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Effect of fertilizers and INM on soil properties under long term rice-wheat cropping system in Mollisols

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Abstract
To evaluate the effects of inorganic fertilization and integrated nutrient management on soil organic carbon (SOC), soil carbon storage, soil chemical properties (pH, electrical conductivity) and bulk density, replicated soil samples were collected in May 2015 from a 32 year old long term field experiment at Norman E. Borlaug Crop Research Centre of the Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, (Uttarakhand). Continuous application of fertilizers either alone or in combination with organic nutrient sources (farmyard manure, wheat straw and mungstraw) decreased the soil pH with lowest pH value of 7.01 in the treatments where 25% of recommended dose of N-fertilizers was substituted by mung straw. But, a reverse trend was obtained in case of EC of soil with maximum increase of 46% in treatment where integration of fertilizers and FYM was done in 50: 50 ratio. However no significant difference was observed in values of soil bulk density among different treatments upto 30 cm depth. Under continuous cultivation of rice-wheat cropping system for 32 years the initial level of organic carbon could not be sustained. However in both surface and sub-surface soil organic carbon content was increased significantly in treatments receiving either fertilizers alone or in combination with organic manures over control. Similar trend was followed in soil organic carbon stock. In surface soil highest values of soil organic carbon (1.19%) and soil organic carbon stock (22.49 t ha^{-1}) were observed in treatments where 50% of N-fertilizer was substituted through mung straw. So, it can be concluded that farmyard manure and green gram straw were best organic sources with respect to soil fertility and can be used as partial substitute of chemical fertilizers.

Keywords: Fertilizers, INM, soil properties under long term rice-wheat cropping system in Mollisols

Introduction
The adoption of modern agricultural input technologies such as fertilizers, high yielding nutrient responsive crop varieties, pesticides and modified tillage practices remarkably improved crop production and productivity but simultaneously our most valuable natural resource, the soil was overexploited. During the last few years the productivity of rice-wheat system is declining or become almost stagnant. The primary reasons for low productivity even in irrigated conditions are the inadequate and imbalanced use of fertilizer (Sharma *et al.*, 2003) [2] and reduced soil organic carbon that led to poor soil health (Yadav *et al.*, 2005 and Swarup *et al.*, 2000) [25, 23]. Further increasing cost of fertilizers also creates a problem to the use of chemical fertilizers. Exclusion of legumes and green manures, burning of crop residues are also responsible for unsustainability of rice-wheat cropping system in India (Kanwar, 1994) [12]. Several long term studies revealed that supplying plant nutrients by sole application of inorganic fertilizers depleted soil organic matter and thus resulted in decreased soil productivity (Jat *et al.*, 2006). Integrated nutrient management (INM) is one of the most important tools for better utilization of resources and to produce crops with less expenditure. INM refers to conjunctive use of all available nutrient sources (organic, inorganic and biofertilizers) based on economic consideration to sustain soil fertility and crop productivity. The integrated application of both organic and inorganic sources of nutrients not only increased the crop production and profitability but also helps in maintaining the soil fertility status (Chandrasoorian *et al.*, 1994) [4]. The long term beneficial impact of integrated nutrient management had proved superior to the use of each component separately (Palaniappan and Annadurai, 2007) [18]. Incorporation of wheat straw, FYM and green manuring with *Sesbania aculeata* improves the soil structure, reduces bulk density, soluble salt concentration, pH and increased porosity, infiltration rate, soil organic carbon of soil (Kumar *et al.*, 2012). Antil and Mandeep (2007) [1] reported that 10 years continuous application organic manures alone or in combination with fertilizers decreased the soil pH. Soil organic carbon (SOC) is the basis of soil fertility.

It promotes the structure, biological and physical health of soil, and is a buffer against harmful substances. Therefore SOC act as key indicator of soil quality and productivity (Bauer and Black, 1994). So incorporation of organic sources of nutrients supplementary to inorganic fertilizers has provided a befitting solution not only to the problem of soil degradation but also to the growing concerns about maintaining long term sustainability of cropping system (Ray and Gupta, 2001) [19].

