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Impact of organic and conventional tea cultivation practices on soil health

Bhuyan S, Kandali GG, Deka K, Karmakar RM, Choudhury M and Borah K

Bhuyan S
Assistant Professor, Kaliabor College, Nagaon, Assam, India

Kandali GG
Assistant Professor, Deptt. of Soil Science, Assam Agricultural University, Jorhat, Assam, India

Deka K
Senior Research Fellow, NICRA Project, Krishi Vigyan Kendra, Cachar, Assam, India

Karmakar RM
Professor & HOD Deptt. of Soil Science, Assam Agricultural University, Jorhat, Assam, India

Choudhury M
Assistant Professor, Deptt. of Soil Science, S.S.S. College of Agriculture, Dhuburi, Assam, India

Borah K
Manager Tata Tea, Teok, Assam, India

Correspondence
Bhuyan S
Assistant Professor, Kaliabor College, Nagaon, Assam, India

Abstract
Attempts have been made in the present study to compare two management systems *viz.,* organic (Hatikhuli Tea Estate) and conventional (Difflo Tea Estate) to see the effect of management practices on Soil health. For this study four composite soil samples were collected from five age groups (<15 years, 15-30 tears, 30-45 years, 45-60 years and >60 years) of plantations and three depths (0-20 cm), (20-40 cm) and (40-60) cm. Altogether 120 numbers of soil samples were collected sixty from two management systems. Samples were analyzed for important soil physico-chemical properties and different forms of acidity components using standard procedures. Conventional system was found to be more acidic than organic system but favorable pH was maintained in organic management. The Organic system was found to maintain higher levels of organic carbon than conventional system. The pH of the soil increased with depth and organic carbon decreased with depth in both the management systems. As acidity is the primary criteria of selection of healthy tea soil, therefore the study showed significant variation of acidity components in conventional tea soil as compared to organic. The study provided relative understanding of both the systems of cultivations to formulate or select beneficial tea cultivation practice to increase production, maintain productivity for long term sustainability without deteriorating soil health and soil fertility.

Keywords: Organic, conventional tea, cultivation practices, soil health

Introduction
A comparative study on organic and conventional tea cultivation would throw light on dominant soil quality parameters as well as status of the soil. Conversion from conventional farming to organic farming causes changes in the soil environment that can affect plant growth. A comprehensive knowledge of chemical and exchange behavior of' these soils is essential for sound management appraisal. Improvement of soil fertility is a critical component of soil health management which plays a key role in sustainable agricultural production. Many studies have shown that organic farming could improve soil health and productivity by increasing soil organic carbon, plant nutrients, biodiversity, microbial activities and even higher food supply compared to conventional farming system (Leifeld and Fuhrer, 2010; Gattinger *et al.,* 2012) [7, 3]. Promoting soil health and encouraging the development of soil organic matter have always been the main objectives of organic approach and the contribution of organic system to this area has therefore been of considerable interest.

Materials & methods
The study was carried out Hatikhuli Tea estate of Assam is located in between latitude 26°35′0.50″N and longitude 93°21′12.40″E. It has a geographical area of 4.80 sq.km. It was established in the year of 1907 and conversion of inorganic tea estate to organic tea estate started in the year of 2007 and got the certification in the year of 2011. Diffloo tea estate of Assam is located in between latitude 26°36′33″N and longitude 93°35′14″E. It has a geographical area of: 486.69 hectares. It was established in the year of 1890.

Soil samples were collected from two tea estates of Golaghat district *viz.,* Hatikhuli tea estate (Organic) and Diffloo tea estate (conventional). Four composite samples from three depth and five age groups of tea plantations *viz.,* <15, 15-30, 30-45, 45-60 and >60 years were collected from each tea gardens. Samples were taken at three depths each (0-20cm and 20-40 cm and 40-60cm) from each of the two tea gardens. Altogether sixty numbers of soil samples were collected from each tea garden.

Analysis of soil properties for Identification of key soil indication were done by standard procedures as described by Baruah and Barthakur (1997) [1]. The physiochemical properties of soil were analyzed by standard methods. The total acidity, exchangeable acidity, extractable acidity and total potential acidity were determined by the method described by Baruah and Barthakur (1997) [1]. The non-exchangeable acidity was estimated indirectly as, Non-exchangeable acidity = Extractable acidity - Exchangeable acidity, the pH-dependent acidity was estimated by the following equation and pH-dependent acidity = Total potential acidity - Exchangeable acidity.

