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Impact of resource conservation technologies on soil health and productivity of wheat in rice-wheat cropping system

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Abstract: A field experiment was conducted to investigate the impact of resource conservation technologies on soil health and productivity of wheat in rice-wheat cropping system in split plot design with three replications. The physico-chemical parameters of the soils like pH and EC both maximum decreased almost significantly over control under treatments T_2 (Ploughing twice by Cultivator, allowed to decompose weeds for a week then puddling by cross ploughing and planking), T_3(Summer ploughing onset of monsoon by mould bold plough to invert the soil once in three years followed by subsequent ploughing by cultivator to puddle the soil) and C_5 (GM + Paddy straw @ 50 q/ ha) and C_6 (GM + Rice husk @ 50 q/ha). Soil data revealed a highly significant increase in organic carbon content along with available N, P_2O_5 and K_2O content under treatments T_3 and C_6 and their interactions (T_3 ×C_6) over control. This might be attributed to the improvement in physico-chemical properties of the soils. The significant ($P<0.05$) increase in yield attributes and yields of wheat grain and straw over control was observed under influence of the treatments T_3 and C_6 and their interaction except height and length of ear head. These observations were confirmed by the positive and highly significant correlation of yield of wheat grain with available N (r = 0.74**), available P_2O_5 (r = 0.64**), and available K_2O (r = 0.52**). Deep ploughing and green manuring in addition with other organic residues (GM+ rice husk) individually and/ or in combination improved the soil health significantly.

Keywords: Green manuring, Ploughing, Rice husk, Wheat

INTRODUCTION

Protection of soil health under intensive land use and fast economic development is a major challenge for sustainable resource use in the developing world. The basic assessment of soil health is necessary to evaluate the changing trends following different land use and management interventions. In Asia, adverse effects on soil health arise from nutrient imbalance in soil, excessive fertilization, soil pollution and soil loss processes (Swaminathan, 2006).

The concept of soil health has consistently evolved with an increase in the understanding of soils. Soil health cannot be measured directly, but soil properties that are sensitive to changes in management can be used as indicators. On-farm assessment of soil health is recommended to assist farmers evaluate the effects of their management decisions on soil productivity (Hobbs and Morris, 1996).

Cropping system refers to temporal and spatial arrangements of crops and management of soil, water and vegetation in order to optimize the biomass/ agronomic production per unit area, per unit time and per unit input. Three components of soil health (e.g. physical, chemical and biological) are determined by soil characteristics, which can be altered by management practices followed under various cropping systems (Liebig *et al*., 2004). Lal (1994) suggested that soil degradation, caused by land misuse and soil mismanagement, should be quantified by measuring management -induced changes in soil properties or processes and their impacts on actual and potential productivity. Establishment of the cause-effect relationship between soil properties and processes on the one hand and crop productivity and environmental moderating functions on the other is crucial to enhancing soil productivity, restoring degraded lands and improving environmental quality.

Intensive cultivation of agricultural soils can lead to deterioration in soil properties and consequently reduction in crop productivity. Thus, the need for tillage has been questioned in the last few decades because of the excessive erosion from farmland after tillage. At the same time, it is known that inappropriate use of

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applied inputs and overexploitation of natural resource base, principally land and water, in many situations in past had led to secondary salinization in low-quality aquifer zones, groundwater table recession in fresh water aquifer zones, physical and chemical deterioration of the soil and water quality due to nutrient mining and pollution of ground water in some locations due to over application of nitrogenous fertilizers and of environment through crop residue burning and pesticide use (Pingali and Shah, 2001; Gupta *et al.*, 2003). Site-specific farming has introduced a management practice by which farmers can begin analyzing and dealing with cropland variability. Site-specific farming is based upon the notion that fields used for agricultural production are not uniform.

Rice–wheat systems of the eastern IGP have remained largely labor intensive and less mechanized. Farmers use low inputs because of socio-economic constraints and serious problems of drainage congestion and rainwater management. In the IGP, new resource conserving technologies for proper land and water management are being developed for enhancing crop productivity. Resource-conserving technologies are defined here as any practice that improves the efficiency of use of natural resources, including water, air, fossil fuels, soils, inputs, and people. Adoption of the resource conserving technologies offers newer opportunities of better livelihood for the resource poor small and marginal farmers. At the same time, these technologies are generating alternative sources of productivity growth through diversification and intensification of production systems (Hobbs and Gupta, 2003).

