

Micronutrients status and soil physico-chemical characteristics of apple orchards of temperate district Doda, Jammu and Kashmir, India

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Abstract

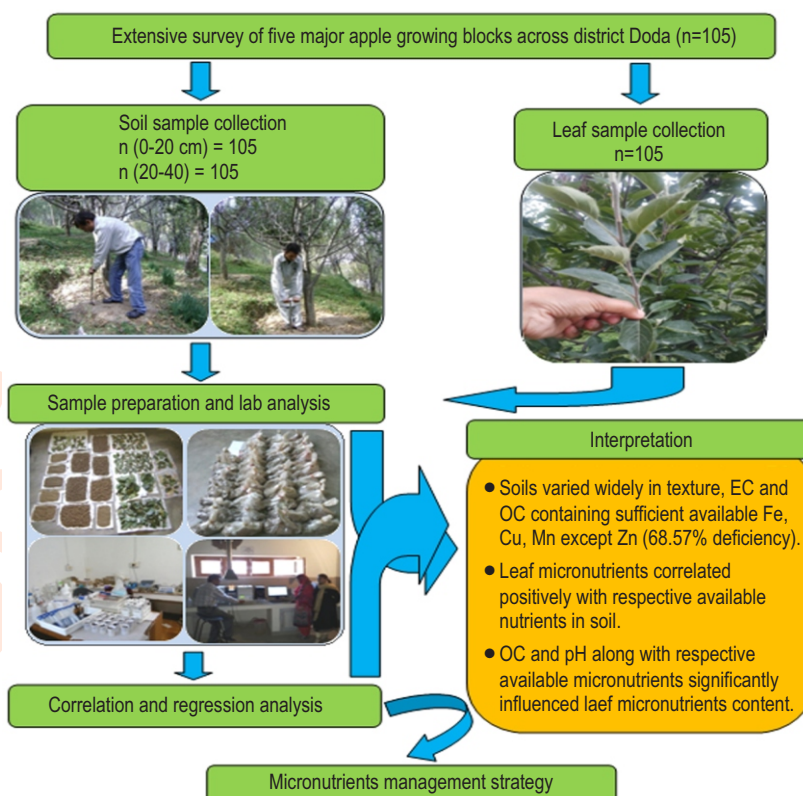
Aim: To evaluate status and establish inter relationship among micronutrients and soil physico-chemical characteristics of apple orchards located in district Doda, Jammu and Kashmir.

Methodology: In an extensive survey, one-hundred and five apple orchards covering five blocks across district Doda were studied for soil physico-chemical characteristics, micronutrients status and their interdependence using standard procedures.

Results: The studied soils varied from loamy sand to clay in texture with organic carbon 1.51%, EC 0.14 dSm⁻¹ and pH range 4.71-8.36 in surface soils. The corresponding values recorded in sub-surface soils were 1.13%, 0.13 dS m⁻¹ and 4.76-8.42. These soils contained sufficient amounts of available Fe, Cu and Mn, about 25% being low in available Zn. Available Zn, Cu and Fe along with soil organic carbon and/or pH could significantly explain about 76, 54 and 55% of total variability in their respective leaf contents. Soil OC and pH explained 26% variability in leaf Mn.

Interpretation: Deficiencies/toxicities of Zn, Cu and Fe in these orchards can be overcome by suitably manipulating their available contents together with soil organic carbon and pH.

Key words: Apple orchards, Correlation coefficients, Jammu & Kashmir, Micronutrients, Temperate region



Introduction

Apple (*Malus domestica* Borkh.) is one of the most important commercially grown temperate fruits in the world. In India, it is the 5th most widely grown fruit crop after mango, citrus, banana and guava. It is mainly cultivated in the states of Jammu and Kashmir, Himachal Pradesh, Uttarakhand, Arunachal Pradesh and Nagaland. Jammu and Kashmir is the largest producer of apple fruit accounting 75% of country's total apple production and 51% of total area under all temperate fruit crops grown in the state. According to the Directorate of Horticulture, Kashmir, area under apple cultivation in Jammu and Kashmir during the year 2021-22 was 168.57 thousand ha with the production of 1898.59 thousand MT fruit. While Kashmir province is the major contributor to the total apple production in the state, Jammu province accounts about 11% of it.