Results & Discussions

Physiochemical characteristics

The texture of the soil was found silty clay in both the management systems under study. Sand, silt and clay fractions of the soils varied from 55.5 to 78.5, 2.4 to 14.8 and 11.3 to 31.9 per cent under organic management whereas in conventional management it varies from 64.00 to 77.4, 2.4 to 14.3 and 17.9 to 29.8 per cent, respectively (Table 2). The pH was found higher ranging from 4.1 to 5.4 (mean value of 5.2) under organic management, whereas under conventional management pH values varies from 3.6 to 5.1 (mean value of 4.7). The conventional management is more acidic as compared to organic management which may be due to more nitrogenous fertilizer used in conventional tea cultivation such as NH_4SO_4, urea, leads to soil acidity (Tee *et al*., 1987; Ma *et al.*, 1990) [13, 8]. The EC ranged from 0.01 to 0.04 (dS $^{m-1}$), with mean value of 0.015 (dS $^{m-1}$) under organic management whereas under conventional management it ranged from 0.01 to 0.04 (dS $^{m-1}$) with mean value of 0.021 (dS $^{m-1}$). The organic carbon content of the soils was found higher (mean value of 0.76 per cent) under organic management. The increase in organic carbon in organic management is due to microbial biomass contained in the organic amendment. These results are in accordance with Glover *et al.* (2000) [4] who observed that organic system maintains soil organic matter at high level than conventional system. The higher value of CEC is found in organic management (7.9 cmol (p^+) kg^{-1}) is due to presence of more organic matter. (Table 1).

Table 1: Soil chemical properties under organic and conventional management system.

Parameters	Organic				Conventional			
	Mean	Range	Standard dev	Variance	Mean	Range	Standard dev	Variance
pH (1:2.5)	5.2	4.1-5. 4	0.34	0.11	4.7	3.6-5.1	0.489	0.24
EC (dS $^{m-1}$)	0.015	0.01-0.04	0.007	4.91	0.021	0.01-0.04	0.0065	4.37
Organic carbon (%)	0.76	0.46-1.81	0.28	0.083	0.57	0.27-0.85	0.137	0.018
Cation exch. Capacity [cmol (p^+) kg^{-1}]	7.9	4.1-14.7	2.38	0.728	7.7	4.6-10.9	1.54	2.40

The bulk density of the soil was found to be lower in organic system (mean value 1.41 g/cm^3) which may be due to addition of organic compost that contributed to increase organic matter input decreasing soil bulk density (Valpassos, 2001) [15]. Particle density value varies from 2.1 to 2.71 g/cm^3 with a mean value of 2.43 g/cm^3 under organic system and from 2.12 to 2.73 g/cm^3 with a mean value of 2.51 g/cm^3 under conventional system. Total porosity of the soil ranges from 27.6 to 48.2 per cent with a mean value of 41.98 per cent and water holding capacity from 30.00 to 34.1 per cent with a mean value of 31.5 per cent under organic management, whereas in conventional management the total porosity of the soil varies from 27 to 42.91 per cent with a mean value of 39.07 per cent and water holding capacity from 27 to 31.4 per cent with a mean value of 28.93 per cent. The results concerning soil bulk density and total porosity indicated that the increase of soil porosity under organic management was accomplished by decrease in soil bulk density as reported by Werner (1997) [18] in organic system. (Table 2).

Table 2: Soil physical properties under organic and conventional management system.

Parameters	Organic				Conventional			
	Mean	Range	Standard dev	Variance	Mean	Range	Standard dev	Variance
BD (gm/cm^3)	1.41	1.05-1.45	0.207	0.043	1.52	1.06-1.62	0.215	0.046
PD (gm/cm^3)	2.43	2.1-.2.71	0.326	0.106	2.51	2.12-2.73	0.346	0.12
Porosity (%)	41.98	27.6-48.2	4.51	20.38	39.07	27-42.91	3.34	11.17
WHC (%)	31.5	30.00-34.12	1.17	1.39	28.93	27.0-31.4	1.24	1.55
Sand (%)	70.3	55.5-78.5	4.94	6.02	71.2	64.0-77.4	2.29	10.6
Silt (%)	6.8	2.4-14.8	2.45	24.44	5.5	2.4-14.3	1.9	3.68
Clay (%)	22.9	11.3-31.9	4.29	18.44	23.4	17.9-29.8	3	9.97
Textural class	Silty clay				Silty clay			

The pH under both the systems were found to be increase with depth (Fig. 2a), because of lower acidity with increase in depth as reported by Pati *et al*. (2010) [10] as pH is inversely related with acidity of soil. The organic carbon was found to be higher at the surface 0-20 cm depth and gradually decreased with the increase in soil depth in both the management system (Fig. 2b). Higher organic carbon content in the surface may be due to more biomass addition through leaf litter in conventional tea cultivation and by both biomass addition and application of organic manure under organic tea cultivation (Gangopadhyay *et al.*, 2016) [2]. CEC showed an irregular trend with respect to depth in both the management systems. A higher value was observed at the surface (D_1), which decreased in D_2 and again showed an increasing trend in D_3 (Fig. 2c). The variation of CEC under both the management systems may be due to difference in nature and amount of clay content, pH and percentage of organic matter content present in soil (Krull, 2004) [6]. Soil bulk density of both the management systems were found to increase with increasing depth probably as subsurface layers are more compacted and have less organic matter, less aggregation, and less root penetration compared to surface layers and therefore contain less pore space. (Figure 3) (Phukan and Baruah, 2015) [11].

