Research Article

Altitudinal and Depth-wise Variation of Soil Physico-chemical Properties and Available Nutrients of Pear Orchards in Jammu & Kashmir, India

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Abstract

A total of thirty six soil samples collected from twelve representative pear orchards were analyzed for fertility parameters using the standard procedures. Interestingly, results revealed that pH showed significant ($p<0.05$) but electrical conductivity recorded non-significant variation with altitude and depth. Significantly higher organic carbon content (1.16%) was recorded at high altitude and in surface soils. Significantly higher amount of calcium carbonate ($p<0.05$) was recorded in sub-surface horizons of mid low and high altitudes. The cation exchange capacity recorded was significantly higher in mid altitude and in sub-surface soils ($p < 0.05$). Available N, P and K were recorded significantly higher in pear orchards at high altitude as well as surface soils ($p<0.05$) whereas Ca recorded non-significant variation with altitude and depth. Significantly higher Mg (286.24 ppm) and S (11.13 ppm) amounts were observed in surface soils only. Zn and Cu showed significant decline with altitude and depth with higher amounts in surface soils of high altitude whereas Mn and Fe observed non-significant variation. However, B and Mo observed significant decline with depth ($p<0.05$) but non-significant variation with altitude.

Keywords: Altitude, depth, nutrients, Pear orchards, physico-chemical properties

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Introduction

The pear native of Central Asia, stands 2nd in ranking after apples as the most important delectable tree fruits and is grown in all the continents of the world under warm temperate to temperate climatic conditions. In India, pear occupies third place in temperate fruits in acreage and production and can be grown from foot hills to high hills experiencing 500 to 1500 chilling hours [1]. Due to very high chilling requirements, the superior cultivars of pear (*Pyrus communis* L.) are confined to valley and high hills of Jammu and Kashmir, Himachal Pradesh and Uttaranchal. In Jammu and Kashmir the diverse agro-climatic zones offer the favourable agro-ecological conditions for pear production. The climate of Kashmir valley is sub-humid temperate. The average annual rainfall is 887.6 mm with average annual temperature of 20.2^{o}C maximum and 8.60^{o}C minimum. Currently the area under pear fruit is 13883 ha with annual production of 54847 MT in our state [2]. Due to the economic importance of this fruit crop, it has drawn the attention of numerous researchers in recent years.

Amongst the various factors required for sustainable pear production, the inherent fertility status of soil influence to a large extent the tree health and fruit production. The physiographic features like slope aspect, relief, altitude and depth have pronounced effect on physico-chemical properties and also on the nutrient supplying capacity of the soils, thereby influencing growth and yield [3]. The most important soil considerations for pear production are water table (soil-depth) and drainage conditions [4]. Many soil fertility characteristics (including organic matter content, pH, cation exchange capacity and phosphorus availability) show significant altitudinal variations. With the variations in altitude, climatic factors (temperature, precipitation and solar radiation) also change which results in a differential composition of soil organic matter dynamics [5] by controlling soil water balance, soil erosion, geologic deposition processes, species and biomass production of the native vegetation and cultivated plants [6]. The altitude and soil depth have pronounced influence on the available nutrients in soil. However, the nutrient supplying power of a soil depends on dissociation of nutrients from the exchange site, which is in turn depend on the degree of saturation of the nutrients on the exchange site, type of clay and complementary ion-effect [7].The detailed information about the relationship between nutrient distribution with changing altitude and depth more particularly for pear orchards is limited in our state. Thus, assessing the influence of altitude and depth variability on nutrient distribution pattern is essential for addressing the issue of the low productivity levels of the soils at the study areas.

