The Pharma Innovation Journal 2023; 12(7): 2439-2444

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2023; 12(7): 2439-2444

www.thepharmajournal.com
Received: 23-04-2023
Accepted: 29-06-2023

Anupam Dube
Department of Soil Science, Dr. Rajendra Prasad Central Agricultural University, Pusa, Samastipur, Bihar, India

Ranjan Laik
Department of Soil Science, Dr. Rajendra Prasad Central Agricultural University, Pusa, Samastipur, Bihar, India

Shankar Jha
Department of Soil Science, Dr. Rajendra Prasad Central Agricultural University, Pusa, Samastipur, Bihar, India

Shiv shanker Prashad Jha
Department of Soil Science, Dr. Rajendra Prasad Central Agricultural University, Pusa, Samastipur, Bihar, India

Santosh Kumar Singh
Department of Soil Science, Dr. Rajendra Prasad Central Agricultural University, Pusa, Samastipur, Bihar, India

Corresponding Author:
Anupam Dube
Department of Soil Science, Dr. Rajendra Prasad Central Agricultural University, Pusa, Samastipur, Bihar, India

Effect of long-term manure & fertilizer application on differentiating chemical properties of top and deep layer on Calcareous soils of Bihar

Anupam Dube, Ranjan Laik, Shankar Jha, Shiv Shanker Prashad Jha and Santosh Kumar Singh

Abstract
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. Using only chemical fertilizers cannot ensure sustainable crop production, just as using only organic manure cannot increase crop productivity. To ensure high yields over an extended period of time, crop production must be boosted through the use of organic manure and inorganic fertilizers. A field experiment was conducted under the rice-wheat cropping system in Bihar region in order to study the long-term effects of both organic and inorganic fertilizers on soil chemical properties at in an on-going (since 1988–1989) under the programme AICRP-STCR at Dr. RPCAU Pusa, Samastipur Bihar, India. A pH of 7.83 to 8.35, an organic carbon concentration between 0.21 and 0.30 dSm^{-1}, and a 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. As compared to the control, available N, P2O5, and K2O were significantly higher. N and P2O5, K2O were found in concentrations of 134 to 416 kg ha^{-1} and 13.9 to 27.8 kg ha-1, 115 to 225 kg ha^{-1}, respectively, at the surface layer, but were found in concentrations of 149 to 357 kg ha^{-1} and 10.9 to 22 kg ha^{-1}, 97 to 150 kg ha^{-1}, respectively, at the subsurface layer.

Keywords: Organic and inorganic fertilizers

Introduction
Organic materials play a fundamental role in supplying a variety of plant nutrients, including micronutrients, improving soil chemical properties, and thereby preserving nutrient holding and buffering capacity, as well as enhancing microbial activity (Suzuki, 1997) [19]. While inorganic fertilizers only provide nutrients to soil, organic manure also improves soil quality while providing nutrients. Over time, chemical fertilizers have an adverse effect on soils and the environment. A soil that is unbalanced with nutrients may become unproductive in the long run due to the use of unbalanced nutrients. A tremendous amount of progress has been made in Indian agriculture since the 1960s. Agricultural production has been successful because high yielding varieties are widely used. Indian agriculture has transformed from subsistence to surplus thanks to fertilizers, among other inputs. Despite the resounding success of the green revolution, crop productivity and input use have declined in recent years. At present, agriculture's main concern is arresting further declines in soil quality and crop productivity. In spite of the fact that high yielding nutrient responsive crop varieties resulted in increased productivity, they resulted in overexploitation of soil reserves and other resources as a result. Since Indian soils have been cultivated continuously for centuries, modern agricultural technologies have been adopted, and fertilizers have been used in imbalances and with poor use efficiency, their finite nutrient resources have been consistently depleted for centuries, making them poor infertile. The food grain production is stagnated as a consequence of fertilizer use efficiency, which refers to the proportion of applied nutrients absorbed by the crop (e.g. kg grain $kilogram^{-1}$ applied nutrient). Agricultural scientists and administrators are concerned about a declining trend in rice-wheat productivity. In order to achieve breakthroughs in food grain production, it is imperative to develop techniques that enhance fertilizer efficiency. In long-term fertilizer experiments, yields of various crops and soil properties are assessed in relation to continuous cropping and intensive fertilization. J. B. Lawes and J. H. Gilbert initiated the oldest long-term experiment in the world at Rothamsted

(United Kingdom) in 1843 (Johnston and Powlson, 1994) [7]. First permanent manurial experiments were started in 1885 at Kanpur (U.P.) on the basis of the Rothamsted model. Organic manure and fertilizers contributed to the study of soil properties, crop yields, and nutrient uptake through long-term experiments. Consequently, long-term studies have been conducted to determine the optimal proportions of organic and inorganic fertilizers. It would be quite promising to monitor soil properties consistently by combining organic manures and fertilizers with a cropping system. Therefore, the present study was conducted to determine how long-term manure & fertilizer application affects the physical & chemical properties of top and deep layers of calcareous soils.