Material and Methods

A long term field experiment had been continued at Norman E. Borlaug Crop Research Centre of the reputed Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, (Uttarakhand) since 1983. Geographically the site was situated in *Tarai* region of Uttarakhand at latitude of 28.97° N, 79.41°E longitude and an altitude of 243.84 meter above mean sea level. Pantnagar had humid sub-tropical climate with heavy rains in monsoon season. Mean annual rainfall was 1400mm. The soils of *Tarai* region were poorly developed alluvial soils. These soils were developed from moderately coarse textured alluvial parent material under the influence of tree vegetation. The soils of present experimental area belonged to Beni silty clay loam series. Following twelve treatments were compared in a permanent plot experiment on integrated nutrient supply system in rice-wheat cropping system using Randomized block design.

Treatments

Treatments	**Rice (Kharif)**	**Wheat (Rabi)**
T_1	Control (no fertilizer or O.M.)	Control (no fertilizer or O.M.)
T_2	50% RECOMMENDED N Dose through urea	50% RECOMMENDED N DOSE through urea
T_3	50% RECOMMENDED N DOSE through urea	100% RECOMMENDED N DOSE through urea
T_4	75% RECOMMENDED N DOSE through urea	75% RECOMMENDED N DOSE through urea
T_5	100% RECOMMENDED N DOSE through urea	100% RECOMMENDED N DOSE through urea
T_6	50% RECOMMENDED N DOSE through urea + 50% N through FYM	100% RECOMMENDED N DOSE through urea
T_7	75% RECOMMENDED N DOSE through urea+ 25% N through FYM	75% RECOMMENDED N DOSE through urea
T_8	50% RECOMMENDED N DOSE through urea + 50% N through Wheat straw	100% RECOMMENDED N DOSE through urea
T_9	75% RECOMMENDED N DOSE through urea+ 25% N through Wheat straw	75% RECOMMENDED N DOSE through urea
T_{10}	50% RECOMMENDED N DOSE through urea + 50% N through Mung straw	100% RECOMMENDED N DOSE through urea
T_{11}	75% RECOMMENDED N DOSE through urea+ 25% N through Mung straw	75% RECOMMENDED N DOSE through urea
T_{12}	Farmer's practice	Farmer's practice

(The recommended dose of nitrogen was 120 kg ha^{-1} for rice as well as wheat).

Soil samples were collected after harvesting of wheat crop from each plot with the help of auger at 0-15 cm and 15-30cm depth. Organic carbon content of soil was determined by modified Walkley and Black Method (1934) [24] as described by Jackson (1967). Soil organic carbon stock provides an index of stored organic carbon in the soil. Joao Carlos *et al.* (2001) [11] gave following formula to calculate soil organic carbon stock: Soil organic carbon stock (t ha^{-1}) = B.D. (Mg m^{-3}) × O.C. (%) × Soil depth (cm). Bulk density of soil was calculated by Blake and Hartage, 1986), pH by glass electrode (Jackson, 1967) and electrical conductivity (EC) by conductivity meter (Bower and Wilcox, 1965).

Results and Discussions

Bulk Density

In the experimental plots the bulk density ranged between 1.26 and 1.31 Mg m^{-3} in surface soil layer (in table 1 and fig 1). Lowest bulk density of 1.26 Mg m^{-3} density was recorded in T_6, T_{10} and T_{11}. On the other hand the highest bulk density of 1.31 Mg m^{-3} was reported in T_1 (control). It shows that in comparison to control, the sole application of fertilizers led to a slight decrement in bulk density. Integrated application of fertilizers and organic sources of nutrient led to more decrement in soil bulk density, however, the difference was not significant. In the sub-surface zone the bulk density ranged between 1.33 and 1.38 Mg m^{-3} but no significant difference in bulk density was observed among different treatments. It was clearly revealed that the bulk density of sub surface was higher than the surface soil. In the surface layer the decrease in bulk density of inorganically fertilized plots might be because applied fertilizers promoted the plant root and shoot growth that increased the plant biomass production (Selvi *et al.* 2005) [21]. Higher biomass resulted in increased soil organic matter, which act as cementing agent and reduced soil bulk density. Similarly, integrated application of organic and inorganic manures directly added the organic matter through applied organic source and indirectly through increased plant biomass production which promoted the soil aggregation and thus increased total porosity and decreased bulk density. Schjonning *et al.* (1994) [20] also reported a decrease in the bulk density of the surface soil due to application of cattle manure. The higher bulk density of subsurface soil in comparison to surface soil might be due greater compaction in sub-surface layer and more organic carbon, higher root biomass production with nutrient application in surface layer. Celik *et al.* (2004) [3] also reported that bulk density of surface soil was lower than sub-surface soil.

