Depth-Wise Fertility Status of Cultivated Soils in Low and Mid Hill Regions of Himachal Pradesh

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Authors' contributions

This work was carried out in collaboration among all authors. Author GN conducted the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author VKS designed the study. Authors DS and Anjali managed the literature searches. All authors read and approved the final manuscript.

Original Research Article

ABSTRACT

Detailed knowledge of the soil nutrient status is required in site-specific crop production systems. Moreover, the vertical distribution of plant nutrients is most important for plant production. Therefore, the study was conducted to assess the depth-wise soil fertility status of low and mid hill zones of Himachal Pradesh based on thirty-one (31)soil profiles. Geo-referenced depth-wise soil samples were collected. These thirty-one (31) soils sampling sites were selected to represent the cultivated soils (*Entisols*, *Alfisols*and *Inceptisols*) under major land-use systemsof low and mid-hill zones of Himachal Pradesh. The results of the soil nutrient status revealed that low to medium content of available N, P and S, low to medium content of available K except fewsubsurface horizons in *Inceptisols*was found in most of the soils of low hill zone. Under different land-use systems in mid-hill zone, medium to high content of available N and K, low to medium of available P, low to high of available Swas found in most of the soils. Generally, surface soils had a higher mean values of N, P, S, Cu and Zn and lower values of K, Ca, Mg, Fe and Mn. *Alfisols* had higher value of all the nutrients as compared to *Entisols* and *Inceptisols*.

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1. INTRODUCTION

The need to meet up with the food demand of the ever-increasing population has brought about the need to harness the fertility of the cultivated soils. Fertile soil is a pre-requisite for sustained high crop productivity. Soil fertility status got depleted due to inadequate and imbalanced use of plant nutrients through fertilizers and manures [1]. Unless nutrients are supplied judiciously, there will be a much greater drain on the native soil fertility and the soil is unlikely to sustain high crop productivity in the years to come. Macro and micro-nutrient status play an important role in the determination of soil fertility in different land-use systems. Knowledge of the vertical distribution of plant nutrients in the soil is beneficial as the roots of most of the crop plants go beyond the surface layer and draw part of their nutrient requirements from the subsurface layers of the soil [2,3]. It is also helpful in understanding the inherent capacity of the soil to supply essential nutrients to the plants [4]. Moreover, soil profile characteristics as conditioned by different processes and factors of soil formation have a great influence on soil fertility and crop productivity. Detailed and scientific study of soil profiles is immensely essential for understanding the prevailing soil forming (soil genesis) factors and processes, without a knowledge of which soil characteristics cannot be clearly interpreted [5]. The crop productivity cannot be boosted further without judicious use of macro and micro nutrient fertilizers to overcome the existing deficiencies. Jobbagy and Jackson [6] explored nutrient distributions in the top meter of soil, hypothesized that vertical nutrient distributions are related to leaching, weathering dissolution, and atmospheric deposition. They also found that most of the nutrients are dominant in surface soil and decreasing with increasing depth.

Generally, farmers have a fair idea of the relative fertility of their fields based on yield variability but this knowledge is not enough to modify fertilizer application rates as per soil fertility and crop demand, especially in present-day farming which involves the external application of several nutrients. Hence, fertilizer use by the farmers in the absence of proper soil fertility assessment may lead to nutrient mining and other undesirable implications viz., lowering nutrient use efficiencies and farm profits, environmental problems, etc. Little attention has so far been paid to monitor the depth-wise distribution of macro and micronutrients under different land-use systems existing in low and mid-hill zones of Himachal Pradesh, which is very important for effective nutrient application. The productivity of soil is directly related to the maintenance of soil fertility parameters over time. Keeping in view that several distinct land-use systems exist in the region with different fertility status, the present investigation was carried out, to study the depth-wise distribution of macro and micronutrients in profiles of different land-use systems to suggest and enhance cultural practices and appropriate fertilizer schedule to improve the crop yield and soil fertility as well.

