J. Agric. Res. Technol., Special Issue (1) : 087-094 (2022) DOI: https://doi.org/10.56228/JART.2022.SP114

Evaluation of Soil Physico-Chemical and Biological Properties under Different Tea (*Camellia sinesis*) Gardens of Himachal Pradesh, India

Ankit Gill[1], V. K. Sharma[2], Dinesh[3] and Praveen Thakur[4]
Department of Soil Science, CCS HAU, Hisar - 125 004 (India)
Corresponding author: ankitgill07@gmail.com

Abstract

Assessment of different soil attributes provides an insight into the soil-related constraints and potentials for sustainable agricultural planning. In the present investigation, 37 tea gardens were selected at random from tea growing areas of Himachal Pradesh during 2017-19 to evaluate the status of different soil attributes in surface (0-0.30 m) and sub-surface (0.30-0.60 m) soils. All the collected soil samples were analyzed for particle density, porosity, water stable aggregates, electrical conductivity, exchangeable Ca and Mg and microbial count as per standard procedures. The particle density, porosity and water stable aggregates in soils of tea gardens varied from 2.58 to 2.64 Mg m3, 39 to 57% and 26 to 58%. The electrical conductivity, exchangeable Ca and Mg were in the range of 85 to 210 dS m^{-1}, 1.2 to 4.0 cmol (p^+) kg^{-1} and 0.6 to 2.3 cmol (p^+) kg^{-1} with a mean value of 134±35.8, 2.7±0.8 and 1.4±0.4, respectively. With regards to microbial count, the bacterial population ranged from 49 to 71 x 10^6 CFU, fungal population ranged from 36 to 69 x 10^4 CFU and actinomycetes population varied from 31 to 58 x 10^4 CFU.

Key words : Tea, water stable aggregates and microbial count.

Soil is a central link in the chain of interconnected domains comprising the terrestrial ecosystem. As human population continue to increase, human disturbance of the earth's ecosystem to produce food and fiber will place greater demand on soils to supply essential nutrients. The practice of intensive cropping with hybrid varieties for boosting food production caused decline in the level of nutrients in the soil at which productivity of crops cannot be sustained.

Tea is one of the most popular and widely consumed hot beverages worldwide. It is mainly grown in Asia, Africa, South America, and around the Black and Caspian Seas. About 75 per cent of the world's tea production is represented by four biggest tea producing countries *viz*., China, India, Sri Lanka and Kenya. Approximately 507,196 ha area of land is under tea cultivation in India, which is confined mainly to Assam, Himachal Pradesh, Kerala, Karnataka, Uttarakhand, Arunachal Pradesh, Meghalaya, Nagaland, Mizoram, Sikkim, Orissa, and Tripura (Jain, 1999). Himachal Pradesh has boast a large area of land dedicated to tea estate in its mid hills sub-humid zone (Sood, 2016).

Tea is a shade loving plant and prefers a warm, humid environment. Its roots penetrate upto 1.5 m soil depth. However, majority of the feeder roots lies up to 0.6 m depth. One tonne of tea leaves removes 40 kg nitrogen, 12 kg phosphorus and 24 kg potassium (Bonheure and Willson, 1992).

Average green leaf tea productivity in Himachal Pradesh is 800 kg ha^{-1} which is much lower as compared to average production of India (1668 kg ha^{-1}) as well as of world (1143 kg ha^{-1}). The low productivity of tea in many states was attributed to poor soil health conditions (Anonymous, 2011). The soil health

1. Ph.D. Scholar, 2. Professor, 3. Jr. Pedologist and 4. Ph.D. Scholar.

Table 1. Location of the selected tea gardens

S.No.	Location	S.No.	Location
1	Dugni	20	Sidhbari
2	Paprola	21	Tanda
3	Tikka Balla	22	Sungal
4	Usthear	23	Dharer
5	Darang	24	Jeahru
6	Oder	25	Ahju
7	Bhadal Devi	26	Dheluhar-I
8	Gugga Saloh-I	27	Lambapatta
9	Gugga Saloh-II	28	Bindraban
10	Bhawarna	29	Chauntra
11	Chhatar	30	Bundla-I
12	Alhilal	31	Bundla-II
13	Salan	32	Kloond
14	Holsu	33	Gopalpur
15	Thakurdwara	34	Balla
16	Dheluhar-II	35	Narghota
17	Deogran	36	Chowgan
18	Khalet	37	Ghaniyara
19	Sidhpur		

problems generally arose as a result of long-term unscientific management choices.

