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Tillage and residue management effects on soil properties and yields of rainfed maize and wheat in a subhumid subtropical climate

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Abstract

Minimum tillage in conjunction with crop residue mulch may be a promising practice of soil management to improve soil properties and crop production in the subtropical climate of north-western Punjab. Therefore, a 5-year field experiment was conducted to study the effect of tillage and crop residue mulch on some properties of a sandy loam soil (Fluvisol) cropped to rainfed maize (*Zea mays* L.)–wheat (*Triticum aestivum* L.) sequence. Three main treatments investigated were minimum tillage (consisting of making a small trench for seed placement) with 3 Mg ha^{-1} crop residue mulch of the previous crop (MTR), minimum tillage without residue mulch (MT), and conventional tillage (involving two diskings followed by a planking) without residue mulch (CT). Subtreatments consisted of five rates of fertilizer N (0, 40, 80, 120 and 160 kg ha^{-1}) applied to wheat. Maize received 80 kg N, 17 kg P and 16 kg K ha^{-1}. Soil quality in terms of increased organic matter content, water retention, infiltration of water and aggregation, and decreased bulk density of the surface soil was improved in the MTR relative to other treatments. Pooled grain yield in the MTR treatment remained below the CT treatment during the first 2 years (1993 and 1994) but was subsequently greater than the CT. However, grain yield in the MT treatment was lower than CT treatment throughout the study period. The results indicated the necessity of using residue mulch in conjunction with minimum tillage in order to improve soil quality and sustain/improve crop production.

Keywords: Minimum tillage; Crop residue; N uptake; Water use efficiency; Subtropics; Punjab

1. Introduction

A large tract (0.32 million ha) of productive alluvial soils lies in the north-western Punjab, India. This area, called ''Kandi area'', receives mean annual rainfall from 750 to 1150 mm. In spite of adequate climatic conditions, crop yields are rather low. Singh et al. (1983) reported average yields of 1620 kg ha^{-1} for maize and 1760 kg ha^{-1} for wheat on farmer's fields. The reasons responsible for the low yields include excessive runoff and soil erosion, low soil fertility, low groundwater availability, erratic rainfall distribution and low inputs. In order to ameliorate some of these limitations to crop production, a sound management system for these soils needs to be developed.

Since these ''Kandi'' area soils are poor in organic matter, which is a primary parameter to evaluate soil quality, it is essential that an alternative tillage practice will increase organic inputs. In temperate regions, the no tillage or minimum tillage concept of soil management has been adopted with some success.

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Working on the tropical soils of Nigeria, Lal (1976) reported that this practice in conjunction with crop residue mulch improved soil quality and crop yield by increasing infiltration of water into soil profile and lessening water runoff and soil erosion. Minimum tillage practices are considered as an important component of sustainable rainfed farming (Carter, 1994; Papendick and Parr, 1997). The system is thought of enhancing soil quality (Steiner et al., 1988). Crop residue mulch improved soil quality in terms of organic carbon and biotic activity (Karlen et al., 1994). An increase in infiltration of water into soil has also been reported by Bruce et al. (1992). However, little work has been done on these aspects for the ''Kandi'' soils.

The present study investigated the effects of tillage and crop residue mulch on soil quality and grain production in a maize (*Zea mays* L.)–wheat (*Triticum aestivum* L.) rotation on an alluvial soil in the ''Kandi'' area of the Punjab in a subhumid subtropical climate.

2. Materials and methods

2.1. Experimental site

Field experiments were conducted at Ballowal Saunkhri (31°08′N latitude; 71°18′E longitude) from June 1993 to April 1998 at the Zonal Regional Research Station of Punjab Agricultural University, Ludhiana, Punjab. The soil ranged in texture from sandy loam near the surface (110 g kg^{-1} clay and 760 g kg^{-1} sand) to loam in the lower layers (170 g kg^{-1} clay and 600 g kg^{-1} sand) with pH of 8.0 and organic carbon content of 3 g kg^{-1} soil. The soil was classified as fine loamy Fluventic Ustochrept by Soil Taxonomy (Raj-Kumar et al., 1998) and as Eutric/Dystric Fluvisols by FAO. Water retention at −33 kPa pressure ranged from 135 to 207 g kg^{-1} and at −1500 kPa pressure from 41 to 75 g kg^{-1}, in different layers of 0–1.8 m soil.

The test crops were rainfed maize and wheat. Rainfall and open-pan evaporation for the summer and winter crop seasons from 1993–1994 to 1997–1998 and the long-term averages at the study site are given in Table 1. July and August were the assured rainfall months. September also received some rain showers in the first fortnight, which carried summer crop (maize) to maturity.

2.2. Tillage experiment

Experiment was laid out as a split-plot design with four replications. The main plot treatments were: (1) minimum tillage + residue of the previous crop left on the surface as mulch at 3 Mg ha^{-1} (MTR), (2)

Table 1
Rainfall (*R* in mm) and pan evaporation (PE in mm) in different cropping seasons

Season and month	1993–1994		1994–1995		1995–1996		1996–1997		1997–1998		1982–1998 (long-term)	
	R	PE	*R*	PE	*R*	PE	*R*	PE	*R*	PE	*R*	PE
Summer												
June	83	372	85	284	10	330	66	120	24	216	70	285
July	576	469	517	104	220	140	246	126	216	126	330	187
August	46	151	555	104	410	93	414	108	510	114	342	129
September	175	132	114	100	321	101	234	84	90	88	175	117
Total	880	1124	1271	592	961	664	960	438	840	544	917	718
Winter												
November	0	70	0	60	5	69	0	75	60	55	9	78
December	0	58	8	45	2	61	0	50	175	20	35	54
January	17	48	56	45	52	41	25	25	5	35	41	50
February	43	72	47	58	111	65	10	60	15	75	56	85
March	34	152	54	123	35	114	5	55	110	76	42	139
Total	94	400	165	331	205	350	40	265	365	261	183	406