2. MATERIALS AND METHODS

2.1 Site Details

The study was conducted in two major physiographic regions of Himachal Pradesh viz*.,* low and mid hill regions.The low hill region is generally characterized by the subtropical climate with the length of growing period (LGP) varying from 180 to 270 days. Mean annual temperature lies between 15 °C to 23 °C. The average annual rainfall is about 1100 mm. Soil moisture and temperature regimes in the region are ustic and thermic, respectively. Generally, soils are shallow to medium in depth, coarse-textured, neutral in reaction, non-calcareous to calcareous and low in soil fertility [7].

Whereas the climate of the mid hill zone varies from sub-tropical to sub-humid with the LGP varying from 270 to 330 days. Mean annual temperature lies between 14°C to 22°C and the average annual rainfall is about 2000 mm. Generally, soil moisture and temperature regimes in the region are udic and thermic, respectively. In mid hill region, majority of soils occurring on ridge tops are shallow in depth, coarse-loamy and acidic to neural in reaction and qualify for *Entisols*. The soils on terraces, valleys and gentle slopes are deep to very deep, coarse to fine loamy, acidic to neutral and qualify for *Inceptisols* and *Alfisoils*. Generally, the soils of Himachal Pradesh are mixed in clay mineralogy [8].

2.2 Soil Sampling and Processing

Thirty-one soil profiles were selected to represent the cultivated soils under major land-use systems in the study area. Fifteen and sixteen profiles were selected from low mid-hill regions, respectively representing *Alfisols, Inceptisols* and *Entisols*. These sites represent the soils under

maize-wheat, paddy-wheat, vegetables, sugarcane, tea gardens and fruit trees, respectively. Subtropical fruits like citrus, litchi, mango and guava are grown both in low as well as mid hill regions. Apple and other temperate fruits are prevalent only in mid-hill region. Further, tea gardens are also found in the region under sub-humid conditions (Mandi and Kangra districts). Keeping in view the root distributional patterns and mobility of nutrients in soil, 0-15, 15-30 and 30-60 cm soil depths have been selected for the soil sampling from lands under field crops and established orchards/ plantations, [9,10]. Geo-referenced depth-wise soil samples were collected from croplands during October, 2016 & 2017 and from orchards during January to February, 2016 to 2017. The collected samples were air dried, lightly crushed in wooden pestle and mortar to break clods and then subsequently passed through the 2 mm sieve and stored in polythene bags for analysis.

2.3 Laboratory Analysis

The processed soil samples were analyzed for available macro and micro-nutrients viz., Nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sulphur (S), copper (Cu), iron (Fe), manganese (Mn) and zinc (Zn). Soils were categorized as low, medium and high by using the same limits as adopted by the State Soil Testing Laboratories. A soil having available nutrient content ranging from 280 to 560 kg N ha^{-1}, 10 to 25 kg P ha^{-1}, 118 to 280 kg K ha^{-1}, 1.5 to 2.5 cmol(p+) Ca kg^{-1}, 0.5 to 1.0 cmol(p+) Mg kg^{-1} and 22.4 to 44.8 kg S ha^{-1}was rated as medium in the respective nutrient status. Using 0.2 mg Cu kg^{-1}, 4.5 mg Fe kg^{-1}, 1.0 mg Mn kg^{-1} and 0.6 mg Zn kg^{-1} as critical limits, soils were rated as deficient or sufficient in the respective micro nutrient. Available N was determined by alkaline potassium permanganate method [11]. Available P was determined by0.5 *M* sodiumbicarbonate-extractant [12]. Available K in the soil was extracted by neutral *N* ammonium acetate and K was determined by flame photometer [13]. Available S by calcium chloride extraction method [14]. Available Ca and Mg extracted by 1 *N* ammonium acetate method [15]. The available Fe, Mn, Zn and Cu in soil samples were estimated by atomic absorption spectrophotometer following diethylene triamine penta-acetic acid (DTPA) extraction method [16].

2.4 Descriptive Statistics

The descriptive statistics like minimum, maximum, mean and standard deviation were calculated for each property using SAS for windows 64.0 (SAS 9.4 Incy. Cary, North Carolina, U.S.A).

