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Effects of 38-year continuous manure and fertilizer application on soil Physico-chemical characteristics at various depths in rice-wheat cropping system in Indo-Gangetic plain

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Abstract
A field experiment was carried out in the Bihar region to investigate the long-term effects of organic inorganic fertilizers on the physical and chemical characteristics of soil under the rice-wheat farming system (since 1988–1989) under the programme AICRP-STCR at RPCAU Pusa, Samastipur Bihar, India. It is well known that chemical fertilizers have negative long-term impacts on soils and the environment. Unbalanced nutrients in soils may lead to unproductive soils over time. It is fact that chemical fertilizers alone cannot support crop output that is sustainable, just as applying exclusively organic manure cannot result in increased crop yields. To increase crop productivity and maintain higher yields over time, a combination of inorganic fertilizer and organic manure is needed. A pH of 7.83 to 8.35, an organic carbon concentration between 0.21 and 0.30 dSm^{-1} and percent of 0.44 to 0.78 were found in the surface layer, while 8.63 to 8.15, 0.18 to 0.25 dSm-1, and 0.34 to 0.65 percent were found in the subsurface layer. A combination of NPK and organic residues increased pH, EC, and organic carbon.

Keywords: Organic and inorganic fertilizers, STCR, Long term

Introduction

Fertilizers are normally applied to soil to increase or sustain crop yields in order to fulfil the growing demand for food (Haynes 1998) [11]. While inorganic fertilizers only provide nutrients to soil, organic manure also improves soil quality while providing nutrients. As a level of SOM and SOC content rise fertilizer treatments may have an immediate or indirect effect on the physical properties of the soil including aggregate stability, water holding capacity and bulk density, By linking mineral particles into the aggregate, humic molecules and polysaccharides in SOM increased aggregate stability and decreased the aggregate stability and aggregate's susceptibility to wind and water erosion. In consequence the development of stable aggregates strengthens the physical protection of SOM from microbial destruction, Six (1998) [25]. Organic manures, such as green manures and farmyard manure, were traditionally used in agriculture to supply nutrients. Organic manure applications improved soil physical properties by increasing soil aggregation Hati (2007) [10], Shukla (2003) [24], Zhang (2007) [28], improving aggregate stability Barzegar (2002) [2], Rachman (2003) [20], decreasing micropore volume while increasing macro-pores Hati (2006) [9], improving soil water-holding capacity and wilting point Hati (2007) [10].

Applications of compost and organic manure resulted in a greater SOC content than an equivalent amount of inorganic fertilizer (Gregorich, 2001) [8]. However, the decomposition process controls the pace at which SOM builds up after applying organic manures. When compared to the non-treated control and NPK treatment alone, the SOM content in winter wheat and summer maize rotation after 13 years of manure application combined with NPK treatment was considerably higher from depth 0-20 cm. Applying FYM + inorganic N to irrigated settings has been shown in several studies to imrove microbial communities, soil structure, bulk density, SOC and hydraulic conductivity, Bhattacharya (2007) [5]. To achieve significant breakthroughs in food grain production, it is critical to develop approaches that improve fertilizer efficiency.

Long-term fertilizer trials compare crop yields and soil parameters under continuous cropping and extensive fertilization. J. B. Lawes and J. H Gilbert established the world's oldest long-term experiment at Rothamsted (United Kingdom) in 1843 (Johnston and Powlson, 1994) [13]. As a result, long term research has been done to determine the ideal ratios of organic and inorganic fertilizer. It would be very promising to continuously check soil parameters by integrating organic manures and fertlizers with a cropping system. Therefore, the present study was conducted to determine how long-term manure & fertilizer application affects the physical properties of different depth in rice -wheat crop on Indo-Gangatic plain.

Materials and Methods

Site description

A major objective of the study (since 1988–1989) was to examine the long-term effects of crop residue management (since 1988–1989) on soil fertility and fertilizer economy. RPACU Pusa in Bihar, India, is conducting the All-India Coordinated Research Project on Soil Test Crop Response Correlation (AICRP-STCR). The experimental site, located in Samastipur district at 25°58'51.92N latitude and 85°40'5.64E longitude, is 52.18 m above mean sea level and has a subtropical humid environment. Initial properties of the soil are detailed in Table 1.