Material and Methods

Twenty four pear (*Pyrus communis cv.* William Bartlett) orchards selected from twelve representative pear production sites located in three different physiographics altitudes viz. Low Altitude (<1600mts.amsl), Mid Altitude (1600-1800mts.amsl) and High Altitude (>1800mts.amsl) of district Pulwama in Jammu and Kashmir (**Figure 1**) were sampled for soils for the variation of physico-chemical properties and available nutrients with altitude and depth variables. The district is situated between $33^{o}50'$ to $33^{o}54'$N Latitude and $74^{o}52'$ to $75^{o}58'$E Longitude with average elevation of about 1630 m amsl. The area has sub-humid temperate climate and temperate variation between -3^{o} to 32^{o}C. The topography of the location is highly uneven characterized by moderately steep to very steep slopes in upper reaches, moderately undulating in the middle and flat to moderately sloping land under cultivation and near habitation. Sampling sites were recorded by GPS coordinated in the center covered by pear orchards of uniform age group (15-30 years). Stratified random soil sampling was preferred due to large number of pear orchards present in this region. Composite soil samples collected at an interval of 30 cm were taken upto 90 cm at more than 8 random points in each selected pear orchard. The soil organic carbon (OC) was analyzed by wet digestion method [8]. Total calcium carbonate content was estimated by Back titration method [9] and pH, Electrical conductivity (EC) were measured as described by [10] by preparing (1:2) soil and water solution. Cation exchange capacity (CEC) was determined by ammonium acetate method described by [11]. Available N was estimated by alkaline permanganate method [12], available phosphorus by [13] method and potassium by flame photometer in normal neutral ammonium acetate extract. Calcium and magnesium were estimated by Versante method, B by hot water, Mo and micronutrient cations (Zn, Cu, Mn and Fe) by [14] reagent. Analytical determination of Fe, Mn, Zn and Cu was performed by atomic absorption spectroscopy. Data generated were analyzed for average, confidence interval at 95% level of significance (95% CI) using the computer program SPSS statistical software 17.0 versions for Windows

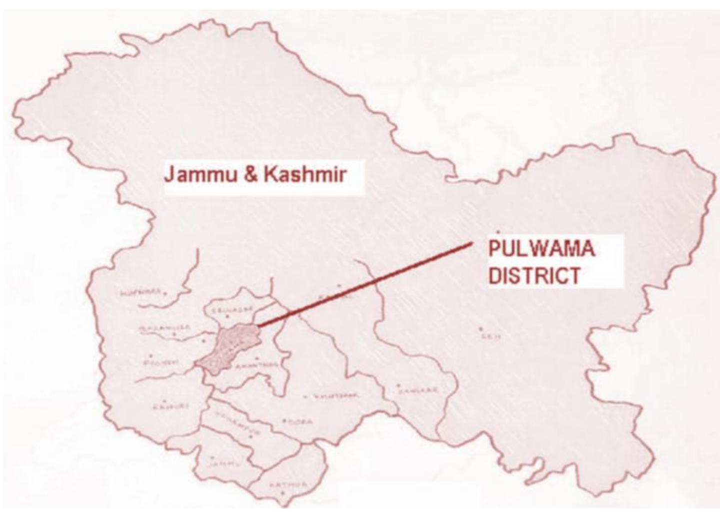

Figure 1 Map of the study area

Results and Discussion

Physico-chemical properties

Although slightly acidic to slightly alkaline in nature, soil pH showed significant decline with increase in altitude with statistical range (95% CI) from 6.46 to 7.36 and 7.01to 7.85 in surface and sub-surface horizons respectively and significant increase with depth ($p = 0.0001$) . This significant variation could be attributed to leaching of bases due to higher precipitation level and organic matter gradient [3-15]. The electrical conductivity (EC) (dSm^{-1}) was observed to be in normal range and showed non-significant variation. The organic carbon (OC) in surface soils of pear orchard of high altitude (1.16%) was significantly higher than low altitude (1.07 %) but at par with mid altitude (1.12%) while as significant difference of organic carbon between surface and sub-surface soils ($p = 0.0001$) was recorded. Low temperature and high rainfall favours luxurious vegetation and increase in soil acidity resulting low rate of decomposition or mineralisation consequently leading to accumulation of organic matter in high altitude soils [3-17].

Table 1 Altitude and depth-wise variation of physico-chemical properties of pear orchards