3. RESULTS AND DISCUSSION

3.1 Low Hill Zone

The results of the soil nutrient status (Table 1) revealed that low to medium content of available N and P were found in all sites, and it varied from 163 to 528and 5.4 to 15.4 kg ha^{-1} in surface soils;54 to 495and 1.6 to 12.2 kg ha^{-1}in sub-surface soils under all land-use systems. The content of available N and P was higher in the surface horizons as compared to subsurface horizons. A regular decreasing pattern of available N and P was observed with depth. The highest amount of available N in the surface horizon may be attributed to high amount of carbon. The lower P in sub-surface horizons as compared to surface horizon was due to the fixation of released P by clay minerals, oxides of iron and aluminum [17]. Mean available N and P (kg ha^{-1}) in surface soils were 329 and 9.7 in Entisols,393 and 11.4 in Inceptisols, respectively. Inceptisols had greater rate of soil development as compared to Entisols, thus high nutrient status is there in case of former.

Under different land-use systems, low to medium content of available K was found in most of the soils except few subsurface horizons in Inceptisols. It ranged from 120 to 262 kg ha^{-1}in surface soils and from 58 to 314 kg ha^{-1}in subsurface soils, respectively. Mean available K (kg ha^{-1}) in surface soils was 166 in Entisols and 190 in Inceptisols, respectively. Available K showed more or less a decreasing trend with depth in Entisols but a reverse trend was observed in case of Inceptisols.

Available Ca (cmol(p$^+$) kg^{-1}) and Mg (cmol(p$^+$) kg^{-1}) ranged from 2.5 to 5.2 and 0.60 to 2.4 in surface soils it was from 1.0 to 6.3 and 0.2 to 4.2 in subsurface soils, respectively (Table 1). Mean available Ca and Mg (cmol(p$^+$) kg^{-1}) in surface soils were 3.7 and1.3 in Entisolsand 4.1 and 1.6 in Inceptisols, respectively. With depth, there was increase in content under Inceptisols and decreased trend under Entisols. Available S (kg ha^{-1}) content was also low to medium in most soils of different land-use systems and varied from 10.0 to 37.0kg ha^{-1} in surface soils and from 5.3 to 36.1 kg ha^{-1}in subsurface soils, respectively (Table 1). Mean available S (kg ha^{-1})in surface soils was 21.3 in Entisols and 24.7 in Inceptisols, respectively. However, the highest

available S was observed in the surface horizons and decreased with depth.

The DTPA-Cu and Zn were higher in surface horizon than sub-surface under all land-use systems and it ranged from 0.16 to 0.44 and 0.36 to 0.9 (mg kg^{-1}) in surface soils, from 0.13 to 0.35 and 0.20 to 0.84 (mg kg^{-1}) in subsurface soils, respectively. Mean available Cu and Zn (mg kg^{-1})in surface soils were 0.29 and 0.55 in Entisolsand 0.32 and 0.61 in Inceptisols, respectively.The DTPA-Fe and Mn varied from 4.7 to 12.8 and 1.6 to 3.7 (mg kg^{-1}) in surface soils; from 10.6 to 22.6 and 2.4 to 6.6 (mg kg^{-1}) in subsurface soils, respectively under all land-use systems. Mean available Fe and Mn (mg kg^{-1}) in surface soils were 7.8 and 2.5 in Entisolsand 8.9 and 2.6 in Inceptisols, respectively. Irrespective of soil orders, both the micronutrients showed an increased trend with depth.

3.2 Mid Hill Zone

The results of the soil nutrient status (Table 2) revealed that medium to high content of available N were found in most of the sites, except one each site of Maize-wheat and Paddy-wheat under Entisols had low N. It varied from268 to 703kg ha^{-1} in surface soilsand from 98 to 520 kg ha^{-1} in sub-surface soils under all land-use systems. The available P was low to medium in most of the sites except Duwara vegetable-based and Sungal Tea gardens which had high P content. The content of available N and P was higher in the surface horizons as compared to subsurface horizons. A regular decreasing pattern of available N and P was observed with depth. Mean available N and P (kg ha^{-1}) in surface soils were 465 and 13.8 in Entisols, 574 and 19.1 in Alfisols and 513 and 15.7 in Inceptisols, respectively. Overall, Alfisols had higher values, followed by Inceptisolsand then Entisols.