Materials and Methods

Tea growing areas in Himachal Pradesh lies between 31°59'19" to 32°17'44" N latitude and 76°18'39" E to 76°46'14" E longitude. The study area is characterized on gently (3 to 5 %) to moderately sloping (10 to 15 %), fluvio-glacial terraces and steeply sloping (>25 %) hill slopes (Sood, 2016). Generally, soils of tea gardens occurring on hill slopes are medium in depth (50 to 100 cm), coarse-loamy and acidic to neutral in reaction and qualify for *Entisols*, while those of tea gardens on terraces are deep, coarse to fine loamy and acidic and qualify for *Inceptisols* and *Alfisoils* (Sidhu *et al*., 1997). Tea growing areas of Himachal Pradesh were thoroughly traversed during December, 2017. Thirty-seven soil sampling sites/tea growers were selected randomly from Kangra and Mandi districts Location of the selected sites has been described in Table 1.

To assess the soil health status of plantation crops, surface (0-0.30 m) soil samples were collected from each tea garden by following the methodology given by (Mishra *et al*., 2009). Soil sampling was done in the month of January to February, 2018. The soil samples collected were processed for laboratory determinations by following the standard procedures (Table 2).

Results and Discussion

The data related to soil physico-chemical and biological attributes presented under the following heads:

Particle density : The particle density in soils of tea gardens varied from 2.57 to 2.63 Mg m^{-3} with a mean value of 2.60±0.02 Mg m^{-3} in the surface soil. The lowest value (2.57 Mg m^{-3}) was recorded in Darang, Narghota and Ghaniyara (Table 3), whereas the highest (2.63 Mg m^{-3}) was recorded in Gugga Saloh-II, Bhawarna, Jeahru, Bindraban and Bundla-II. In sub-surface soils, the particle density in soils

Table 2. Analytical methods used for soil analysis

Parameter	Method	Reference
PD	Pycnometer method	Gupta and Dhakshinamoorthy (1980)
Porosity	Empirical method	Gupta and Dhakshinamoorthy (1980)
% WSA (>0.6 m)	Wet sieving method	Ekwue et al. (2018)
EC	Conductimetric method	Jackson (1973)
Available nutrients: Ca & Mg	Flame photometric method/ Atomic Absorption Spectrophotometric (AAS) method	Jackson (1973)
Microbial population	Standard plate count technique	Wollum (1982)

varied from 2.59 to 2.65 Mg m^{-3} with a mean value of 2.61±0.02 Mg m^{-3}. The increasing trend of particle density in the subsurface soils was registered during the study. This might be due to higher soil organic matter content of surface soils in comparison to sub-surface soils, which lead to increase in the volume of soil without much effect on weight of soil, resulting in decrease in particle density of surface soil. The results were in consonance with the findings of Tolimir *et al*. (2020).

Porosity : Data pertaining to porosity in table 3 revealed that the soil porosity of tea gardens ranged between 40 to 58% with a mean value of 44±5% in the surface soil. The minimum porosity (40%) was recorded in Bhawarna, Jeahru and Bindraban, whereas the