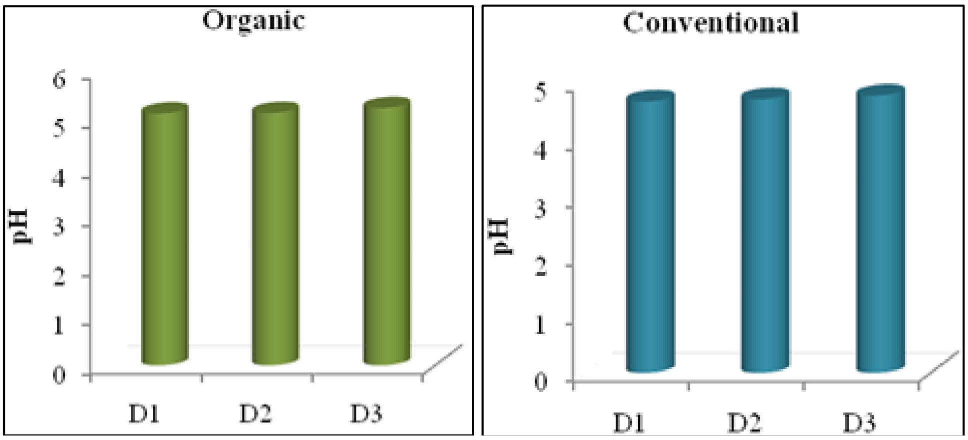

Fig 2(a): pH under organic and conventional management wih depth

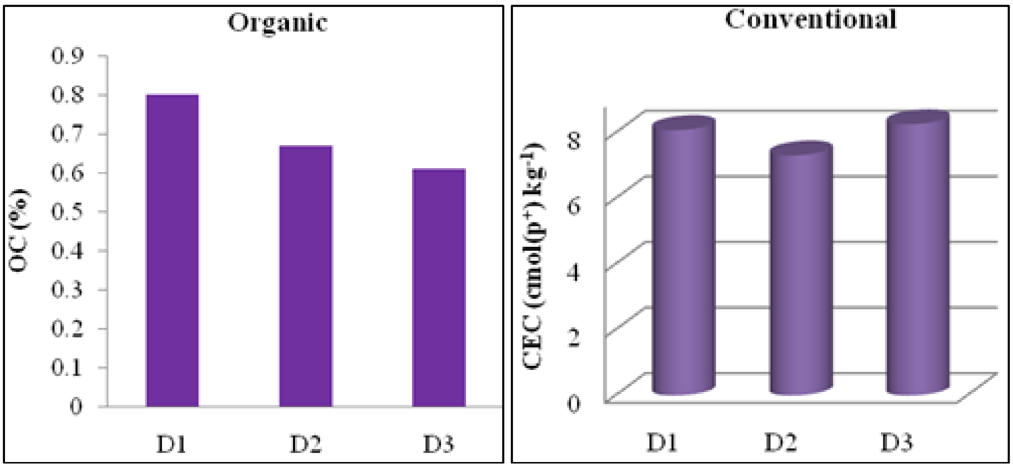

Fig 2(b): Organic carbon under organic and conventional management with depth

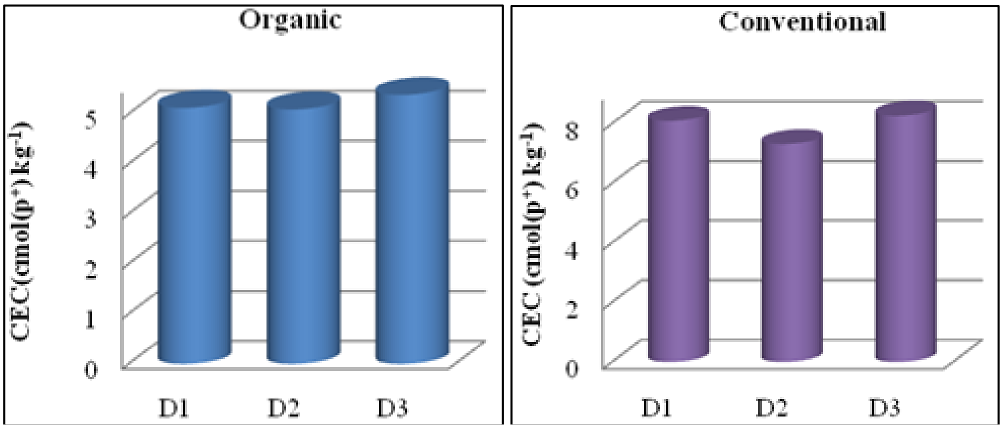

Fig 2(c): Cec under organic and conventional management with depth

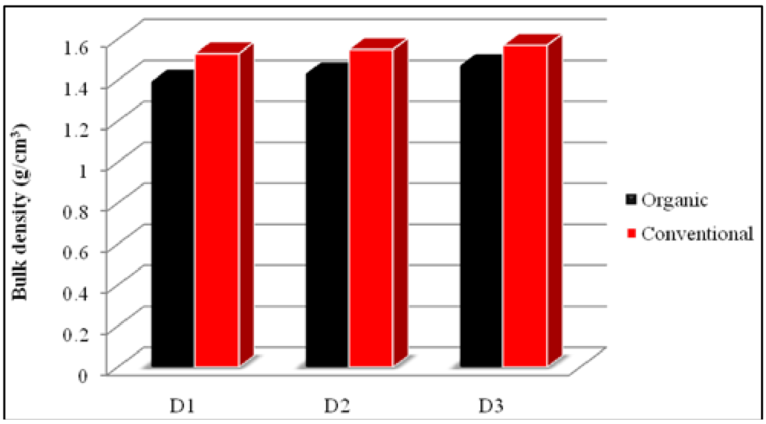

Fig 3: Variation of bulk density with depth under organic and conventional management.

Available macronutrients and micronutrients

The available nitrogen, phosphorus, potassium, calcium, magnesium, sulphur, iron, zinc, manganese, copper content of organic and conventional management are presented in Table 3.

Available macronutrient

The N content varies from low to medium (100.3 to 338.6 kg ha^{-1}) with a mean value of 180.4 kg ha^{-1} under organic management, and whereas in conventional management value varies from low to medium (100.3 to 351.2 kg ha^{-1}) with a mean value of 193.1. Higher concentration of nitrogen in the conventional system may be due to excessive application of nitrogenous fertilizer under conventional system of tea plantation. Excessive amount of fertilizers are usually applied to ensure N is available for tea crop use. It is explained by the fact that there are frequent harvest of tender young shoots containing high N content and in addition regular pruning, is carried out to maintain a vigorous vegetative growth (Vorgelegt, 2005) [16]. Whereas in organic farming system nitrogen availability to plants depends on many environmental factor such as aeration, moisture, pH and temperature of soil as well as the C:N ratio of the organic material before decomposition and mineralization can take place (Zech *et al*., 1997) [19]. In other words, organic fertilizer require more time before nutrient became available for plant use as compared to chemical fertilizer (Tisdale and Nelson, 1975) [14].