Under different land-use systems, medium to high content of available K was found in most of the soils. It ranged from 156 to 410 kg ha^{-1}in surface soils and from 120 to 434 kg ha^{-1}in subsurface soils, respectively. Mean available K (kg ha^{-1}) in surface soils was 261.7 in Entisols, 304 in Alfisolsand 270.7 in Inceptisols. Available K showed more or less a decreasing trend with depth in Entisols but a reverse trend was observed in case of Alfisols and Inceptisols.

Available Ca (cmol(p$^+$) kg^{-1}) and Mg (cmol(p$^+$) kg^{-1}) were medium to high in all sites of different land-use systems, ranged from 2.3 to 7.3 and 0.60 to 2.4 in surface soils and from 2.4 to 7.5 and 0.8 to 2.6 in subsurface soils, respectively (Table 2). Mean available Ca and Mg (cmol(p$^+$) kg^{-1}) in surface soils were 4.2 and 1.2 in Entisols, 4.1 and 1.7 in Alfisolsand 4.4 and 1.5 in Inceptisols, respectively. With depth, there was increase in content under different land-use systems and orders. Available S (kg ha^{-1}) content is low to high in most soils of different land-use systems and varied from 12.3 to 61.8 kg ha^{-1} in surface soils and from 5.2 to 49.5 kg ha^{-1} in subsurface soils, respectively (Table 2). Mean available S (kg ha^{-1}) in surface soils was 33.6 in Entisols, 41.7 in Alfisols and 34.4 in Inceptisols, respectively. However, the highest available S was observed in the surface horizons and decreased with depth.

The DTPA-Cu and Zn were higher in surface horizon than sub-surface under all land-use systems and it ranged from0.21 to 0.51 and 0.4 to 1.4 (mg kg^{-1}) in surface soils and from 0.15 to 0.50 and 0.20 to 1.3 (mg kg^{-1}) in subsurface soils, respectively (Table 2). Mean available Cu and Zn (mg kg^{-1}) in surface soils were 0.35 and 0.84 in Entisols, 0.43 and 1.1 in Alfisolsand 0.36 and 0.97 in Inceptisols, respectively. The DTPA-Fe and Mn varied from 4.8 to 28.5, and 1.2 to 4.1 (mg kg^{-1}) in surface soils and from 6.3 to 35.7 and 1.6 to 5.3 (mg kg^{-1}) in subsurface soils, respectively under all land-use systems. Mean available Fe and Mn (mg kg^{-1}) in surface soils were 14.8 and 2.2 in Entisols, 16.5 and 3.2in Alfisolsand 13.9 and 2.4 in Inceptisols, respectively. Irrespective of soil orders, both the micronutrients showed an increased trend with depth.

The available nutrient status (Table 2) revealed that soils varied considerably in available nutrient content. It may be attributed to the differences in soil management practices, land-use types etc. The highest amount of available N, P, S, Cu and Zn in the surface horizon may be attributed to high amount of carbon. Processes like leaching and clay illuviation may be responsible for more amounts of available K, Ca, Mg, Fe and Mn in most sub-surface horizons. Majority of the farmers in the study area adopt traditional management practices for growing different crops. They apply farmyard manure and fertilizers to almost all the crops, but at varying rates. Such a variation in cultural practices may also account for spatial variability of nutrient status of soils. Similar observations were also made by Verma and Tripathi [18,19,20].