Table 1: Effect of integrated nutrient management on soil bulk density

Treatment	Bulk density (Mg m^{-3})	
	0-15 cm	15-30 cm
T_1	1.31	1.36
T_2	1.29	1.36
T_3	1.30	1.35
T_4	1.28	1.33
T_5	1.30	1.38
T_6	1.26	1.33
T_7	1.28	1.34
T_8	1.27	1.34
T_9	1.28	1.35
T_{10}	1.26	1.33
T_{11}	1.26	1.36
T_{12}	1.28	1.34
SEm±	0.036	0.013
C.D. (p=0.05)	NS	NS
Initial value (1983)	1.33	1.40

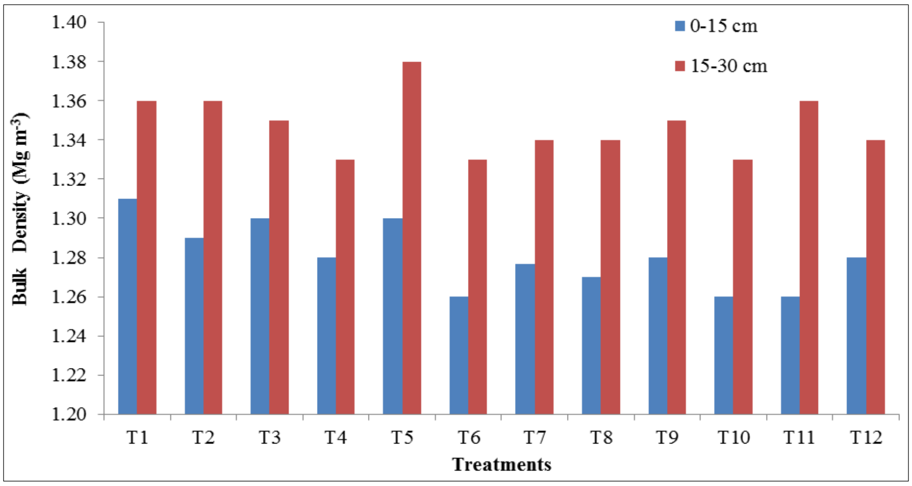

Fig 1: Effect of integrated nutrient management on soil bulk density

Electrical Conductivity

Combined application of fertilizers and organic manures led to a significant increase in soil EC over sole application of fertilizers (in table 2). The EC of soil was ranged from 0.323 to 0.511dSm^{-1} and lowest EC was recorded in control (0.323dSm^{-1}) which was about 7.71% lower than initial value. Maximum EC value of 0.511 dSm^{-1} was observed in T_6 followed by T_8 (0.489 dSm^{-1}). In T_6 and T_8 the EC of soil increased by 46% and 39.71%, respectively, over initial value. There was marginal increase in soil EC on fertilization and among the inorganically fertilized plot maximum EC (0.403 dSm^{-1}) was reported in T_5. The increase in the soil EC on fertilization may be due to presence of soluble salts in these chemical fertilizers (Kumara *et al.*, 2013) [16]. The increase in soil EC with application of organic manures might be due to release of soluble salts through decomposition of organic manures. The results of present study are in strong line with results reported by Antil *et al.* (2007) [1] and Escobar *et al.* (2008) [5].

