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Tillage and brown manuring effects on soil properties and yield in Shivalik

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ABSTRACT

The present study aimed to determine the effect of tillage and brown manuring in sandy loam soil under maize (*Zea mays* L.)-wheat (*Triticum aestivum* L.) sequence. Six treatments implemented were Conventional tillage (CT); Deep tillage once in three years (DT); Conventional tillage with integrated nutrient management (CT-INM); Conventional tillage with brown manuring in maize + cowpea (1:2) and wheat + pea (4:1) ratio (CT-BM); Conservation tillage (CST) ; Conservation tillage with brown manuring (CST-BM). Maize equivalent yield (MEY) was 51.8% higher in CT-INM, over control; DT, CST, CST-BM and CT-BM produced 4.92, 14.1, 30.8 and 39.3 % higher yield over control (CT), respectively. The mean soil organic carbon (SOC) was 12.1, 11.3 and 17.7% higher under CT-BM, CST, CST-BM treatments, respectively, over the control (CT) in surface soil. Brown manuring in conjunction with both conventional (CT-BM) and conservation tillage (CST-BM) reduced soil loss to the extent of 91.70% and 93.32% as compared to CT. The highest net return per rupee of investment was recorded in CT-INM, being lowest in DT.

Key words: Brown manuring, Conservation tillage, Economics, Maize-wheat, Shivalik Himalaya, Yield

The agricultural production in the Shivalik region is constrained by low organic carbon, poor soil moisture, erratic rainfall and soil erosion. Several commonly used farming practices such as intensive tillage in sloping lands, harvest of every component of biological produce and no return of plant residue to soil further accelerate the process of soil degradation (Sharma *et al.* 2012).

Conservation agriculture (CA) is the concept for resource conservation and mitigation of adverse climatic impacts that has higher profitability (Das *et al.* 2014). Conservation tillage is defined as any tillage and planting system, that leaves at least 30% of the soil surface covered by residue after planting (Lal 2003). Minimum and zero tillage are recommended for soils of the Indian Himalayan region due to reduced cost of cultivation, retention of soil water, and physical protection of soil organic carbon (Bhattacharyya *et al*. 2012). Brown manuring is a 'no-till' version of green manuring, using an herbicide to desiccate intercrop (and weeds). In 'Brown manuring' practice, both the main crop and intercrops are seeded together and allowed to grow for 30 days and after which the intercrop is knocked down with herbicide (Singh *et al.* 2007).

India loses around 13.4 million tonnes of food grain worth 162.8 billion (2008–2009) due to soil erosion by water in rainfed areas (Sharda *et al.* 2010). In case of maize, a loss in productivity to the extent of 8.0–10.3 kg/ha for loss of each mm of top soil has been reported (Ghosh *et al.* 2012). Information regarding effect of conservation tillage (CT) on crop yield in the Shivalik region is meagre. The farmers' adoption of conservation tillage in India has been limited due to the lack of sufficient field level research.

To address the above mentioned challenges, a combination of tillage methods along with intercrop and nutrient management strategies were designed with objectives (i) to determine impact of tillage and resource conservation practices on grain yield in maize (*Zea mays* L.) -wheat (*Triticum aestivum* L.) cropping system, (ii) to determine soil organic carbon and moisture storage, (iii) to evaluate economics of various resource conservation practices.

MATERIALS AND METHODS

The experiment was conducted at the Research Farm located at the Mansa Devi, district Panchkula in Haryana, India (30° 45' N latitude, 70 ° 45'E longitude and 370 m amsl). The soil is sandy loam in texture, well drained, with low water-holding capacity. The average soil pH (1:2) is 7.8; EC 0.29 dS/m organic carbon 0.54%; available N 303 kg/ha, P_2O_5 27.5 kg/ha, K_2O 217 kg/ha, Zn 1.03 mg/kg, Cu 0.52 mg/kg, Fe 2.85 mg/kg and Mn 5.87 mg/kg. The area receives 1100 mm mean annual rainfall, of which 80% occurs during the monsoon season (June to September).

The study was initiated in the year of 2009-10, an

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experimental trial was taken in Randomized Block Design with four replications. Twenty four plots of size 8 m × 5 m were prepared with a uniform slope of 1.5% in 2009-10. Ramser's samplers were installed in one replication and plot size was increased to 10 m × 5 m for runoff to happen in natural way. Treatment details: T_1, Conventional tillage in maize-wheat (CT); T_2,Deep tillage in maize-wheat (DT) once in three years; T_3, Conventional tillage in maize-wheat with integrated nutrient management (CT-INM); T_4, Conventional tillage with brown manuring in maize +cowpea (1:2) wheat + pea (4:1) cropping sequence (CT-BM); T_5, Conservation tillage in maize-wheat cropping sequence (CST); T_6, Conservation tillage in maize-wheat cropping sequence with other interventions to enhance organic matter accumulation (CST-BM).