Table 1. Depth-wise distribution of macro and micro-nutrients in soils of different land-use systems of low hill zone of Himachal Pradesh

SN	Site	Land-use type	Depth (cm)	N (kg ha⁻¹)	P (kg ha⁻¹)	K (kg ha⁻¹)	Ca {cmol(p⁺) kg⁻¹}	Mg {cmol(p⁺) kg⁻¹}	S (kg ha⁻¹)	Cu (mg kg⁻¹)	Fe	Mn	Zn
							Entisols						
1	Sugal	Maize-wheat	0-15	432	12.6	168	4	1.4	26	0.35	8.0	2.8	0.67
			15-30	292	7.8	153	3.1	1	21.8	0.28	15.2	3.7	0.58
			30-60	117	2.7	127	2.9	0.9	19.6	0.26	21.5	4.8	0.56
2	SidhChalehr	Maize-wheat	0-15	163	6.6	132	3.4	1.2	10	0.18	7.2	2.2	0.40
			15-30	97	4.3	128	2.4	1.0	7.6	0.12	14.5	3.5	0.32
			30-60	54	1.8	113	2.2	0.7	5.4	0.10	20.2	4.7	0.30
3	Naggal	Paddy-wheat	0-15	502	14.5	230	4.8	2.0	36	0.42	10	3	0.70
			15-30	361	9.6	214	3.9	1.5	31.7	0.33	16.3	3.8	0.62
			30-60	185	4.5	187	3.5	1.3	29.2	0.31	20.8	4.9	0.60
4	Fatehpur	Vegetable-based	0-15	178	6.4	124	2.5	1.0	13	0.20	4.7	1.6	0.40
			15-30	86	3.7	110	1.4	0.7	9.8	0.14	10.6	2.9	0.31
			30-60	54	1.6	87	1.1	0.4	6.7	0.10	16.5	4.1	0.29
5	GharJarot	Vegetable-based	0-15	514	15	230	5	2.2	37	0.40	10.2	2.8	0.72
			15-30	370	10	213	3.8	1.7	32	0.32	16.4	3.1	0.62
			30-60	193	4.8	185	3.5	1.4	29	0.28	21.5	4.3	0.60
6	Jankaur	Sugarcane based	0-15	310	9.2	168	3.8	1.3	19	0.28	7.4	2.5	0.48
			15-30	167	5.7	146	3.1	0.9	15.2	0.18	14.3	3.9	0.40
			30-60	69	2.3	127	2.6	0.5	12.6	0.16	21.2	4.7	0.38
7	Sarsan	Sugarcane based	0-15	278	8.2	168	3.6	1.4	18	0.26	8.2	3.5	0.62
			15-30	136	5.8	124	2.8	1.0	13.7	0.22	15.3	5.9	0.53
			30-60	76	2.3	106	2.1	0.6	11.8	0.20	22.6	6.6	0.51
8	Indpur	Orchards	0-30	163	5.4	120	2.8	0.6	10	0.16	5.9	1.6	0.36
			30-60	65	1.7	79	1.1	0.2	5.3	0.10	13.5	3.7	0.20
9	Panjahra	Orchards	0-30	424	9.8	154	3.6	1.3	23	0.36	8.6	2.6	0.60
			30-60	126	2.2	58	1.0	0.4	10.8	0.18	15.6	5.2	0.28
							Inceptisols						
10	BeliDiawar	Maize-wheat	0-15	502	15.2	262	4.8	2.1	37	0.42	10.4	3.7	0.70
			15-30	471	12.2	283	5.1	2.4	36.1	0.31	16.4	4.3	0.62
			30-60	379	11.1	314	5.8	2.5	34.5	0.30	19.5	5.7	0.60
11	Har	Maize-wheat	0-15	263	8.8	180	3.9	1.5	16	0.22	8.9	2.4	0.58
			15-30	231	5.3	201	4.2	1.8	15	0.13	14.7	3.1	0.47
			30-60	138	3.8	233	4.9	1.9	13.2	0.11	16.9	4.6	0.45
12	Rampur Bharapur	Paddy-wheat	0-15	352	10.2	146	3.6	1.0	21	0.30	6.0	1.7	0.42
			15-30	319	6.7	167	3.8	1.3	20.1	0.21	11.8	2.4	0.32