Soil pH

The pH of surface soil (0-15 cm depth) was decreased as compared to control and initial value (in table 2). The pH of surface soil ranged from 7.01 to 7.28 with a maximum pH under controlled plot (7.28) and minimum pH was reported under T_{11} (7.01). Sole application of chemical fertilizers led to a significant decrement in soil pH. The decrement in pH was more pronounced with combined application of inorganic sources and organic sources (FYM, wheat straw and mung straw) in comparison to sole application of fertilizers. Among different organic manures application of mungstraw led to more decrease in soil pH. Further, application of 75%recommended N through fertilizer and 25% through organic sources caused more decrease in pH as compared to application of 50% recommended N dose through fertilizer and remaining 50% through organic sources. The slight decrement in pH of control plot as compared to initial pH value might be due to net removal of salts including bases under continuous cropping without any application of nutrients sources (Gangola *et al.*, 2012) [6]. The significant decrement in soil pH on sole application of inorganic fertilizers might be due to acid producing nature of nitrogenous fertilizers. Nitrogenous fertilizers increase ammonium ion concentration in soil which can exchange the basic cations on soil exchange complex due to which leaching losses of basic cations were enhanced and it resulted in increased soil acidity or reduction in soil pH. The higher reduction in soil pH on integrated nutrient management might be due production of CO_2 and organic acids during microbial decomposition of applied organic manures complemented by residual acidity of nitrogen fertilizers. The more decrease in soil pH on substitution of 25% fertilizers by organic sources as compared to 50% substitution may be due to production of more amount of NH_4^+ ion through hydrolysis of fertilizers in former case. Kharche *et al.* (2013) [13] also reported similar ameliorating effect of integrated use of organic and synthetic fertilizers on soil pH.

Table 2: Effect of integrated nutrient management on soil pH, EC

Treatment	pH 0-15 cm	Change in pH overInitial value (%)	EC (dSm^{-1}) 0-15 cm	Change in EC overInitial value (%)
T_1	7.28	-0.27	0.323	-7.71
T_2	7.16	-1.9	0.372	+6.28
T_3	7.19	-1.5	0.360	+2.86
T_4	7.15	-2.05	0.389	+11.14
T_5	7.13	-2.3	0.403	+15.14
T_6	7.08	-3.0	0.511	+46.00
T_7	7.06	-3.3	0.466	+33.14
T_8	7.08	-3.0	0.489	+39.71
T_9	7.10	-2.74	0.451	+28.86
T_{10}	7.04	-3.56	0.484	+38.29
T_{11}	7.01	-3.97	0.450	+28.57
T_{12}	7.18	-1.64	0.381	+8.86
SEm±	0.013	-	0.004	-
C.D. (p=0.05)	0.037	-	0.012	-
Initial Value (1983)	7.30	-	0.35	-

Organic Carbon

The data presented in table 3 and fig 2 revealed that after continuous application of fertilizers either alone or in conjunction with organic manures in rice wheat cropping system for 32 years, the organic carbon content of soil increased in all the treatments with respect to the control (in table 3 and fig 2). In the surface layer (0-15cm) the content of organic carbon varied from 0.67% to 1.19%. The lowest organic carbon was reported in T_1 (0.67%) and highest amount of organic carbon was reported in T_{10} (1.19%) followed by treatment T_6 (1.11%). In T_{10} and T_6 the organic carbon was increased by 77.61% and 65.67% respectively, over control. Application of fertilizers alone raised the level of organic carbon in comparison to control. It was further observed that organic carbon content increased with increased rate of chemical fertilizers and among the inorganically fertilized plots the maximum organic carbon was recorded ins T_5 (0.86). Integration of fertilizers with organic manures has more positive effect on soil organic carbon in comparison to fertilizers alone. The influenced of different organic sources in maintaining the soil organic carbon followed the order: mung straw > FYM > wheat straw. Application of 50% of recommended dose through fertilizers and 50% through organic sources (T_6, T_8 and T_{10}) is found to be more efficient than application of 75% of recommended dose through fertilizers and 25% through organic sources (T_7, T_9 and T_{11}). In the sub-surface (15-30 cm) soil layer the value of organic carbon ranged from 0.31% to 0.69%. Lowest value of organic carbon (0.31%) was recorded in $T_1$and highest value (0.69%) was recorded in T_{10} followed by T_6 (0.62%). In the sub-surface, organic carbon values followed the similar trend as that followed in surface soil.

