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Hareesh Kumar
Department of Soil Science and Agricultural Chemistry Indira Gandhi Agricultural University, Raipur, Chhattisgarh, India

Dr. SS Sengar
Department of Soil Science and Agricultural Chemistry Indira Gandhi Agricultural University, Raipur, Chhattisgarh, India

Bharat Desmukh
Department of Soil Science and Agricultural Chemistry Indira Gandhi Agricultural University, Raipur, Chhattisgarh, India

Dr. RN Singh
Department of Soil Science and Agricultural Chemistry Indira Gandhi Agricultural University, Raipur, Chhattisgarh, India

Corresponding Author:
Hareesh Kumar
Department of Soil Science and Agricultural Chemistry Indira Gandhi Agricultural University, Raipur, Chhattisgarh, India

Distribution of different forms of soil acidity in Dhamtari block of Chhattisgarh

Hareesh Kumar, Dr. SS Sengar, Bharat Desmukh and Dr. RN Singh

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Abstract
Soil samples were collected over a period of 2017-2018 from the entire block, to study physico-chemical parameters of three seasons. A comparative study has been carried out in order to study the extent of pollution caused due to application of chemical fertilizers to soil and water systems.
Total acidity (TA), exchange acidity (EA), aluminium acidity and pH-dependent acidity (PDA) and total potential acidity (TPA) ranged from 0.1–2.2, 0.1–2.5, 0.1–2.7, 0.0– 4.5 and 0.1– 4.9 cmol(p+) kg^{-1}, respectively. Relative order for all forms of acidity was: Inceptisol >Alfisols >Vertisol. On average contribution of soil acidity due to TPA in Inceptisol, Alfisol and Vertisol was found maximum 35.5%, 35.6% and 32.3% at 0-30 cm soil depth, 36.0%, 34.3% and 33.0% at 30-60 cm soil depth and 35.5%, 34.6% and 33.0% at 60 - 90 cm soil depth, respectively, while, the minimum contribution in soil acidity was due to exchangeable acidity i.e. 9.2, 8.5 and 9.2% at 0-30 cm soil depth, 7.5%, 6.5% and 7.5% at 30-60 cm depth and 5.6, 4.8 and 5.5% at 60 - 90 cm soil depth, respectively. All forms of acidity showed significant positive correlations with organic carbon (OC) but negative correlations with pH of soil. They also showed significant correlations with each other. Soil pH, organic C and exchangeable Al caused most of the variations in different forms of soil acidity.

Keywords: Soil acidity, forms of acidity, Dhamtari Chhattisgarh

Introduction
The rapid weathering and intense leaching under high rainfall condition favours the development of soil acidity. Besides uncontrollable climate, geological and environmental factors, land use also affect the acidity. Soil acidity is an important agricultural problem leading to severe toxicity of iron, aluminium and manganese in many crops, coupled with deficiency of phosphorus and low microbial activity that led to poor yield of crops (Reza *et al*., 2012) [19] Exchangeable acidity refers to the sum of the concentrations of hydrogen (H) and aluminium (Al) ions in the soil exchange complex and is inversely related to base saturation and pH of the soil. It is caused by the nature of parent material, weathering process, rainfall and heavy leaching, decomposition of OM, management factors and crop removal of basic cations (Owolabi *et al*., 2003) [15], which lead to the deterioration of the soils, thus giving rise to low soil pH and nutrient deficiency among others. Continuous application of nitrogenous fertilizers alone has been reported to aggravate the problem of soil acidity by lowering the soil pH from 5.8 to 4.7 and increasing aluminium (Sharma and Subehia, 2003) [22]. Soil pH response changed with N addition rate. It was significantly reduced when the added-N amount was more than 5 gm−2 yr−1. Below this level, there was no significant response. Moreover, soil pH decreased linearly with increased N addition rate. For different ecosystem types, a negative linear relationship existed between N addition rate and pH response ratios in tropical forest and grassland, while no relationship was detected in temperate and boreal forests. It was not observed that NH4+ form fertilizer addition decreased soil pH, while NH4 + and NO3- form fertilizer and urea addition significantly reduced soil pH. (Tian and Niu 2015) [24].

Materials and Methods
Ninety (90) soil samples were collected from 10 replications as 10 random farmers for each combination dose of fertilizer (F) and soil type (T) during pre monsoon, during monsoon and post monsoon season in April, August and November 2017 respectively at random depth 0-30, 30-60 and 60-90 cm. Location of sampling point were determined using a Global Positioning

System (GPS) presented in table 3.2. They were carefully packed in polythene bags. The pH of the soils were estimated by using soil suspension (1:2.5) (Piper 1967) [18]; organic carbon by the method of Walkley and Black (1934) [25]. The total potential acidity were measured by the method of Peech *et al*., (1962) [17]. The pH dependent acidity was estimated by the following equation: pH dependent acidity = Total potential acidity - Exchange acidity. Total soil acidity was measured by shaking the soil with 1N NaOAc for an hour (Kappen, 1934) [9]; the Exchangeable Al was determined by the principle of Baruah and Barthakur (1999) [4].