The P content varies from low to medium (25.8 to 42.5 kg ha^{-1}) with a mean value of 35.7 kg ha^{-1} under organic management whereas in conventional management the value ranged from low to medium (21.3 to 48.0 kg ha^{-1}) with a mean value of 32.23 kg ha^{-1}. Phosphorus content was found to be lower under conventional tea cultivation which due to large amount of phosphorus applied as fertilizer in the form of super phosphate are fixed by Al^{3+} and Fe^{3} rendering it unavailable under conventional system (Devi *et al*., 2012) [5].

The K content varies from low to medium (49.1 to 267.8 kg ha^{-1}) with a mean value of 141.1 kg ha^{-1} under organic management whereas in conventional management the value ranges from low to medium (64.7 to 372.4 kg ha^{-1}) with a mean value of 234.6 kg ha^{-1}.

The Ca and Mg content was found to be lower under organic management compared to conventional management. The Ca value varies from 0.1 to 2.8 cmol(p^+) kg^{-1} with mean values of 0.82 cmol(p^+) kg^{-1} in organic, whereas in conventional the value ranges from 0.04 to 2.00 cmol(p^+) kg^{-1} with a mean value 0.92 cmol(p^+) kg^{-1}, respectively. The Mg value varies from 0.1 to 2.9 cmol(p^+) kg^{-1} with mean values of 0.95 cmol(p^+) kg^{-1}, whereas in conventional the value ranged from 0.20 to 3.30 cmol(p^+) kg^{-1} with a mean value 1.1 cmol(p^+) kg^{-1}, respectively.

Among the exchangeable bases Mg was dominant cation followed by Ca in most of the soils. The higher amount of exchangeable bases in the surface may be due to phytocyclic of the nutrient released from decomposition of the leaf and litter fall (Gangopadhay *et al*., 2016) [2].

