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Assessing cation exchange capacity (CEC) in old alluvium soils (Agro-climatic zone IIIB of Bihar) under Different tillage and management practices

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Abstract
To assess cation exchange capacity (CEC) under different tillage and management practice, a laboratory experiment was carried out at IARI, Pusa, New Delhi. The soils samples varying in depth 0-15, 15-30, 30-45 and 45-60 cm were collected from all the three replications of four different treatments (scenarios) and one uncultivated site of conservation agriculture field of Cereal System Initiative for South Asia (CSISA) project, Indian Council of Agricultural Research Complex for the Eastern Region (ICAR-RCER) in Patna, Bihar, India. The experimental soil is non-calcareous non saline old alluvium with silty clay texture and above neutral pH and the climate of the experimental site is sub humid with average annual rainfall of 1130 mm. Cation exchange capacity (CEC) in cmol (p^+) kg^{-1} of the old alluvium soils was found lower (36.59 cmol (p^+) kg^{-1}) in surface soils (0-15 cm) than sub-surface soils (15-30 cm).This might be due to migration of fine clay-humus particles especially in puddled soils i.e. farmers practices in rice-fallow-wheat cropping system with puddled rice and conventional tillage wheat without crop residue (FP in R-F-W) and partial conservation agriculture practices in rice-wheat-mungbean cropping system with puddle rice, zero till wheat and conventional tillage mungbean and partially (anchored) incorporated rice and wheat residue and fully incorporated Mungbean (PCA in R-W-M). Among the treatments highest CEC of 43.81 cmol(p^+) kg^{-1} CEC was found in farmers practice soil (FP in R-F-W) followed by PCA in R-W-M having CEC of 39.95cmol(p^+) kg^{-1} and the lowest CEC of 33.14 was found in uncultivated soils (US).

Keywords: Cation exchange capacity, old alluvium, puddled soil, conservation agriculture uncultivated soil

Introduction
Cation exchange capacity (CEC) is a parameter of soil which represents the capability of soil to attract, retain and hold exchangeable cations (K^+, Na^+, Ca^{2+}, Mg^{2+}, Al^{3+}, etc.). Many soil parameters influence the soil exchangeable capacity especially soil pH, soil texture, and organic matter content up to a certain extent. Soils with high CEC typically have a high clay and organic matter. These soils are considered to be more fertile, as they can hold more plant nutrients. Soil pH is an important soil parameter which is positively correlated with CEC (Foth, 1990) [1], thereby high pH values increase numbers of negative charges on the colloids and CEC. High content of organic matter and clay conduces to the higher CEC values because both have a large number of negative charges on their surface which attract and hold cations. Negative charges of soil particles are the result of isomorphic substitutions in phyllosilicate structures, non-compensated bonds at the edges of reticular plans, or dissociation of functional organic groups (Pansu and Gautheyrou, 2006) [2]. A positive correlation between soil CEC and soil organic C and soil clay content in calcareous soils was observed by Wang *et al.* (2005) [3]. Cation exchange reactions in soils occur mainly near the surface of clay and humus particles, called micelles (Foth, 1990) [1]. Cations from the soil surface can be quite easily exchangeable with the cations from the solution. The upland physiography of old alluvial soils under immediate influence of the river Chandan are characterized by yellowish brown in colour, sandy clay loam in texture, presence of low organic carbon, neutral to slightly alkaline reaction

(pH 6.4- 7.7), very slow to slow hydraulic conductivity, lower CEC, while the soils on upland under, immediate influence of Chandan river are light olive in colour, sandy loam to sandy – clay –loam texture (Pandey and Kumar, 20-14) [4]. Various methods have been proposed for measuring CEC and exchangeable cations. The CEC determination involves measuring the total quantity of negative charges per unit weight of the material. The amount of CEC measured varies somewhat according to nature of the cation employed, concentration of salt and equilibrium pH. Cation Exchange Capacity (CEC) assessment was least studied in old alluvium soils (Agro-climatic zone IIIB of Bihar) under different tillage and management practices.

Materials and Methods

Soil sampling details: Patna conservation agriculture site: The soil samples varying in depth of 0-15, 15-30, 30-45 and 45-60 cm were collected from all three replications of four different treatments (scenarios) and one uncultivated site of conservation agriculture field of Cereal System Initiative for South Asia (CSISA) project, ICAR Complex for the Eastern Region (ICAR-RCER), Patna, Bihar, India ($25^0$24.912-$25^0$24.971'N latitude and $85^0$03.536'-$85^0$03.624'E longitude). The experimental soil is non-calcareous, non-saline, old alluvium with silty clay texture and slightly above neutral pH. The climate of the experimental site is sub humid with average annual rainfall of 1130 mm and relative humidity of 60-90% throughout the year. The design of the experimental field is randomized completely block design (RCBD). The soil samples were air dried and ground to pass through 2 mm sieve by the usual method described by Piper (1966) [5]. Soil pH was determined with the help of glass electrode pH meter (Jackson 1967) [6]. Organic carbon was determined by Walkeley and Black (1934) [7] rapid titration method (Jackson 1967) [6]. Cation exchange capacity (CEC) of soil was determined by Neutral normal ammonium acetate method (Jackson 1973) [8].