Materials and Method

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. The All India Co-ordinated Research Project on Soil Test Crop Response Correlation (AICRP-STCR) is being carried out by RPACU Pusa Bihar India. At an altitude of 52.18 m above mean sea level in the subtropical humid climate, the experimental site is located at 25°58'51.92N latitude, 85°40'5.64E longitude in Samastipur district. Table 1 summarizes the initial properties of the soil.

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	Available N (kg ha^{-1})	236
5	Available P (kg ha^{-1})	19.3
6	Available K (kg ha^{-1})	100.0

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} (M1), crop residue (M2), and compost + crop residue (M3).

Collection and processing of soil samples

In December 2021, after rice harvest, soil samples were collected in triplicates from each plot at two depth layers (0–15 and 15–30 cm). Soil sample was processed through a 2 mm (i.e. 10 mesh) sieve, Store in room temperature and used for soil chemical and physical analysis.

Soil chemical analysis

Wet oxidation (Walkley and Black, 1934) [22] was used to determine soil organic carbon (Jackson, 1973) [6] as well as pH and electrical conductivity (EC). In order to determine the amount of N, P, and K available, Bremner and Keeney (1965) [4], Hanway and Heidel (1952) [5] used standard procedures.

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

According to results obtained after 39 years of continuous rice-wheat cultivation and fertilization, different treatments at different depths did not affect the pH of the soil. (Grewal *et al*., 1981) 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 continuous cropping, organic carbon content increases in the soil, which results in a slight decrease in soil pH. Singh (1997) [25] also reported a non-significant change in soil pH after 39 years of continuous cropping 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) [14]. 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 in the long run, 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		
S.Em (±)	0.17	0.15	0.31	CV (a)	7.12	S.Em (±)	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 non-significant. The maximum and minimum EC values were measured with the ranges of 0.21 to 0.30 dSm-1 at both surface and subsurface depths represented in table no 3 and Similar result was reported by Benbi and Brar (2009).

Table 3: Fertilizer application in the long run, organic and inorganic 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		
S.Em (±)	0.01	0.01	0.01	CV (a)	9.12	S.Em (±)	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

The organic carbon content ranged from 0.44 to 0.78 percent at 0-15 cm depth whereas at 15-30 cm depth, it was 0.34 to 0.65 percent, and the difference was significant (Table 4). As soil depth increased from 0-15 cm to 15-30 cm, soil organic carbon decreased. The maximum value of organic carbon was recorded in 150% NPK + Compost + CR (0.78%) where followed by 150% NPK + Compost (0.74%). The minimum organic carbon was found in (0.44%) which was under control. Then subsurface soil layer (15-30 cm) are showed maximum value of organic carbon was recorded in 150% NPK + Compost + CR (0.65%) where followed by 150% NPK + Compost (0.61%). During the evaluation (0.34%) organic carbon was determined 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. Kumpawat and Jat (2005) [8], Balyan *et al*. (2006) [1], and Brar *et al*. (1998) [2] have reported about the similar findings. Similarly, Parmar and Sharma (2000) [13] 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. Compared to subsurface soil, surface soil retains more carbon in active or passive pools since organic manure is regularly added and blended with inorganic fertilizers every year. Over the years under rice-wheat cropping, C might have been built up in the subsurface soil depth due to climatic and crop management factors. In a long-term lantana amended soil in rice-wheat systems, Raina and Bharati (2013) [15] reported a similar result regarding carbon sequestration and nutrient dynamics.