The S content was found to be almost equal in mean values under organic (31.90 kg ha^{-1}) with an average 16.8 to 50.1 kg ha^{-1} and conventional management (31.75 kg ha^{-1}) with an average value 16.8 to 49.5 kg ha^{-1} (organic management).

Table 3: Soil available nutrients under organic and conventional management.

Parameters	Organic				Conventional			
	Mean	Range	Standard dev	Variance	Mean	Range	Standard dev	Variance
Nitrogen (kg ha^{-1})	180.4	100.3-338.6	53.6	2878.7	193.1	100.3-351.2	62.4	193.1
Phosphorus (kg ha^{-1})	35.7	25.8-42.5	3.40	11.5	32.2	21.3-48.07	6.47	32.2
Potassium (kg ha^{-1})	141.1	49.1-267.8	53.3	2850.8	234.6	64.7-372.4	73.00	234.6
Calcium (cmol (p^+) kg^{-1})	0.82	0.1-2.8	0.51	0.26	0.92	0.04-2.00	0.327	0.92
Magnesium (cmol (p^+) kg^{-1})	0.951	0.1-2.9	0.532	0.283	1.1	0.20-3.30	0.681	1.16
Sulphur (kg ha^{-1})	31.9	16.8-50.1	8.9	80.86	31.7	16.85-49.57	9.30	31.75
Iron (ppm)	74.8	29.1-193.0	30.4	74.8	96.0	41.2-192.0	34.4	96.0
Copper (ppm)	0.94	0.43-1.46	0.190	0.036	0.70	0.22-1.42	0.39	0.70
Manganese (ppm)	8.83	4.42-15.18	2.75	7.56	5.90	2.97-12.14	2.30	6.90
Zinc (ppm)	0.39	0.18-0.96	0.189	0.035	0.63	0.14-3.38	0.53	0.63

Available Micronutrients

The Fe content varies from 29.1 to 193.02 ppm with a mean value of 74.8 ppm in organic management whereas in conventional management ranges from 41.2 to 192.0 ppm with a mean value of 96.0 ppm. The Mn content varies from 4.4 to 15.1 ppm with a mean value of 8.8 ppm in organic whereas in conventional management value ranges from 2.9 to 12.1 ppm with a mean value of 5.90 ppm. The Zn content varies from 0.18 to 0.96 ppm with an average value of 0.39 ppm in organic management whereas in conventional management the Zn value ranges from 0.14 to 3.38 ppm with an average value of 0.63 ppm. The Cu content varies from 0.43 to 1.46 ppm with an average value of 0.94 ppm in organic management whereas in conventional management the value ranges from 0.22 -1.42 ppm with a mean value of 0.70 ppm. Under organic cultivation lower level of availability micronutrients was found which indicates slow rate of mineralization of nutrients under organic system. A general trend of decrease of micronutrients with the increase of the depth of the soils was observed in both the systems of tea cultivation (figure 4). Similar results were also obtained by Pati *et al*. (2010) [10].