Orchard Location	Depth (cm)	pH (1:2.5)	EC (dSm^{-1})	OC (%)	$CaCO_3$ (%)	CEC ($cmol_c\ kg^{-1}$ soil)
High Altitude (H)						
Tujan (H-1)	0-30	6.60	0.18	1.09	0	12.38
	30-60	6.96	0.22	0.75	0.54	13.78
	60-90	7.22	0.26	0.53	1.26	14.03
Rohmu (H-2)	0-30	6.72	0.13	1.27	0.18	14.02
	30-60	6.98	0.18	0.72	0.76	14.52
	60-90	7.26	0.21	0.40	1.48	15.03
Parigam (H-3)	0-30	6.51	0.18	1.25	0.30	14.24
	30-60	6.95	0.18	0.78	0.90	16.02
	60-90	7.18	0.28	0.5 4	1.66	15.27
Khrew (H-4)	30-60	6.78	0.20	1.04	0.78	12.65
	60-90	7.06	0.35	0.73	1.60	14.02
	48-90	7.21	0.26	0.36	2.28	14.22
Surface	Average	6.65	0.17	1.16	0.31	13.32
	95%CI	6.46- 6.84	0.12-0.22	0.98-1.34	0.22-0.84	11.82-14.82
Sub-surface	Average	7.10	0.24	0.60	1.31	14.61
	95%CI	7.01-7.19	0.19-0.29	0.46-0.74	0.84-1.78	13.97-15.25
Mid Altitude (M)						
Newa (M-1)	0-30	6.62	0.32	1.20	0.96	13.64
	30-60	6.98	0.43	0.80	1.56	16.00
	60-90	7.27	0.46	0.32	2.38	13.41
Bundzoo (M-2)	0-30	6.75	0.26	1.04	0.96	13.20
	30-60	7.20	0.44	0.73	1.74	13.64
	60-90	7.40	0.40	0.30	2.48	14.37
Chakora (M-3)	0-30	6.84	0.40	1.14	0.72	13.04
	30-60	7.30	0.38	0.80	1.46	13.65
	60-90	7.48	0.50	0.36	2.28	13.74
Urcherso (M-4)	0-30	6.95	0.45	1.09	1.32	12.82
	30-60	7.38	0.44	0.70	1.70	13.04
	60-90	7.56	0.52	0.36	2.60	13.12
Surface	Average	6.79	0.36	1.12	0.99	13.17
	95%CI	6.65-6.92	0.23-0.49	1.01-1.23	0.60-1.38	12.62-13.72
Sub-surface	Average	7.32	0.45	0.54	2.02	13.87
	95%CI	7.17-7.47	0.41-0.48	0.35-0.72	1.64-2.40	13.07-14.66
Low Altitude (L)						
Katibug (L-1)	0-30	6.84	0.18	1.09	0.46	13.07
	30-60	7.43	0.35	0.72	0.86	13.26
	60-90	7.58	0.34	0.32	1.42	13.37
Pampore (L-2)	0-30	7.03	0.22	1.04	0.58	12.23
	30-60	7.68	0.39	0.84	0.92	13.08
	60-90	7.75	0.32	0.45	1.26	12.45
Pahu (L-3)	0-30	6.42	0.30	1.06	0.80	12.47
	30-60	7.74	0.45	0.70	1.28	12.52
	60-90	7.92	0.36	0.37	1.65	13.01
Gundbag (L-4)	0-30	7.15	0.38	1.08	1.12	12.51
	30-60	7.78	0.34	0.80	1.32	13.65
	60-90	7.90	0.43	0.52	1.58	12.62
Surface	Average	6.86	0.27	1.07	0.74	12.57
	95%CI	6.35-7.36	0.13-0.41	1.03 -1.10	0.28-1.20	12.00-13.14
Sub-surface	Average	7.72	0.37	0.59	1.29	12.99
	95%CI	7.58-7.85	0.33-0.41	0.42-0.76	1.05-1.52	12.62-13.35
Surface Sub-surface	p-value	0.0001	0.092	0.0001	0.0001	0.006

95%CI = Confidence Interval at 95 per cent

Calcium carbonate though present in meager amounts in most of the pear orchards, was significantly higher in mid altitude than high but statistically at par with low altitude orchards. Significantly higher amount of calcium carbonate ($p = 0.0001$) was recorded in sub-surface horizons especially in the pear orchards of mid (0.99%) followed by low (0.74%) and high (0.31%) altitude zones (**Table 1)**. The higher status might be attributed to calcareous nature of these soils [15-16]. At 95% CI, the overall cation exchange capacity (CEC) ranges from 12.00 to 14.82 and 12.62 to 15.25 $Cmol_c$ kg^{-1} in surface and subsurface soils respectively. CEC was significantly higher in mid altitude soils than low altitude orchards. Significantly higher CEC recorded in sub-surface soils ($p = 0.006$) might be attributed to higher accumulation of clay content resulting from leaching. These results are in agreement with the findings of soils [4-15].

