"Assessment of Physico-chemical properties of Tea Garden soils of Darjeeling, West Bengal, India."

ABSTRACT

The experiment was conducted in 2023 to assess the physical and chemical properties of tea garden soils of Darjeeling, West Bengal within its geographical coordinates ranging from 27° 2' 9.6252" N latitude to 88° 15' 45.6192"E longitude. Nine distinct villages located in the Darjeeling district covering Glenburn, Soureni, and Selimbong tea gardens was chosen for the study. The physical properties of tea garden soils, soil colour, texture, bulk density (Mg m^{-3}), particle density (Mg m^{-3}), percent pore space and percent water holding capacity were analysed with the following standard procedure Munsell, (1971), Bouyoucos (1927), Muthuvel *et al.,* (1992) and chemical properties pH, EC (dSm^{-1})$_{at\ 25^{\circ}C}$, percent organic carbon, available nitrogen, phosphorus and potassium (kg ha^{-1}), Ca^{+3} C mol(p^{+}) kg^{-1} and Mg^{+3} C mol(p^{+}) kg^{-1} were analysed by following Jackson (1958), Wilcox (1950), Walkley and Black (1947), Subbiah and Asija (1956), Olsen *et al.,* (1954), Toth and Prince (1949) and Jackson (1973) at 0-15, 15-30 and 30-45cm depth. The results showed that the soil colour varied from brown to yellowish brown in dry condition and dark brown to dark reddish brown in wet. The soils of Selimbong were sandy loam to sandy clay loam, Soureni were clay loam, and soils of Glenburn were clay loam to sandy clay loam in texture. The variation in bulk density and particle density was recorded non-significant whereas percent pore space and percent water holding capacity were found significant. While organic carbon, available NPK, exchangeable calcium and magnesium were recorded significant, the pH and EC were found non-significant.

Keywords: Physico-chemical properties, soil analysis, tea garden soil, Darjeeling.

INTRODUCTION

One of the most vital natural resources for human well-being is soil. **(Zubber et al. 2021)**. The Darjeeling hill region of West Bengal, India is renowned for producing the world's best-quality tea due to its optimal combination of altitude, sloping terrain, fertile soil, and climate **(Datta, 2010).** Tropical to subtropical climates with more than 200 cm of annual precipitation are ideal for the growth of tea **(Ray et al., 2012).** Tea grows well in sandy loam, diverse soil, slope, acidic, and well-drained environments **(Tarun *et al.* 2018)**. The region's soil makeup is mostly made up of rocky, clay, and loamy soils, each of which has unique qualities **(Pramanik, 2016).** The world-renowned Darjeeling tea is of exceptional quality and is renowned for its muscatel taste **(Anil *et al.* 2016).** Organic tea cultivation in Darjeeling hills is getting popularity day by day due to growing health awareness of consumers, fetching good prices and high demand in international market. **(Bisen & Singh, 2012).**

MATERIALS AND METHODS

Soil samples were collected from nine different villages which lie in the Selimbong, Soureni, and Glenburn tea gardens of Darjeeling District at three respective depths of 0-15, 15-30 and 30-45 cm for the analysis of physical and chemical properties of soil. The total 81 soil samples were collected from three tea gardens, nine villages at three depths out of which 27 samples are representing three depths of a tea garden to analyse the physical and chemical properties. These samples were air dried in shade for one week to obtain constant weight then crushed with wooden hammer, after that it was sieved with 0.2mm sieve to obtained composite samples of each site and each depth. The physical properties of soils, soil colour, texture, bulk density ($Mg\ m^{-3}$), particle density ($Mg\ m^{-3}$), percent pore space and percent water holding capacity were analysed with the following standard procedure Munsell, (1971), Bouyoucos (1927), Muthuvel *et al.,* (1992) and chemical properties pH, EC (dSm^{-1}) $_{at\ 25^{\circ}C}$, percent organic carbon, available nitrogen, phosphorus and potassium ($kg\ ha^{-1}$), Ca^{+3} C mol(p^{+}) kg^{-1} and Mg^{+3} C mol(p^{+}) kg^{-1} were analysed by following Jackson (1958), Wilcox (1950), Walkley and Black (1947), Subbiah and Asija (1956), Olsen *et al.,* (1954), Toth and Prince (1949) and Jackson (1973) at 0-15, 15-30 and 30-45cm depth. The data recorded during the course of the investigation was completely randomized design, as per the method "Analysis of Variance technique" as given by Fisher (1960).