Table 3. Distribution of physical soil attributes in tea gardens studied

Site	PD (Mg m^{-3})			Porosity (%)			WSA (%)		
	S	Sb	Mean	S	Sb	Mean	S	Sb	Mean
Dugni	2.60	2.61	2.61	43	42	43	39	36	38
Paprola	2.61	2.62	2.62	41	40	41	30	26	28
Tikka Balla	2.60	2.61	2.61	42	40	41	46	41	44
Usthear	2.61	2.62	2.62	41	41	41	38	32	35
Darang	2.57	2.59	2.58	56	54	55	54	49	52
Oder	2.61	2.62	2.62	41	40	41	41	33	37
Bhadal Devi	2.60	2.62	2.61	42	41	41	46	45	46
Gugga Saloh-I	2.62	2.63	2.63	41	39	40	37	35	36
Gugga Saloh-II	2.63	2.64	2.64	41	40	40	27	24	26
Bhawarna	2.63	2.64	2.64	40	39	39	26	23	25
Chhatar	2.58	2.60	2.59	48	48	48	49	45	47
Alhilal	2.58	2.59	2.59	50	49	50	49	44	47
Salan	2.60	2.61	2.61	43	42	43	42	39	41
Holsu	2.60	2.62	2.61	42	40	41	44	39	42
Thakurdwara	2.62	2.64	2.63	41	39	40	38	31	35
Dheluhar II	2.61	2.63	2.62	41	40	41	40	35	38
Deogran	2.61	2.63	2.62	41	39	40	38	33	36
Khalet	2.62	2.64	2.63	41	39	40	40	36	38
Sidhpur	2.59	2.60	2.60	46	44	45	48	42	45
Sidhbari	2.59	2.60	2.60	46	46	46	48	42	45
Tanda	2.58	2.59	2.59	48	47	48	50	45	48
Sungal	2.59	2.61	2.60	47	46	47	50	45	48
Dharer	2.59	2.60	2.60	44	43	44	45	39	42
Jeahru	2.63	2.65	2.64	40	40	40	30	24	27
Ahju	2.59	2.60	2.60	48	46	47	55	49	52
Dheluhar I	2.62	2.63	2.63	41	41	41	40	36	38
Lambapatta	2.59	2.60	2.60	45	43	44	52	47	50
Bindraban	2.63	2.64	2.64	40	39	39	34	29	32
Chauntra	2.59	2.60	2.60	44	43	43	39	32	36
Bundla-I	2.60	2.61	2.61	42	42	42	47	40	44
Bundla-II	2.63	2.64	2.64	41	40	41	27	24	26
Kloond	2.59	2.60	2.60	46	45	46	44	40	42
Gopalpur	2.58	2.59	2.59	52	51	52	49	42	46
Balla	2.60	2.62	2.61	42	40	41	47	42	45
Narghota	2.57	2.59	2.58	58	56	57	59	52	56
Chowgan	2.60	2.61	2.61	42	40	41	47	41	44
Ghaniyara	2.57	2.59	2.58	54	53	53	56	50	53
Mean ± SD	2.60±0.02	2.61±0.02	2.61±0.02	44±5	43±5	44±5	43±8	38±8	41±8

Note: S=surface, Sb=sub-surface

maximum (58%) was recorded in Narghota. In sub-surface soils, the porosity in soils varied from 39 to 56% with a mean value of 43±5%. While comparing surface vs. sub-surface soils, the porosity of subsurface soils was less than the surface soils. This might be due to higher compaction along with increasing bulk density with depth, which resulted in lower porosity in the sub-surface soils. Similar findings were reported by Pongmala *et al*. (2022) and Tolimir *et al*. (2020) who recorded depth wise decrease in porosity in soils.

Water stable aggregates : Data presented in Table 3 depicts the water stable aggregates in soils of tea gardens. In the surface soils, the