Available macronutrients

Among the available macronutrients, nitrogen in surface and subsurface soils from the statistical range (95% CI) in **Table 2**, indicated significantly higher average value of 400.04 and 268.12 $kgha^{-1}$ respectively in pear orchards located in high altitude than corresponding mid and low altitude orchards. This significant variation with altitude may be attributed to the altitudinal and climatic gradients responsible for the accumulation of higher organic matter content in high altitude soils [17] and significantly higher amounts ($p = 0.0001$) in surface soils than sub-surface soils may result from favourable environmental conditions for higher rate of mineralization at the surface soils and the depletion of nitrogen by crops supplemented through nitrogenous fertilizers. However, phosphorus in surface soils of pear orchards of high altitude showed significantly higher average value of 15.80 kg ha^{-1} than low altitude orchards (12.46 kg ha^{-1}) but statistically at par with mid altitude orchards (14.79 kg ha^{-1}) while as in sub-surface soils of mid altitude it was statistically at par with low altitude orchards. Phosphorus content varied with soil depth significantly ($p=0.0001$). Higher levels of phosphorus of pear orchards at high altitude could be attributed to favourable soil pH and high organic matter status leading to the formation of organophosphate complexes and coating of iron and aluminium particles by humus [17-18]. Potassium showed significant variation with altitude and depth ($p = 0.048$). At 95% CI, significantly higher potassium content (274.06 and 219.57 kg ha^{-1}) in surface and sub-surface soils were recorded in pear orchards of high altitude than corresponding mid and low altitudes. This higher status in high altitudes might be attributed to more intense weathering [16] release of labile K from organic residues and application of K fertilizers [19]. The available calcium revealed non-significant variation with altitude and depth ($p = 0.343$). Higher calcium content (2312.0 and 2284.6 ppm) observed in surface and sub-surface soils in pear orchards of mid altitude could be attributed to either leaching of soluble salts due to rainfall or calcareous nature of the parent material [16 -18]. Available magnesium varied significantly with depth ($p = 0.017$). Significantly higher magnesium was recorded in surface and sub-surface soils (286.24 and 273.37 ppm) of the mid altitude soils. Significantly higher available sulphur was observed (11.13 ppm) in surface soils of pear orchards located in high altitude. Significant variation with depth ($p = 0.0001$) could be attributed due to higher amounts of organic matter content of surface soils. This is supported by the findings of [3] and [17].

Available micronutrients

Among the available micronutrients, zinc in surface and sub-surface soils of high altitude indicated significantly higher amounts with average value of 1.66 and 1.72 ppm respectively (**Table 3**). Zinc content showed significantly decreasing trend with depth ($p = 0.001$) and altitude may thus attributed to the accumulation of high organic matter, the major source of Zn in surface soils. These results are in line with observations of [5-18]. Copper varied significantly in pear orchards of high and mid altitude and significantly ($p = 0.001$) higher average values were recorded in surface (2.46 ppm) than sub-surface (1.48 ppm) soils of pear orchards. This significant decrease in copper content with depth may be attributed to increase in pH which makes it less soluble after oxidation thereby reducing its availability [20-21]. The available manganese in pear orchards showed regular but non-significant decline with altitude and depth. This decrease in manganese content may be attributed to increase in pH which makes it less soluble or insoluble after oxidation hence precipitating it thereby decreasing its availability [21]. Similarly, iron showed non-significant variation with altitude as well as depth although higher average values in surface (59.03 ppm) and sub-surface (37.97 ppm) were recorded in pear orchards of higher altitude. This might be attributed to the greater amounts of organic matter and lower pH favouring conversion to highly soluble forms. These results are supported by the findings of [5-20]. Micronutrient anions of boron and molybdenum observed significant decreasing trend with depth but non-significant variation with altitude. Significantly higher amounts of boron in surface soils (1.53 ppm) of high altitude might be attributed to lower pH and renders its adsorption or sorption on the soil colloid surface thereby improving B availability [22].

Table 2 Altitude and depth-wise variation of available macro-nutrients of pear orchards