Table 4: Fertilizer application in the long run, 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		
S.Em (±)	0.0	0.0	0.0	CV (a)	7.4	S.Em (±)	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

Available N

The Available N of soil maximum and minimum ranged between 134 to 416 (kg ha^{-1}) at 0-15 cm depth and 149 to 357(kg ha^{-1}) at 15-30 cm depths, respectively and significant differences (Table 5) were observed. The soil Available N decreased with increase in depth from 0-15 to 15-30 cm depths. The maximum value of Available N was recorded in 150% NPK + Compost + CR (416kg ha^{-1}) where followed by 150% NPK + Compost (351kg ha^{-1}). The minimum Available N was found in (134kg ha^{-1}) which was under control. Then subsurface soil layer (15-30 cm) are showed maximum value of Available N was recorded in 150% NPK + Compost + CR (357 kg ha^{-1}) where followed by 150% NPK + Compost (212 kg ha^{-1}). The minimum Available N was found in (149 kg ha^{-1}) which was under control. A reduction in pH during production of organic acids due to decomposition of organic matter might have limited the alkalinity to a level below which urea ammonia volatilization is limited thereby reduced N loss and better accumulation (Shade *et al*., 2020) [17]. Studies have reported, improved levels of soil NH_4-N and NO_3-N over control due to combined application of organic and inorganic fertilizer in calcareous and alkaline soils (Walia *et al*., 2010; Wu *et al*., 2017; Yang *et al*., 2020) [21, 23, 24].

Table 5: Fertilizer application in the long run, organic and inorganic on SOC (%) in calcareous soil under RWCS

STCR	Available- N (kg ha^{-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	171	188	182	200	187	F_0	149	166	153	179	162
F_1	134	194	178	277	194	F_1	153	167	159	192	168
F_2	176	214	207	303	225	F_2	164	180	170	222	184

F_3	193	351	273	416	308	F_3	176	212	182	357	232
Mean	170	237	208	299		Mean	160	181	166	238	
	F	M	F × M				F	M	F × M		
S.Em (±)	6.2	4.2	9.6	CV (a)	9.4	S.Em (±)	5.3	4.9	10.0	CV (a)	9.9
CD (p=0.05)	21.4	12.3	28.0	CV (b)	6.4	CD (p=0.05)	18.4	14.2	29.1	CV (b)	9.1

Available P

The Available P of soil maximum and minimum ranged between 13.9 to 27.8 (kg ha^{-1}) at 0-15 cm depth and 10.9 to 22 (kg ha^{-1}) at 15-30 cm depths, respectively and significant differences (Table 6) were observed, The soil Available P decreased with increase in depth from 0-15 to 15-30 cm depths. The maximum value of Available P was recorded in 150% NPK + Compost + CR (27.8kg ha^{-1}) where followed by 150% NPK + Compost (26.4 kg ha^{-1}). The minimum Available P was found in (13.9kg ha^{-1}) which was under control. Then subsurface soil layer (15-30 cm) are showed maximum value of Available P was recorded in 150% NPK + Compost + CR (22 kg ha^{-1}) where followed by 150% NPK + Compost (20.8 kg ha^{-1}). The minimum Available P was found in (10.9 kg ha^{-1}) which was under control. As calcareous soils are deficient in soil available P, application of P fertilizers might have increased its availability in soil (Lu *et al*., 2020) [9]. As compost makes the soil environment suitable for nutrient and water mobility by improving soil organic carbon and modifies soil pH suitably and crop residue incorporation reduces the adsorption of P in soil, hence have been reported to enhance P availability in soil (Brar *et al*., 2015; Malobane *et al*., 2020) [3, 11]. Mineral surfaces are less likely to adsorb P due to crop residue retention and increases its availability in soil (Malobane *et al*., 2020) [11]. The above-mentioned reasons make the combined application of fertilizers (NPK), compost and crop residue most suitable for the availability of P in soil. Brar *et al*. (2015) [3] reported similar results in maize-wheat cropping systems. An increase in available P was reported by Mtyobile *et al*. (2019) [12] due to crop residue incorporation in wheat based cropping system.

Table 6: Fertilizer application in the long run, organic and inorganic on Available -P (kg ha^{-1}) in calcareous soil under RWCS

STCR	Available -P (kg ha^{-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	13.9	17.6	16.8	18.2	16.6	F_0	10.9	12.9	11.7	14.3	12.5
F_1	16.8	18.4	17.7	23.0	19.0	F_1	12.6	16.9	14.2	19.2	15.7
F_2	20.0	22.8	20.3	23.2	21.6	F_2	16.0	19.7	19.1	20.3	18.8
F_3	19.5	26.4	24.5	27.8	24.6	F_3	19.4	20.8	19.4	22.0	20.4
Mean	17.5	21.3	19.8	23.1		Mean	14.7	17.6	16.1	19.0	
	F	M	F × M				F	M	F × M		
S.Em (±)	0.5	0.4	0.9	CV (a)	8.1	S.Em (±)	0.5	0.3	0.8	CV (a)	11.2
CD (p=0.05)	1.7	1.3	2.6	CV (b)	7.5	CD (p=0.05)	1.9	0.9	2.2	CV (b)	6.3