Results and Discussion

Soil pH

The pH value of collected soil samples were ranged between 4.7 to 7.9, 4.4 to 7.7 and 4.7 to 8.7 with a mean value of 6.1, 6.2 and 6.8 in *Inceptisol*, *Alfisol* and *Vertisols*, respectively. Whereas, the overall minimum soil pH was recorded 4.4 and the maximum soil pH was 8.7 with an average value of 6.4 (Table 1).

Table 1: Summarized Range and mean of soil under study area

SN	Parameters	Range and mean		
		Inceptisols	Alfisols	Vertisols
1	pH	4.7 – 7.9 6.1	4.4 – 7.7 6.2	4.7 – 8.7 6.8
2	OC (%)	0.1 – 0.8 0.33	0.1 – 0.7 0.35	0.1 – 0.8 0.40
3	Ex. acidity.	0.2 - 2.5 0.6	0.1 - 1.8 0.5	0.1 - 1.6 0.4
4	Total acidity.	0.1 - 2.2 1.0	0.2 - 1.9 0.9	0.1 - 1.9 0.9
5	Aluminium acidity	0.1 - 2.6 0.9	0.1 - 2.2 0.8	0.1 - 2.7 0.9
6	TPA	0.8 - 4.5 2.3	0.1 - 4.6 2.3	0.1 - 4.9 1.9
7	pH dependent acidity	0.2 - 3.8 1.9	0.0 - 4.5 1.8	0.0 - 4.3 1.5

It is obvious from table 2 showed that the pH value of soil during mid-monsoon season was 6.2 which was significantly lower as compare to pre-monsoon (6.8) and post-monsoon season (6.5) for the fixed levels of < 92 Kg/ha nitrogen level *Inceptisol*, however the pH value of *Inceptisol* were 6.1, 6.0, 6.1 under 92-138 Kg/ha nitrogen level which were at par during pre, mid and post- monsoon season, respectively. On the other hand, soil pH increased when the nitrogen level was increased beyond 138 Kg/ha in *Inceptisol* during both, the mid- monsoon (5.6) and post-monsoon (5.7) season which was at par among themselves but significantly lower than that of pre-monsoon season (6.1).

In *Alfisol* also, all the nitrogen levels, namely <92, 92-138 and >138 kg/ha produce the same effects on soil pH as incase of Inceptisol. However, significantly lower soil pH values were observed in the mid-monsoon season (6.3, 6.0 and 5.7) as compared to both pre (6.8, 6.4 and 6.1) and post monsoon seasons (6.7, 6.2 and 6.1), respectively.

Table 2: Effect of different levels of nitrogen (N), soil types (T), seasons (S) and their interactions on soil pH

Soil type	pH			
	Nitrogen level	Pre- monsoon	Mid -monsoon	Post- monsoon
Inceptisol	<92 Kg/ha	$^{B}6.8^{a}$	$^{B}6.2^{c}$	$^{BC}6.5^{b}$
	92-138 Kg/ha	$^{A}6.1^{a}$	$^{AB}6.0^{a}$	$^{B}6.1^{a}$
	>138 kg/ha	$^{A}6.1^{a}$	$^{A}5.6^{b}$	$^{A}5.7^{b}$
Alfisols	<92 Kg/ha	$^{A}6.8^{a}$	$^{B}6.3^{b}$	$^{BD}6.7^{a}$
	92-138 Kg/ha	$^{A}6.4^{a}$	$^{AB}6.0^{b}$	$^{B}6.3^{a}$
	>138 kg/ha	$^{A}6.1^{a}$	$^{A}5.7^{b}$	$^{B}6.1^{a}$
Vertisols	<92 Kg/ha	$^{D}7.4^{a}$	$^{D}7.0^{b}$	$^{DE}7.1^{b}$
	92-138 Kg/ha	$^{BC}7.1^{a}$	$^{BC}6.5^{b}$	$^{D}7.0^{a}$
	>138 kg/ha	$^{AB}6.5^{a}$	$^{B}6.3^{b}$	$^{BC}6.5^{a}$
TXNXS				CD (0.05)
Sub plot at the same level of main plot				0.197
Main plot at the same or diff level of sub plot				0. 317

Note: The capital alphabets, as prefixes, are showing the significance/ parity among different combination of soil types and nitrogen level for given levels of monsoon on the other hand the small alphabets, as suffixes, are showing the significance/ parity among the monsoon levels for given combination of soil types and nitrogen levels.
A = It is computing the fixed level of main-plot (Column)
a= It is computing the fixed level of sub-plot (Row)