Now the main issue is regarding the selection of appropriate resource conservation technology for a given soil type, climatic condition and crop. Since not much work has been done on development of RCT's for different regions of IGP, the present investigation was formulated so in order to evaluate the impact of resource conservation technologies on the soil environment and productivity of wheat in rice-wheat cropping system.

MATERIALS AND METHODS

A field experiment was conducted during 2009-2011 to study residual impact of resource conservation technologies on soil health and productivity of wheat in rice-wheat cropping system with wheat as test crop (Tables 1 and 2). The experimental site is situated $25^0$15'40" North latitude and $87^0$21'42" East longitude with an altitude of 45.75 m above MSL (mean sea level). The sub-tropical climate of the area is characterised by dessicating summer and moderate rainfall. The total rainfall during the crop period was 78.6 mm. Distribution pattern of rainfall during early period of crop growth was nil. The soil of experimental site was clay in texture with pH 8.3, EC 0.38 dSm^{-1} at 25^0C, organic carbon 0.58 per cent, available nitrogen 311 kg/ha, available P_2O_5 36 kg/ha and available K_2O 205 kg/ha as estimated by international pipette method (Kilmer and Alexander, 1949), soil-water suspension method, titration method (Walkley and Black, 1934), alkaline $KMnO_4$ (Subbaiah and Asija, 1956), Olsen method (Olsen *et al.*, 1954) and neutral normal ammonium acetate (Jackson, 1973), respectively were determined.

The experiment was conducted during Kharif season under irrigated conditions in split plot design (SPD) replicated thrice and their impact was tested in rabi wheat. Main plot treatments comprising of tillage (T) were:

T_1 = Ploughing with desi plough twice (Cross) left for one week to decompose the weeds and residues and then planking in standing wheat (puddling) for paddy cultivation

T_2 = Ploughing twice by Cultivator, allowed to decompose weeds for a week then puddling by cross ploughing and planking

T_3= Summer ploughing onset of monsoon by mould bold plough to invert the soil once in three years followed by subsequent ploughing by cultivator to puddle the soil.

T_4= Disc ploughing once in three years after onset of monsoon to invert the soil. Residues were incorporated by cultivator then puddling was done after one week.

Sub-plot treatments related to organic residues and green manuring (C) were:

C_1 = Control; C_2 = FYM @ 50 q/ha; C_3 = Paddy straw @ 50 q/ha; C_4= Green manuring with Dhaincha (incorporated 45 DAS); C_5 = GM + Paddy straw @ 50 q/ha, C_6= GM + Rice husk @ 50 q/ha

RESULTS AND DISCUSSION

Soil pH : The tillage treatments in same cropping system did not show any significant (P<0.05) change in pH over control, while significant change in pH under influence of the treatment of organic residues was observed (Table 3). This effect of tillage on change in pH was inconformity with the findings of Hargroves *et al.* (1982) who reported more rapidly decrease in pH under on tillage. Further, the significant decrease in pH under influence of the treatments of organic residues might be attributed to the release of different organic acids as intermediate products during decomposition process solubilising salts, which were lost with leaching.

Sadana and Bajwa (1986) reported a decrease in pH of the soil on application of green manure and gypsum whereas Badnaur et al. (1990) observed similar results on incorporation of Subabul and sunhemp over fertilizer treatment alone in a vertisol. Haq *et al.* (2007) reported that lowest significant (P<0.05) pH value was attained in treatment of 100% GR(gypsum requirement) + 10t/ha FYM compared to other closely followed by 100% GR and 50% GR + 10t/ha FYM represented 9, 6 and 4% reduction, respectively from control. Manure produces organic acids and CO_2 to dissolve native $CaCO_3$ to liberate more Ca^{2+} for replacement of Na^+. Gal *et al.* (2007) reported that significant change may occur in zero tillage due to more addition of organic matter.

Table 1. Characteristics of the soil.