Fertilizer was applied at the rate of 80 kg N/ha, 40 kg P/ha and 20 kg/K ha for maize and 60 kg N/ha, 40 kg P/ha and 20 kg K/ha for wheat. In control, deep tillage and INM treatments, atrazine was sprayed for pre-emergence and two manual weeding for post-emergence weed control were done. During 2009-10, wheat (*var*. WH 711) was grown after maize (*var.* Bisco X92) with one pre-sowing and two post sowing supplemental irrigations.

Runoff and soil loss were measured by a standard Ramser's sampler. The soil loss for each rainfall event was determined following the method of Khybri and Gupta (1980).

In May 2015, after the harvest of wheat crop, plot-wise soil samples in triplicate were collected from the surface (0–15 cm) and sub surface (15-30 cm) layer. The soil samples were air dried, ground and passed through a 0.2 mm sieve for determination of soil organic carbon (OC) by Walkley and Black (1934) method.

Standard enterprise budgeting technique was used to estimate average variable cost of production for each tillage system (Hinman and Essar 1999). The average rate of return per rupee investment was calculated by the following formula:

Average rate of return = (Average income – Average cost)/Average cost

RESULTS AND DISCUSSION

Yield of maize and wheat crops under different treatments: Mean MEY (Maize Equivalent Yield) varied significantly between treatments. The MEY was 51.8% higher in CT-INM, compared to control. The treatments DT, CST, CST-BM and CT-BM produced 4.92, 14.1, 30.8 and 39.3 % higher yield over the control (CT), respectively. Addition of residues through brown manuring caused significant yield increase both under conventional and conservation tillage systems.

Soil properties under different treatments: The mean soil moisture was 12.5, 20.3, 42.7, 41.9 and 47.0 % higher under DT, CT-INM, CT-BM, CST, CST-BM treatments respectively, over the control (CT). The percentage soil moisture was found to be proportional to the amount of biomass added under various treatments.

Soil organic carbon showed an overall increase over the initial SOC of 0.54%. The mean SOC (%) was 12.1, 11.3 and 17.7 % higher under CT-BM, CST, CST-BM treatments respectively, over the control (CT). The mean SOC (%) in sub surface soil was 20.4, 17.5 and 21.1 % higher under CT-BM, CST, CST-BM treatments respectively, over the control (CT). The soil organic carbon followed a trend similar to the quantity of biomass added under various treatments. Soil microbial biomass were found to be higher in conservation tillage with brown manuring treatment (Fig 1 and Fig 2).

CST-MB, CST and CT-BM favoured better organic carbon build up. Reduction of runoff and soil through bio-resources recycling is expected as carbon input from organic sources helps in formation of more water stable macro-aggregates (Bhattacharyya *et al.* 2012).

Tillage systems retaining large crop residues, viz. CST-BM, CST and CR-BM had higher soil moisture in 0-60 cm. Total crop residues added in the cropping sequence followed the pattern: CST-BM>CST> CT-BM > CT-INM = CT = DT. Water conservation benefits of conservation tillage involving residues result from protection of soil surface against raindrop impact, reduced soil aggregate dispersion, thus providing more time for infiltration; and reduced soil water evaporation by shading and cooling the

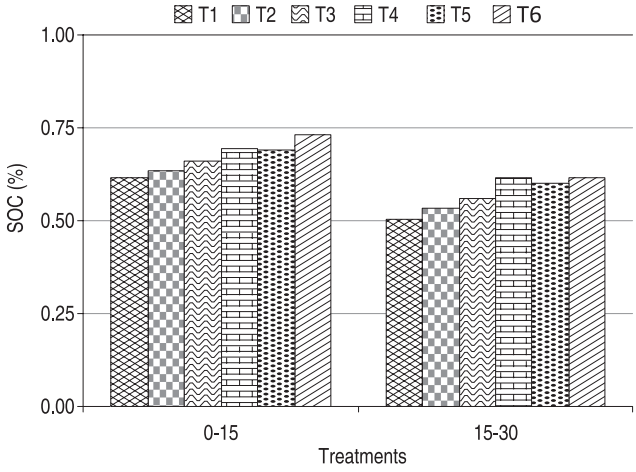

Fig 1 Soil organic carbon under different treatments.

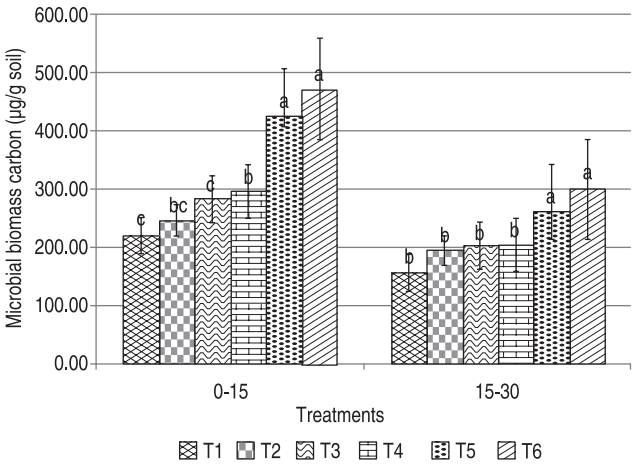

Fig 2 Microbial biomass carbon under different treatments.