In *Vertisols*, nitrogen levels namely <92 Kg/ha observed significantly lower pH value during mid-monsoon (7.0) and post-monsoon (7.1) season as compared with pre-monsoon season which recorded higher soil pH (7.4). On the other hand, both the nitrogen level i.e. 92-138 and >138 Kg/ha observed the same effect on soil pH during both the season Pre- monsoon (7.1 and 6.5) and post- monsoon season (6.7 and 6.5) which were at par among themselves but significantly higher than that of mid-monsoon(6.5 and 6.3) season, respectively. and the maximum soil pH value (7.4) was reported under < 92 kg/ha nitrogen level in Vertisol during pre-monsoon season and the minimum soil pH value (5.6) was reported under > 138 kg/ha nitrogen level in *Inceptisol* during mid-monsoon season table 2.

Bernstein L. *et al*., (1975) [5] reported that the soil pH was decreased due to continuous application of acid-forming fertilizers such as urea and field the experiment conducted in which soil pH was decreased during rainy season due to leaching of basic soluble cations (i.e. Ca^{2+} Mg^{2+} and Na^{+}) from the soil. When urea is added to the soil, it undergoes a reaction to form bicarbonate and ammonium-N. The bicarbonate then reacts with H ions in the soil solution, which temporarily reduces acidity, but acidity is again produced when ammonium-N undergoes nitrification process. Similar results were also reported by De S, *et al.* (2009) [8], Tian and Niu (2015) [24]. Kumar *et al.* (2009) [11] also observed pH Value ranging between 4.6 to 7.7. Similar, results were also concluded by Singh *et al.* (2009) [23].

Soil organic carbon (OC)

The OC of collected soil samples were ranged between 0.1 to 0.8, 0.1 to 0.7 and 0.1 to 0.8% with a mean value of 0.33, 0.35 and 0.40% in *Inceptisol*, *Alfisol* and *Vertisol*, respectively. While, the minimum soil OC content was recorded 0.1% and the maximum soil OC was 0.8% with an average value of 0.4% (Table 1).

Table 3: Effect of different levels of nitrogen (N), soil types (T), seasons (S) and their interactions on the organic carbon (%)

Soil type	Organic carbon (%)			
	Nitrogen level	**Pre-monsoon**	**Mid - monsoon**	**Post-monsoon**
Inceptisol	<92 Kg/ha	^{A}0.32 ^{a}	^{A}0.33 ^{a}	**^{A}0.31 ^{a}**
	92-138 Kg/ha	**^{A}0.31 ^{a}**	^{A}0.35^{b}	^{A}0.32 ^{a}
	>138 kg/ha	^{A}0.35 ^{a}	^{A}0.37 ^{ab}	^{B}0.39 ^{b}
Alfisols	<92 Kg/ha	^{A}0.34 ^{a}	^{AB}0.39 ^{b}	^{A}0.32 ^{a}
	92-138 Kg/ha	^{ABC}0.38 ^{a}	^{A}0.35^{a}	^{AB}0.36 ^{a}
	>138 kg/ha	^{AB}0.36 ^{a}	^{AB}0.39 ^{a}	^{B}0.36 ^{a}
Vertisols	<92 Kg/ha	^{BCD}0.40 ^{a}	^{ABC}0.40 ^{a}	^{B}0.38 ^{a}
	92-138 Kg/ha	^{AB}0.36 ^{a}	^{BD}0.42 ^{b}	^{BD}0.41^{b}
	>138 kg/ha	^{CD}0.42 ^{a}	^{DE}0.46^{b}	^{BD}0.42 ^{a}
TXNXS				CD (0.05)
Sub plot at the same level of main plot				0.030
Main plot at the same or different level of sub plot				0.040

Note: The capital alphabets, as prefixes, are showing the significance/ parity among different combination of soil types and nitrogen level for given levels of monsoon on the other hand the small alphabets, as suffixes, are showing the significance/ parity among the monsoon levels for given combination of soil types and nitrogen levels.

A = It is computing the fixed level of main-plot (Column)

a= It is computing the fixed level of sub-plot (Row)

It is evident from the table 3 that the organic carbon content of soil during mid-monsoon season was higher (0.33) as compared to pre-monsoon (0.32) and post-monsoon season (0.31) but at par with each other for the same level of < 92 Kg/ha nitrogen level in *Inceptisol,* however the organic carbon of *Inceptisol* during mid-monsoon season was significantly higher (0.35) as compared to post-monsoon (0.32) and pre-monsoon season (0.31) were under 92-138 Kg/ha nitrogen level. On the other hand, soil organic carbon increased when the nitrogen level was increased beyond 138 Kg/ha in *Inceptisol* during both the pre- monsoon (0.35) and post-monsoon (0.37) season which was significant differed but mid-monsoon season was (0.37) at par with pre and post monsoon season.