The lowest level of organic carbon in control in both surface and sub-surface layer could be ascribed to poor crop growth due to less availability of nutrients which resulted in lower crop biomass production and lower organic residue incorporation in soil (Kumar *et al.,* 2011) [15]. Applied fertilizers supplied nutrients to plants due to which plant root and shoot biomass production increased which ultimately led to addition of more organic residues (roots, stubbles etc) to soil which on decomposition added to soil organic carbon (Gathala *et al*., 2007) [7]. In case of INM organic matter was directly added to soil through applied organic manures and indirectly through increased plant biomass production which on mineralization significantly improved soil organic carbon status (Narwal and Antil, 2005) [17]. It was clear from the data obtained that sub-surface soil contained lower organic carbon than surface soil which might be because addition of fertilizers, organic manures, crop residues and cultivation practices are generally limited to surface soil.

In the present study the organic carbon content in all the treatments was decreased in comparison to initial value which might be ascribed to enhanced mineralization of organic matter which increased losses of carbon as carbon dioxide, immobilization and due to reduced carbon input under continuous arable cropping (Sparling *et al.*, 1992) [22].

Soil Organic Carbon Stock

The soil organic carbon stock increased in all the treatments over the unfertilized control. The lowest SOC-stock in control might be because no organic matter was incorporated in it. Further continuous cultivation disturbed the soil which increased rate of decomposition of native organic matter and further reduced SOC stock (Jenny and Raychaudhuri, 1960) [10]. In the surface soil layer (0-15cm) the soil organic carbon stock ranged between 13.17 t $ha^{-1}$and 22.49 t ha^{-1}.The lowest status of soil organic carbon stock was observed in T_1 (13.17 t ha^{-1}) and highest status was observed in T_{10} (22.49 t ha^{-1}) followed by treatment T_6 (20.98 t ha^{-1}).The level of soil organic carbon stock was increased by 70.77% and 59.30% in treatments T_{10} and T_6, respectively, over unfertilized control. Further an increasing trend of SOC-stock was observed with the increasing rate of fertilizer application. Among the chemically fertilized plot highest value of SOC-stock was reported in T_5 (16.77 t ha^{-1}) followed by T_4 (16.32 t ha^{-1}) and T_2 (15.29 t ha^{-1}). SOC-stock was significantly higher in treatments where integrated application of inorganic fertilizers and organic manures was done as compared to fertilizers alone. The SOC stock values of 22.49, 20.98, 20.22, 18.58, 17.91 and 17.47 t ha^{-1} were reported in treatments T10, T6, T11, T7, T8 and T9, respectively. Among the three organic manures- FYM, mung straw and wheat straw the soil incorporation of mung straw caused maximum increase in SOC-stock values. In the sub-surface soil layer (15-30 cm) the SOC-stock values were lower in comparison to surface soil. The lowest value of SOC-Stock (6.34 t ha^{-1}) was recorded in treatment T_1 and highest value of SOC-stock (13.77 t ha^{-1}) was observed in T_{10} followed by treatment T_6 (12.37 t ha^{-1}) and others. In sub-surface also the application of fertilizers alone was less effective in improving SOC-stock as compared to combined application of both fertilizers and organic manures. In INM the higher improvement in SOC stock as compared to sole application of fertilizers might be because besides chemical fertilizers significant amount of organic manures (FYM, wheat straw and mungstraw) were incorporated in soil which directly increased SOC stock on decomposition and indirectly by increasing crop biomass production. These results are in close line with results of Kukal *et al.* (2009) [14] who reported that application of recommended dose of NP fertilizers alone or in conjunction with organic manures (FYM, poultry manure and pressmud) improved the SOC-stock. The higher SOC-stock values in the surface soil in comparison to sub-surface soil might be attributed to the strong influence of N fertilization on SOC-stock in the top soil than on lower soil depth (Jagadamma *et al.*, 2007) [9].