Table 1: Initial soil characteristics experimental soil (1988)

S. No.	Soil Characteristics	Values
1	pH (1:2.5 Soil-water suspension)	8.5
2	EC (dSm^{-1} at 25°C)	0.3
3	Organic carbon ($g\ kg^{-1}$)	0.51
4	Bulk Density ($Mg\ m^{-3}$)	1.48
5	Water holding capacity (% w/w)	30.12

Experimental details

split-plot design was used for the experiment with four different levels of fertilizer application. A main plot was treated with no nitrogen, potassium, and salt (Fo), 50% of the recommended amount of nitrogen, potassium, and salt (F1), 100% of the recommended amount of nitrogen, potassium, and salt (F2), and 150% of the recommended amount of nitrogen, potassium, and salt (F3). Four subplots were used for the main plots, containing treatments such as. A total of 16 treatments with three replications were superimposed over NPK levels: no manure (M0), compost at 10 t ha-1 (C), crop residue (CR), and compost + crop residue (C+CR).

Collection and processing of soil samples

During rice harvest in December 2021, soil samples were taken intriplicate from each plot at two depth layers (0-15 and 15-30 cm). Soil samples were processed through a 2 mm (i.e. 10 mesh) sieve, stored at room temperature and used for soil physical evaluation.

Soil physo-chemical analysis

Wet oxidation (Walkley and Black, 1934) [27] was employed to measure soil organic carbon, pH and electrical conductivity (EC). The water holding capacity [W/W%] was determined using the keen's Raczkowski box method (Piper, 2005) [18]. The bulk density [g/cc] of soil was measured using the core method with a metalcore in the middle of each soil layer (Blake and Hartage, 1986) [6].

Statistical analysis

We analysed all soil properties using Analysis of Variance (ANOVA) for a split-plot design. Krus wallis test were conducted for similarity test.

Results and Discussion

Soil pH

After 39 years of continuous rice-wheat farming and fertilization, the pH of the soil was not influenced by different treatments at different depths according to findings also reported similar results for 0- 15 cm and 15-30 cm. At the surface, pH ranged from 7.83 to 8.35, while below the surface, pH varied from 7.63 to 8.15 (Table 2). The value of pH decreases slightly as compared to its initial value. As a result of continual cropping the soil's organic carbon content increases and causes the pH to fall slightly likewise found no significant change in soil pH after 39 years of continuous cultivating and fertilizing. When fertilizers and manure were integrated into treatments, soil pH was slightly low. As organic molecules have been shown to moderate the effect of exchangeable Al^{3+} ions in soil solution through their chelating effect over the years, this decreed soil pH might result from integrated treatments (Prasad *et al*., 2010) [19]. A Hapludoll, as observed by Tyagi (1989), and an Ustochrept was observed by Goyal and Singh (1987). As calcareous soils in this region have a slight gradient in pH, salts accumulate on the surface soil depths.

Table 2: Fertilizer application over a long period of time, organic and inorganic on Soil pH in calcareous soil under RWCS

STCR	Soil pH										
	0-15 cm					15-30 cm					
Treatments	M_0	C	CR	C+CR	Mean	Treatments	M_0	C	CR	C+CR	Mean
F_0	8.35	7.85	8.13	7.83	8.04	F_0	8.15	7.70	7.74	7.75	7.84
F_1	8.08	7.93	8.03	7.83	7.97	F_1	8.02	7.71	7.92	7.79	7.86
F_2	8.06	8.19	8.09	7.93	8.07	F_2	8.07	7.87	7.63	7.86	7.86
F_3	7.89	8.03	8.12	8.04	8.02	F_3	7.96	7.93	7.78	7.91	7.89
Mean	8.09	8.00	8.09	7.91		Mean	8.05	7.80	7.77	7.83	
	F	M	F × M				F	M	F × M		
SEm (±)	0.17	0.15	0.31	CV (a)	7.12	SEm (±)	0.21	0.15	0.33	CV (a)	9.11
CD (p=0.05)	NS	NS	NS	CV (b)	6.47	CD (p=0.05)	NS	NS	NS	CV (b)	6.59

Electrical conductivity

Soil EC (dSm^{-1}) indicated an increment in units though nonsignificant. The maximum and minimum EC was recorded with the ranged of between 0.21 to 0.30 dSm^{-1} and 0.18 to 0.25 dSm^{-1} at the both surface and sub-surface depths in table no 3 and Similar result was reported by Benbi and Brar (2009) [3].