		Soil characteristics
1	Location	Northern Section of Bihar Agricultural College Farm, Sabour
2	Family	Fine, mixed, hyperthermic, Vertic Haplustalf
3	Soil colour	Grey D 5 Y 6/1, Dark grey (M5Y4/1)
4	Parent material	Alluvium
5	Mechanical composition	
	Sand	24 %
	Silt	31 %
	Clay	45 %
6	Texture	Clay
7	pH	8.04
8	EC	0.33 dSm^{-1} at 25^0C
9	Water stable aggregates	
	Mean weight diameter	0.478 mm
	Aggregate of size (>0.25 mm)	28.00 %
10	Hydraulic conductivity	0.148 cm hr^{-1}
11	Bulk density	1.44 Mg m^{-3}
12	Soil strength	9.10 MPa
13	Organic carbon	0.62 %
14	Available N	338.5 kg ha^{-1}
15	Available P_2O_5	48.0 kg ha^{-1}
16	Available K_2O	225.6 kg ha^{-1}

Table 2. Agro-management adopted for wheat crops.

	Operation	Date of operation
1	Variety	Sonalika
2	Spacing	23 cm row to row
3	Seed rate	120 kg ha^{-1}
4	Fertilizer dose	100:60:40 N, P_2O_5 and K_2O

The effect of interactions of these tillage and organic residues treatments was non–significant. This slow change might be attributed to the buffering capacity of the soils. Similar results were also advocated by Muthuvel *et al.* (1979) and Badanur *et al.* (1990).

Electrical conductivity (EC): A significant (P<0.05) decrease in EC of the soils under the influence of the treatments of tillage and organic residues and their interactions both after harvest of paddy and wheat was observed (Table 3). Maximum decrease in EC was noted under the influence of the treatments T_3 and C_6. This could be ascribed chiefly to the effect of release of different organic acids as intermediate products during decomposition process solubilizing soluble salts which were lost with leaching enhanced under loosened soils as a result of tillage treatments. Chaudhary *et al.* (1981) found that the electrical conductivity of soil decreased on application of FYM while Badanur *et al.* (1990) studied the incorporation effect of Subabul and sunhemp.

Soil organic carbon content (%): There was significant (P<0.05) increase in organic carbon (OC) content of the soils under influence of the treatments of tillage operations and application of organic residues over control after both paddy and wheat harvest (Table 3). Moreover, the maximum increase in organic carbon was noted in case of treatments T_3 (mould board ploughing) and C_6 (GM+ rice husk). This might be attributed to the addition of organic carbon to the soils by organic residues with high organic carbon content and vigorous growth of roots of the crops under well tilled conditions as a result of tillage treatments.

Biswas and Khosla (1971) found that the organic carbon content of alluvial soil of Sabour (Bhagalpur) increased to 2.28% by regular application of organic manure. Sharma et al. (1988) reported that the organic wastes (Lantana litter, rice husk and saw dust) markedly increased the organic carbon content by 29, 19 and 18 percent, respectively over control in silty clay loam soil. Badanur and Malabasari (1996) also observed that the incorporation of Subabul and Sunhemp in conjunction with sorghum stuble increased the organic carbon content of soil significantly. Gal *et al.* (2007) assessed the impacts of long-term (28 years) tillage and crop rotation on OC content and depth distribution on a dark-colored Chalmers silty clay loam in Indiana from moldboard plow and no-till treatments. Distribution of OC with soil depth differed dramatically under the different

Table 3. Changes in physico-chemical properties of the soils.

	pH (1:2.5)		EC (dS m^{-1})		OC (g kg^{-1})	
	After paddy harvest	After wheat harvest	After paddy harvest	After wheat harvest	After paddy harvest	After wheat harvest
T_1	8.15	8.14	0.39	0.4	0.62	0.58
T_2	8.10	8.09	0.37	0.37	0.62	0.85
T_3	8.21	8.21	0.35	0.34	0.64	0.60
T_4	8.15	8.12	0.36	0.35	0.63	0.60
SEm±	0.040	0.104	0.012	0.013	0.004	0.007
CD (P=0.05)	NS	NS	0.025	0.025	0.010	0.016
C_1	8.22	8.21	0.41	0.41	0.58	0.56
C_2	8.15	8.17	0.36	0.35	0.61	0.58
C_3	8.20	8.19	0.36	0.37	0.61	0.58
C_4	8.14	8.14	0.38	0.36	0.63	0.60
C_5	8.09	8.08	0.36	0.35	0.65	0.60
C_6	8.10	8.04	0.34	0.33	0.67	0.62
SEm±	0.043	0.036	0.014	0.016	0.005	0.005
CD (P=0.05)	0.176	0.073	0.029	0.030	0.011	0.010