Doda, a hilly district in Jammu province is the leading producer of apples, occupying 5.49 thousand ha area under apple cultivation (38.6% of total area of the district under fruit production) with the fruit production of 2.55 thousand MT. However, despite congenial climatic conditions, the average productivity of commercially grown apple cultivars in the district is low (0.47 t ha⁻¹) as compared to Jammu and Kashmir state as a whole (10-13 t ha⁻¹), which is rated as the highest producer of apples in the country (Wani *et al.*, 2021). Poor nutrient management, in addition to other factors like coarse soil texture, shallow soil depth, steep gradient and rain fed conditions *etc.*, contribute largely towards low productivity of these orchards. Heavy snowfall/rains cause severe nutrients loss through leaching and erosion, further depleting the fertility of these hilly soils. Micronutrients though present in relatively smaller amounts in the soil, play a vital role in crop growth, yield and quality through their involvement in the synthesis of chlorophyll, proteins, lipids, nucleic acids, carbohydrate metabolism and tolerance to stress *etc.* (Barker and Pilbeam, 2015) and are just as important as macronutrients. Unlike major nutrients, plants need micronutrients in relatively smaller amounts.

Likewise, their threshold levels for deficiency, sufficiency and toxicity lie relatively closer to each other and hence, these need to be applied precisely in accordance with the soil/leaf test values to achieve balanced plant nutrition. Nutrient imbalance created by the exclusive use of macronutrient fertilizers in recent times has resulted in the emergence of micronutrient deficiencies in many Indian soils (Shukla *et al.*, 2018). Micronutrient deficiencies have been reported to be one of the major production constraints which affect more than two billion people worldwide (Bailey *et al.*, 2015). In soil-plant system, the bioavailability of micronutrients is profoundly affected by their status and soil physico-chemical characteristics as well as soil depth. Therefore, it is imperative to study the status of micronutrients in soil and plants and their relationship with soil physico-chemical characteristics for better understanding of inherent capacity of soil to supply these elements to plants. There have been few studies on the production and marketing aspects of apple crop

(Ali and Kachroo, 2020; 2023) and nutritional status of soils under different land uses (Alaie *et al.*, 2020; Wani *et al.*, 2023) in and around district Doda. However the information regarding micronutrients in apple orchards of the district Doda is still lacking. Hence, the present study was undertaken to assess the status of available micronutrients and identify important soil characteristics influencing their availability to apple plants in this hilly landscape where drastic changes in soil properties and climatic conditions are expected at relatively shorter intervals.

Materials and Methods

Study area and climate: The present study was conducted in the district Doda that lies between 32°53'-34°21' N latitude and 75°1'-76°47' E longitude in the Eastern part of Indian state of Jammu and Kashmir. It is covered by SOI Toposheet no. 43O/07, 43O/08, 43O/11, 43O/12, 43O/16, 43P/05, 43P/09, 43P/13, 52C/04 and 52D/01 sharing boundaries with districts Anantnag on its north, Kishtwar in the north-east, Chamba in the south, Kathua and Udhampur in the south and south-west, and Ramban in the west. The entire district is hilly having rugged, undulating terrain with more than 85% area as rain fed. Climate of the district ranges from sub-tropical to sub-humid temperate type. The sub-tropical part (below 1000m amsl) is characterized by quite hot and dry summers with scanty rainfall, while the temperate part experiences relatively mild summers receiving significant rainfall during July-September months and remains snow-covered from December-March with cold, wet winters characterized by heavy snowfall (135 mm annually) due to western disturbances. Varied agro-climate and topographic features make it ideal for horticultural development besides traditional hill agro-ecosystem. Apple, pear, plum, peach, apricot, cherry, almond, walnut, persimmon, strawberry and olive are the major temperate fruit crops of the area having commercial potential.