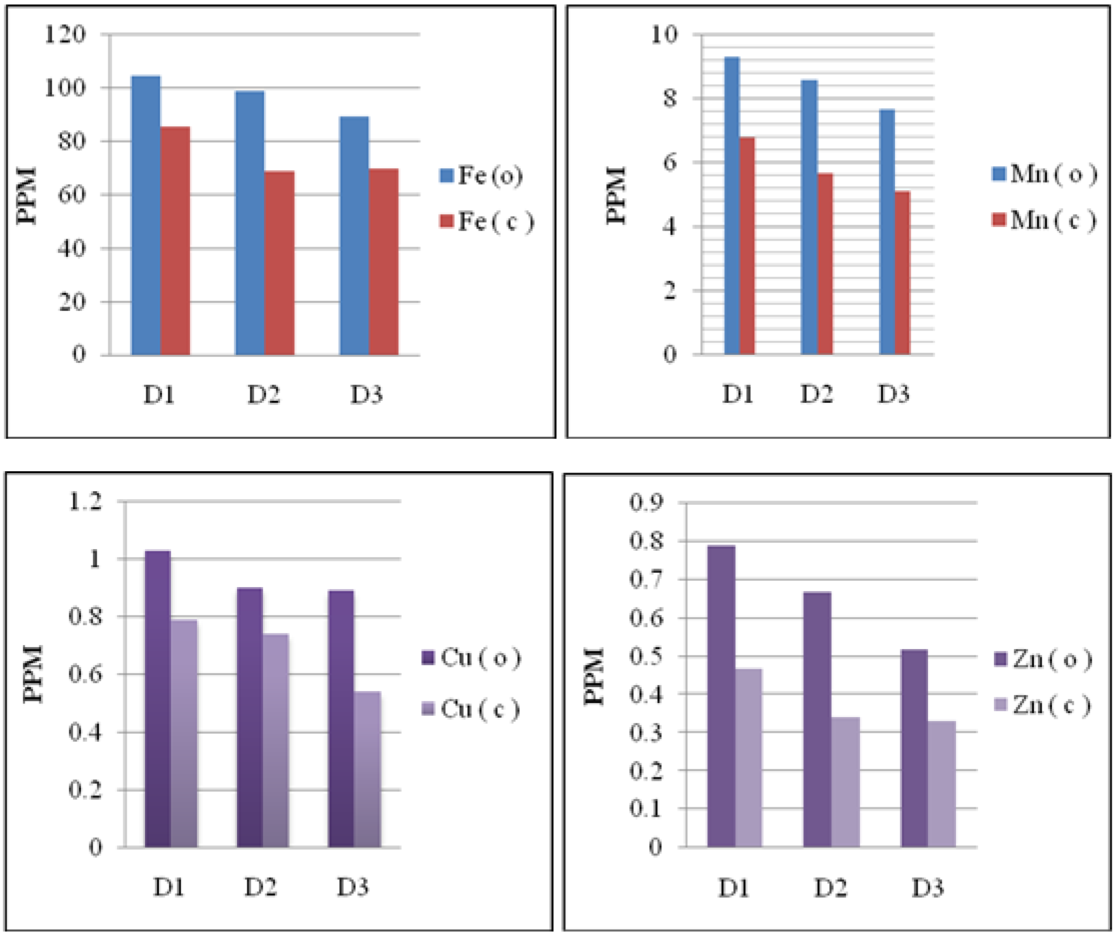

Fig 4: Variation of micronutrient with depth forms of soil acidity

The occurrence of various forms of acidity is explained in (Table 4 & figure 5).

Total potential acidity: The total potential acidity ranges from 4.80 to 10.60 cmol(p^+) kg^{-1} with a mean value of 6.89 cmol(p^+) kg^{-1} in organic management whereas in conventional the total potential acidity values increases with a mean value of 7.10 cmol(p^+) kg^{-1}

The total acidity: The total acidity ranges from 1.20 to 2 cmol(p^+) kg^{-1} with a mean value of 2.47 cmol(p^+) kg^{-1} in organic management whereas in conventional total acidity ranges increases (1.47 to 4.10 cmol(p^+) kg^{-1}) with a mean value of 2.78 cmol(p^+) kg^{-1}

Exchange acidity: Exchangeable acidity includes the exchangeable H- and Al+ held at permanent charge sites of the exchange complex. The exchange acidity varies from 1.37 to 4.45 cmol(p^+) kg^{-1} with a mean value of 2.60 cmol(p^+) kg^{-1} in organic management whereas in conventional, the value varies from 1.00 to 5.30 cmol(p^+) kg^{-1} with a mean value of 3.75 cmol(p^+) kg^{-1}. The exchangeable H^+ varies from 0.10 to 0.75 cmol(p^+) kg^{-1}, with a mean value of 0.29 cmol(p^+) kg^{-1} in organic management whereas in conventional the exchangeable H^+ varies from 0.22 to 0.60 cmol(p^+) kg^{-1}, with a mean value of 0.35 cmol(p^+) kg^{-1}. The exchangeable Al varies from 1.25 to 4.25 cmol(p^+) kg^{-1}, with a mean value of 2.32 cmol(p^+) kg^{-1} in organic management whereas in conventional the value ranges from 0.75 to 4.75 cmol(p^+) kg^{-1}, with a mean value of 3.39 cmol(p^+) kg^{-1}

The pH dependent acidity: The pH dependent acidity varies from 1.56 to 4.50 cmol(p^+) kg^{-1} with a mean value of 4.25 cmol(p^+) kg^{-1} in organic whereas in connventional the value increases (1.38 to 6.7 cmol(p^+) kg^{-1})with a mean value of 3.36 cmol(p^+) kg^{-1}.

The extractable acidity: The extractable acidity varies from 1.56 to 4.50 cmol(p^+) kg^{-1} with a mean value of 2.93 cmol(p^+) kg^{-1} in organic management whereas in conventional management the value increases (1.25 to 5.42 cmol(p^+) kg^{-1}) with a mean value of 4.08 cmol(p^+) kg^{-1}.

The non exchangeable Al: The non exchangeable Al varies from 0.05 to 0.98 cmol(p^+) kg^{-1} with a mean value of 0.39 cmol(p^+) kg^{-1} in organic management whereas in conventional the value ranges from 0.02 to 1.08 cmol(p^+) kg^{-1} with a mean value of 0.34 cmol(p^+) kg^{-1}.