SN	Site	Land-use type	Depth (cm)	N (kg ha⁻¹)	P (kg ha⁻¹)	K (kg ha⁻¹)	Ca {cmol(p⁺) kg⁻¹}	Mg {cmol(p⁺) kg⁻¹}	S (kg ha⁻¹)	Cu (mg kg⁻¹)	Fe	Mn	Zn
			30-60	223	5.1	199	4.6	1.5	18.3	0.20	13.9	3.8	0.30
13	Khajurna	Vegetable-based	0-15	528	15.4	236	5.2	2.4	37	0.44	12.8	3.2	0.90
			15-30	495	11.9	257	5.5	2.7	35.9	0.35	18.6	4.0	0.84
			30-60	400	10.4	291	6.3	4.2	34.1	0.32	20.1	5.4	0.81
14	KotliByas	Sugarcane-based	0-15	386	11.4	168	3.9	1.5	22	0.30	6.8	2.5	0.60
			15-30	352	7.4	189	4.2	1.8	20.9	0.24	12.7	3.4	0.53
			30-60	256	5.8	223	5.1	3.0	19	0.22	14.8	4.9	0.50
15	Kalera	Orchards	0-30	325	7.4	150	3.1	1.1	15	0.26	8.4	2.2	0.46
			30-60	220	3.4	190	3.9	1.4	12.6	0.14	15.4	4.3	0.22
Mean±SD (surface soils)				355±128.8	10.4±3.4	176±43.8	3.87±0.8	1.47±0.50	23±9.8	0.30±0.09	8.3±2.1	2.55±0.64	0.57±0.15
Mean±SD (Sub - surface soils)				220±133.9	5.7±3.3	174±66.7	3.48±1.5	1.43±0.92	19±10.0	0.22±0.08	16.7±3.3	4.29±0.97	0.47±0.16

Table 2. Depth-wise distribution of macro and micro-nutrients in soils of different land-use systems of mid hill zone of Himachal Pradesh

SN	Site	Land-use type	Depth (cm)	N (kg ha⁻¹)	P (kg ha⁻¹)	K (kg ha⁻¹)	Ca {cmol (p⁺) kg⁻¹}	Mg {cmol (p⁺) kg⁻¹}	S (kg ha⁻¹)	Cu (mg kg⁻¹)	Fe	Mn	Zn
Entisols													
1	Panjla	Maize-wheat	0-15	268	5.4	178	2.6	0.8	14.3	0.24	5.4	1.2	0.4
			15-30	120	2.9	165	2.7	1.0	9.9	0.23	7.2	1.6	0.3
			30-60	98	1.6	134	2.9	1.1	5.4	0.22	8.9	2.2	0.2
2	Sukrayin	Maize-wheat	0-15	410	8.4	249	2.26	0.6	34.3	0.24	10.2	1.4	0.6
			15-30	270	6.6	220	2.39	0.8	29.6	0.22	12.1	1.9	0.5
			30-60	110	4.9	201	2.41	0.9	18.3	0.21	14.2	2.1	0.3
3	Bsal	Paddy-wheat	0-15	272	7.4	156	2.49	0.75	12.3	0.21	4.8	1.3	0.6
			15-30	189	5.1	146	2.51	0.82	8.9	0.16	6.3	1.6	0.5
			30-60	132	3.9	124	2.53	0.85	5.2	0.15	10.5	1.9	0.4
4	Deor	Vegetable based	0-15	510	11.2	195	4.0	1.3	34.3	0.49	27.3	4.1	1.4
			15-30	349	9.3	145	4.1	1.4	25.8	0.48	29.2	4.3	1.3
			30-60	143	6.0	120	4.3	1.6	16.3	0.47	32.1	4.8	1.2
5	Duwara	Vegetable based	0-15	640	27	339	6	1.2	61.8	0.51	24.2	3.7	1.2
			15-30	439	23	289	6.2	1.4	49.5	0.50	27.2	4.0	1.1
			30-60	212	19	260	6.4	1.5	32.7	0.49	31.2	4.2	1.0
6	Jia	Orchards	0-30	578	19	305	4.8	1.6	32.5	0.38	14.5	2.1	0.8