RESULTS AND DISCUSSION

The results depicted in table 1 shows the soil colour in dry condition varied from brown (7.5YR 5/4) to dark yellowish brown (10YR 3/4) in 0-15, brown (7.5YR 5/4) to yellowish brown (10YR 5/4) in 15-30 and brown (7.5YR 5/4) to pale brown (7.5YR 6/3) in 30-45cm depth and in wet condition from dark brown (7.5YR 4/4) to dark reddish brown (5YR 3/3) in 0-15, brown (7.5YR 5/4) to dark brown (7.5YR 4/4) in 15-30 and yellowish brown (10YR 5/4) to dark brown (7.5YR

4/4) in 30-45cm depth. Yellow colour of the soil was due to hydrated iron oxides. The brown colour indicates that the soil contains a high concentration of iron oxides and the dark colour suggests a high level of organic matter in the soil. Wet soils are darker due to similarity in refractive properties of water and soil (Anushka *et al.* 2021). Similar results were also reported by Nayak *et al*., (2002). The results depicted in table 2 shows that the soil texture of Selimbong ranged from sandy clay loam (sand 64.3%, silt 13.9% and clay 21.8%) to sandy loam (sand 67.0%, silt 17.8% and clay 15.2%). The soil texture of Soureni was found to be clay loam (sand 26.2%, silt 39.4% and clay 32.6). The soil texture of Glenburn ranged from clay loam (sand 48.9%, silt 21.9% and clay 29.2) to sandy clay loam (sand 53.8%, silt 26.1% and clay 21.1%). It may be due to igneous and metamorphic rocks at an altitude of 2500 m in Darjeeling have been eroded by various physical, chemical and biological weathering disorders to form such type of soil (Zubber et al. 2021). The results were found similar to that of Majumdar *et al*., (2014). The bulk density of soil at 0-15, 15-30 and 30-45cm depth was found non-significant at 5% critical difference, the maximum bulk density was 1.22 Mg m^{-3} at 0-15, 1.13 Mg m^{-3} at 15-30 and 1.11 Mg m^{-3} at 30-45cm depth found in Selimbong. The minimum bulk density was 1.01 Mg m^{-3} at 0-15 and 30-45 found in Selimbong and Glenburn respectively and 1.02 Mg m^{-3} at 15-30cm depth found in Selimbong mentioned in figure 1. The higher values of bulk density indicates that the soil is widely composed of clay and aggregated loams and the lower values indicate the presence of high organic matter (Pratistha *et al.,* 2020). The results were found similar to that of Wankhade *et al.,* (2015). The results graphically presented in figure 1 also shows the particle density of soil at 0-15, 15-30 and 30-45cm depth was found non-significant at 5% critical difference, the maximum particle density was 2.58 Mg m^{-3} at 0-15, 2.63 Mg m^{-3} at 15-30 and 2.64 Mg m^{-3} at 30-45cm depth found in Soureni. The minimum particle density was 2.20 Mg m^{-3} at 0-15 found in Glenburn and 2.21 Mg m^{-3} in 15-30 as well as 30-45cm depth found in Selimbong and Glenburn respectively. The high particle density values indicates that the soil has comparatively low organic matter content and the low particle density values indicates the presence of organic matter content (Anushka *et al.,* 2021). Similar results were obtained by Barthwal *et al.,* (2019). The results mentioned in table 3 shows the percent pore space of soil at 0-15, 15-30 and 30-45cm depth was found significant at 5% critical difference, the maximum percent pore space 68.96% at 0-15, 62.96% at 15-30 were found in Glenburn and 59.86% at 30-45cm depth found in Soureni. The minimum percent pore space was 52.96% at 0-15, 50.30% at 15-30 found in Glenburn and 50.53% at 30-45cm depth found in Selimbong. The pore space decreases with increase in depth and it may be due to the lower content of organic matter present in the sub-surface soils than that of the surface soils (Pratistha *et al.,* 2020). The similar findings were also reported by Pandey *et al.,* (2013). The water holding capacity of soil at 0-15, 15-30 and 30-45cm depth was found significant at 5% critical difference, the maximum water holding capacity 79.43% at 0-15, 78.83% at 15-30 and 72.66% at 30-45cm depth was recorded in Soureni. The minimum 60.23% at 0-15 found in Glenburn, 53.36% at 15-30 found in Selimbong and 61.01% at 30-45cm depth was found in Glenburn presented in table 3. The sandy loam and clay loam soils indicate high clay content which can absorb a considerable amount of water for a long period in the micropores (Anushka *et al.,* 2021). Water holding capacity depends upon number, capillary spaces of the soil and size of the soil's pore spaces (Shirsath, 2021). These findings were similar with that of Deb *et al.