Table 3: Long-term application of organic and inorganic fertilizers on EC (ds m^{-1}) in calcareous soil under RWCS

STCR	EC (ds m^{-1})										
	0-15 cm					**15-30 cm**					
Treatments	**M_0**	**C**	**CR**	**C+CR**	**Mean**	**Treatments**	**M_0**	**C**	**CR**	**C+CR**	**Mean**
F_0	0.23	0.21	0.23	0.23	0.23	F_0	0.22	0.18	0.19	0.19	0.19
F_1	0.29	0.27	0.27	0.27	0.28	F_1	0.25	0.22	0.23	0.24	0.23
F_2	0.29	0.28	0.26	0.28	0.28	F_2	0.24	0.21	0.24	0.23	0.23
F_3	0.30	0.28	0.28	0.28	0.29	F_3	0.26	0.24	0.25	0.24	0.25
Mean	0.28	0.26	0.26	0.27		Mean	0.24	0.21	0.23	0.23	
	F	M	F × M				F	M	F × M		
SEm (±)	0.01	0.01	0.01	CV (a)	9.12	SEm (±)	0.01	0.01	0.01	CV (a)	8.22
CD (p=0.05)	0.02	NS	NS	CV (b)	7.10	CD (p=0.05)	0.02	0.01	NS	CV (b)	7.68

Organic carbon

Organic carbon concentrations ranged from 0.44 to 0.78 percent at 0-15 cm depth and 0.34 to 0.65 percent at 15-30 cm depth, with a significant difference (Table 4). As soil depth climbed from 0-15 cm to 15-30 cm, soil organic carbon reduced. The highest value of organic carbon was obtained with 150% NPK + compost+ CR (0.78%), followed by 150% NPK + compost (0.74%). The lowest organic carbon content was reported in (0.44%), which was under control. The subsurface soil layer (15-30 cm) revealed the highest value of organic carbon in 150% NPK+ compost + CR (0.65%), followed by 150% NPK + compost (0.61%). During the evaluation, organic carbon (0.34%) was found to be below control at the lowest level. When manures and fertilizers are combined, they may result in more organic residues in soil, which may increase the amount of organic carbon after decomposition due to enhanced root growth. These results agree with those reported by Kumpawat and Jat (2005) [14], Balyan *et al*. (2006) [1], and Brar *et al*. (1998) [7]. Similarly, Parmar and Sharma (2000) [17] observed a decrease in soil organic carbon as depth was increased from 0-30 cm in the rice-wheat sequence of the North Western Himalayas. Surface soil retains more carbon in active or passive pools than subsurface soil because organic manure is supplied and extensively mixed with inorganic fertilizer each year. The buildup of C that was observed in the subsurface soil depth might be due to climatic and crop management factors that have occurred over the years under rice-wheat cropping. In a long-term lantana amended soil in rice-wheat systems, Raina and Bharati (2013) [21] reported a similar result regarding carbon sequestration and nutrient dynamics.

Bulk density

The treatment receiving 150% NPK recorded the lowest bulk density i.e., 1.23 Mg m^3 which was statistically at par with 100% NPK (1.29 Mg m^{-3}), and, both were significantly lower than 50% NPK (1.39 Mg m^{-3}) and control (1.49 Mg m^{-3}) among inorganic fertilizer treatments (table no.5). There was a percentage reduction of 17, 13, and 7 of bulk density with 150% NPK, 100% NPK, and 50% NPK, respectively, over the control. The reduction in bulk density value followed the trend 150% NPK = 100%NPK < 50% NPK < No NPK due to the application of inorganic fertilizers. Due to the balanced application of fertilisers, root development, better growth of soil microorganisms, and soil aggregation might be responsible for reducing the bulk density (Zhang *et al.*, 2006) [29]. An increase in organic matter content in fertilized plots compared to the control plot might be the reason for the decreased bulk density of the plots receiving fertilizers periodically over years (Rasool *et al.*, 2007) [22].

