International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2017; 5(6): 2107-2111

Received: 25-09-2017
Accepted: 27-10-2017

Bablu Chouhan
Department of Soil Science and Agricultural Chemistry, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, Madhya Pradesh, India

Hitendra Kumar Rai
Department of Soil Science and Agricultural Chemistry, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, Madhya Pradesh, India

Arpit Suryawanshi
Department of Soil Science and Agricultural Chemistry, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, Madhya Pradesh, India

Correspondence
Bablu Chouhan
Department of Soil Science and Agricultural Chemistry, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, Madhya Pradesh, India

Assessment of chemical properties of a Vertisol under long-term fertilizer experiment in soybean-wheat cropping system

Bablu Chouhan, Hitendra Kumar Rai and Arpit Suryawanshi

Abstract
Field experiments was conducted under All India Co-ordinate Research Project on "Long term Fertilizer Experiment" since 1972, but the present work was conducted during 2015-16 with soybean-wheat cropping sequence at the Research Farm Department of Soil Science and Agricultural Chemistry, J.N. Krishi Vishwa Vidyalaya, Jabalpur (M.P.), India to the assessment of chemical properties of a Vertisol under long -term fertilizer experiment in soybean-wheat cropping system. Eight treatments were imposed with four replications in simple randomized block design in both soybean and wheat crops. The treatments were T_1 (Control), T_2 (50% NPK), T_3 (100% NPK), T_4 (150% NPK), T_5 (100% NP), T_6 (100% N), T_7 (100% NPK+FYM), T_8 (100% NPK-S). The results obtained from the present investigation clearly indicated that chemical properties changes in pH and EC in surface and sub-surface soils under different treatments were statistically non-significant. However, the treatments of long-term application of balanced nutrients with and without FYM have significant effect on organic carbon content, cation exchange capacity and calcium carbonate in surface and sub-surface soils under soybean-wheat cropping system.

Keywords: chemical properties, (pH, EC, organic carbon content, cation exchange capacity and calcium carbonate), soybean and wheat sequence and FYM

Introduction
Soil is the key constituent of any agricultural production system which performs a fundamental task within the ecosystem and land-use restrictions to enhance crop productivity and maintain or augment environmental quality by direct or indirect resilience at temporal and spatial scales. Poor soil quality (physical and chemical properties and fertility) of soil is the major cause for the low productivity of soybean-wheat system in Vertisols (Tomar and Dwivedi, 2007 and Dakshinamurthy *et al*., 2005) [22, 5]. Strategies for soil management have always been focused on quality aspects and soil quality is mainly a composite set of measurable physical and chemical attributes which related to functional soil processes and affected by management and natural drivers. Growing of crops one after another without giving due consideration to nutrient requirement has resulted in decline in soil productivity in long-term (Ghosh *et al*., 2003) [9]. Studies on soil properties have been suggested as an effective tool for evaluating sustainability of soils and productivity of crops (Karlen *et al*., 1994 and Hussain *et al*., 1999) [12, 10]. Long-term fertilizer experiments give the valuable information on effect of continuous application of different level of fertilizer nutrients alone and in combination with organic manure under intensive cropping on soil fertility and crop productivity. These experiments can be used for precise monitoring of changes in soil fertility and productivity and could be of paramount help in solving the complex problems related to the soil fertility management. There is an apprehension that the use of chemical fertilizers over the year might impair the physical and chemical properties and soil fertility as well. Continuous cropping (soybean-wheat) with use of imbalanced nutrients (N or NP alone) through inorganic fertilizer without organic manure leads to deterioration in soil chemical and physical properties and cannot sustain desired level of crop production (Tiwari *et al*., 2002, Dejene and Lamlam, 2012) [21, 7]. Integration of inorganic fertilizers with organic manures will not only sustain the crop production but also improve the physical, chemical and biological properties as well as nutrient use efficiency in Vertisols (Verma *et al*., 2005) [23].