*, (2013). The results mentioned in figure 2 shows the soil pH and EC dSm^{-1} $_{at\ 25^{\circ}C}$ at 0-15, 15-30 and 30-45cm depth was found non-significant at 5% critical difference, the maximum soil pH 5.16 at 0-15, 5.28 at 15-30 as well as 30-45cm depth was found in Selimbong. The minimum soil pH 4.40 at 0-15 as well as 15-30 and 4.46 at 30-45cm depth was found in Soureni. The results indicated that the soil is highly acidic in nature. This level of high acidity may be due to heavy rainfall and leaching persisting in the region (Majumdar et al., 2014). Similar findings were recorded by Ganorker et al., 2017. Similarly, the maximum EC 0.13 at 0-15 as well as 15-30 and 0.14 at 30-45cm depth was found in Glenburn. The minimum EC 0.03 at 0-15, 0.05 at 15-30 and 0.06 at 30-45cm depth was found in Selimbong. The low values of EC might be due to leaching of soluble salts by heavy rainfall (Ray et al., 2012). These findings were similar with that of Santhi et al., (2017). The per cent organic carbon of soil at 0-15, 15-30 and 30-45cm depth was found significant at 5% critical difference, the maximum per cent organic carbon 2.02 at 0-15 found in Selimbong, 1.45 at 15-30 and 1.42 at 30-45cm depth was found in Soureni. The minimum per cent organic carbon 1.46 at 0-15, 0.74 at 15-30 and 0.63 at 30-45cm depth was recorded in Selimbong presented in table 3. The high per cent organic carbon seem in the surface soils may be due to the undecomposed and partially decomposed organic matter and lower values seen in the sub-surface soils may be due to decomposed organic matter which has undergone chemical and biological changes already (Anushka *et al.* 2021). These findings were similar with that of Arya, (2014). The table 4 shows the available nitrogen kg ha^{-1} of soil at 0-15, 15-30 and 30-45cm depth was found significant at 5% critical difference, the maximum available nitrogen 696.3 kg ha^{-1} at 0-15, 340.7 kg ha^{-1} at 15-30 was recorded in Soureni and 209.73 kg ha^{-1} at 30-45cm depth was recorded in Selimbong. The minimum available nitrogen 441.3 kg ha^{-1} at 0-15 found in Selimbong, 212.7 at 15-30 and 177.70 kg ha^{-1} at 30-45cm depth was found in Glenburn. The high nitrogen content may be due to leaf litter or application of organic amendments in the soil. It may also be because of the high organic matter content in soil and addition of chemical fertilizers by the tea growing farmers. (Pratistha *et al.,* (2020). These findings were similar with that of Mishra *et al*., (2000). The available phosphorus of soil at 0-15, 15-30 and 30-45cm depth was found significant at 5% critical difference, the maximum available phosphorus 29.54 kg ha^{-1} at 0-15, 27.79 kg ha^{-1} at 15-30 and 25.02 kg ha^{-1} at 30-45cm depth was found in Glenburn. The minimum available phosphorus was 17.23 kg ha^{-1} at 0-15, 16.55 kg ha^{-1} at 15-30 and 16.13 kg ha^{-1} at 30-45cm depth found in Soureni presented in table 4. The available phosphorus content maybe due to the influence of soil pH which is acidic in nature and often limits nutrients remains present in plant nuclei and act as an energy storage (Kekane *et al.,*2015). These findings were similar with that of Ram *et al*., (2014). The table 4 also shows the available potassium of soil at 0-15, 15-30 and 30-45cm depth was found significant at 5% critical difference, the maximum available potassium was 334.92 kg ha^{-1} at 0-15, 322.32 kg ha^{-1} at 15-30 and 320.32 kg ha^{-1} at 30-45cm depth found in Selimbong. The minimum available potassium was 101.43 kg ha^{-1} at 0-15, 99.90 kg ha^{-1} at 15-30 and 97.43 kg ha^{-1} at 30-45cm depth found in Glenburn. High proportion of potassium may be due to the feldspar and muscovite mica found in the Darjeeling region (Laitpharlang Cajee, 2018). These findings were similar with that of Ram *et al*., (2014). The results mentioned in figure 3 shows the exchangeable calcium of soil at 0-15, 15-30 and 30-45cm depth was found significant at 5% critical difference, the maximum exchangeable calcium 0.42 C mol(p^+) kg^{-1} at 0-15, 0.39 C mol(p^+) kg^{-1} at 15-30 and 0.38 C mol(p^+) kg^{-1} at 30-45cm depth found in Selimbong. The minimum exchangeable calcium was 0.03 C mol(p^+) kg^{-1} at 0-15 as well as 15-30 and 0.02 C mol(p^+) kg^{-1} at 30-45cm depth found in Soureni. Very low values of calcium were recorded which may be due to the leaching of calcium as hydrogen is added to the soil by decomposition of organic matter as well as due to heavy rainfall (Pratistha *et al.,* 2020). These findings were similar with that of Ray *et al.*, (2012). The exchangeable magnesium of soil at 0-15, 15-30 and 30-45cm depth was found significant at 5% critical difference, the maximum exchangeable magnesium 0.22 C mol(p^+) kg^{-1} at 0-15, 0.20 C mol(p^+) kg^{-1} at 15-30 and 0.19 C mol(p^+) kg^{-1} at 30-45cm depth found in Selimbong. The minimum exchangeable magnesium was 0.02 C mol(p^+) kg^{-1} at 0-15 as well as 15-30 and 0.01 C mol(p^+) kg^{-1} at 30-45cm depth found in Soureni presented graphically in figure 3. Very low magnesium was recorded in all sites which may be due to heavy rainfall prevailing in the area and surface leaching of basic cations (Mg^{+2}) by the excessive rainfall (Ray *et al*., 2012). These findings were similar with that of Ray *et al.*, (2012).