SN	Site	Land-use type	Depth (cm)	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})	Ca	Mg	S	Cu	Fe	Mn	Zn
			30-60	337	15	257	5.0	1.9	21.7	0.34	25.2	3.2	0.5
7	Drabad	Orchards	0-30	579	18	410	7.3	2.4	45.5	0.39	16.9	1.9	0.9
			30-60	356	13	376	7.5	2.6	31.2	0.36	27.2	2.8	0.6
Inceptisols													
8	Dun	Maize-wheat	0-15	289	8.7	270	4.6	1.5	25.8	0.25	5.7	1.3	0.6
			15-30	190	5.4	291	4.8	1.7	18.3	0.23	7.8	1.6	0.4
			30-60	126	3.7	302	4.9	1.9	12.2	0.22	9.7	1.9	0.3
9	Sambar-8-mile	Maize-wheat	0-15	563	13	185	3.7	1.2	34.3	0.35	10.6	1.9	1.1
			15-30	320	8.2	210	3.9	1.4	28.3	0.34	12.8	2.1	0.9
			30-60	117	4.8	232	4.1	1.5	22.7	0.32	10.5	2.6	0.8
10	Sutiara	Paddy-wheat	0-15	350	9.2	279	3.8	1.3	23.1	0.31	6.8	1.6	1.4
			15-30	230	7.8	298	3.9	1.4	18.5	0.28	8.9	1.9	1.3
			30-60	134	6.4	312	4.1	1.7	15.7	0.24	12.7	2.2	1.2
11	Bharatkoop	Vegetable based	0-15	623	25	339	5.1	1.7	47	0.48	21.4	3.9	0.9
			15-30	520	19	350	5.2	1.9	41	0.47	23.2	4.4	0.8
			30-60	312	15	365	5.5	2.0	34	0.46	27.2	5.1	0.6
12	Tarked	Tea gardens	0-30	695	23	331	4.8	1.6	44.6	0.47	28.0	3.9	0.9
			30-60	302	13	365	5.1	1.9	27.2	0.44	35.7	5.3	0.7
13	Bhuntar	Orchards	0-30	560	15.2	220	4.5	1.5	31.8	0.32	10.7	1.8	0.9
			30-60	349	9.2	278	4.8	1.7	22.8	0.29	22.1	2.9	0.7
Alfisols													
14	Kroth	Paddy-wheat	0-15	396	9.2	236	3.95	2.42	22.8	0.32	6.9	1.7	1.4
			15-30	195	6.6	267	4.12	2.48	17.2	0.28	9.1	2.2	1.3
			30-60	112	2.9	282	4.24	2.51	14.8	0.23	13.2	2.7	1.1
15	Taragarh	Tea gardens	0-30	623	21	287	3.6	1.2	51.7	0.48	14.0	3.8	0.7
			30-60	220	12	345	3.9	1.5	35.2	0.46	20.4	4.5	0.5
16	Sungal	Tea gardens	0-30	703	27	389	4.8	1.6	50.6	0.49	28.5	4.0	1.3
			30-60	390	19	434	5.1	1.8	32.9	0.46	34.6	4.9	1.1
Mean±SD (surface soils)				**504±150.69**	**15.48±7.43**	**273±76.10**	**4.27±1.29**	**1.42±0.51**	**35.42±13.95**	**0.37±0.11**	**14.74±8.60**	**2.48±1.17**	**0.94±0.32**
Mean±SD (Sub - surface soils)				**241±116.64**	**9.36±5.94**	**260±86.55**	**4.33±1.29**	**1.59±0.50**	**22.90±11.01**	**0.33±0.12**	**18.43±9.69**	**3.03±1.26**	**0.75±0.36**

4. CONCLUSIONS

It may be concluded from the present investigation thatthe descriptive statistics showed wide variation in the studied soil properties. Thesurface soils had higher mean values of N, P, S, Cu and Zn and lower values of K, Ca, Mg, Fe and Mn. Also, *Alfisols* had higher value of all the nutrients as compared to *Entisols* and *Inceptisols.* The deficiency of nutrients, may impose threat to sustain the soil productivity in this region. Thus, there is urgent need to adopt soil test based balanced nutrient management for enhancing crop productivity and profitability in the region.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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