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Effect of inorganic and integrated nutrient management on soil carbon and nutrient status in Mollisols

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Abstract
From an ongoing long term field experiment at Norman E. Borlaug Crop Research Centre of the Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, (Uttarakhand) soil samples were collected in 2015 to study the effect of sole application of fertilizers and their integration with different organic sources (farmyard manure, wheat straw and mungstraw) on soil nutrient status, organic carbon status and total carbon. The study revealed that under continuous cultivation of rice-wheat cropping system for 32 years all the nutrient management treatments failed to sustain the initial level of N (392 Kg ha^{-1}), however soil phosphorus level was increased in all the treatments over initial value (18 Kg ha^{-1}). In surface soil layer highest value of available nitrogen (316.46 Kg ha^{-1}) and available phosphorus (26.64 Kg ha^{-1}) was recorded in treatment where recommended dose of nitrogen was applied through both fertilizers and moong straw. The level of available potassium was decreased with sole application of fertilizers but increased slightly with integration of fertilizers with either FYM or moong straw. Although in both surface and sub-surface layers soil organic carbon content was increased significantly over control in all treatments receiving either fertilizers alone or in combination with organic manures but all these nutrient managements failed to sustain initial level (1.48%) of soil organic carbon. Integrated nutrient management raised organic carbon content to a higher level as compared to fertilizers alone. Similar trend was followed in soil total carbon. In surface soil highest values of soil organic carbon (1.19%) and total carbon (1.57%) were observed in treatments where 50% of N-fertilizer was substituted through moong straw followed by treatment where 50% of N-fertilizer was substituted through farmyard manure. So, it can be concluded that farmyard manure and green gram straw were better organic sources of plant nutrients and thus can be used as partial substitute of chemical fertilizers to maintain soil fertility and to sustain crop productivity.

Keywords: Integrated nutrient management, soil organic carbon, soil fertility, green gram straw

Introduction
Due to increasing human population, the demand for food, feed, fodder, fiber and shelter is rapidly increasing. Kumar and Shivay (2010) [11] estimated that by 2025 total food grain demand of the country will reach 291 million tones comprising 109 million tones of rice and 91 million tones of wheat. The high input agriculture has led to self sufficiency in food-grains but it has posed several new challenges. The results emanating from long-term fertilizer experiments across the country have clearly indicated that imbalance use of chemical fertilizers has resulted in numerous problems *viz.* micronutrient deficiencies, nutrient imbalances in soil and plant system, environmental degradation and deterioration of soil health. Presently, Indian soils are 70% deficient in N, 50% in P, 13% in K, 4.7% in Zn, 4.8% in Cu, 11.5% in Fe and 4.0% in Mn (M. S. Pal, 2007). The instability in crop production and high cost of fertilizers and these other agricultural constraints leads to call for substituting inorganic fertilizers by locally available low cost organic sources viz., manures, green manures, bio-fertilizers etc. in an integrated manner for sustainable crop production and to maintain soil health (Acharya, 2002) [1]. Bhattacharya and Chakraborthy (2005) [3] reported that in our country there is high availability of the organic sources of nutrients like animal dung manure (791.6 mt), crop residues (603.5 mt), green manure (4.50 mha), rural compost (148.3 mt), city compost (12.2 mt) and biofertilizer (0.41 mt) and these manures can possibly be good substitute of chemical fertilizers to maintain the soil properties. The organic manures help in improving the use efficiency of inorganic fertilizers (Singh and Biswas, 2000) [22]. In addition to this, the presence of microbes growth hormones and enzymes make them essential for improvement of soil fertility and productivity. Mathew and Nair (1997) [15] revealed that the application of cattle manure alone or in conjunction with NPK fertilizers in rice raised the

level of total N, available P and K of soil. The suitability of organic materials as fertilizer depends to a great extent on its rapidity of mineralization and liberating the nutrients present in them (Weeraratna, 1979) [28]. The accurate amount of manure could efficiently be calculated from precise measurement of nutrient mineralization. The organic sources available presently in the country could meet only 1/3rd of total nutrients required therefore the use of organic is supplementary rather complimentary. Therefore, the present investigation was undertaken to find out the effects of inorganic sources of nutrients and integrated nutrient management on soil nutrient status and organic carbon status.