Table 1: Soil colour of different villages in dry and wet condition of tea garden soils of Darjeeling district at 0-15cm, 15-30 and 30-45cm

Village	Dry condition			Wet condition		
	0-15cm	15-30cm	30-45cm	0-15cm	15-30cm	30-45cm
Pokhribung Khasmahal (V1)	7.5YR 4/4 Dark Brown	7.5YR 5/4 Brown	7.5YR 5/4 Brown	5YR 3/3 Dark Reddish Brown	7.5YR 5/4 Brown	7.5YR 4/4 Dark Brown
Soolbongs Tea Garden (V2)	7.5YR 5/4 Brown	7.5YR 6/3 Pale Brown	7.5YR 6/3 Pale Brown	10YR 5/4 Yellowish Brown	10YR 6/4 Light Yellowish Brown	10YR 5/4 Yellowish Brown
Selimbong (V3)	7.5YR 4/4 Dark Brown	7.5YR 5/4 Brown	7.5YR 5/4 Brown	2.5YR 4/4 Reddish Brown	7.5YR 4/4 Dark Brown	7.5YR 5/4 Brown
Phuguri Forest (V4)	10YR 5/4 Yellowish Brown	10YR 6/6 Brownish Yellow	7.5YR 6/3 Pale Brown	7.5YR 4/4 Dark Brown	7.5YR 4/4 Dark Brown	7.5YR 5/4 Brown
Sourinibasti (V5)	10YR 3/4 Dark Yellowish Brown	10YR 5/4 Yellowish Brown	10YR 8/6 Pale Yellow	7.5YR 4/4 Dark Brown	7.5YR 5/4 Brown	7.5YR 5/4 Brown
Singbulli Tea Garden(V6)	10YR 5/4 Yellowish Brown	10YR 5/4 Yellowish Brown	10YR 6/6 Brownish Yellow	7.5YR 5/4 Brown	7.5YR 6/3 Pale Brown	7.5YR 4/4 Dark Yellow
Singringtam (V7)	7.5YR 5/4 Brown	10YR 5/4 Yellowish Brown	10YR 5/4 Yellowish Brown	10YR 5/4 Yellowish Brown	7.5YR 4/4 Dark Brown	7.5YR 4/4 Dark Brown
Kambal Tea Garden (V8)	10YR 5/4 Yellowish Brown	10YR 5/4 Yellowish Brown	7.5YR 5/4 Brown	7.5YR 4/4 Dark Brown	5YR 3/4 Dark Reddish Brown	7.5YR 4/4 Dark Brown
Manedara (V9)	7.5YR 5/4 Brown	10YR 5/4 Yellowish Brown	7.5YR 4/4 Dark Brown	7.5YR 4/4 Dark Brown	7.5YR 4/4 Dark Brown	7.5YR 5/4 Brown