Table 4. Changes in chemical properties of the soils**.**

	Available nitrogen (kg ha^{-1})		Available P_2O_5 (kg ha^{-1})		Available K_2O (kg ha^{-1})	
	After paddy harvest	After wheat harvest	After paddy harvest	After wheat harvest	After paddy harvest	After wheat harvest
T_1	337.6	320.2	45.6	45.5	234.4	231.5
T_2	338.6	320.6	47.4	46.6	236.7	236.1
T_3	340.6	323.6	53.9	51.0	242.4	241.0
T_4	341.9	324.0	50.9	49.5	240.3	239.3
SEm±	0.545	0.533	0.768	0.768	1.526	1.589
CD(P=0.05)	1.335	1.304	1.879	1.880	3.735	3.889
C_1	323.9	313.9	37.6	36.4	199.6	195.0
C_2	339.6	319.8	49.5	48.2	235.8	232.0
C_3	338.6	318.8	47.5	44.8	226.0	218.0
C_4	342.1	322.5	51.0	50.5	244.3	240.7
C_5	344.7	326.3	52.8	51.6	259.0	262.4
C_6	349.7	331.1	57.6	57.3	267.0	263.6
SEm±	0.342	0.349	0.605	0.612	1.551	1.471
CD(P=0.05)	0.690	0.706	1.222	1.236	3.134	2.873

tillage systems. While no-till clearly resulted in more OC accumulation in the surface layer than moldboard plow. Yadav *et al.* (2000) observed the long-term effect of green manuring and chemical fertilizer input practices utilising the trends in soil organic carbon content. At one location with high initial OC, a depletion of OC was noticed whereas OC increased at another location with low initial OC, with OC stabilizing between 0.60 and 0.65%.

The values of organic carbon were higher after paddy harvest than that after wheat harvest. This might be attributed to anaerobic condition of paddy soils with slow decompositions of organic residues and aerobic conditions of the soils during wheat cultivation with faster decomposition of the organic residues followed by relatively higher loss of organic carbon. It might be further supported by the fact that anaerobic cultivation of paddy would have added more organic matter than that of aerobic wheat cultivation.

Available N (Kg ha^{-1}) : As revealed from the data (Table 4), the available N of the soils increased significantly ($P<0.05$) over control under influence of the treatments of tillage operations and application of organic residues and their interactions. The maximum increases in

Table 5. Interaction effect of ploughing and residue on chemical properties of the soils.
Interaction effect of ploughing and residue on chemical properties of the soils.

	Available nitrogen (kg ha^{-1})								Available P_2O_5 (kg ha^{-1})								Available K_2O (kg ha^{-1})							
	After paddy harvest				After wheat harvest				After paddy harvest				After wheat harvest				After paddy harvest				After wheat harvest			
	T_1	T_2	T_3	T_4	T_1	T_2	T_3	T_4	T_1	T_2	T_3	T_4	T_1	T_2	T_3	T_4	T_1	T_2	T_3	T_4	T_1	T_2	T_3	T_4
C_1	323.2	322.0	323.3	325.2	313.7	312.0	314.5	315.3	35.3	37.6	39.3	38.3	34.6	36.6	37.3	36.3	191.0	198.6	202.9	202.8	186.8	191.7	202.0	199.3
C_2	337.9	339.5	340.6	340.3	318.3	318.9	321.6	320.3	45.4	48.2	54.0	50.3	46.6	45.6	51.4	49.3	232.4	234.4	240.2	236.2	226.5	202.1	236.3	232.4
C_3	335.2	337.6	338.8	342.9	316.5	317.7	318.6	322.4	43.6	46.3	51.0	49.3	43.2	41.0	49.0	46.3	225.6	220.2	230.1	228.0	212.3	217.3	222.6	219.6
C_4	338.6	340.7	342.7	346.3	320.7	320.4	324.2	324.7	47.2	49.2	56.3	53.3	47.3	50.4	52.3	52.0	240.6	240.9	250.5	245.6	236.2	239.5	242.0	245.4
C_5	341.7	343.4	346.4	347.3	322.6	323.9	329.9	329.2	49.0	50.3	57.3	54.7	48.4	51.0	54.3	53.3	252.4	259.5	262.0	261.4	257.3	262.4	265.2	264.7
C_6	348.9	349.7	350.7	349.4	329.2	330.7	332.5	332.2	53.0	52.6	65.3	59.3	52.7	54.9	61.8	60.0	264.8	266.3	268.8	267.5	270.0	273.5	276.2	274.2
			SE (±)	CD (5%)		SE(±)	CD (5%)			SE (±)	CD (5%)			SE (±)	CD (5%)			SE (±)	CD (5%)			SE(±)	CD (5%)	
C at same T			0.683	1.507		0.699	1.535			1.209	2.613			1.223	2.639			3.102	6.566			2.942	6.271	
T at same C			0.829	1.828		0.832	1.826			1.345	2.905			1.356	2.925			3.217	6.809			3.121	6.651	