Orchard Location	Depth (cm)	N (kg ha^{-1})	P	K	Ca (ppm)	Mg	S
High Altitude (H)							
Tujan	0-30	408.80	17.00	271.44	2114	285.90	9.24
(H-1)	30-60	341.49	13.48	218.72	1890	255.12	10.14
	60-90	205.27	10.78	237.30	2236	260.08	9.38
Rohmu	0-30	414.67	13.14	265.43	2410	275.70	11.78
(H-2)	30-60	320.77	10.31	207.14	2178	280.16	11.02
	60-90	180.70	9.53	226.69	2250	285.27	9.24
Parigam	0-30	394.91	17.20	280.40	2010	278.40	10.65
(H-3)	30-60	335.44	11.60	241.72	2346	260.28	8.46
	60-90	193.08	11.75	190.33	2392	268.04	9.02
Khrew	30-60	381.80	15.85	278.98	2252	264.30	12.15
(H-4)	60-90	349.44	13.79	237.58	2421	269.15	10.01
	48-90	218.81	10.32	197.07	2478	273.72	8.00
Surface	Average	400.04	15.80	274.06	2196	276.04	11.13
	95%CI	376.63-423.44	12.84-18.75	262.99-285.13	1920.7-2472.3	269.1-283.1	9.51- 12.75
Sub-surface	Average	268.12	11.44	219.57	2273.87	268.98	9.41
	95%CI	205.88-330.35	10.17-12.72	203.19-235.95	2119.3-2428.7	260.3-277.6	8.60-10.21
Mid Altitude (M)							
Newa (M-1)	0-30	373.14	15.74	267.37	2148	289.56	11.00
	30-60	279.55	11.30	233.94	1976	278.45	9.66
	60-90	183.90	11.46	195.23	2082	285.78	10.40
Bundzo	0-30	360.46	17.51	250.64	2475	283.65	11.90
(M-2)	30-60	264.14	13.52	219.02	2192	294.20	10.64
	60-90	173.60	10.45	185.35	2276	280.00	9.32
Chakora	0-30	349.08	14.13	257.17	2334	276.94	10.38
(M-3)	30-60	246.40	9.90	227.0	2586	250.25	9.54
	60-90	144.88	8.96	196.63	2658	258.00	8.15
Urcherso	0-30	329.84	11.77	260.12	2290	294.80	10.12
(M-4)	30-60	256.25	9.80	218.98	2122	265.42	9.14
	60-90	160.11	9.91	233.91	2385	274.85	7.46
Surface	Average	353.13	14.79	258.82	2312	286.24	10.85
	95%CI	323.90-382.35	10.91-18.67	247.78-269.85	2097.6-2526.2	274.0-298.5	9.59-12.10
Sub-surface	Average	215.85	10.66	213.76	2284.6	273.37	9.29
	95%CI	169.85-261.92	9.48-11.84	198.04-229.48	2082.3-2486.9	261.2-285.6	8.39-10.18
Low Altitude (L)							
Katibug	0-30	345.36	15.26	255.48	2180	268.74	11.74
(L-1)	30-60	247.41	11.89	219.87	1835	240.10	10.32
	60-90	135.16	9.83	189.52	1922	278.36	10.48
Pampore	0-30	292.88	11.78	260.42	2325	272.54	11.02
(L-2)	30-60	235.64	10.11	226.17	2435	265.05	10.12
	60-90	126.78	9.89	198.96	2130	270.55	9.28
Pahu	0-30	324.48	12.72	246.73	2242	276.35	10.00
(L-3)	30-60	221.54	10.42	202.27	2360	251.70	8.80
	60-90	112.63	9.27	182.23	2494	251.70	7.94
Gundbag	0-30	312.57	10.09	262.42	2430	264.38	10.38
(L-4)	30-60	211.12	9.31	229.24	2605	262.04	9.92
	60-90	106.71	9.45	191.83	2470	253.22	10.18
Surface	Average	318.82	12.46	256.26	2294.25	270.73	10.78
	95%CI	283.90 -353.74	9.02-15.89	245.13-267.39	2188.2-2400.3	262.3-278.9	9.57-11.99
Sub-surface	Average	174.62	10.02	204.89	2281.37	259.09	9.63
	95%CI	124.89-224.28	9.31-10.73	189.83-219.95	2044.0-2518.4	248.9-269.3	8.90-10.36
Surface Sub-surface	p-value	0.0001	0.0001	0.048	0.343	0.017	0.001

95%CI = Confidence Interval at 95 per cent

Table 3 Altitude and depth-wise variation of available micro-nutrients of pear orchards