Table 2: Soil texture of different villages of tea garden soils of Darjeeling district at 0-15cm, 15-30 and 30-45cm

Tea Garden	Village	Sand %	Silt %	Clay %	Textural Class
Selimbong	**V1**	64.3	13.9	21.8	Sandy Clay Loam
	V2	67.0	17.8	15.2	Sandy Loam
	V3	61.5	22.0	16.5	Sandy Loam
Soureni	**V4**	26.2	39.2	34.6	Clay Loam
	V5	29.4	37.5	33.1	Clay Loam
	V6	23.9	37.1	39	Clay Loam
Glenburn	**V7**	48.9	21.9	29.2	Clay Loam
	V8	45.9	29.3	24.8	Clay Loam
	V9	53.8	26.1	21.1	Sandy Clay Loam

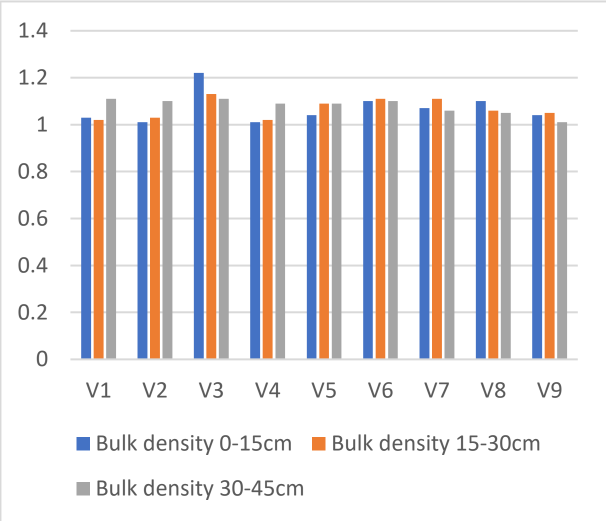
Table 3: Pore space, water holding capacity and percent organic carbon of soil in different villages of Darjeeling at 0-15cm, 15-30 cm and 30-45cm depth

	Villages	Pore space			Water holding capacity			Organic carbon		
		0-15cm	15-30cm	30-45cm	0-15cm	15-30cm	30-45cm	0-15cm	15-30cm	30-45cm
	V1	57.16	54.73	50.53	69.70	65.06	68.13	1.46	0.74	0.71
Selimbong	V2	54.63	57.83	56.14	71.03	53.36	63.16	2.02	1.02	0.63
	V3	55.50	54.36	52.13	69.93	70.53	68.03	1.76	1.02	0.86
	V4	53.13	52.30	56.73	71.96	71.16	70.69	1.87	1.30	1.25
Soureni	V5	56.43	55.63	55.33	79.43	78.83	70.86	1.81	1.45	1.42
	V6	57.66	55.40	59.86	74.13	70.05	72.66	1.71	1.27	1.27
	V7	52.96	50.30	52.06	70.56	68.68	68.40	1.59	1.44	1.31
Glenburn	V8	68.96	62.67	54.36	65.96	63.86	66.25	1.51	1.27	1.03
	V9	58.73	62.96	53.23	61.01	62.51	60.23	1.53	1.15	1.09
F-test		S	S	S	S	S	S	S	S	S
S. Em. (±)		4.84	4.28	2.87	5.27	7.08	3.74	0.18	0.22	0.27
C.D @5%		1.24	4.39	4.4	1.92	0.57	8.73	3.10	1.41	1.59

Table 4: Available potassium, available nitrogen, available phosphorus of soil in different villages of Darjeeling at 0-15cm, 15-30 cm and 30-45cm depth