Materials and methods

Field experiments were conducted during *Kharif* and *Rabi* seasons of 2015-16 at the AICRP on LTFE research field of Department of Soil Science and Agricultural Chemistry, JNKVV, Jabalpur, situated at $23^0$10' N latitude, $79^0$57' E longitudes and at elevation 393.0 meter above mean sea level in the South-Eastern part of the Madhya Pradesh**.** The chemical characteristics of the soil were: Kheri series of fine montmorillonitic hyperthermic family of T*ypic Haplustert* and known as medium deep black soil. CEC [C mol (P^+) kg^{-1}] 49, pH 7.6, EC 0.18 dSm^{-1}, organic carbon 5.6 g kg^{-1} and calcium carbonate 46.1 g kg^{-1}. Eight treatments were imposed with four replications in simple randomized block design in both soybean and wheat crops. The treatments were T_1 (Control) T_2 (50% NPK), T_3 (100% NPK), T_4 (150% NPK), T_5 (100% NP), T_6 (100% N), T_7 (100% NPK+FYM), T_8 (100% NPK-S). Where 100% NPK stands for 20:80:20 kg ha^{-1} and 120:80:40 kg ha^{-1} N: P_2O_5: K_2O. In a randomized block design with four replications. Respectively for soybean and wheat crops and NPK-S stated that phosphorus was supplied through DAP. Crops were raised with all the standard recommended agronomic practices other than those under treatments. For the present study two sets of soil samples each for chemical analysis were collected with the help of core sampler from selected sites from each plot as per the treatments for surface (0-15 cm) and sub-surface (15-30 cm) soils after harvest of soybean and wheat crops grown during 2015-16. Soil pH was determined in a 1:2.5 soil-water suspension by glass electrode of Beckman pH meter (Piper, 1950) [15]. The soil suspension used for pH determination was allowed to settle down and conductivity of supernatant liquid was determined by using conductivity meter (Black, 1965) [3]. The results are expressed in dSm^{-1} at 25 ^{0}C. Organic carbon in soil was determined by Walkley and Black rapid titration method (1934) [26]. The CEC of soil sample was measured by leaching it with neutral 1N NH_4OAc solution which saturates the soil surface with NH_4^+ ions. The residual electrolytes were then removed by leaching with 99% isopropyl alcohol until the leachate was free of residual electrolytes. The NH_4^+ ions which was adsorbed by soil sample, finally, determined by Kjeldhal distillation method into 2% H_3BO_3. The boric acid containing ammonium borate was titrated by standard acid in the presence of mixed indicator to find out the meq. of exchangeable NH_4^+ adsorbed by soil sample (Amma, 1989) [1]. Analysis of soil calcium carbonate content was done using rapid titration method (Jackson, 1973) [11].

Result and discussion

Effect of long-term application of integrated nutrients on chemical properties of soil after harvest of soybean and wheat crop in soybean-wheat cropping system:

Soil pH

Data on pH of surface and sub-surface soils as influenced by long term integrated nutrient application after harvest of soybean and wheat crops are given in Table 1. Data clearly indicated that pH of surface and sub-surface soils were not affected significantly by long-term application of integrated nutrient. It is also evident from data that pH of surface soil was lower than the sub-surface soil in all the treatments. Data further showed that pH of surface and sub-surface soils were slightly increased in treatments of inorganic nutrients application alone, while slight decrease in soil pH was recorded in the treatments received FYM along with inorganic nutrients. Results clearly indicated that effect of long-term application of integrated nutrients on pH of surface and sub-surface soils after harvest of soybean and wheat was statistically not significant. Results also indicated that addition of FYM along with inorganic nutrient slightly reduced the soil pH in both the soil depths, whereas pH of sub-surface soil was higher than the surface soil. No significant change in soil pH under different treatments was might be due to higher buffering capacity of Vertisols. Dwivedi *et al*., 2007 [8] also reported that soil pH remained almost unchanged if balanced fertilizers were used along with organic manure (FYM) might be due to stabilizing effects of FYM. However, findings of Prasad *et al*., 2010 and Lal Bahadur *et al*., 2012 [16, 13] indicated that pH of sub-surface soil increased under integrated treatments might be due to the moderating effect of organics over the years as it decreases the activity of exchangeable Al^{3+} in soil solution due to chelating effect of organic molecules.