Table 4. Distribution of chemical soil attributes in tea gardens studied

Site	EC (µs cm^{-1})			Exchangeable bases {cmol (p^+) kg^{-1}}					
	S	Sb	Mean	Ca			Mg		
				S	Sb	Mean	S	Sb	Mean
Dugni	150	180	165	2.9	3.1	3.0	1.3	1.4	1.3
Paprola	120	160	140	2.1	2.2	2.2	0.9	1.0	0.9
Tikka Balla	80	120	100	2.2	2.3	2.2	1.1	1.1	1.1
Usthear	180	210	195	2.3	2.4	2.3	1.4	1.5	1.4
Darang	130	160	145	3.5	3.9	3.7	1.8	2.0	1.9
Oder	120	160	140	2.2	2.4	2.3	1.2	1.2	1.2
Bhadal Devi	90	130	110	1.8	1.9	1.8	1.0	1.1	1.1
Gugga Saloh-I	110	140	125	2.3	2.4	2.3	1.1	1.2	1.2
Gugga Saloh-II	80	120	100	1.5	1.5	1.5	0.8	0.9	0.9
Bhawarna	140	170	155	1.2	1.3	1.2	0.6	0.7	0.6
Chhatar	90	120	105	3.7	3.8	3.8	2.0	2.1	2.0
Alhilal	130	160	145	3.5	3.8	3.7	1.9	2.0	2.0
Salan	190	230	210	2.8	3.0	2.9	1.2	1.3	1.2
Holsu	180	210	195	2.4	2.5	2.4	1.1	1.2	1.1
Thakurdwara	150	170	160	2.1	2.2	2.2	1.0	1.0	1.0
Dheluhar-II	80	110	95	1.6	1.8	1.7	1.0	1.1	1.0
Deogran	180	210	195	1.9	2.1	2.0	1.2	1.3	1.3
Khalet	120	150	135	2.1	2.5	2.3	1.2	1.4	1.3
Sidhpur	110	140	125	3.0	3.2	3.1	1.7	1.8	1.8
Sidhbari	190	220	205	3.0	3.3	3.1	1.7	1.9	1.8
Tanda	90	130	110	3.0	3.3	3.1	1.8	2.0	1.9
Sungal	100	140	120	3.8	4.2	4.0	1.7	1.9	1.8
Dharer	170	200	185	2.8	2.8	2.8	1.7	1.7	1.7
Jeahru	110	140	125	2.0	2.0	2.0	1.3	1.3	1.3
Ahju	100	130	115	3.3	3.5	3.4	2.1	2.2	2.2
Dheluhar-I	80	110	95	1.7	1.8	1.7	1.0	1.0	1.0
Lambapatta	90	120	105	2.7	3.0	2.9	1.7	1.9	1.8
Bindraban	120	150	135	1.7	1.9	1.8	0.7	0.8	0.8
Chauntra	70	100	85	2.9	3.1	3.0	1.5	1.7	1.6
Bundla-I	110	140	125	2.3	2.4	2.3	1.2	1.3	1.2
Bundla-II	160	190	175	1.9	2.0	2.0	0.9	0.9	0.9
Kloond	100	130	115	3.3	3.6	3.5	1.6	1.8	1.7
Gopalpur	70	110	90	3.8	3.9	3.8	1.9	2.0	2.0
Balla	120	160	140	2.3	2.6	2.4	1.0	1.1	1.1
Narghota	90	120	105	3.7	4.0	3.9	2.2	2.4	2.3
Chowgan	70	110	90	2.2	2.5	2.3	1.1	1.2	1.2
Ghaniyara	90	120	105	3.5	3.6	3.5	2.1	2.1	2.1
Mean ± SD	118±36.5	151±35.2	134±35.8	2.6±0.7	2.8±0.8	2.7±0.8	1.4±0.4	1.5±0.5	1.4±0.4

Note: S = Surface, Sb = Sub-surface

water stable aggregates varied from 26 to 59% with a mean value of 43±8% in the surface soil, however in the sub-surface soil samples, the water stable aggregates ranged from 23 to 52% with a mean value of 38±8%. From the mean value of both surfaces, it was revealed that the the lowest value (25%) was recorded in Bhawarna, whereas the highest (56%) was recorded in Narghota, Higher water stable aggregates in soils might be due to higher organic matter content and enhanced microbial activity which secretes binding material during the decomposition process, giving rise to better structure and stable aggregates. The results were in consonance with the findings of Bless *et al*. (2022) and Baker *et al*. (2004).