	Villages	Available potassium			Available nitrogen			Available phosphorus		
		0-15cm	15-30cm	30-45cm	0-15cm	15-30cm	30-45cm	0-15cm	15-30cm	30-45cm
	V1	314.44	306.67	302.16	484.0	268.5	209.73	25.35	25.02	24.35
Selimbong	V2	334.92	322.32	320.32	441.3	241.5	194.56	20.12	19.90	19.25
	V3	278.84	273.00	268.47	442.9	279.6	193.86	17.86	17.29	16.13
	V4	125.76	124.02	120.88	612.1	282.7	189.90	18.72	17.28	16.89
Soureni	V5	110.92	106.10	100.64	679.4	314.2	189.03	24.03	23.43	22.84
	V6	149.90	145.31	141.08	696.3	340.7	182.30	17.23	16.55	16.20
	V7	219.46	214.37	210.83	543.5	217.5	183.16	28.79	27.79	25.02
Glenburn	V8	143.84	138.48	136.76	553.8	212.7	185.76	24.26	22.87	21.73
	V9	101.43	99.90	97.43	574.8	275.4	177.70	29.54	27.50	24.13
F-test		S	S	S	S	S	S	S	S	S
S. Em. (±)		91.29	88.54	88.53	93.30	41.96	9.35	4.61	4.39	3.65
C.D @5%		5.63	9.58	5.99	1.10	2.81	3.16	0.001	0.008	0.138

Fig 1: Graphical representation of bulk density (Mg m^{-3}) and particle density (Mg m^{-3}) of soil in different villages of tea garden soil of Darjeeling at 0-15cm, 15-30 cm and 30-45cm depth



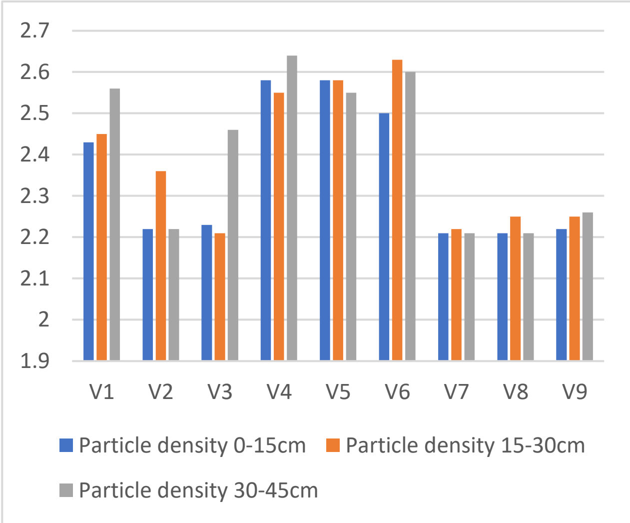
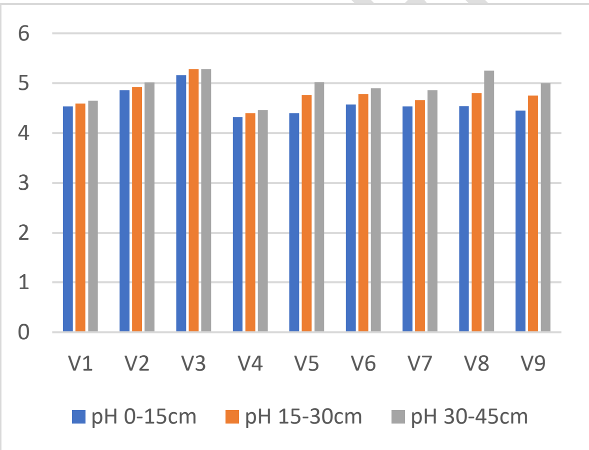


Fig 2: Graphical representation of soil pH and EC (dSm^{-1}) at 25°C of soil in different villages of tea garden soil of Darjeeling at 0-15cm, 15-30 cm and 30-45cm depth