Available K_2O

A significant difference was found between soil available K_2O maximum and minimum at 0-15 cm depth and at 15-30 cm depth respectively (Table 7). A decrease in soil K_2O availability with increasing depth was observed between 0-15 and 15-30 cm. The maximum value of available K was recorded in 150% NPK + Compost + CR (220 kg ha^{-1}) where followed by 150% NPK + Compost (168 kg ha^{-1}). The minimum Available K was found in (115 kg ha^{-1}) which was under control. Then subsurface soil layer (15-30 cm) are showed maximum value of Available K was recorded in 150% NPK + Compost + CR (150 kg ha^{-1}) where followed by 150% NPK + Compost (143 kg ha^{-1}). The minimum Available K_2O was found in (97 kg ha^{-1}) which was under control. The interaction effects of fertilizers and organics were found non-significant. The increase in Available K_2O with increased dose of fertilizer was due to the continuous input of K through fertilizers improved the K supplying capacity of the soil. Application of rice and wheat straw could directly add significant amount of K to soil after decomposition. The decomposition of crop residue proceeds faster when applied with organic manure by lowering the C: N ratio increasing soil available K levels even faster as compared to its sole application (Tisdale *et al*., 1995; Rezig *et al*., 2014) [20, 16].

Table 7: Fertilizer application in the long run, organic and inorganic on Available- K_2O (kg ha^{-1}) in calcareous soil under RWCS

STCR	Available- K_2O (kg ha^{-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	115	157	133	167	143	F_0	97	133	117	139	121
F_1	136	160	145	164	151	F_1	113	134	125	141	128
F_2	143	152	151	160	152	F_2	120	137	131	145	133
F_3	157	168	163	220	177	F_3	126	143	136	150	139
Mean	138	159	148	178		Mean	114	137	127	144	
	F	M	F × M				F	M	F × M		
S.Em (±)	4.0	3.3	7.0	CV (a)	8.8	S.Em (±)	2.7	3.2	6.2	CV (a)	7.2
CD (p=0.05)	13.7	9.7	20.4	CV (b)	7.4	CD (p=0.05)	9.4	9.3	NS	CV (b)	8.5

Table 8: Correlation study of Soil pH, EC, SOC, Available N, and Available P, Available K of Fertilizer application in the long run, organic and inorganic on calcareous soil under RWCS

	Soil pH	EC	SOC	Available N	Available P	Available K
Soil pH	1					
EC	0.670**	1				
SOC	0.279NS	0.501*	1			
Available N	0.156NS	0.574*	0.632**	1		
Available P	0.296NS	0.756**	0.700**	0.902**	1	
Available K	0.295NS	0.694**	0.814**	0.911**	0.911**	1

*Significance level at 5%, ** significance level at 1%

Correlation was seen among all parameters except pH. pH only shows high level of correlation with EC (r=0.67). Potassium shows high level of significance with SOC (r=0.69), available N (r=.91) and available P (r=.91). This high level of correlation shows that nutrient availability highly dependent on change in another variable i.e. SOC and EC.

Conclusion

Balanced application of increased inorganic fertilizers and organics in experimental calcareous soil was found beneficial by overcoming the nutrient fixation and nutrient mining as a result of continuous rice-wheat cropping system. In preview of soil health and crop performance, 150% recommended dose of NPK along with compost and crop residue was considered best with crop performance, and 150% recommended dose of NPK along with crop residue returning was most economical.