Orchard Location	Depth (cm)	Zn	Cu	Mn	Fe	B	Mo
		(ppm)					
High Altitude (H)							
Tujan (H-1)	0-30	1.56	2.85	45.15	78.20	1.84	0.38
	30-60	0.74	2.30	38.50	63.90	1.60	0.31
	60-90	0.43	1.70	26.28	50.26	1.12	0.24
Rohomu	0-30	2.0	1.95	38.12	53.04	1.56	0.30
(H-2)	30-60	1.32	1.30	27.48	34.78	1.14	0.25
	60-90	0.66	0.85	16.10	22.80	1.75	0.18
Newa	0-30	1.36	2.72	55.70	61.00	1.04	0.35
(H-3)	30-60	0.74	1.92	48.42	50.12	0.80	0.27
	60-90	0.38	0.88	31.24	36.85	0.64	0.20
Khrew	30-60	1.72	2.72	64.50	43.90	0.70	0.45
(H-4)	60-90	0.95	2.32	33.82	28.82	0.32	0.37
	48-90	0.48	1.74	22.90	16.20	0.90	0.26
Surface	Average	1.66	2.46	50.86	59.03	1.53	0.37
	95%CI	1.25-2.07	1.85-3.07	32.38-69.34	35.88-82.18	0.97-2.09	0.31- 0.43
Sub-surface	Average	1.72	1.48	30.60	37.97	1.03	0.26
	95%CI	0.46-0.97	1.13-1.91	19.43- 41.75	24.70-51.24	0.76-1.30	0.22- 0.30
Mid Altitude (M)							
Newa (M-1)	0-30	1.51	2.53	60.24	65.08	0.92	0.26
	30-60	0.95	1.80	22.08	52.25	0.76	0.19
	60-90	0.54	0.94	16.80	34.40	0.60	0.15
Bundzoo	0-30	1.16	2.43	48.96	46.00	1.35	0.42
(M-2)	30-60	0.82	1.74	45.00	32.80	1.12	0.32
	60-90	0.38	0.83	33.10	17.61	0.85	0.23
Chakora	0-30	1.35	1.84	42.00	57.90	1.64	0.38
(M-3)	30-60	0.78	1.68	33.20	43.02	1.26	0.31
	60-90	0.45	0.75	20.12	25.48	0.85	0.22
Urcherso	0-30	1.71	2.16	33.40	50.10	1.90	0.32
(M-4)	30-60	0.67	1.75	36.18	37.62	1.64	0.23
	60-90	0.32	0.62	25.60	24.70	1.24	0.16
Surface	Average	1.43	2.24	46.15	54.77	1.45	0.34
	95%CI	1.06-1.80	1.75-2.73	28.11-64.18	41.32 -68.22	0.78-2.12	0.27- 0.41
Sub-surface	Average	0.61	1.24	29.01	33.48	1.04	0.23
	95%CI	0.42- 0.80	0.82-1.65	21.04-36.92	27.21-39.75	0.76-1.32	0.19-0.27
Low Altitude (L)							
Katibugh	0-30	0.79	1.64	39.70	40.12	1.24	0.44
(L-1)	30-60	0.46	1.30	29.15	28.20	1.06	0.35
	60-90	0.32	0.78	18.40	17.35	0.88	0.27
Pampore (L-2)	0-30	1.44	1.50	25.80	48.08	0.96	0.28
	30-60	0.86	1.18	18.25	37.45	0.78	0.21
	60-90	0.42	0.75	14.35	25.10	0.65	0.16
	0-30	1.30	1.72	46.50	55.00	1.45	0.34
Pahu	30-60	0.67	1.33	35.25	42.40	1.26	0.25
(L-3)	60-90	0.36	0.86	22.72	27.15	0.95	0.18
Gundbag	0-30	0.96	1.36	52.90	34.20	0.78	0.40
(L-4)	30-60	0.55	1.04	42.26	24.00	0.65	0.34
	60-90	0.34	0.65	28.52	13.45	0.54	0.23
Surface	Average	1.12	1.56	41.22	44.36	1.11	0.36
	95%CI	0.64-1.60	1.30-1.80	22.74-59.69	29.88- 58.82	0.64-1.58	0.29-0.43
Sub-surface	Average	0.50	0.99	26.11	26.89	0.85	0.25
	95%CI	0.34- 0.65	0.81- 1.17	18.20- 34.02	18.94- 34.84	0.65- 1.05	0.20-0.29
Surface Sub-surface	p-value	0.0001	0.0001	0.068	0.343	0.017	0.001

95%CI = Confidence Interval at 95 per cent

Conclusion

In general, almost all soil physico-chemical properties observed significant variation with altitude and depth except presence of soluble salts (EC). Higher status of all the available nutrients barring calcium, magnesium and molybdenum were recorded in the pear orchards located in high altitude followed by orchards in mid and low altitudes. Significant variation with altitude and depth of the nutrients except calcium, magnesium, manganese and iron were remarkable observations recorded during the study. These results demonstrate the potential zones suitable for higher pear production. However, this study demands more attention for advanced spatio-temporal and site-specific nutrient management approaches along the altitudinal gradients for sustainable production.

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