Table 1 Mean grain yield (Mg/ha) of maize and wheat under different treatments

Treatment		Maize Equivalent Yield (Mg/ha) of maize-wheat cropping system (2010-11 to 2014-15)	Mean annual soil loss (Mg/ha) (2012-13 to 2014-15)	% reduction in soil loss over control	Mean residue addition (Mg/ha) (*Kharif*/ Rainy season)	Mean residue addition (Mg/ha) (*Rabi*/ Winter season)	Gross return/₹ (2010-11 to 2014-15)	Net return/ ₹ (2010-11 to 2014-15)
T1	CT	6.64	6.99	0.00			1.90	0.90
T2	DT	6.79	4.07	41.73			1.80	0.80
T3	CT-INM	8.22	3.97	43.16			2.30	1.30
T4	CT-BM	7.84	0.58	91.70	3.33	0.27	2.16	1.16
T5	CST	7.07	1.91	72.68	3.48	2.10	2.05	1.05
T6	CST-BM	7.58	0.47	93.32	6.32	2.50	2.13	1.13
	CD (P=0.05)	1.01			0.62	0.31		

CT: Conventional tillage in maize-wheat; DT: Deep tillage in maize-wheat once in three years; CT-INM: Conventional tillage in maize-wheat with integrated nutrient management; CT-BM: Conventional tillage with brown manuring in maize +cowpea (1:2) wheat + pea (4:1) cropping sequence; CST: Conservation tillage in maize-wheat cropping sequence; CST-BM: Conservation tillage in maize-wheat cropping sequence with other interventions to enhance organic matter accumulation.

soil; and by reducing wind speed at the soil surface (Loch 1989).

Soil loss under different treatments: During 2012-13 to 2014-15, the highest mean annual soil loss of 6.99 Mg/ha was observed under conventional tillage (CT) treatment, whereas in conservation tillage plots (CST), the mean annual soil loss was 1.91 Mg/ha, a reduction to the tune of 72.68%. Brown manuring in conjunction with both conventional (CT-BM) and conservation tillage (CST-BM) proved highly effective in reducing soil loss, to the extent of 91.70 and 93.32 % as compared to conventional tillage alone (CT). Among the treatments, the soil loss followed the trend CT > DT > CT-INM > CST > CT-BM > CST-BM (Table 1). Conservation tillage caused marked reduction in soil loss over conventional tillage.

Residue addition under different treatments: Mean maximum amount of 6.32 Mg/ha residue was added under CST-BM treatment. This was the cumulative addition from grasses, cowpea and maize straw. Conservation tillage alone (CST) added 3.48 Mg/ha of residue through grasses and maize straw. The amount of residue added followed the order CST-BM > CST > CT-BM. The mean residue addition in wheat was 0.27, 2.10 and 2.50 Mg/ha under CT-BM, CST and CT-BM tillage treatments, respectively. Brown manuring through pea added 0.27 and 0.31 Mg/ha of residue from pea under CT-BM and CST-BM treatments, respectively (Table 1).

Economic analysis of different treatments (2010-11 to 2014-15): The highest net return was recorded under CT-INM, followed by CT-BM, CST-BM, CST, CT and the lowest being in DT. The net return under CT, DT, CT-BM, CST and CST-BM were 17.79, 16.72, 7.22, 20.13 and 12.41 %, respectively, lesser than CT-INM treatment. The highest net return per rupee of investment was also recorded in CT-INM (conventional tillage + INM), followed by CST-BM (conservation tillage + brown manuring). A higher economic return in CT-INM is due to higher yield. The lower yield in CST-BM as compared to CT-INM was somewhat levelled off by the higher intangible benefits in terms of better saving of soil, water and nutrients (Table 1).

Highest gross returns were under CT-INM followed by CT-BM as these produced higher grain yields. Earlier workers have also reported that the conservation tillage improves economic performance, reduces production risks, decreases soil disturbance, improves and benefits soil quality (Zentner *et al.* 2004).

It was concluded that the conservation tillage based practices did not offer advantage over the conventional tillage in terms of grain yield. But, under conservation tillage based practices, the cropping system as a whole was found to be better in terms of reduced soil loss, improved SOC and moisture storage. In the long run, the technology has the potential to provide higher net returns as well as environmental benefits to the farmers because of higher carbon retention potential and lesser soil loss. Appropriate interventions like integration of conservation tillage with brown manuring improved the efficiency of tillage systems.

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