Table 6. Changes in growth and yield attributes of wheat plant.

	Height (cm)	Effective tillers per linear meters	Length of ear head (cm)	Grain per panicle	1000 grain weight (gm)	Grain yield (q ha^{-1})	Straw yield (q ha^{-1})
T_1	80.87	35.33	9.39	32.39	39.69	16.75	35.20
T_2	84.00	35.77	9.45	32.99	39.71	17.46	35.63
T_3	82.56	40.05	9.78	33.90	40.01	18.82	38.30
T_4	79.72	36.72	9.39	33.21	39.73	18.16	37.63
SEm±	0.649	0.346	0.209	0.389	0.988	0.314	0.553
CD(P=0.05)	1.589	0.846	NS	0.954	NS	0.767	1.365
C_1	79.16	35.50	9.33	30.16	38.84	15.30	30.75
C_2	81.95	36.00	9.78	32.77	39.81	17.72	34.65
C_3	80.02	35.50	9.44	35.23	39.88	17.32	35.12
C_4	83.25	37.08	9.64	33.45	39.97	17.69	37.90
C_5	83.35	37.42	9.59	32.56	40.02	18.32	38.85
C_6	83.00	40.33	9.58	33.88	40.20	20.46	42.98
SEm±	1.289	0.529	0.197	0.554	0.095	0.253	0.573
CD(P=0.05)	2.605	1.068	NS	1.119	0.192	0.512	1.578

available N was noted in T_3 (Mould board ploughing) and C_6 (GM+rice husk) and their interactions ($T_3 \times C_6$) and minimum under T_1 (desi plough) and C_3 (Paddy straw) and their interaction ($T_1 \times C_3$) (Table 5). It might be probably due to addition of available N by organic residues and larger root portions of the crops under well tilled conditions as a result of tillage treatments. It might be due to the fact that addition of organic residues and pulverised soil condition would have activated microbes for enhanced mineralization, which resulted into increase in available N. It was further confirmed by the positive and highly significant correlation of available N with yield of wheat crop (r = 0.74**) (Table 8). Singh and Verma (1995) revealed that deep tillage in the sub-surface sandy loam soil of Agra region improved available nitrogen contents. Sharma and Mitra (1991) observed that application of organic material with phosphorous increased the residual value of available N in soil after rice harvest and it was maximum noted in case of wheat straw and Azolla. The maximum increase in available N under GM+ rice husk (C_6) might be attributed to the symbiotic N–fixation by G.M. plants and quick decomposition of fresh plant residues. The values of available N were higher after paddy harvest than that after wheat harvest. Here, it might be accentuated that available N was more associated with organic carbon. Moreover, it might be due to more utilization of available N by the microbes engaged in faster mineralization under aerobic condition (Gattani *et al.*, 1976).