Table 3: Effect of various long-term treatments on Soil Organic carbon (%) and Soil organic carbon stock (t ha^{-1})

Treatment	Organic carbon (%)		Soil organic carbon stock (t ha^{-1})	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm
T_1	0.67	0.31	13.17	6.34
T_2	0.79	0.41	15.29	8.36
T_3	0.77	0.35	15.02	7.09
T_4	0.85	0.48	16.32	9.58
T_5	0.86	0.32	16.77	6.62
T_6	1.11	0.62	20.98	12.37
T_7	0.97	0.43	18.58	8.64
T_8	0.94	0.51	17.91	10.25
T_9	0.91	0.35	17.47	7.08
T_{10}	1.19	0.69	22.49	13.77
T_{11}	1.07	0.48	20.22	9.79
T_{12}	0.86	0.42	16.51	8.44
SEm±	0.046	0.015	0.043	0.044
C.D. (p=0.05)	0.134	0.043	0.127	0.128
Initial value (1983)	1.48	-	-	

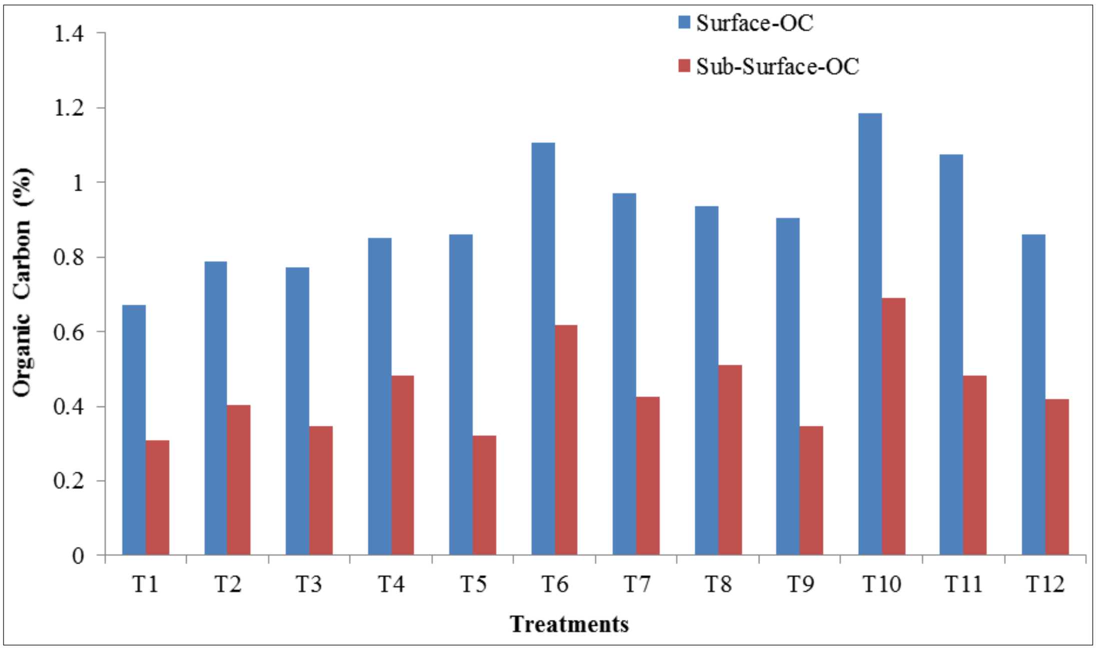

Fig 2: Effect of integrated nutrient management on soil organic carbon (%)

Conclusion

The overall results demonstrated that continuous use of crop straw and FYM in partial replacement of inorganic fertilizers would significantly improved soil physical, chemical properties as well as soil nutrient status. The increment of nitrogenous fertilizer doses had significant effect on soil properties especially pH, soil organic carbon and soil organic carbon stock. The mung straw proved to be the best organic substitute of nitrogenous fertilizers in respect to its influence on soil fertility

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