Compared to organic tea cultivation the value all the acidity components were higher in conventional tea cultivation which may be due to application of more nitrogenous fertilizer except pH dependent acidity which was higher in organic management. This may be due to high content of Fe and Al oxides and organic matter in the soils (Misra *et al.*, 1987) [9], and dissociation of proton from the functional groups like -COOH and phenol (Sanyal, 1991) [12].

Table 4: Soil acidity components under organic and conventional management.

Parameters	Organic				Conventional			
Unit: cmol (p^+) kg^{-1})	Mean	Range	Standard dev	Variance	Mean	Range	Standard dev	Variance
Total acidity	2.47	1.20-2.00	0.23	0.05	2.78	1.47-4.10	0.53	0.28
Exch H^+	0.29	0.10-0.75	0.10	0.01	0.35	0.22-0.60	0.09	0.01
Exch Al^+	2.32	1.25-4.25	0.66	0.43	3.39	0.75-4.7	0.85	0.72
Exch acidity	2.60	1.37-4.45	0.66	0.44	3.75	1.00-5.30	0.90	0.82
Non exch Al	0.39	0.05-0.98	0.24	0.06	0.34	0.02-1.08	0.30	0.09
Total potential acidity	6.89	4.80-10.60	1.33	1.76	7.10	4.90-10.40	1.24	1.54
pH dep acidity	4.25	1.56-4.50	0.71	0.50	3.36	1.38-6.73	1.18	1.40
Extractable acidity	2.93	1.56-4.50	0.71	0.50	4.08	1.25-5.42	0.84	0.70

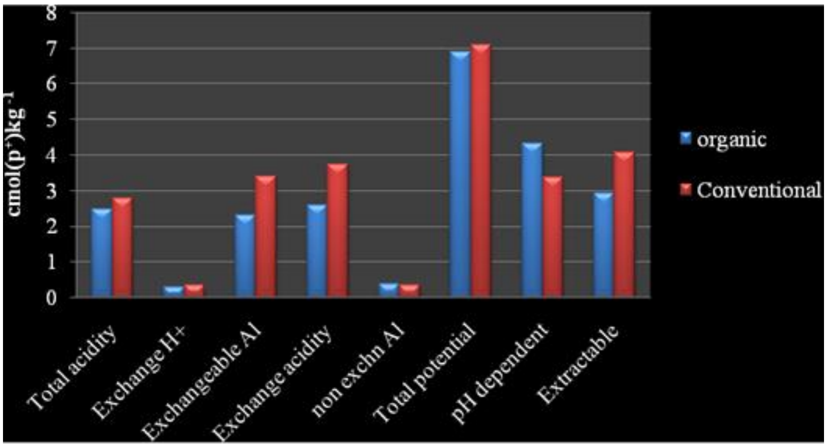

Fig 5: Soil acidity components under organic & conventional management.

Statistical analysis

In case of almost all the acidity components it was found that the age group 45-60 yrs showed highest acidity which gradually decreased at the age group > 60 yrs i.e. above 60 yrs almost all the acidity components attains a stable value.

Significant difference in acidity components was found among organic and conventional management. Highest acidity was recorded in conventional system which is significantly higher than organic system except pH dependant acidity which was found to be significantly higher under organic management (Table 5). Higher value of exchangeable Al, exchangeable acidity, total potential acidity and pH-dependant acidity under conventional tea cultivation with increasing age of plantations indicated that acidity components are significantly altered by long term fertilization. Similarly, Wang *et al.* (2010) [17] also observed that continuous cultivation of tea caused soil acidification leading to decrease in basic cations. Organic tea cultivation decreased exchangeable Al but under conventional system, reducing the concentration of exchangeable Al could reduce soil acidification.

Table 5: Variation of acidity components with age and management systems.

Age (yrs)	Management	TA	EH	E Al	Exch Al	Non Exch Al	TPA	PDA	Ext A
<15	Organic	2.467	0.254	2.711	2.965	0.341	6.492	3.527	3.306
	Conventional	2.550	0.310	3.129	3.469	0.357	7.333	3.864	3.826
15-30	Organic	2.525	0.333	2.454	2.787	0.239	6.450	3.662	3.068
	Conventional	2.835	0.319	3.497	3.816	0.187	6.908	3.093	4.003
30-45	Organic	2.458	0.263	2.425	2.687	0.389	7.542	4.854	3.077
	Conventional	2.600	0.318	2.771	3.088	0.507	6.767	3.678	3.596
45-60	Organic	2.475	0.292	1.956	2.247	0.613	6.604	4.540	2.572
	Conventional	3.149	0.462	4.102	4.563	0.250	7.680	3.117	4.813
>60	Organic	2.408	0.291	2.065	2.356	0.372	7.367	5.094	2.643
	Conventional	2.814	0.435	3.478	3.913	0.374	6.842	3.028	4.118
S.Ed(±)		0.157	0.041	0.282	0.295	0.101	0.502	0.450	0.278
CD (P=0.05)		0.312	0.081	0.252	0.387	0.200	0.999	0.896	0.555