In *Alfisol* all the nitrogen levels, namely 92-138 and >138 kg/ha observed the similar effects on soil OC. However, significantly higher organic carbon value was observed in the mid-monsoon season (0.35 and 0.39) as compare to both pre (0.38 and 0.36) and post monsoon seasons (0.36 and 0.36), respectively.

In the *Vertisol* under nitrogen levels of<92 Kg/ha recorded the higher OC value during pre-monsoon (0.40) and mid-monsoon (0.40) season followed by lower soil OC content (0.38) in post-monsoon season which were at par with each other. However the organic carbon of *Vertisol* during pre-monsoon season was (0.36) significantly lower as compared to mid-monsoon (0.42) and post-monsoon season (0.41) at 92-138 Kg/ha nitrogen level. On the other hand, soil OC was increased when the nitrogen level was increased beyond 138 Kg/ha in *Vertisol* during both the pre- monsoon (0.42) and post-monsoon (0.42) season which was at par among themselves but significantly lower than mid-monsoon season (0.46).

The interaction effects showed that the maximum OC content (0.48%) was observed under >138 kg/ha nitrogen level in Vertisol during mid-monsoon season and the minimum organic carbon content (0.31%) in soil was reported under both <92 kg/ha-N during post-monsoon season and 92 – 138 kg/ha- N during pre-monsoon season in *Inceptisol*.

During the investigation, organic carbon content were increased in rainy season followed by winter seasons and summer season. In case of summer season organic carbon content were found to be less which implies that the rate of mineralization of carbon were higher during summer. The variations in organic carbon content in all the sampling places is due to variations in rate of mineralization under existing climatic conditions on the surface or may be due to low leaching from surface layers or might be due to absorption by clay particles. The high organic carbon is due to accumulation of crop residues on soil surface and also due to addition of organic manures during cropping season to agricultural lands (Ashok, 1998) [2].

Total acidity in soil

The total acidity in soil samples varied between 0.1 to 2.2, 0.2 to 1.9 and 0.1 to 1.9 cmol(+) kg^{-1} with a mean value of 1.0, 0.9 and 0.9 cmol(+) kg^{-1} in *Inceptisol*, *Alfisol* and *Vertisols*, respectively. Whereas, overall minimum and maximum total acidity in soil was 0.1 and 2. 2 cmol(+) kg^{-1}, respectively with an average value of 2.2 cmol(+) kg^{-1}(Table 1).

Table 4: Effect of different soil types (T), depth (D) and their interactions on the total acidity in soil

Soil type	Total acidity (cmol(+) kg^{-1}) Soil depth			
	0-30 cm	**30-60 cm**	**60-90 cm**	**Mean**
Inceptisol	^{A} 1.32 a	^{A} 0.94 b	^{A} 0.82 c	1.02
Alfisols	^{B} 1.09 a	^{A} 0.93b	^{A} 0.80 c	0.94
Vertisols	^{B} 1.05 a	^{A} 0.84 b	^{A} 0.71 c	0.86
Mean	1.15	0.90	0.77	
TXD			CD (0.05)	
Two sub plot at the same level of main plot			0.069	
Two main plot at the same or diff level of sub plot			0.139	

Note: The capital alphabets, as prefixes, are showing the significance/ parity among different combination of soil types for given levels of depth on the other hand the small alphabets, as

suffixes, are showing the significance/ parity among the depth for given combination of soil types and nitrogen levels.
A = It is computing the fixed level of main-plot (Column)
a= It is computing the fixed level of sub-plot (Row)

Total acidity of the soil samples at different soil depth and soil type are presented in table 4.22. The total acidity of soil was significantly different from each other at all the soil depths 0-30 cm (1.32, 1.09 and 1.05 cmol(+) kg^{-1}), 30-60 cm (0.94, 0.93 and 0.84 cmol(+) kg^{-1}) and 60 - 90 cm (0.82, 0.80 and 0.71 cmol(+) kg^{-1}), respectively, however higher total acidity was recorded in 0-30 cm depth in all types of soil. Total acidity were obtained may be due to high organic matter content of all the soils and the lower value of total acidity may be due to low contents of organic carbon as the organic matter might have contributed to total acidity through their functional groups like –COOH and phenolic-OH. Total acidity is present in soil in the pH range of 5.5 to 7.0, as hydroxyl Al-polymers among acidic soil components when soil pH decreased total acidity increased. The total acidity values were found significant either due to depth. However, surface soils recorded higher total acidity content compared to subsurface layer and total acidity was highest in Inceptisol followed by Alfisol and Vertisol. simillar result were reported by Bhat *et al.* (2017) [6] and Bandyopadhyay and Chattopadhyay (1997) [3]. Also observed exchangeable acidity ranging between 0.80 to 2.17 cmol(+) kg^{-1}).

