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Manuring and residue management effects on physical properties of a soil under the rice–wheat system in Punjab, India

Gurpreet Singh *, S.K. Jalota, Yadvinder Singh

Department of Soils, Punjab Agricultural University, Ludhiana 141004, India

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Abstract

Sustainability of the rice–wheat rotation is important to Asia's food security. Intensive cropping with no return of crop residues and other organic materials results in loss of soil organic matter and is not sustainable. We evaluated effect of eight treatments comprised of various combinations of green manure (GM), wheat straw (WS), rice straw (RS), farmyard manure (FYM) and urea alone (control) on physical and hydraulic properties of soil in a rice–wheat experiment (1988–2001) on a loamy sand in Punjab, India. After rice harvest, organic carbon (OC) content in the FYM (0.51%), WS (0.56%) and WS + RS (0.59%) treatments were significantly greater as compared to control (0.42%). With addition of GM to all these treatments; FYM + GM (0.59%), WS + GM (0.60%), WS + RS + GM (0.64%) and GM (0.47%), organic carbon content further increased significantly. Increased OC content of the soil in turn improved its aggregation status, infiltration rate and decreased the bulk density, dispersion ratio and soil strength correspondingly. After wheat harvest mean effects of these organic treatments continued, but their magnitude decreased. The differences in rice yield were not significant among urea, GM and WS applied alone or in combination. However, FYM + GM + urea produced highest yield. There was no residual effect of the long-term application of GM, WS and RS incorporation in wheat yields, but FYM application to rice showed significant residual effects on wheat.

Keywords: Organic manures; Soil organic carbon; Soil physical properties; Rice; Wheat

1. Introduction

Rice–wheat is a major cropping system in north-west India because of the availability of high-yielding rice and wheat varieties and favourable climate conditions together with subsidized inputs and price support. The area under rice cultivation in the Punjab (India) increased from 0.29 million ha in 1965–1966 to 2.53 million ha in 2002–2003. In rice–wheat cropping system, puddling (working the soil in wet conditions) the soil for rice growing damages the soil structure and affects the physical and hydraulic properties of the soil (Meelu et al., 1979). Furthermore, ready availability of low cost inorganic fertilizers has increased the use of inorganic fertilizers and pushed apart the use of organic manures in rice–wheat system. Yaduvanshi (2001) and Khan et al. (1986) have reported that continuous cropping of rice–wheat with inorganic fertilizers has decreased the organic carbon content of the soil. Because of deteriorated physical and hydraulic properties and low organic carbon content of the soil, the present productivity potential of rice–wheat cropping system in this region is under threat despite increased use of inorganic fertilizers. The soil productivity is linked with soil organic carbon (SOC). Reduced productivity of rice–wheat system due to decline in

* Corresponding author. Tel.: +91 1636 236010; fax: +91 161 2400945.
E-mail addresses: gurpreetpau@yahoo.com (G. Singh), skjalota03@yahoo.co.in (S.K. Jalota).

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SOC has been reported by Bhandari et al. (2002) and Regmi et al. (2002). For maintaining the productive potential of these structurally damaged soils which are low in organic matter content, it is imperative to improve the organic carbon content and restore structural status of the soil through the integrated use of organic manures and inorganic fertilizers in the rice–wheat cropping system.

The present study was undertaken to assess the magnitudes of change in organic carbon content, physical and hydraulic properties of the soil with long-term applications of green manure, farmyard manure and crop residue in rice–wheat cropping system.

2. Methods and materials

Effects of green manure, farmyard manure and crop residue recycling on organic carbon content and physical and hydraulic properties of the soil in a rice–wheat cropping system were studied in a long-term field experiment at the Research Farm of the Department of Soils, Punjab Agricultural University, Ludhiana (30°56′N, 75°52′E and 247 m a.s.l.), India. The daily average minimum air temperature during rice growth (July–October) was 18 °C and maximum temperature was 35 °C, whereas during wheat growth (November–April) the average daily minimum air temperature was 6.7 °C and maximum was 22.6 °C. The experiment was started in 1988 on loamy sand (Typic Ustipsamment) soil. The initial soil physical and chemical characteristics (0–15 cm layer) were sand 785 g kg^{-1}, silt 89 g kg^{-1}, clay 126 g kg^{-1}, bulk density 1.62 Mg m^{-3}, soil water content 0.14 m^3 m^{-3} at −0.033 MPa potential and 0.065 m^3 m^{-3} at −15 MPa potential, saturated hydraulic conductivity 0.04 mm s^{-1}, pH 7.6 (1:2 soil water suspension, w/w), electrical conductivity 0.19 dS m^{-1}, cation exchange capacity 6.8 C mol kg^{-1}, organic carbon 3.6 g kg^{-1} and nitrogen 0.44 g kg^{-1}. Eight treatment combinations of organic amendments and urea applied to rice in a complete randomized block design with three replications were studied after 13 years.

2.1. Rice treatments and management

T_1	150 kg N ha^{-1} as urea (un-amended control) to rice
T_2	Green manure (*Sesbania aculeata*) + urea to rice
T_3	Farmyard manure (applied at 12 Mg ha^{-1} on fresh weight basis or 5.8 Mg ha^{-1} on dry weight basis) + urea to rice
T_4	Farmyard manure + green manure to rice
T_5	Wheat straw + urea to rice
T_6	Wheat straw + green manure + urea to rice
T_7	Wheat straw + urea to rice followed by rice straw incorporation before wheat seeding
T_8	Wheat straw + green manure + urea to rice followed by rice straw incorporation before wheat seeding

Total mean dry biomass additions from green manure (GM), farmyard manure (FYM), wheat straw (WS) and rice straw (RS) were 3.5, 5.8, 6.4 and 7.4 Mg ha^{-1}, respectively. Nitrogen additions through FYM ranged from 75 to 107 kg N ha^{-1} and above ground portion of *Sesbania* ranged from 78 to 129 kg N ha^{-1}. In rice crop total dose of 150 kg N ha^{-1} 1 was given in T_2–T_8 through green manure or farmyard manure or crop residues with the balance N through urea. The amounts of nitrogen applied through different sources are given in Table 1 (Singh et al., 2004). No fertilizer N was applied to rice in GM + FYM treatment. Rice received no application of P and K fertilizers. Within 1 week after wheat harvest, wheat straw (6.4 ± 0.5 Mg ha^{-1} dry mass) was disked (0–15 cm deep) into soil. Thereafter, seeds (50 kg ha^{-1}) of

Table 1
Nitrogen applied to rice and wheat through fertilizer (urea), green manure (GM), farmyard manure (FYM) and wheat straw (WS) and rice straw (RS) treatments

Treatments	Nitrogen added to wheat (Kg ha^{-1})			Nitrogen added to rice (Kg ha^{-1})				
	Urea	RS	Total	GM	FYM	WS	Urea	Total
T_1—urea (150 kg N ha^{-1})	90	0	90	0	0	0	150	150
T_2—GM + urea	90	0	90	98	0	0	52	150
T_3—FYM + urea	90	0	90	0	88	0	62	150
T_4—FYM + GM	90	0	90	98	88	0	0	186
T_5—WS + urea	90	0	90	0	0	26	150	150
T_6—WS + GM + urea	90	0	90	98	0	26	52	150
T_7—WS + urea + RS	90	41	90	0	0	26	150	150
T_8—WS + GM + urea + RS	90	41	90	98	0	26	52	150

RS was applied to wheat; GM, WS and FYM to rice in T2–T8, N added through wheat straw/rice straw was not accounted for in the total N applied to rice/wheat.