Table 5. Distribution of biological soil attributes in tea gardens studied

Site	Microbial population								
	Bacteria (CFU x 10^6)			Fungi (CFU x 10^4)			Actinomycetes (CFU x 10^5)		
	S	Sb	Mean	S	Sb	Mean	S	Sb	Mean
Dugni	79	30	55	42	37	43	45	30	38
Paprola	77	28	53	44	31	44	43	20	32
Tikka Balla	89	33	61	46	37	49	56	34	45
Usthear	78	26	52	54	24	49	45	26	36
Darang	94	33	64	73	35	64	62	27	45
Oder	83	31	57	68	28	58	50	43	47
Bhadal Devi	89	31	60	77	29	65	57	41	49
GuggaSaloh-I	74	29	52	40	24	41	42	20	31
GuggaSaloh-II	73	28	51	37	21	39	42	40	41
Bhawarna	72	26	49	32	14	36	41	48	45
Chhatar	95	37	66	63	33	59	63	37	50
Alhilal	96	32	64	83	36	69	64	51	58
Salan	78	25	52	52	25	48	44	37	41
Holsu	84	31	58	61	32	55	52	38	45
Thakurdwara	73	28	51	46	22	44	41	22	32
Dheluhar-II	81	32	57	46	28	46	46	38	42
Deogran	83	36	60	55	19	51	49	35	42
Khalet	82	31	57	65	36	56	48	41	45
Sidhpur	86	30	58	53	20	52	53	26	40
Sidhbari	86	35	61	49	32	50	54	24	39
Tanda	92	28	60	73	23	64	60	26	43
Sungal	97	41	69	64	28	60	66	45	56
Dharer	88	36	62	71	31	61	55	33	44
Jeahru	76	29	53	40	22	41	43	32	38
Ahju	94	29	62	71	34	63	61	39	50
Dheluhar-I	81	29	55	47	16	47	47	36	42
Lambapatta	85	33	59	67	20	59	52	27	40
Bindraban	75	28	52	55	32	49	42	37	40
Chauntra	80	30	55	50	25	48	46	32	39
Bundla-I	90	32	61	49	23	51	58	23	41
Bundla-II	77	32	55	48	17	46	44	33	39
Kloond	87	27	57	48	26	50	55	25	40
Gopalpur	97	35	66	74	36	65	65	29	47
Balla	91	36	64	79	23	66	59	40	50
Narghota	99	38	69	67	37	62	68	32	50
Chowgan	84	40	62	45	19	47	51	41	46
Ghaniyara	98	43	71	66	38	62	67	47	57
Mean±SD	85±8.0	32±4.3	58±5.7	57±13.2	27±6.9	42±8.8	52±8.4	34±8.1	43±6.4

Note: S = Surface, Sb = Sub-surface

Electrical conductivity : The electrical conductivity in soils of tea gardens varied from 70 to 190 µS cm^{-1} with a mean value of 118±36.5 µS cm^{-1} in the surface soil. The lowest value (70 µS cm^{-1}) was recorded in Chauntra, Gopalpur and Chowgan (Table 4), whereas the highest (190 µS cm^{-1}) was recorded in Salan and Sidhbari. In sub-surface soils, the electrical conductivity in soils varied from 100 to 230 µS cm^{-1} with a mean value of 151±35.2 µS cm^{-1}. The increasing trends of electrical conductivity in the subsurface soils were recorded during the study. This might be due to leaching of soluble salts from surface to sub-surface layers, which lead to their accumulation in the lower layers (Wani *et al*., 2017). These results are in agreement with the findings of soils Kumar *et al*. (2021), Singh *et al*. (2016), Muche *et al*. (2015) and Mahajan *et al*. (2007).