Exchangeable acidity in soil

The exchangeable acidity in collected soil samples were ranged between 0.2 to 2.5, 0.1 to 1.8 and 0.1 to 1.6 cmol(+) kg^{-1}with a mean value of 0.6, 0.5 and 0.4 cmol(+) kg^{-1} in *Inceptisol*, *Alfisol* and *Vertisols*, respectively. Whereas, the overall minimum and maximum exchangeable acidity in soilwas 0.1 and 2.5cmol(+) kg^{-1}, respectively with an average value of 0.5 cmol(+) kg^{-1} (Table 1).

Table 5: Effect of different levels of nitrogen (N), soil type (T), season (S) and their interactions on the exchangeble acidity in soil

Soil type	Exchangeble acidity(cmol(+) kg^{-1})			
	Nitrogen level	**Pre-monsoon**	**Mid - monsoon**	**Post-monsoon**
Inceptisol	<92 Kg/ha	^{A}0.46 ^{a}	^{A}0.51 ^{a}	^{A}0.47 ^{a}
	92-138 Kg/ha	^{AB}0.54 ^{a}	^{BC}0.70 ^{b}	^{ABC}0.58 ^{a}
	>138 kg/ha	^{BC}0.62 ^{a}	^{D}0.88 ^{c}	^{D}0.72 ^{b}
Alfisols	<92 Kg/ha	^{A}0.39 ^{a}	^{A}0.43 ^{a}	^{A}0.44 ^{a}
	92-138 Kg/ha	^{A}0.43 ^{a}	^{AB}0.57 ^{b}	^{AB}0.54 ^{b}
	>138 kg/ha	^{AB}0.51 ^{a}	^{AB}0.60 ^{b}	^{ABC}0.55 ^{ab}
Vertisols	<92 Kg/ha	^{A}0.33 ^{a}	^{A}0.43 ^{b}	^{A}0.37 ^{ab}
	92-138 Kg/ha	^{A}0.38 ^{a}	^{A}0.54 ^{b}	^{A}0.43 ^{a}
	>138 kg/ha	^{AB}0.51 ^{a}	^{A}0.52 ^{a}	^{A}0.46 ^{a}
Interaction				
TXNXS				CD (0.05)
Two sub plot at the same level of main plot				0.088
Two main plot at the same or diff level of sub plot				0.137

Note: The capital alphabets, as prefixes, are showing the significance/ parity among different combination of soil types and nitrogen level for given levels of monsoon on the other hand the small alphabets, as suffixes, are showing the significance/ parity among the monsoon levels for given combination of soil types and nitrogen levels.
A = It is computing the fixed level of main-plot (Column)
a= It is computing the fixed level of sub-plot (Row)

The data on the exchangeable acidity of soils are presented in table 5. Exchangeable acidity of soils were significantly increased with increasing fertilizer dose i.e. 92-138 and >138 kg/ha N during mid-monsoon season (0.70, and 0.88 cmol(+) kg^{-1}) as compared to pre (0.54 and 0.62 cmol(+) kg^{-1}) and post-monsoon (0.58 and 0.72 cmol(+) kg^{-1}) period of *Inceptisol*, respectively, however it was observed that the exchangeable acidity was at par atlower fertilizer dose (92 kg/ha) during all the Pre (0.46 cmol(+) kg^{-1}), mid (0.56 cmol(+) kg^{-1}) and post-monsoon (0.47 cmol(+) kg^{-1}) in *Inceptisol*, while the higher exchangeable acidity was recorded during mid-monsoon season.
In the case of *Alfisol*, exchangeable acidity in collected soil samples were reported at par to each other during pre (0.39 cmol(+) kg^{-1}), mid (0.43 cmol(+) kg^{-1}) and post-monsoon season (0.44cmol(+) kg^{-1}) when < 92 kg/ha N was applied. While the exchangeable acidity was at par during mid (0.57cmol(+) kg^{-1}) and post monsoon (0.54 cmol(+) kg^{-1}) but significantly higher with pre (0.43 cmol(+) kg^{-1}) monsoon season at 92-136 kg/ha -N applied. However, when the nitrogen level nitrogen level increased beyond the 138 kg/ha in Alfisol than the exchangeable acidity was significantly higher during mid monsoon season (0.60 cmol(+) kg^{-1}) as compare to pre monsoon (0.51) and post monsoon (0.55) season. But post monsoon was (0.55 cmol(+) kg^{-1}) at par with pre and mid-monsoon season.
Whereas, the exchangeable acidity was increased significantly with the application of 92 and 92-138 kg/ha –N during mid-monsoon (0.43 and 0.54cmol(+) kg^{-1}) season as compared to pre (0.33 and 0.38 cmol(+) kg^{-1}) and post-monsoon (0.37 and 0.43 cmol(+) kg^{-1}) season in *Vertisol*, however at >138 kg/ha N the exchangeable acidity was recorded at par due to various season. The exchangeable acidity of different soils increased significantly with increasing levels of nitrogen in most of the cases during various season.
Sarangthem *et al.*, (2017) [20] reported that the soil having dominance of hydrogen (H^+) ion and aluminium (Al^{3+}) ion relatively to hydroxyl (OH^-) ion is called an acid soil. Exchangeable acidity includes the exchangeable $H^+$and Al^+ held at the permanent charge sites of the soil exchange complex and soil acidity is common in all regions where precipitation is high enough to leach appreciable quantities of exchangeable base forming cations (Ca^{2+}, Mg^{2+}) from the soil layers due to increased exchangeable acidity. Similar results were also reported by Sharma and Sarangthem (2017) [20], Das *et al.* (1991) [7], Kumar *et al*. (1995) [10] and Ananthnarayana and Ravi (1997) [1]. Pati and Mukhopadhyay (2010) [16] also observed exchangeable acidity ranging between 0.80 to 2.17 cmol(+) kg^{-1}). Similar, results were also concluded by Bhat *et al.*, (2017) [6], and Kundu (2017) [12].