Available P_2O_5 (Kg ha^{-1}): There was significant ($P<0.05$) increase in available P_2O_5 over control under influence of the treatments of tillage operations (T) and application of organic residues (C) and their interactions

Table 7. Interaction effect of ploughing and residue on yield attributes of wheat crop

	Effective tillers per linear meters				Grain yield (q ha^{-1})				Straw yield (q ha^{-1})			
	T_1	T_2	T_3	T_4	T_1	T_2	T_3	T_4	T_1	T_2	T_3	T_4
C_1	34.00	32.66	39.33	36.00	15.02	15.13	15.00	16.03	31.10	28.50	33.00	30.40
C_2	33.33	36.00	36.66	38.00	16.69	17.14	19.76	17.30	35.20	33.80	35.60	34.00
C_3	32.66	34.66	39.33	35.33	16.88	17.36	18.08	16.97	35.30	34.30	36.20	34.70
C_4	36.66	37.33	38.33	36.00	16.08	17.47	18.64	18.56	35.00	38.10	40.90	37.60
C_5	36.66	35.33	42.00	35.66	17.05	17.92	19.47	18.86	35.40	37.80	40.60	41.60
C_6	38.66	38.66	44.66	39.33	18.82	19.72	21.99	21.26	39.20	41.60	43.50	47.60
			SE(±)	CD (5%)		SE(±)	CD (5%)			SE(±)	CD (5%)	
	C at same T		1.056	2.187		0.507	1.091			1.146	2.423	
	T at same C		1.025	2.121		0.559	1.203			1.186	2.507	

Table 8. Correlation coefficient between soil and plant parameters.

	Av. N	Av. P_2O_5	Av. K_2O	pH	EC	Plant height	Wheat yield
Av. N	1	0.688**	0.785**	-0.526**	0.125	0.326	0.744**
Av. P_2O_5		1	0.852**	-0.164	-0.218	0.522**	0.643**
Av. K_2O			1	-0.411*	0.196	0.393	0.519**
pH				1	-0.252	-0.189	-0.316
EC					1	-0.216	-0.270
Plant height						1	0.272
Wheat yield							1

*5 % level of significance, **1% level of significance

(T × C) (Tables 4 and 5). The maximum increase in available P_2O_5 was observed in case of mould board ploughing (T_3) and green manuring + rice husk (C_6) and their interactions ($T_3 \times C_6$) and minimum in a case of desi plough (T_1) and paddy straw (C_3) and their interactions ($T_1 \times C_3$). The increase in available P_2O_5 on application of treatments might be probably due to addition of P_2O_5 by organic residues larger amount of roots of the growing crops under well tilled condition as a result of tillage operations. It might be further supported by the fact that addition of organic residues and pulverized soil condition would have activated phosphobacterins of enhanced transformation of organic P of the organic residues, which resulted into increase in available P_2O_5. It was further confirmed by the positive and highly significant correlation of available P_2O_5 with plant height (r = 0. 52**) and yield of wheat crop (r = 0.64**) (Table 8). Pandey *et al*. (1985) observed that the wheat straw incorporation was most effective in increasing the available P and Saha *et al*. (1995) find same result on application of barseem + straw, bagasse + rice straw. Badanur and Malabasari (1996) also observed that the incorporation of Subabul and Sunhemp in conjunction with sorghum stubble increased the organic carbon content of soil significantly. Carter and Rennie (1982) observed that the available P was significantly higher under 16 years of continuous use of zero tillage than the conventional shallow tillage in the surface soil. Similarly, the continuous direct drilling caused a marked increase in P content in the top soil than ploughing, chisel ploughing and reduced tillage (Millard and Vez, 1982).

Moreover, the beneficial effect of organic residues might also be due to formation of organic phosphate and release of inherent P from the organic residues. Further, the formation of organic acids as intermediate products due to decomposition of green manuring materials might have contributed towards the maximum response of C_6 in increasing available P_2O_5.

Available K_2O (Kg ha^{-1}): Significant (P<0.05) increase in available K_2O over control under influence of the treatments of tillage operations (T) and application of organic residues (C) and their interactions (T × C) (Table 4 and 5) were observed. The maximum increase was noted under tillage treatment T_3 (Mould board Ploughing) and organic residues C_6 (GM + rice husk) and minimum under T_1 (Desi plough) and C_3 (paddy straw). This might be attributed to high K reserves of the organic residues and release of native K under microbiological decomposition as evident from the high organic carbon of the treated plots. It might be supported by the fact that the NH_4^+ ions which were increased due to faster ammonification (mineralization) by the ammonifiers would have exchanged K^+ and released them from the exchange complex resulting in increases in available K_2O. Ruhal and Shukla (1979) reported that available K decreased from 498 to 318 kg/ha due to continuous cropping without FYM. However, continuous application of FYM for 9 years increasd the availability of K to 655 kg/ha and the highest K content was noted when FYM was applied in both the seasons. The relative build-up of K was more when FYM was applied to winter crop than that of monsoon. Pandey *et al.* (1985) observed that addition of all organic material and fly ash gave significant increase in K status of soil. Similarly, Subabul and subabul with sorghum stuble significantly increased available K content in soil (Badanur *et al*., 1995). Hargroves *et al.* (1982) indicated an increase in available K_2O under influence of continuous 5 years no tillage.

