation technology in Indo-Gangetic Plains (Erenstein et al., 2007a; Erenstein and Laxmi, 2008) with 5–16% decrease in production cost (Thakur et al., 2004; Laxmi et al., 2007; Erenstein et al., 2007b) and substantial yield increase (Gathala et al., 2011). However, weed flora changes while switching from conventional to conservation agriculture (Farooq et al., 2011b). Tillage helps to control certain weeds (Clement et al., 1996; Swanton et al., 2000); nonetheless tillage may encourage the emergence of certain other weed species (Shrestha et al., 2003).

Although several studies have been conducted to compare the performance of conservation and conventional rice–wheat cropping system, information on resource conservation, stand establishment and weed dynamics is lacking. Therefore, this study was conducted to compare the conservation and conventional rice-based wheat production systems for soil physical health, stand establishment, resource conservation and weed dynamics.

2. Materials and methods

2.1. Site and soil

This two-year study was conducted at the Agronomic Research Area, University of Agriculture, Faisalabad (latitude 31° N, longitude 73° E and altitude 184.4 masl), Pakistan during 2010–2011 and 2012–2013 as a part of long term experiment. The experimental soil belongs to Lyallpur soil series (aridisol-fine-silty, mixed, hyperthermic Ustalfic, Haplarged in USDA classification and Haplic Yermosols in FAO classification. Other physico-chemical properties of experimental soil are given in Table 1. Weather data during the experimental period are given in Table 2.

2.2. Plant material

Seeds of wheat cultivar Mairaj-2008 were collected from Wheat Research Institute, Ayub Agricultural Research Institute, Faisalabad, Pakistan. Initial moisture and germination percentages were 9.1% and 95%, respectively.

2.3. Experimental details

The experiment was laid out in randomized complete block design in split plot arrangement keeping rice production systems in main plots and wheat tillage systems in sub-plot with four replications and a net plot size of 3.3 m × 1.80 m. The rice crop in aerobic culture was sown on June 22, 2010 and was harvested on November 15, 2010. The nursery for alternate wetting and drying (AWD) and conventional flooding systems was sown on June 22, 2010 and was transplanted in puddled field on July 22, 2010. The rice crop from AWD and conventional flooding systems was harvested on November 20, 2010 at harvest maturity. In aerobic rice, land was prepared by four cultivations followed by two planking. To ensure a good soil for aerobic rice, rotavator was also operated in the field before sowing. Rice seed was drilled in aerobic soil and irrigation was applied when required to maintain the soil moisture. In AWD, field was prepared in standing water to reduce

Table 1
Some physical and chemical characteristics of soil profile.

	2010–2011	2011–2012
Sand (%)	59	58
Silt (%)	23	23
Clay (%)	18	19
Soil texture	Sandy loam	Sandy loam
Soil pH	8.20	8.19
EC (dS m^{-1})	0.34	0.33
Organic matter (%)	0.90	0.87
N (%)	0.05	0.06
P (ppm)	5.00	4.97
K (ppm)	168.0	166.7

Table 2
Weather data during the wheat season of 2010–2011 and 2011–2012 at experimental site.

Months	Rainfall (mm)		Relative humidity (%)		Temperature (°C)						Sunshine (h)	
					Daily maximum		Daily minimum		Daily mean			
	2010–2011	2011–2012	2010–2011	2011–2012	2010–2011	2011–2012	2010–2011	2011–2012	2010–2011	2011–2012	2010–2011	2011–2012
November	0.00	0.00	62.3	61.2	27.1	27.6	10.5	13.3	18.8	20.5	8.50	8.50
December	1.00	0.00	70.5	59.1	20.8	20.9	05.9	04.2	13.3	12.5	7.00	6.90
January	0.00	3.8	73.4	69.6	15.9	17.3	04.3	03.2	10.1	10.2	5.40	7.20
February	20.6	8.0	73.0	62.1	20.2	18.4	08.7	04.6	14.4	11.5	5.50	7.30
March	6.80	1.50	59.8	58.2	26.4	25.9	13.1	11.7	19.8	18.8	8.40	8.30
April	20.9	10.5	47.0	59.1	32.0	32.7	17.2	18.0	24.8	25.3	9.30	9.20

Source: Agricultural Meteorology Cell, Department of Crop Physiology, University of Agriculture, Faisalabad, Pakistan.