Table 4: Fertilizer application over a long period of time, organic and inorganic on SOC (%) in calcareous soil under RWCS

STCR	SOC (%)										
	0-15 cm					**15-30 cm**					
Treatments	**M_0**	**C**	**CR**	**C+CR**	**Mean**	**Treatments**	**M_0**	**C**	**CR**	**C+CR**	**Mean**
F_0	0.44	0.62	0.67	0.71	0.65	F_0	0.34	0.52	0.42	0.60	0.47
F_1	0.60	0.68	0.61	0.65	0.66	F_1	0.34	0.51	0.40	0.57	0.46
F_2	0.54	0.65	0.62	0.70	0.63	F_2	0.42	0.58	0.57	0.57	0.54
F_3	0.52	0.74	0.55	0.78	0.58	F_3	0.47	0.61	0.51	0.65	0.55
Mean	0.53	0.69	0.61	0.69		Mean	0.39	0.54	0.48	0.61	
	F	M	F × M				F	M	F × M		
SEm (±)	0.0	0.0	0.0	CV (a)	7.4	SEm (±)	0.0	0.0	0.0	CV (a)	8.1
CD (p=0.05)	0.0	0.0	0.1	CV (b)	7.0	CD (p=0.05)	0.0	0.1	0.2	CV (b)	12.6

Water holding capacity

The treatment receiving 150% NPK recorded the highest value for per cent water holding capacity of 37%, followed by 100% NPK (35%) and 50% NPK (33%). All these treatments were significantly superior to control, the least (32%) among inorganic fertilizer treatments (Table 5). There was a percentage increment of 16, 9, and 3 of water holding capacity with 150% NPK, 100% NPK, and 50% NPK respectively over the control. The enhanced water holding capacity of the treated plots might be due to the increase in root biomass as compared to the control plots (Rasool *et al.*, 2008) [23]. Increased organic carbon due to increased application of inorganics has been reported to contribute towards better water holding capacity of the fertilized plots (Pant *et al.*, 2018) [16]. Compost + Crop residue had the maximum water retention capacity (38%), followed by compost (36%) and crop residue (34%) and these values were considerably higher than the control (29%). The water holding capacity of treatment Compost + crop residue was 31% superior to the control. The highest soil organic carbon because of the combination of application of compost and crop residue may result in an increased water retention capacity when compared to control (Bhatt *et al.*, 2017) [4]. Soil organic carbon has a direct effect on soil aggregate stability and soil porosity or water holding capacity (Ojeda *et al.*, 2015) [15]. Soil aggregate stabilization due to the continuous application of organics increased its total porosity by improving the pore structure. On the other hand, increases the moisture retention capacity of the soil in comparison to the control.

Table 5: Effect of long-term application of organic and inorganic fertilizers on bulk density (Mg m^{-3}) and water Holding Capacity (W/W%) in STCR field

STCR	Bulk Density (Mg m^{-3}) 0-15 cm					Water Holding Capacity (w/w %) 0-15 cm					
Treatments	**M_0**	**C**	**CR**	**C+CR**	**Mean**	**Treatments**	**M_0**	**C**	**CR**	**C+CR**	**Mean**
F_0	1.58	1.43	1.51	1.43	1.49	F_0	26.91	34.01	31.84	36.94	32
F_1	1.53	1.38	1.36	1.29	1.39	F_1	29.55	34.66	32.90	37.72	33
F_2	1.39	1.28	1.35	1.14	1.29	F_2	31.07	37.70	35.34	38.76	35
F_3	1.32	1.25	1.26	1.10	1.23	F_3	32.27	39.73	35.98	42.16	37
Mean	1.45	1.34	1.37	1.24		Mean	29	36	34	38	
	F	M	F × M				F	M	F × M		
SEm (±)	0.03	0.03	0.06	CV (a)	6.93	SEm (±)	0.92	0.79	1.65	CV (a)	9.19
CD (p=0.05)	0.09	0.09	NS	CV (b)	7.66	CD (p=0.05)	3.20	2.31	NS	CV (b)	7.86

Conclusion

When the continuous rice-wheat cropping system causes nutrient fixation and mining, enhancing inorganic fertilizers and organics were shown to be effective in overcoming these issues. The most effective and cost-effective NPK doses combined with compost and crop residue were found to improve soil health and crop performance at a rate of 150% recommended.

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