The study was conducted in old alluvium soils of Patna district under three different cropping systems namely Rice-Fallow-Wheat, Rice- Moongbean-Wheat, Rice-Cowpea-Wheat and Rice- Cow pea-Potato+ Maize with different tillage practices and crop residue retention as detailed below:

1. Farmers practices in rice-fallow-wheat cropping system with puddled rice and conventional tillage wheat without crop residue (FP in R-F-W)
2. Partial conservation agriculture practices in rice-wheat-mungbean cropping system with puddled rice, zero till wheat and conventional tillage mungbean and partially (anchored) incorporated rice and wheat residue and fully incorporated Mungbean (PCA in R-W-M)
3. Full conservation agriculture practices in rice-wheat-cowpea cropping system with zero till rice, reduced till wheat, zero till cowpea; and with one-third crop residue of rice and wheat and full of cowpea retained on soil surface (FCA in R-W-C)
4. Partial conservation agriculture practices in rice-potato+ maize- cowpea cropping system with reduced till rice, conventional till potato, reduced till maize and reduced till cowpea (PCA in R-P+M-C)
5. Uncultivated soil (US)

Results

Organic carbon as determined by Walkley and Black method in per cent (%) of old alluvium soils was found highest (0.676 %) in surface soils (0-15 cm) followed by sub-surface soils (15-30 cm) having 0.358 % organic carbon (Table 1). The highest value of 0.479 % organic carbon was found in uncultivated soils (US) and the lowest organic carbon was found in farmers practices in rice-fallow-wheat cropping system with puddle rice and conventional tillage wheat without crop residue (FP in R-F-W). The pH of soils was found to be lowest (7.96) in surface soils (0-15 cm) and in sub-surface soils (15-30 cm) it was 8.13. The value (8.04) was found in 45-60 cm depth which was at par with 30-45 cm soil layer having pH value 8.08 (Table 2). Among the treatments highest value of 8.16 pH was found in FP in R-F-W. The lowest pH of 7.97 was observed in full conservation agriculture practices in rice-wheat-cowpea cropping system with zero till rice, reduced till wheat, zero till cowpea; and with one-third crop residue of rice and wheat and full of cowpea retained on soil surface (FCA in R-W-C). Cation exchange capacity (CEC) in cmol (p^+) kg^{-1} of soils was found lowest (36.59 cmol (p^+) kg^{-1}) in surface soils (0-15 cm) followed by sub-surface soils (15-30 cm). The highest value of CEC (38.21 cmol (p^+) kg^{-1}) was found in 45-60 cm depth followed by 30-45 cm depth with CEC of 38.10 cmol (p^+) kg^{-1}. Among the treatments highest CEC of 43.81 cmol (p^+) kg^{-1} was found in farmers practice soil (FP in R-F-W) followed by Partial conservation agriculture practices in rice-wheat-mungbean cropping system with puddle rice, zero till wheat and conventional tillage mungbean and partially (anchored) incorporated rice and wheat residue and fully incorporated Mungbean (PCA in R-W-M) having CEC of 39.95 cmol (p^+) kg^{-1} and the lowest CEC of 33.14 was found in uncultivated soils (Table 3).

Discussion

The pH of the surface soil of old alluvium soils of Patna was lower than sub-surface soil. Among the treatments highest pH (8.16) was found in FP in R-F-W.The lowest pH (7.97) was observed in FCA in R-W-C (Table 2). The increase in pH at lower layers in all the treatments might be due to leaching and accumulation of basic cations in the lower depth of the profiles. Similar results were reported by Kumar *et al.* 2012 [9] and Getachew *et al.* 2012 [10]. The pH value was lower in PCA in R-W-M, FCA in R-W-C and Partial conservation agriculture practices in rice-potato+ maize- cowpea cropping system with reduced till rice, conventional till potato, reduced till maize and reduced till cowpea (PCA in R-P+M-C) than that of FP in R-F-W which may be due to decomposition of organic matter and liberation of organic acid in crop residues and green manure received in this scenario (Datta *et al.* 2015) [11]. Cation exchange capacity (CEC) in cmol(p^+) kg^{-1} of of old alluvium soils was found lower (36.59cmol(p^+) kg^{-1}) in surface soils (0-15 cm) than sub-surface soils (15-30 cm).This might be due to migration of fine clay-humus particles especially in puddled soils scenario (FP in R-F-W & PCA in R-W-M). Among the treatments highest CEC of 43.81cmol (p^+) kg^{-1} CEC was found in farmers practice soil (FP in R-F-W) followed by PCA in R-W-M having CEC of 39.95 cmol(p^+) kg^{-1} and the lowest CEC of 33.14 was found in uncultivated soils. This might be due to variation of organic carbon and silt plus clay content among different scenarios. With increase in depth clay content increased and accumulation of clay was observed in the sub-surface layers with a simultaneous decrease in sand content. Higher content of finer particles (clay) in lower depths might be due to the translocation of finer particles from the surface horizons and subsequent illuviation in sub-surface horizons. These observations are in accordance with the results of Walker and Desanker (2004) [12], Datta *et al.* (2015) [11] and Arevalo *et al.* (2009) [13].