Exchangeable Ca : Data pertaining to exchangeable Ca in table 4 revealed that the exchangeable Ca of tea gardens ranged between 1.2 to 3.8 cmol (p^+) kg^{-1} with a mean value of 2.6±0.7 cmol (p^+) kg^{-1} in the surface soil. The minimum exchangeable Ca (1.2 cmol (p^+) kg-1) was recorded in Bhawarna (Table 1), whereas the maximum (3.8 cmol (p^+) kg^{-1}) was recorded in Sungal and Gopalpur. In sub-surface soils, the exchangeable Ca in soils varied from 1.3 to 4.2 cmol (p^+) kg^{-1} with a mean value of 2.8±0.8 cmol (p^+) kg^{-1}. While comparing surface vs. sub-surface soils, the exchangeable Ca of subsurface soils were higher than the surface soils. This might be due to the leaching of basic cations from the surface soil to the sub-surface layer, which lead to their deposition in the sub-surface layer. Similar findings were reported by Wani *et al*. (2017) and Kirmani *et al*. (2013)

Exchangeable Mg : Data presented in Table 4 depicts the exchangeable Mg in soils of tea gardens. In the surface soils, the exchangeable Mg varied from 0.6 to 2.2 cmol (p^+) kg^{-1} with a mean value of 1.4±0.4 cmol (p^+) kg^{-1} in the surface soil, however in the sub-surface soil samples, the exchangeable Mg ranged from 0.7 to 2.4 cmol (p^+) kg^{-1} with a mean value of 1.5±0.5 cmol (p^+) kg^{-1}. From the mean value of both surfaces, it was revealed that the the lowest value (0.6 cmol (p^+) kg^{-1}) was recorded in Bhawarna, whereas the highest (2.3 cmol (p^+) kg^{-1}) was recorded in Narghota. Higher exchangeable Mg in soils might be due to enhanced organic matter content, which released exchangeable nutrients from the exchange sites in soil upon decomposition of organic matter. The results were in consonance with the findings of Dar *et al*. (2013) and Sharma *et al*. (2005).

Microbial Count : Data pertaining to microbial count presented in Table 5. It was evident from data that bacterial population, in soils of selected tea gardens of Himachal Pradesh ranged from 72 to 99 CFU x 10^6 in surface and 25 to 43 CFU x 10^6 in sub-surface soil. Also, the fungal population ranged from 25 to 43 CFU x 10^4 with mean value of 43 CFU x 10^4 in the surface soil, whereas 14 to 38 CFU x 10^4 in sub-surface soil. The actinomycetes population under different tea gardens varied from 41 to 68 CFU x 10^5 in surface soil samples and 20 to 51 CFU x 10^5 in sub-surface soil samples. The microbial population in the sub-surface soils drastically decreases, while comparing with the surface samples. This might be due to better aeration, moisture availability and higher organic matter content in the surface soil, which stimulate microbial population in the soil. Similar findings were reported by Raghukumar *et al*. (2001) and Krishna *et al*. (2012) who recorded depth wise decrease in microbial community in soils of Kerala.

Conclusion

Last of all, it is inferred that constant removal of nutrients from the soil in the tea gardens requires continuous fertilization to sustain fertility and productivity of the soil. The balanced nutrient application is essential approach in order to get optimum yield along with minimal cost. From the experimental data it is revealed that 0-0.30 m depth having higher physical and biological properties, whereas chemical properties showed lowered status as compared to 0.30-0.60 m in all tea gardens. These figures indicated that there is a considerable scope of improving soil health and thereby, increasing soil productivity by adopting scientific soil management practices in tea gardens.

References

Anonymous. 2011. Global Hot Beverages (Coffee and Tea). Global Industry Analysts, Inc., USA.

Baker, B. J., Fausey, N. R. and Islam, K. R. 2004. Comparison of Soil Physical Properties under Two Different Water Table Management Regimes. Soil Science Society of America Journal 68: 1973-1981.

Bless, A. E. S., Colin, F., Crabit, A. and Follain, S. 2022. Soil Aggregate Stability in Salt-Affected Vineyards: Depth-Wise Variability Analysis. Land 11(4): 541.