References

1. Balyan JK, Singh P, Kumpawat BS, Jain LK. Effect of integrated nutrient management on maize growth and its nutrient uptake. Current Agriculture. 2006;30:79-82.
2. Brar BS, Pasricha MS. In long-term soil fertility management through integrated plant nutrient supply system, Indian Institute of Soil Science, Bhopal; c1998. p. 154.
3. Brar S, Singh B, Singh J, Kaur G. Effects of Long Term Application of Inorganic and Organic Fertilizers on Soil Organic Carbon and Physical Properties in Maize–Wheat Rotation. Agronomy. 2015;5(2):220-238.
4. Bremner JM, Keeney DR. Steam distillation methods for determination of ammonium, nitrate and nitrite. Anal. Chim. Acta. 1965;32:485-495.
5. Hanway JJ, Heidel H. Soil analysis methods as used in Iowa state college soil testing laboratory. Iowa Agric. 1952;57:1-31.
6. Jackson ML. Soil Chemical Analysis, Prentice Hall of India (P) Ltd., New Delhi; c1967. p. 83-192.
7. Johnston AE, Powlson DS. Long-term field experiment: their importance in understanding sustainable land use. in D.J. Greenland and I. Szaboes, eds. Soil resilience and sustainable land use CAB International, Wallingford, U.K; c1994. p. 367-393.
8. Kumpawat BS, Jat ML. Profitable and energy efficient integrated nutrient management practices for maize mustard cropping system in Southern Rajasthan. Current Agriculture. 2005;29:97-102.
9. Lu X, Mahdi AK, Han X, Chen X, Yan J, Biswas A, *et al*. Longterm application of fertilizer and manures affect P fractions in Mollisol. Scientific Reports. 2020;10:14793.
10. Malewar GU. Micronutrient stresses in soils and crops: serious sicknesses and clinical approaches for sustainable agriculture. Journal of Indian Society of Soil Science. 2005;53(4):484-499
11. Malobane ME, Nciizah AD, Mudau FN, Wakindiki IIC. Tillage, Crop Rotation and Crop Residue Management Effects on Nutrient Availability in a Sweet Sorghum-Based Cropping System in Marginal Soils of South Africa. Agronomy. 2020;10:776.
12. Mtyobile M, Muzangwa L, Mnkeni PNS. Tillage and Crop Rotation Effects on Selected Soil Chemical Properties and Wheat Yield in a Sandy Loam Oakleaf Soil in the Eastern Cape, South Africa. International Journal of Agricultural Biology. 2019;21:367-374.
13. Parmar DK, Sharma V. Studies on long-term application of fertilizers and manure on yield of maize-wheat rotation and soil properties under rainfed conditions in Western Himalayas. Journal of the Indian Society of Soil Science. 2000;50:311-312.
14. Prasad J, Karmakar S, Kumar R, Mishra B. Influence of integrated nutrient management on yield and soil properties in maize-wheat cropping system in an Alfisol of Jharkhand. Journal of the Indian Society of Soil Science. 2010;58(2):200-204.
15. Raina, Bharati. Carbon sequestration and nutrient dynamics in a long-term lantana amended soil in rice wheat system. Ph.D. (Ag) Thesis submitted to Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishvavidyalaya; 2013.
16. Rezig FAM, Elhadi EA, Abdalla MR. Decomposition and nutrient release pattern of wheat (*Triticum aestivum*) residues under different treatments in desert field conditions of Sudan. International Journal of Recycling Organic Waste in Agriculture. 2014;3:10.
17. Shade J, Cattell N, Seufert LV. Decreasing reactive nitrogen losses in organic agricultural systems. Organic Agriculture. 2020;11:217-223.
18. Singh RA. Soil Physical Analysis. New Delhi, Kalyani Publisher; c1980.
19. Suzuki A. Fertilization of rice in Japan. Japan FAO Association, Tokyo, Japan; c1997.
20. Tisdale SL, Nelson WL, Beatson JD, Havlin JL. Soil fertility and fertilizer. Fifth Edition Prentice Hall of India Pvt. Ltd.; c1995. p. 266-288.
21. Walia MK, Walia SS, Dhaliwal SS. Long-Term Effect of Integrated Nutrient Management of Properties of Typic Ustochrept after 23 Cycles of an Irrigated Rice (Oryza sativaL.)-Wheat (*Triticum aestivum* L.) System. Journal of Sustainable Agriculture. 2010;34(7):724-743.
22. Walkley A, Black IA. An examination of the Degtjareff method for determining soil organic matter, and a proposed modification of the chromic acid titration

method. Soil Sci. 1934;37:29–38.
23. Wu D, Senbayram M, Well R, Bruggemann N, Pfeiffer B, Loick N. Nitrification inhibitors mitigate N2O emissions more effectively under straw induced conditions favoring DE nitrification. Soil Biology and Biochemistry. 2017;104:197–207.
24. Yang Q, Liu P, Dong S. Combined application of organic and inorganic fertilizers mitigates ammonia and nitrous oxide emissions in a maize field. Nutrient Cycling in Agro ecosystem. 2020;117:13–27.
25. Lei Y, Singh MP. A comparison of workflow metamodels. In Proceedings of the ER-97 Workshop on Behavioral Modeling and Design Transformations: Issues and Opportunities in Conceptual Modeling; c1997 Nov 6.