Aluminium acidity in soil

The aluminium acidity in soil samples varied between 0.1 to 2.6, 0.1 to 2.2 and 0.1 to 2.7 cmol(+) kg^{-1}with a mean value of 0.9, 0.8 and 0.9 cmol(+) kg^{-1}in *Inceptisol*, *Alfisol* and *Vertisol*, respectively. Whereas, the overall minimum and maximum aluminium acidity in soilwas 0.1 and 2.7 cmol(+) kg^{-1}, respectively with an average value of 0.9 cmol(+) kg^{-1}(Table 1).

Table 6: Effect of different levels of nitrogen (N), soil type (T), season (S) and their interactions on the Aluminium acidityin soil

Soil type	Aluminium acidity(cmol(+) kg^{-1})			
	Nitrogen level	**Pre- monsoon**	**Mid -monsoon**	**Post- monsoon**
Inceptisol	<92 Kg/ha	$^{A}0.74^{a}$	$^{A}0.80^{a}$	$^{A}0.76^{a}$
	92-138 Kg/ha	$^{A}0.84^{a}$	$^{AB}1.09^{b}$	$^{A}0.72^{a}$
	>138 kg/ha	^{A}B1.00 ^{a}	$^{C}1.56^{b}$	$^{AB}0.88^{a}$
Alfisols	<92 Kg/ha	$^{A}0.68^{a}$	$^{A}0.94^{b}$	$^{A}0.71^{a}$
	92-138 Kg/ha	$^{A}0.73^{a}$	$^{A}0.84^{a}$	$^{A}0.78^{a}$
	>138 kg/ha	$^{A}0.87^{a}$	$^{AB}1.14^{b}$	$^{A}0.77^{a}$
Vertisols	<92 Kg/ha	$^{A}0.85^{a}$	$^{A}1.03^{b}$	$^{A}0.75^{a}$
	92-138 Kg/ha	$^{A}0.91^{a}$	$^{A}0.83^{a}$	$^{A}0.82^{a}$
	>138 kg/ha	$^{AB}1.02^{a}$	$^{AB}1.19^{b}$	$^{A}0.90^{a}$
Interaction				
TXNXS				CD (0.05)
Two sub plot at the same level of main plot				0.157
Two main plot at the same or diff level of sub plot				0.251

Note: The capital alphabets, as prefixes, are showing the significance/ parity among different combination of soil types and nitrogen level for given levels of monsoon on the other hand the small alphabets, as suffixes, are showing the significance/ parity among the monsoon levels for given combination of soil types and nitrogen levels.
A = It is computing the fixed level of main-plot (Column)
a= It is computing the fixed level of sub-plot (Row)

The aluminum acidity in soil are presented in table 6 the aluminum acidity of soil samples were significantly higher during mid (1.09 and 1.56) monsoon season as compared to pre (0.84 and 1.0) and post (0.72 and (0.88), respectively, at 92 - 138 kg/ha and >138 kg/ha -N applied in *Inceptisol*. However, aluminum acidity showed non-significant difference various season at < 92 kg/ha N applied.
In case of *Alfisol* aluminum acidity in soil samples were reported significantly higher during mid (0.94 and 1.14) monsoon season as followed by post (0.71 and 0.77) and pre (0.68 and 0.87) at <92 and >138 kg/ha -N applied, but it was at par with pre and post monsoon season. While the aluminum acidity was at par during pre (0.73), mid (0.84) and post (0.78) monsoon season at 92 - 138 kg/ha N applied. In *Vertisol*, the aluminum acidity increased in nitrogen levels and followed almost the similar trend as in *Alfisol*.
Pati *et al*. (1996) [16] reported that the aluminum is an extremely important cation in exchange equilibrium and acidifying process and has detrimental influence on plant growth when present in high concentration in surface soil. Exchangeable Al is a measure of reserve acidity and has great significance on plant growth and yield. Irrespective of land use it ranged from 0.15 to 2.0 cmol (p+) kg^{-1} with mean value 0.65 cmol(p+) kg^{-1}. Similar result was also reported by Bhat *et al*. (2017) [6].