Material and Methods

The experiment was conducted at Norman E. Borlaug Crop Research Centre of the Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, District Udham Singh Nagar (Uttarakhand). The site was situated in the South of the Shivalik ranges of Himalayan mountains in the humid sub-tropical climate zone locally known as the *Tarai* region, at latitude of 28.97° N, 79.41°E longitude and an altitude of 243.84 meter above mean sea level. The soils of *Tarai* region were poorly developed alluvial soils. The soils of present experimental area belonged to Beni silty clay loam series. These soils are usually rich in organic matter, low to medium in available P, available N and medium to high in available K. Following twelve treatments were compared in a permanent plot experiment on integrated nutrient supply system using randomized block design in rice-wheat cropping system.

Detail of all 12 treatments used is as follow

Treatments	Rice	Wheat
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).

From each plot were collected from a depth of 0-15 cm, after harvesting of wheat. Available nitrogen in soil was estimated by alkaline potassium permanganate ($KMnO_4$) method (Subbiah and Asija, 1956) [26]. Available soil phosphorus was determined by Olsen's method (Olsen *et al.*, 1954) [18]. Available potassium in soil was determined by a 2 step neutral normal ammonium acetate (NH_4OAc) method given by Jackson (1973) [8]. Organic carbon content of soil was determined by modified Walkley and Black Method (1934) as described by Jackson (1967). Total soil C was determined by the dry combustion process using a CHNS (Pansu *et al.*, 2001) [19].

Results and Discussions

Available soil nitrogen

The data presented in table 1 and fig 1 showed that after 32 years of continuous application of fertilizers alone or in conjunction with organic manures in rice wheat cropping system, the available nitrogen of soil decreased as compared initial value (392 Kg ha^{-1}). Chesti *et al.* (2013) [6] supposed that decrease in available nitrogen even after continuous fertilization and integrated nutrient management might be attributed to the losses of N in different ways, uptake of available N by crops, or conversion of nitrogen to such forms, which cannot be not extracted by alkaline potassium permanganate. In surface soil layer highest value of available nitrogen (316.46 Kg ha^{-1}) was recorded in T_{10} and lowest value of available nitrogen (205.10 Kg ha^{-1}) was observed in T_1. It was further observed that level of available nitrogen was increased with increased rate of chemical fertilizers. According to Bhardwaj and Omanwar (1994) [2] this increase in soil available nitrogen on increasing rate of NPK fertilizers might be because of supply of more amount of mineral nitrogen (NH^+_4 and NO^-_3) by higher doses of fertilizers. Higher value of available nitrogen was recorded in plots where combined application of fertilizers and organic manures was done as compared to only chemically fertilized plots and among the organic sources wheat straw has least effect and maximum effect on available nitrogen was shown by moong straw, followed by FYM. 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}).

The increase in surface available N over control on integration of fertilizers and organic manure might be ascribed that application of mineral N along with organic manure narrowed the C:N ratio of organic manure which increased the rate of mineralization of organic manure and thus resulted in rapid release of nutrients from the organic matter (Singh *et al.*, 2014) [24].

Available soil phosphorus

Long term application of fertilizers alone or in integration with organic sources resulted an increment in soil available phosphorus over the initial level (table 1 and fig 1). Soil phosphorus ranged from 14.25 kg ha^{-1} to 26.64 kg ha^{-1}. Minimum status of 14.25 kg ha^{-1} soil phosphorus was obtained in control while maximum build up of available phosphorus was recorded in T_{10} (26.64 kg ha^{-1}) followed by T_6. In T_{10} and T_6 due to integrated nutrient management the level of available P was raised by 48.00% and 40.22% over the initial value in 32 years. The decrease in phosphorus level of control plot was due to the crop removal of soil available phosphorus which in turn was not added to soil neither through fertilizers nor by manures. The amount of available soil phosphorus was enhanced with increasing the level of inorganic fertilizers although the difference was insignificant. This increase in soil available P on application of fertilizers may be attributed to direct addition of small amount of P through applied fertilizers and through their residual effect. It was also reported that integration of organic sources and inorganic fertilizers has more positive impact on soil available phosphorus in comparison to fertilizers alone. The influenced of different organic sources in increasing the soil available phosphorus followed the order: Mung straw > FYM > Wheat straw. Application of 50% recommended N dose through organic manure (moong straw, wheat straw and farmyard manure) was more effective in increasing soil available P in comparison to application of only 25% recommended n dose through these organic sources.