Electrical Conductivity

Data (Table 1) clearly showed that electrical conductivity (EC) of surface (0-15 cm) and sub-surface (15-30 cm) soils after harvest of soybean and wheat crops was not affected significantly by the treatments of long-term application of integrated nutrients. Electrical conductivity of sub-surface and surface soils was varied from 0.20-0.24 dSm^{-1} and 0.17-0.20 dSm^{-1} in soybean crop and from 0.16 to 0.19 dSm^{-1} and 0.18 to 0.21 dSm^{-1} in wheat crop respectively. Further it was observed that electrical conductivity of surface soil was lower than the sub-surface layer and lowest EC was obtained in control treatment at both the soil depths. The electrical conductivity (EC) of surface (0-15 cm) and sub-surface (15-30 cm) soil after harvest of soybean and wheat crops grown in soybean -wheat cropping system was not affected significantly by the treatments of long-term application of integrated nutrients. Electrical conductivity of sub-surface soil was slightly higher than those of surface soil, while the minimum value of electrical conductivity was obtained in control treatment at both the soil depths. The values of EC did not show remarkable alternation and this may be attributed to the low residual effect of applied inputs and high buffering capacity of soil. The findings are well supported by those reported by Babu *et al*., 2007 and Lal Bahadur *et al*., 2012 [2, 13]. They have also reported no marked influence of continuous use of inorganic fertilizers alone or in combination of FYM on electrical conductivity of soil may be due to buffering capacity of the soil.

Soil organic carbon

Data pertaining to effect of long-term application of integrated nutrients on organic carbon content in surface and sub-surface soils after harvest of soybean crop is given in table 1. Data clearly emphasized that organic carbon content of soil was significantly affected by long-term application of integrated nutrients. It is also evident from the data that after harvest of soybean and wheat crop maximum organic carbon contents were recorded in T_7 (100% NPK with FYM) treatment, while minimum values were obtained in control for surface and sub-surface soils, respectively. Further it was observed that organic carbon content in surface soil was higher than the sub-surface soil while minimum organic carbon content was obtained in control treatment at both the soil depths. Results showed that organic carbon content of soil was significantly increases under different treatments of long-term application of integrated nutrient in soybean-wheat cropping system. Maximum organic carbon content recorded under T_7 treatment which statistically at par with those recorded in T_4 (150% NPK) treatment and minimum in control treatments. It was might be because of addition of FYM, more root biomass and microbial activities in T_7 and T_4 treatments resulted in higher soil organic carbon content. The findings are in good agreement to those reported by Santhy *et al*., 2001 and Singh *et al*., 2007 [18, 20]. They have reported that integrated nutrient application (100% NPK + FYM) under soybean-wheat cropping system significantly increased the organic carbon content (0.34%) as compared to control plots (0.08%). Results further revealed that organic carbon content in surface and sub-surface soil was higher after harvest of wheat as compared to the soils after harvest of soybean in respective treatments. It may be because of decomposition of applied FYM and root biomass of soybean added organic carbon to the soil.

Cation Exchange Capacity

Data pertaining to cation exchange capacity (CEC) of surface and sub-surface soils as influenced by long-term application of integrated nutrients after harvest of soybean and wheat crops (Table 2) data clearly showed a significant effect. Data further indicated that CEC of surface and sub-surface soils varied from 27.43 - 42.93 and 25.18 - 29.33 C mol (P^+) kg^{-1}, in soybean and varied from 29.18 - 44.60 C mol (P^+) kg^{-1} and from 26.65 - 34.93 C mol (P^+) kg^{-1} in wheat crop, respectively with the highest value in T_7 (100% NPK with FYM) and lowest in T_1 (control) treatments. Data also showed that CEC values of surface soil were higher than those of sub-surface soil under all the treatments. Results also indicated that long-term application inorganic nutrient along with organic manure significantly increased the cation exchange capacity of soil. The results clearly revealed that treatments of long-term application of integrated nutrients significantly increased the CEC of surface and sub-surface soils over those treatment received only inorganic nutrient in imbalanced manner in surface soil, whereas the treatments received balanced fertilizers (100% NPK and 150% NPK) were statistically at par. Higher CEC in the treatments of long-term application of integrated nutrients along with FYM was might be due to higher soil organic carbon hiving elevated CEC under these treatments. The results are in good agreements with the findings of Verma *et al*., 1990; Laxminarayana, 2001 and Verma *et al*., 2010 [25, 14, 24]. They have also reported higher CEC of soil due to integrated use of organic and inorganic fertilizer in soybean-wheat cropping system mainly because of increased organic carbon content in soil.