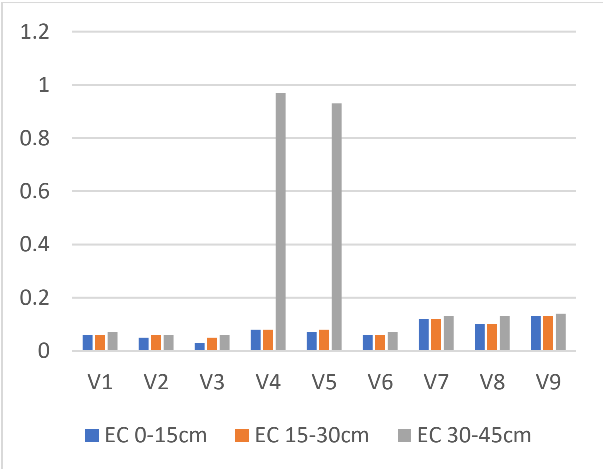
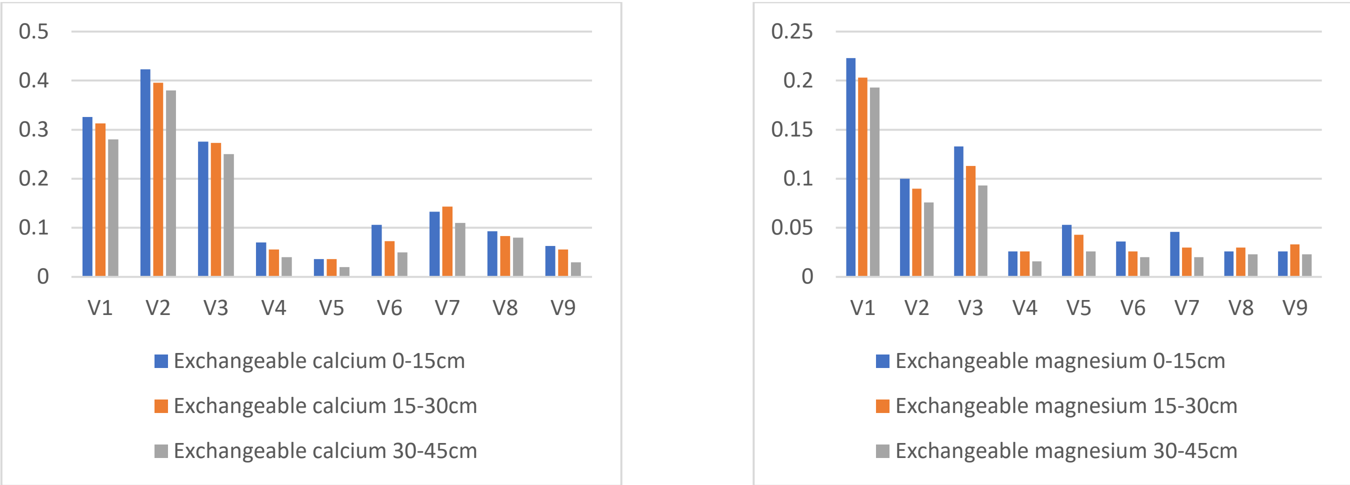


Fig 3: Graphical representation of exchangeable calcium (C mol(p^{+}) kg^{-1}) and exchangeable magnesium (C mol(p^{+}) kg^{-1}) of soil in different villages of tea garden soil of Darjeeling at 0-15cm, 15-30 cm and 30-45cm depth



CONCLUSION

It is evident that the Darjeeling district soils are in good physical condition, which is favourable for tea cultivation. The sub-surface layer showed darker-coloured soil while the surface layer soil was found to be lighter in colour. The soil texture was found to be dominant in clay loam. The bulk density and particle density of soil was found to be in low levels. The high clay component of the soil was discovered to contribute to its good pore space and water-holding capacity. Low pH and EC values have been recorded. Mostly all the villages showed high organic carbon content as well as high available nitrogen concentration which may be due to the adoption of organic farming in the tea gardens. The soils had a medium to high range of phosphate and potassium, with values decreasing as depth increased. Very low values of exchangeable calcium and magnesium was found in all the regions which may be due to heavy rainfall prevailing in the area and surface leaching of basic cations (Ca^{+2} and Mg^{+2}) by the excessive rainfall. The results of the study indicated that maintaining the sustainability of tea crop output and quality may benefit from the implementation of good agriculture practises, which involve the application of organic amendments, herbicides, and micronutrients. However, application of more labile organic inputs, liming materials and suitable inorganic fertilizers (N-P-K) would be effective for sustainable management and improving fertility status of the soils under tea growing region.

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