Table 1: Effect of integrated nutrient management on availability of primary nutrients in soil

Treatment	Available N (Kg ha^{-1})	Change in Available N over initial value (%)	Available P (Kg ha^{-1})	Change in Available P over Initial value (%)	Available K (Kg ha^{-1})	Change in Available K over Initial value (%)
T_1	205.10	-47.67	14.25	-20.83	110.63	-11.49
T_2	250.45	-36.11	19.26	7.00	113.28	-9.38
T_3	227.39	-41.99	18.93	5.17	114.69	-8.25
T_4	257.68	-34.27	19.87	10.39	116.83	-6.54
T_5	275.20	-29.80	21.42	19.00	119.48	-4.42
T_6	308.04	-21.42	25.24	40.22	125.73	0.06
T_7	298.50	-23.85	22.98	27.67	129.92	3.94
T_8	286.70	-26.86	22.02	22.33	117.91	-5.67
T_9	273.37	-30.26	23.86	32.56	123.10	-1.52
T_{10}	316.46	-19.27	26.64	48.00	125.74	0.06
T_{11}	303.27	-22.64	24.14	34.11	134.02	7.22
T_{12}	265.13	-32.37	22.60	25.56	115.86	-7.32
SEm±	2.349		0.678		1.552	
C.D. (p=0.05)	6.89		1.99		4.55	
Initial value (1983)	392		18		125	

The more significant improvement in soil available P on integration of fertilizers with organic manure might be because of precipitation of P-fixing cations like Al^{+3}, Fe^{+3} and Ca^{+3}, by organic acids released during mineralization of these organic sources (Nagar *et al.*, 2016) [16]. Further several anions (eg. humate ion) were released during mineralization of organic sources which cause desorption of adsorbed phosphate ion by anion exchange. The superior effect of integrated application of manures and fertilizers on soil phosphorus level in comparison to fertilizers alone was also reported by Singh *et al.* (2013) [21]. More significant effect of moong straw in raising soil available phosphorus level might be ascribed to its narrow C: N ratio which favored its mineralization.

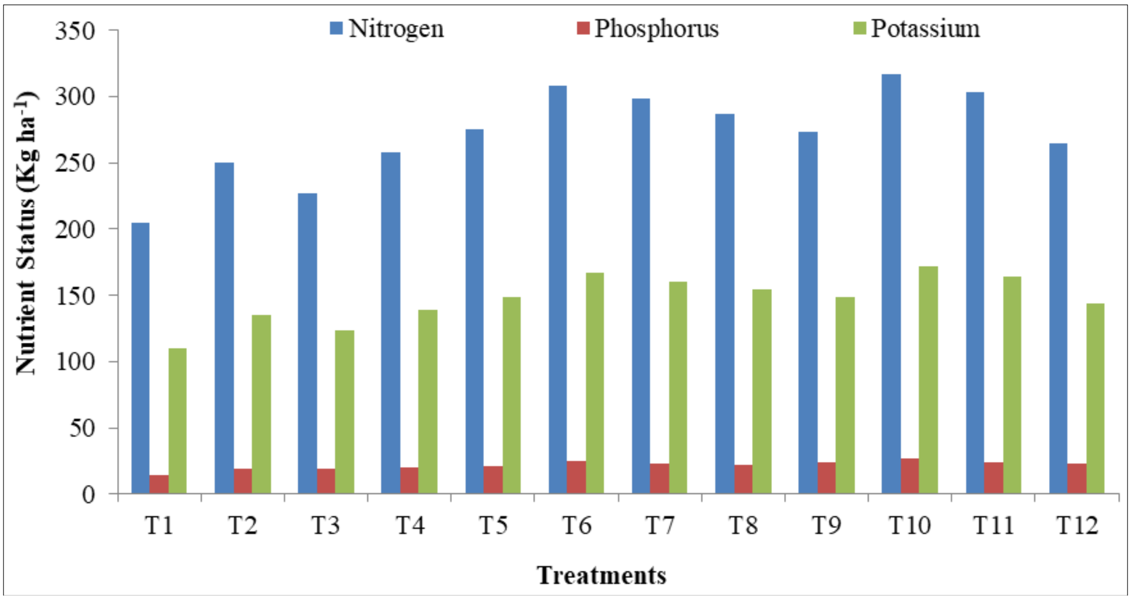

Fig 1: Effect of integrated nutrient management on post harvest available- nutrients status in soil