Calcium carbonate

The data pertaining to the effect of long-term application of integrated nutrients on calcium carbonate content in soil at 0-15 cm and 15-30 cm depths are given in Table 2. Data clearly indicated that calcium carbonate in soil at both the depths was significantly affected by different treatments of nutrient application. Data further revealed that calcium carbonate of surface and sub-surface soils was maximum under T_4 (150% NPK) treatment while, it was lowest under T_1 (control) treatment. Data also showed that calcium carbonate in sub-surface soil was higher as compared to surface soil layer in all the treatments. The results clearly indicated that integration of organic source increase the calcium carbonate of soil irrespective of the nutrients application treatments. Results clearly indicated that long term nutrient application significantly increased the calcium carbonate of soils. Results showed that calcium carbonate content of soil was significantly increased under different treatments of long-term application of integrated nutrients in soybean-wheat cropping system. Higher value of $CaCO_3$ in surface and sub-surface soil after harvest of soybean and wheat crops was recorded in the treatments of balanced application of nutrients (100% NPK and 150% NPK) and lower values in imbalanced nutrient application treatments. It may be due to long term application of SSP which also contains calcium. Identical finding were also reported by Choudhari *et al*., 2005 [4]. Further it was found that content of calcium carbonate in surface soil was lower than the sub-surface soil might be due to dissolution effect of organic acids produced during decomposition of organic matter in soil. The finding are well supported by those reported by Sangwan and Singh, 1993; Dang and Verma, 1996 and Satyavathy, 1998 [17, 16, 19]. They also stated under long-term nutrient application trials concentration of $CaCO_3$ was higher in lower profile of soil.

Table 1: Effect of long-term application of integrated nutrients pH, EC and organic carbon content of soil after harvest of soybean and wheat, respectively.

Treatments	Soil pH		EC		Soil OC		Soil pH		EC		Soil OC	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
T_1	7.44	7.73	0.17	0.20	5.20	4.40	7.38	7.65	0.16	0.18	4.64	4.28
T_2	7.45	7.58	0.19	0.22	7.08	6.43	7.42	7.48	0.18	0.20	6.39	5.85
T_3	7.54	7.65	0.20	0.22	7.72	6.88	7.44	7.60	0.19	0.20	7.35	6.25
T_4	7.49	7.88	0.19	0.23	7.53	6.90	7.39	7.50	0.18	0.21	7.85	6.68
T_5	7.73	7.75	0.19	0.21	6.70	6.55	7.63	7.68	0.17	0.19	6.64	6.10
T_6	7.49	7.70	0.18	0.21	6.60	6.18	7.34	7.48	0.17	0.18	5.56	5.50
T_7	7.50	7.78	0.20	0.24	7.83	7.05	7.39	7.63	0.19	0.21	7.96	6.88
T_8	7.57	7.63	0.19	0.21	7.45	6.83	7.44	7.50	0.18	0.20	6.85	6.50
SEm+	0.392	0.401	0.013	0.015	0.472	0.416	0.334	0.388	0.016	0.015	0.395	0.444

Table 2: Effect of long-term application of integrated nutrients on cation exchange capacity and calcium carbonate content of soil after harvest of soybean and wheat crops, respectively.

Treatments	CEC		$CaCO_3$		CEC		$CaCO_3$	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30cm	0-15 cm	15-30 cm
T_1	27.43	25.18	46.5	53.8	29.18	26.65	50.3	59.0
T_2	31.03	26.40	50.5	57.5	31.95	27.90	54.5	63.3
T_3	36.93	27.85	57.3	61.9	38.70	30.63	62.0	68.0
T_4	38.65	28.05	58.5	62.3	40.15	32.18	63.3	68.5
T_5	35.70	26.13	56.0	61.5	37.13	29.70	60.5	67.5
T_6	30.55	24.65	50.3	55.8	31.90	27.20	54.3	61.3

T_7	42.93	29.33	55.8	60.3	44.60	34.93	60.0	66.3
T_8	37.18	23.30	48.3	55.3	39.55	31.25	52.0	60.8
SEm$\pm$	2.451	1.200	2.29	2.02	2.889	1.729	2.53	2.17
CD ($p=0.05$)	7.387	3.616	6.91	6.09	8.698	5.211	7.63	6.50

Conclusions

Our results showed that the chemical (OC, CEC and $CaCO_3$) properties of surface and sub-surface soil after harvest of soybean and wheat crops were significantly altered by long-term application of integrated nutrients. However, treatments of long-term application of integrated nutrients did not affected pH and EC of surface and sub-surface soils, significantly neither after harvest of soybean nor wheat.

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