Conclusion

From the study it can be summarized that organic system of tea cultivation has a tremendous effect on the Soil Health which is seen to improve considerably compared to conventional system. The physical and chemical properties like bulk density, water holding capacity and porosity appeared to be favorable under organic system in terms of maintaining the pH of the soil at a desired level which significantly decreased the different acidity components under organic tea cultivation compared to conventional tea cultivation. The availability of nutrients are little bit lower in organic system as compared to conventional but the availability will be enhances in accordance with the conversion periods & rate of application of organic amendment in soil. The favorable acidity is found in organic management which is a primary indicator of healthy tea soil.

References

1. Baruah TC, Barthakur HP. A Text book of Soil analysis. Vikas Publishing House Pvt. Ltd., New Delhi, 1997, 94-103.
2. Gangopadhyay SK, Nayak DC, Singh SK. Characteristics of tea growing soils in relation to soil acidity in Upper Brahmaputra Valley of Assam. J Indian Soc. Soil Sci. 2016; 64(4):341-350.
3. Gattinger A, Muller A, Haeni M, Skinner C, Fliessbach A, Buchmann N *et al*. Enhanced top soil carbon stocks under organic farming. Proc. of the National Academy of Sciences. 2012; 109(44):18226-18231.
4. Glover JD, Reganold JP, Andrews PK. Systematic method for rating soil quality of conventional, organic, and integrated apple orchards in Washington State. Agric. Ecosyst. Environ. 2000; 80(1):29-45.
5. Devi KN, Singh LNK, Devi TS, Devi HN, Singh TB, Singh KK *et al*. Response of soybean [*Glycine max* (L.) Merrill] to sources and levels of phosphorus. J Agril. Sci. 2012; 4(6):44.
6. Krull ES, Skjemstad JO, Baldock JA. Functions of soil organic matter and the effect on soil properties. Cooperative Research Centre for Greenhouse Accounting, 2004, 129.
7. Leifeld J, Fuhrer J. Organic farming and soil carbon sequestration: what do we really know about the benefits? Ambio. 2010; 39(8):585-599.
8. Ma WC, Brussaard L, Ridder JA. Long term effect of nitrogenous fertilizer on grassland earthworms (Oligochaeta: Lumbricidae): their relation to soil acidic fixation. Agril. Ecosyst. Environ. 1990; 30(2):71-80.
9. Misra UK, Satapathy S, Panda N. Characterization of some acid soils of Orissa. I. Nature of Soil acidity. J Indian Soc. Soil Sci. 1987; 37:22-28.
10. Pati R, Mukhopadhyay M. Forms of acidity and the distribution of DTPA extractable micronutrients in some soils of West Bengal (India). In: 2010 19th World Congress of Soil Science. Soil Solutions for the Changing World, 2010, 1-6.
11. Phukan IK, Baruah A. Studies on soil physical, chemical and microbiological properties under compacted and non-compacted tea soils of south bank. Intern. J Sci. Environ. Technol. 2015; 4(1):253-263.
12. Sanyal SK, De Datta SK. Chemistry of phosphorus transformations in soil. In: Advances in soil science. Springer New York, 1991, 1-120.
13. Tee BG, Dudas JM, Pawluk S, Harapiak JT. Physical, chemical and micromorphological effects of nitrogen fertilizers on Chernozemic soils. Geoderma. 1987; 40(2):177.
14. Tisdale SL, Nelson WL. Soil Fertility and Fertilizers, 1975.
15. Valpassos MAR, Cavalcante EGS, Cassiolato AMR, Alves MC. Effects of soil management systems on soil microbial activity, bulk density and chemical properties. Pesquisa Agropecuária Brasileira. 2001; 36(12):1539-1545.
16. Vorgelegt V. Quality-related constituents in tea (*Camellia sinensis* (L.) O. Kuntze) as affected by the form and concentration of nitrogen and the supply of chloride. Ph.D. Thesis, Christian-Albrechts-Universität zu Kiel (University of Kiel), 2005.
17. Wang H, Xu RK, Wang N, Li XH. Soil acidification of alfisols as influenced by tea cultivation in Eastern China. Pedosphere. 2010; 20(6):799-806.
18. Werner MR. Soil quality characteristics during conversion to organic orchard management. Appl. Soil Ecol. 1997; 5(2):151-167.
19. Zech W, Senesi N, Guggenberger G, Kaiser K, Lehmann J, Miano TM *et al*. Factors controlling humification and mineralization of soil organic matter in the tropics. Geoderma. 1997; 79(1-4):117-161.