Available soil potassium

The level of available potassium in soil varied from 110.63 kg ha^{-1} to 134.02 kg ha^{-1}(in fig 1 and table 1). The lowest value of available K was recorded in control and highest value was recorded in T_{11} (134.02 kg ha^{-1}). Among the treatments supplied with inorganic fertilizers alone the content of available K was lowered over initial value (125 kg ha^{-1}) except T_5 treatment. All the treatments where combined application of fertilizers and organic manures was done only in the treatments where integration was done with FYM or moong straw showed higher content of available K over initial level. In treatments T_{11} and T_7 the level of available phosphorus was increased by 21.41% and 17.44% over the control. In Nepal, Gami *et al.* (2001) also observed negative K balance in treatments receiving either fertilizer alone or with wheat straw except the treatment receiving FYM. The lowest level of potassium in control might be because continuous intensive cropping in soil without application of any nutrient sources have depleted the soil nutrients (Singh *et al.*, 1999) [23]. The lowering of available K over initial level in treatments applied with only fertilizers might be because of higher removal of potassium by crops than its annual addition. The increase in soil available K on INM might be attributed to direct addition of K by these sources, reduction in fixation of available K in soil matrix and release of potassium from exchange site of soil because of interaction between clay and applied organic sources (Singh *et al.*, 2014) [24].

Organic Carbon

In all the treatments organic carbon content decreased as compared to initial value (1.48%) however it increase in all the treatments with respect to the control (in table 2 and fig 2). 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%). Organic carbon content increased with increased rate of chemical fertilizers and among the inorganically fertilized plots the maximum organic carbon was recorded in T_5 (0.86). Integration of fertilizers with organic manures has more positive effect on soil organic carbon as compared to fertilizers alone. The influenced of different organic sources in maintaining the soil organic carbon followed the order: mung straw > FYM > wheat straw. In the sub-surface (15-30 cm) soil layer lowest value of organic carbon (0.31%) was recorded in T_1 and highest value (0.69%) was in $T_{10.}$ In the sub-surface, organic carbon content followed the similar trend as that followed in surface soil. It was clear from the data obtained that sub-surface soil contained lower organic carbon than surface soil.

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

Treatment	Organic carbon (%)		
	0-15 cm	Change over initial value(%) in 0-15 cm	15-30 cm
T_1	0.67	-54.73	0.31
T_2	0.79	-46.62	0.41
T_3	0.77	-45.95	0.35
T_4	0.85	-42.57	0.48
T_5	0.86	-41.89	0.32
T_6	1.11	-25.00	0.62
T_7	0.97	-34.46	0.43
T_8	0.94	-36.349	0.51
T_9	0.91	-38.51	0.35
T_{10}	1.19	-19.59	0.69
T_{11}	1.07	-27.70	0.48
T_{12}	0.86	-41.89	0.42
SEm±	0.046	-	0.015
C.D. (p=0.05)	0.134	-	0.043
Initial value (1983)	1.48	-	-

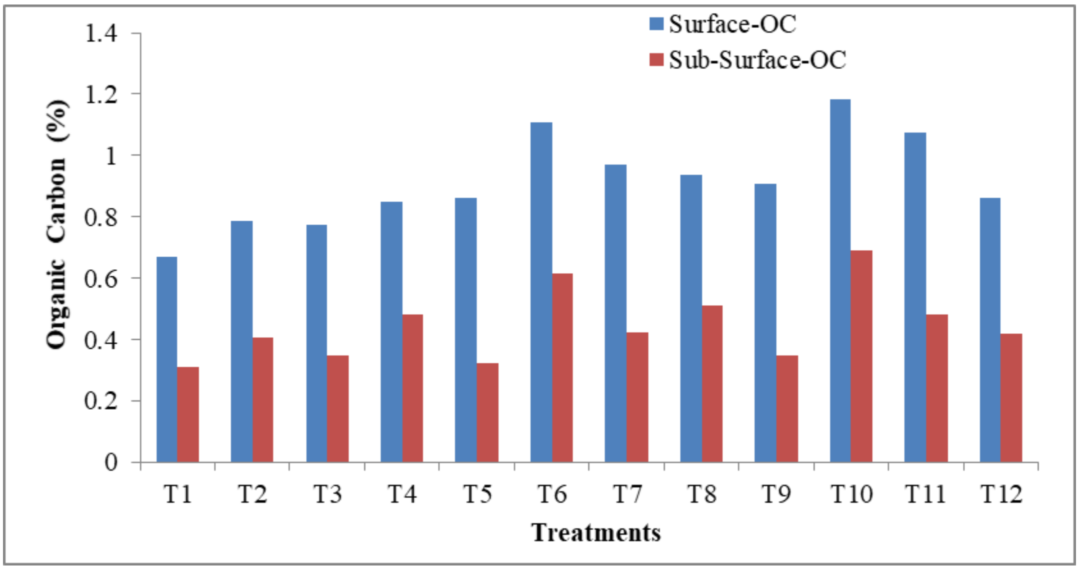

Fig 2: Effect of integrated nutrient management on soil organic carbon (%)