Maximum values of available K_2O (268.8 and 276.2 kg ha^{-1}) might be ascribed chiefly to the effect of faster decomposition of green manuring materials and higher K content of GM and rice husk as supported by deep ploughing (Mould board ploughing) which ultimately provided maximum sites for NH_4^+ and K^+ interactions in soil under loosened condition. The results were supported by the positive highly significant correlation of available K_2O with yield of wheat (r = 0. 52**) (Table 8).

Yield attributes and yield of wheat crop: The data on yield attributes (heights, number of effective tillers /linear meter, length of ear head, number of grains /panicle and 1000 grain weight) and yield of wheat grain and straw presented in table 6 revealed that significant (P<0.05) increase almost in all these characters over control with a few exception under influence of the treatments of tillage operations and application of organic residues.

Maximum increase in yield attributes and yield of wheat grain and straw was under influence of the treatments

Mould board ploughing (T_3) and GM+ rice husk (C_6). With few exception of height and length of ear head where T_2 (cultivator) and C_2 (FYM) were found most effective. It was observed that the minimum increase in yield attributes was under influence of the common tillage treatment T_1 (Desi plough) and variable organic residue treatments like C_2, C_3 and C_5. But, the effect of C_3 treatment seemed to be general with exception of C_2 and C_5.

Moreover, some of the characters did not show correlation among themselves. It might be attributed to the deviation in such characters from that of optimum varietal characters. On the basis of highest height of the plant, it could not be aimed at highest yield of straw, because straw yield would not only depend on only height of the plants, but also on number of effective tillers and diameter and thickness of wheat shoot. However, a positive correlation of yield of wheat grain with plant height (r = 0.27) was noted.

The maximum increase in the yield of wheat grain and straw was under influence of the tillage treatment T_1 (Desi plough), C_2 (FYM) and C_3 (Paddy straw) and their interactions (Table 7). The increase in yields might be ascribed chiefly to the effect of tillage and organic residues treatments on the improvement of physical, physico-chemical and chemical properties of the soils along with the availability of nutrients. These observations were further confirmed by positive and highly significant correlation of yield of wheat grain with that of available N (r = 0.74*), available P_2O_5 (r = 0.64**), and available K_2O (r =0.52**) (Table 8). It was supported by the previous finding of Ghildyal (1978) who was of the opinion that the tillage methods were known to favourably moderate soil physical environment for efficient water and nitrogen management and higher grain yield of rice. Kavimandan *et al.* (1987) observed that organic amendments like wheat straw, rice straw and FYM increased seed and straw yield of wheat significantly, whereas Singh *et al.* (1991) reported that only one tillage cum sowing operation was enough for better plant establishment and higher grain yield of lentil.

Deep ploughing and treatment of green manuring (GM) in addition to other organic residues individually and in combination improved the soil characters significantly, which led to the maximum increase in yields of wheat grain and straw. Moreover, the contribution of different tillage and organic residues treatments and their interactions were evaluated in terms of degree of improvement of yield attributing characters which resulted in increased yield of wheat crop. Actually, the increase in yield attributes and yield of wheat crop was not only contributed by a single factor, but a combination of factors was responsible for that.

Conclusion

The results indicated a significant improvement in soil health along with yield attributes and yields of wheat grain and straw over control under influence of these treatments of tillage operations (T) and application of different organic residues and their interactions (T × C). The maximum impact on improvement of soil health and plant parameters were observed under the treatments of T_3 (MB) and C_6 (GM + rice husk) and their interactions ($T_3 \times C_6$). Positive and highly significant correlation of yield of wheat grain with available N (r = 0.74**), available P_2O_5 (r = 0.64**), and available K_2O (r = 0.52**) were observed. Moreover, the increase in yield attributes and yield of wheat crop was not only contributed by a single factor, but a combination of factors was responsible for such significant increase.

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