Bonheure, D. and Willson, K. C. 1992. Mineral nutrition and fertilizers. In: Tea: Cultivation to Consumption (KC Willson and MN Clifford, eds.) Springer, Dordrecht. p 269-276.

Dar, M. A., Wani, J. A., Raina, S. K., Bhat, M. Y., Malik, M. A. and Najar, G. R. 2013. Effect of altitude and depth on available nutrients in pear orchard soils of Kashmir. Agropedology 22(2): 115-118.

Ekwue, E., Dookhoo, T. and Chakansingh, A. 2018. A wet sieving apparatus for determining aggregate stability of soils. Journal of the Association of Professional Engineers of Trinidad and Tobago 46(1): 35-40.

Gupta, R. P., and Dhakshinamoorthy, C. 1980. Procedures for Physical Analysis of Soils and collection of Agrometerological Data, Division of Agricultural Physics, Indian Agricultural Research Institute, New Delhi

Jackson, M. L. 1973. Soil Chemical Analysis. Prentice Hall, India Private Limited, New Delhi. p. 678.

Jain, N. K. 1999. Global Advances in Tea Science. Aravali Books, International Private Limited, New Delhi. p. 405.

Kirmani, N. A, Wani, M. A. and Sofi, J. A. 2013. Characterization and Classification of Alfisols under lesser Himalayan Temperate region. Agropedology 23(2): 118-121.

Krishna, M. P., Varghese, R. and Mohamed, H. A. A. 2012. Depth wise variation of microbial load in the soils of midland region of Kerala: a function of important soil physicochemical characteristics and nutrients. Indian Journal of Education and Information Management 1: 126-129.

Kumar, A., Kumar, S., Khan, K., Arya, R. and Kumar, A. 2021. Studies of depth wise distribution of physico-chemical properties of soil under different cropping systems. International Journal of Advanced Biological Research 11: 52-55.

Mahajan, A., Sharma, S. K., Gupta, R. D. and Sharma, R. 2007. Morphological, physical and chemical properties of soils from Northwest Himalayas. Bulgarian Journal of Agricultural Science 13: 607-618.

Mishra, T. K., Saha, A., Nanda, A. K. and Mandal, P. 2009. Soil sampling in tea plantation for fertility evaluation: A Guideline. The Assam Review and Tea News. 97(12): 12-15.

Muche, M., Kakeb, A. and Molla, M. 2015. Assessing the physicochemical properties of soils under different land use types. Journal of Environmental and Analytical Toxicology 5(5): 123-130.

Pongmala, K., Pierret, A., Oliva, P., Pando, A., Davong, V., Rattanavong, S., Silvera, N., Luangraj, M., Boithias, L., Xayyathip, K., Menjot, L., Macouin, M., Newall, E. R., Robain, H., Vongvixay, A., Simpson, A. J. H., Dance DAB and Ribolzi O. 2022. Distribution of Burkholderia pseudomallei within a 300-cm deep soil profile: implications for environmental sampling. Scientific Reports 12: 8674.

Raghukumar, C., Sheelu, G. P., Loka Bharathi P. A., Nair, S. and Mohandass, C. 2001. Microbial Biomass and Organic Nutrients in the Deep-Sea Sediments of the Central Indian Ocean Basin. Marine Georesources & Geotechnology 19: 1-16.

Sharma, S. D., Bhatia, H. S., and Singh, R. P. 2005. Influence of climate on bloom, fruit set, yield and quality of apple in Himachal Pradesh. Progressive Horticulture 37(2): 298-302.

Sidhu, G. S., Rana, K. P. S., Sehgal, J. and Velayutham, M. 1997. Soils of Himachal Pradesh for optimizing land use. National Bureau of Soil Survey and Land Use Planning. Nagpur, India.

Singh, G., Sharma, M., Manan, J. and Singh, G. 2016. Assessment of soil fertility status under different cropping sequences in district Kapurthala. Journal of Krishi Vigyan 5(1): 1-9.

Sood, M. 2016. Development of Tea Industry in Himachal Pradesh. International Journal on Emerging