Table 1: Organic carbon (Walkley and Black Carbon) (%) in old alluvium soils as affected by tillage and residue management at different depth

Depth (cm)	FP in R-F-W	PCA in R-W-M	FCA in R-W-C	PCA in R-P+M-C	US	Mean A
0-15	0.670	0.708	0.570	0.636	0.795	0.676
15-30	0.335	0.301	0.329	0.405	0.422	0.358
30-45	0.289	0.331	0.313	0.373	0.373	0.336
45-60	0.258	0.286	0.375	0.34	0.325	0.317
Mean B	0.388	0.407	0.397	0.439	0.479	
Factors	Factor(A)	Factor(B)	Factor (A X B)			
C.D.(P<0.05)	0.017	0.019	0.038			

FP in R-F-W= Farmers practices in rice-fallow-wheat cropping system with puddled rice and conventional tillage wheat without crop residue
PCA in R-W-M= Partial conservation agriculture practices in rice-wheat-mungbean cropping system with puddled rice, zero till wheat and conventional tillage mungbean and partially (anchored) incorporated rice and wheat residue and fully incorporated Mungbean
FCA in R-W-C= Full conservation agriculture practices in rice-wheat-cowpea cropping system with zero till rice, reduced till wheat, zero till cowpea; and with one-third crop residue of rice and wheat and full of cowpea retained on soil surface
PCA in R-P+M-C= Partial conservation agriculture practices in rice-potato+ maize- cowpea cropping system with reduced till rice, conventional till potato, reduced till maize and reduced till cowpea
US= uncultivated soils

Table 2: pH (1:2.5 soil water**)** in old alluvium soils as affected by tillage and residue management at different depth

Depth (cm)	FP in R-F-W	PCA in R-W-M	FCA in R-W-C	PCA in R-P+M-C	US	Mean A
0-15	7.85	7.94	8.00	8.08	7.92	7.96
15-30	8.23	8.17	8.06	8.15	8.03	8.13
30-45	8.32	8.07	7.93	8.05	8.04	8.08
45-60	8.25	7.99	7.90	8.00	8.07	8.04
Mean B	8.16	8.04	7.97	8.07	8.01	
Factors	Factor(A)	Factor(B)	Factor (A X B)			
C.D.(P<0.05)	0.061	0.068	0.136			

FP in R-F-W= Farmers practices in rice-fallow-wheat cropping system with puddled rice and conventional tillage wheat without crop residue
PCA in R-W-M= Partial conservation agriculture practices in rice-wheat-mungbean cropping system with puddled rice, zero till wheat and conventional tillage mungbean and partially (anchored) incorporated rice and wheat residue and fully incorporated Mungbean
FCA in R-W-C= Full conservation agriculture practices in rice-wheat-cowpea cropping system with zero till rice, reduced till wheat, zero till cowpea; and with one-third crop residue of rice and wheat and full of cowpea retained on soil surface
PCA in R-P+M-C= Partial conservation agriculture practices in rice-potato+ maize- cowpea cropping system with reduced till rice, conventional till potato, reduced till maize and reduced till cowpea
US= uncultivated soils

Table 3: Cation exchange capacity (cmolp$^+$ kg^{-1}) in old alluvium soils as affected by tillage and residue management at different depth

Depth (cm)	FP in R-F-W	PCA in R-W-M	FCA in R-W-C	PCA in R-P+M-C	US	Mean A
0-15	40.90	39.13	35.03	36.50	31.40	36.59
15-30	40.27	43.39	31.00	43.59	31.91	38.03
30-45	40.39	35.87	32.57	37.20	34.49	38.10
45-60	43.70	41.43	34.68	36.47	34.77	38.21
Mean B	43.82	39.95	33.32	38.44	33.14	
Factors	Factor(A)	Factor(B)	Factor (A X B)			
C.D.(P<0.05)	N/A	1.54	3.09			

FP in R-F-W= Farmers practices in rice-fallow-wheat cropping system with puddled rice and conventional tillage wheat without crop residue
PCA in R-W-M= Partial conservation agriculture practices in rice-wheat-mungbean cropping system with puddled rice, zero till wheat and conventional tillage mungbean and partially (anchored) incorporated rice and wheat residue and fully incorporated Mungbean
FCA in R-W-C= Full conservation agriculture practices in rice-wheat-cowpea cropping system with zero till rice, reduced till wheat, zero till cowpea; and with one-third crop residue of rice and wheat and full of cowpea retained on soil surface
PCA in R-P+M-C= Partial conservation agriculture practices in rice-potato+ maize- cowpea cropping system with reduced till rice, conventional till potato, reduced till maize and reduced till cowpea
US= uncultivated soils

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