Total potential acidity (TPA) in soil

The total potential acidity in the soil samples were ranged between 0.8 to 4.5, 0.1 to 4.6 and 0.1 to 4.9 cmol(+) $kg^{-1}$with a mean value of 2.3, 2.3 and 1.9 cmol(+) kg^{-1}in *Inceptisol*, *Alfisol* and *Vertisols*, respectively. Whereas, the overall minimum and maximum total potential acidity in soilwas 0.1 and 4.9 cmol(+) kg^{-1}, respectively with an average value of 2.2 cmol(+) kg^{-1} (Table 1).
The data presenting with the total potential acidity of soil are presented in table 7 The total potential acidity in soil was significantly lower (2.0 cmol(+) kg^{-1}) in Vertisol and higher in both the Inceptisol and Alfisol (2.3 cmol(+) kg^{-1}). Whereas, the total potential acidity of soil was significantly higher (2.3 cmol(+) kg^{-1}) during mid-monsoon season as compared with pre-monsoon season (2.1 cmol(+) kg^{-1}) and post-monsoon season (2.2 cmol (p+) kg^{-1}) which were at par among each other. The maximum total potential acidity was 2.4 cmol (p+) kg^{-1} under > 138 kg/ha-N which was at par with 92-138 kg/ha-N (2.2 cmol (p+) kg^{-1}) application, while the significantly low total potential acidity (1.9 cmol(+) kg^{-1}) was observed when the <92 kg/ha-N applied. The total potential acidity decreased significantly with increasing soil depth which were 2.7, 2.1 and 1.8 cmol(+) kg^{-1} at 0-30, 30-60 and >60 cm soil depth, respectively.

Table 7: Effect of different soil type (T), season (S) and their interactions on the Total potential acidity in soil

Soil Type	Total potential acidity (cmol(+) kg^{-1})			
	Seasons			
	pre-monsoon	**Mid- monsoon**	**Post- monsoon**	**mean**
Inceptisol	2.2	2.5	2.3	$^{A}2.3$
A	2.2	2.4	2.2	$^{A}2.3$
Vertisols	1.8	2.1	2.0	$^{B}2.0$
Mean	2.1^{a}	2.3^{b}	2.2^{ab}	
				CD (0.05)
Soil Type				0.292
Season				0.108

Note: The capital alphabets, as prefixes, are showing the significance/ parity among different combination of soil types for given levels of monsoon on the other hand the small alphabets, as suffixes, are showing the significance/ parity among the monsoon levels for given combination of soil types.
A = It is computing the fixed level of main-plot (Column)
a= It is computing the fixed level of sub-plot (Row)

Effect of different soil type (T), depth (D) and their interactions on the Total potential acidity in soil

Soil Type	Total potential acidity (cmol(+) kg^{-1})			
	Soil Depth (cm)			**Mean**
	0-30	**30-60**	**60 - 90**	
Inceptisol	2.9	2.2	1.9	$^{A}2.3$
Alfisols	2.7	2.2	1.8	$^{A}2.3$
Vertisols	2.4	1.9	1.7	$^{B}2.0$
Mean	2.7^{a}	2.1^{b}	1.8^{c}	
				CD (0.05)
Soil Type				0.292
Soil depth				0.108

Note: The capital alphabets, as prefixes, are showing the significance/ parity among different combination of soil types for given levels of depth on the other hand the small alphabets, as suffixes, are showing the significance/ parity among the depth for given combination of soil types and nitrogen levels.
A = It is computing the fixed level of main-plot (Column)
a= It is computing the fixed level of sub-plot (Row)

Effect of different levels of nitrogen (N), season (S) and their interactions on the Total potential acidity in soil

Soil Type	Total potential acidity (cmol(+) kg^{-1})			
	Seasons			
	pre-monsoon	Mid-monsoon	Post-monsoon	mean
<92 Kg/ha-N	1.7	2.1	1.9	^{A}1.9
92-138 Kg/ha-N	2.1	2.3	2.2	^{B}2.2
>138 kg/ha-N	2.3	2.6	2.4	^{B}2.4
Mean	2.1 ^{a}	2.3 ^{b}	2.2 ^{ab}	
				CD (0.05)
N level				0.292
Season				0.108