In the present study decrease in organic carbon content in all the treatments over initial value might be because of 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) [25]. The lowest level of organic carbon in control in both surface and sub-surface layer might be attributed to very poor crop growth, poor above ground and root biomass production as compared to fertilized or manured plots (Kumar *et al.*, 2011) [12]. The increase in soil organic carbon with increasing the dose of applied fertilizers might be because increasing dose of applied fertilizer increase the crop biomass and so was increased the addition of root stubbles and leaf litter to soil which on decomposition contribute to soil organic carbon (Rawankar *et al*., 2001 and Gathala *et al*., 2007) [20, 7]. Narwal and Antil (2005) [17] documented that increased soil organic carbon status in surface soil on INM might be attributed to increased crop growth that led to higher roots biomass production and higher contribution of crop residues which on decomposition contribute organic carbon in surface soil. Increased level of organic carbon in sub-surface on INM might be because surface applied organic manures can also move to lower layer through leaching with water or through earthworm burrows that finally increased the carbon input in soil (Kanchikerimath and Singh, 2001) [9].

Total Carbon

The data presented in table 3 revealed that the total carbon level of soil in all the treatments was increased with respect to the control. In the surface soil layer the lowest level of total carbon (0.90%) was recorded in T_1 while highest level of total carbon (1.57%) was in T_{10} followed by T_6 (1.47%). Sole application of chemical fertilizers led a significant increment in total soil carbon and an increasing pattern of total carbon was observed with increasing rate of fertilization. INM had more positive impact on total carbon status of soil in comparison to impact of fertilizers alone. The level of total carbon in treatments receiving both manures and fertilizers followed the order: $T_{10} > T_6 > T_{11} > T_7 > T_8 > T_9$. Among the organic sources mung straw has more positive role in improving soil total carbon followed by FYM and wheat straw. At the sub-surface soil layer (15-30 cm) the values of total carbon followed the trend similar to that in surface layer with total carbon values varied from 0.41% to 0.95%. It could be clearly noticed that sub-surface soil contained lesser total carbon than surface soil.

The increase in total carbon content in treatments receiving inorganic fertilizers might be due increased organic matter input to soil in the form of root biomass due to better plant growth (Manjaiah and Singh, 2001) [14]. Further the increment in total soil carbon with increasing rate of fertilizer application might be because of application of lower rate of fertilizer negatively affected the crop growth due to which biomass production was severely affected and indirectly lesser crop residue was returned to soil (Khambalkar *et al.*, 2013) [10]. Integrated application of organic manure and inorganic fertilizers led to significant improvement in crop growth, yield and increased carbon return to the soil which could probably a reason for higher values of total carbon in treatment receiving nutrients from both organic and inorganic sources (Mandal *et al.*, 2008) [13]. Lower status of total carbon in subsurface as compared to surface layer might be attributed to lesser addition of organic matter in sub-surface, less microbial population and activity, less disturbance that led to reduced mineralization of organic matter (Chashire and Griffith, 1999) [5].

Table 3: Effect of integrated nutrient management on soil total carbon (%)

Treatment	**Total carbon (%)**	
	0-15 cm	**15-30 cm**
T_1	0.90	0.41
T_2	1.06	0.53
T_3	1.04	0.46
T_4	1.14	0.63
T_5	1.25	0.42
T_6	1.47	0.83
T_7	1.30	0.57
T_8	1.26	0.68
T_9	1.22	0.47
T_{10}	1.57	0.95
T_{11}	1.33	0.67
T_{12}	1.16	0.56
SEm±	0.033	0.005
C.D. (p=0.05)	0.10	0.02

Conclusion

From this study it can be concluded that soil carbon content and nutrient content increases significantly with increasing dose of nitrogenous fertilizer. Partial substitution of fertilizers with FYM and moong straw would leads to higher improvement in soil carbon status as well as primary nutrients as compared to inorganic fertilizers alone. Among FYM, wheat straw and moong straw, the mung straw proved to be the best organic substitute of nitrogenous fertilizers with regards to its influence on soil fertility.

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