Nayak *et al*. (1996) reported that in general surface horizons showed higher values of total potential acidity, while the lower total potential acidity reported in sub- surface soil. The high values in the surface layer are possibly due to high organic carbon status. The soil organic matter contributes to TPA through their –COOH and –OH functional group. The high amount of H^+ and Al^{3+} ions might be due to the extraction of pH dependent H^+ and Al^{3+} ions, which were otherwise inactive in combination with organic colloid. Total potential acidity (TPA) refers to the acidity caused by hydrogen ion held in different chemical combination and those adsorbed on surfaces of solid clay particle and organic colloids. Data also revealed that high total potential acidity is due to high content of organic matter and clay. Similar finding were also observed by Nayak *et al*. (1996) [13] and Bandyopadhyay and Chattopadhyay (1997) [3].

pH dependent acidity (PDA)in soil

The pH dependent acidity in the soil samples varied between 0.2 to 3.8, 0.0 to 4.5 and 0.0 to 4.3 cmol(+) $kg^{-1}$with a mean value of 1.9, 1.8 and 1.5 cmol(+) kg^{-1}in *Inceptisol*, *Alfisol* and *Vertisols*, respectively. Whereas, the overall minimum and maximum pH dependent acidity content in soilwas 0.0 and 4.5 cmol(+) kg^{-1}, respectively with an average value of 1.7 cmol(+) kg^{-1} (Table 1).

The data on the pH dependent acidity of soil are presented in table 8. The pH dependent acidity was recorded significantly higher in soil of Dhamtari block under > 138 kg/ha-N application (1.8 cmol(+) kg^{-1}) as compared with application of 92-138 kg/ha-N (1.7 cmol(+) kg^{-1}) and <92 kg/ha-N (1.5 cmol(+) kg^{-1}). The higher pH dependent acidity 1.8 cmol(+) $kg^{-1}$was recorded during mid-monsoon season which was at par with post-monsoon season (1.7 cmol (p+) kg^{-1}) however, during pre-monsoon season it was significantly lower (1.6 cmol(+) kg^{-1}). With increase insoil depth the pH dependent acidity decreased significantly from 1.9, 1.7 and 1.5 cmol(+) kg^{-1} at 0-30, 30-60 and >60 cm soil depth, respectively.

Table 8: Effect of different levels of nitrogen (N), season (S) and their interactions on the pH dependent acidity in soil

N- level	pH dependent acidity cmol(+) kg^{-1}			
	Seasons			
	pre-monsoon	Mid- monsoon	Post- monsoon	mean
<92 Kg/ha-N	1.4	1.7	1.5	^{A}1.5
92-138 Kg/ha-N	1.7	1.7	1.7	^{A}1.7
>138 kg/ha-N	1.8	1.9	1.8	^{B}1.8
Mean	1.6 ^{a}	1.8 ^{b}	1.7 ^{b}	
				CD (0.05)
N level				0.270
Season				0.111

Note: The capital alphabets, as prefixes, are showing the significance/ parity among different combination of nitrogen level for given levels of monsoon on the other hand the small alphabets, as suffixes, are showing the significance/ parity among the monsoon for given combination of nitrogen levels.
A = It is computing the fixed level of main-plot (Column)
a= It is computing the fixed level of sub-plot (Row)

Effect of different levels of nitrogen (N), depth (D) and their interactions on the pH dependent acidityin soil

N- level	pH dependent acidity cmol(+) kg^{-1}			
	Soil depth (cm)			Mean
	0-30	30-60	60-90	
<92 Kg/ha-N	1.8	1.5	1.3	^{A}1.5
92-138 Kg/ha-N	1.9	1.7	1.5	^{A}1.7
>138 kg/ha-N	2.0	1.8	1.7	^{B}1.8
Mean	1.9 ^{a}	1.7 ^{b}	1.5 ^{c}	
N level				0.270
Soil depth				0.111

Note: The capital alphabets, as prefixes, are showing the significance/ parity among different combination of nitrogen level for given levels of depth on the other hand the small alphabets, as suffixes, are showing the significance/ parity among the depth for given combination of nitrogen levels.
A = It is computing the fixed level of main-plot (Column)
a= It is computing the fixed level of sub-plot (Row)

When urea is applied on soils nitrate ions were formed as an end product after hydrolysis of urea which is not strongly adsorbed by the soil particles which will move down through the soil profile. The negatively charged nitrate ions carry positively charged basic cations such as calcium, magnesium, sodium, potassium in order to maintain the electrical charge on the soil particles. The depletion of these basic cations will accelerate the acidification process in soil which was another reason for decrease in soil pH and also revealed that high pH dependent acidity is due to high content of organic carbon. The important soil factors which control significantly the different forms of soil acidities are pH, organic matter, exchangeable and extractable Al and clay. Similar findings were also observed by Nayak *et al*. (1996) [13] and Nel *et al.* (1996) [14].

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