Sample collection, preparation and analysis: An extensive survey of the apple orchards of district Doda was undertaken during 2014 to explore their micronutrients status and soil physico-chemical characteristics. Depending upon productivity, altitude and hill aspect, 105 orchards from major apple growing localities in Bhaderwah, Ghatt, Maramat, Doda and Bhalessa Blocks were selected (Table 1). Leaf samples from selected orchards were collected following the procedure described by Kenworthy (1964). Composite soil samples were also drawn with the help of a steel auger at 0-20 cm (surface soil) and 20-40 cm (sub-surface soil) depth from drip line of the same trees in the month of October/ November. In all, 105 samples each of leaf, surface and sub-surface soils were collected. Leaf samples were sequentially washed with tap water, acidulated water (0.1 N HCl), distilled water, double distilled water and air dried followed by oven drying at 60±5°C till a constant weight was observed. These samples were ground in a stainless steel grinder and digested in di-acid mixture (nitric, perchloric acid in 4:1 ratio). Soil samples were air dried, ground and passed through 2 mm stainless steel sieve, homogenized and placed in labelled cloth bags for further laboratory analysis. Particle size analysis was done by

International Pipette Method (Piper, 1966). Soil texture was determined using textural triangle of International Society of Soil Science. Soil pH in 1:2 soil-water suspension was determined potentiometrically (Hesse, 1971) using a digital pH meter (Cyberscan pH Tutor, range 0.0-14.0±0.01, Eutech Instruments, Singapore) and EC in the same supernatant using a EC bridge (Conductivity Meter 306, range 0.1 µS-200 mS±1%, Systronics, India). Soil organic carbon (SOC) was determined by wet digestion and rapid titration method of Walkley and Black (1934).

Available Zn, Fe, Cu and Mn in soil samples were extracted with a solution of 0.005M DTPA, 0.01M CaCl₂ and 0.1M triethanolamine adjusted to pH 7.3 (Lindsay and Norvell, 1978). The concentration of micronutrients in soil and plant extracts was measured using a polarized Zeeman Atomic Absorption Spectrophotometer (Z-2300, wavelength range 190-900 nm, Hitachi, Japan) with real-time quality control functionality. Precautions were taken to avoid contamination/errors at all stages of sample handling, i.e., collection, preparation, storage and laboratory analyses. Standard operating procedure for micronutrients analysis (like using analytical grade standardised reagents, running proper blanks, frequent calibration of instruments using suitable standards in compliance with specifications, repeated analyses of doubtful samples, random sub-sample replication to ensure precision/ repeatability, observing good laboratory practices etc.) was followed to confirm to the quality protocol.

Statistical analyses: Statistical parameters viz. mean, standard deviation, coefficient of variation (CV) accepted as indicators of central tendency and of data spread, were worked out. Pearson correlation coefficients (r) were computed in order to establish relationship among soil physico-chemical characteristics and micronutrients and supplement the results of regression analysis. Multiple linear regression equations were worked out (Panse and Sukhatme, 1967) between leaf micronutrient content as dependent variable and the soil parameters which can be practically manipulated (pH, SOC and available micronutrients) as independent variables. Step down regression procedure was followed to identify soil variables significantly influencing the leaf micronutrients content. Microsoft Excel-2007 and Fast Statistics v2.0.4 Build 0627 softwares were used for graphical and statistical analyses.

Results and Discussion

The perusal of data related to soil physical characteristics (Table 1) showed that the sand content in surface soils ranged from a minimum of 14.5% in Bhaderwah Block to a maximum of 74.4% in Ghatt Block with an overall mean value of 42.52% across the blocks whereas for sub-surface soils, it ranged between 15.6-75.2% in these respective blocks having an overall mean value of 42.81%. Similar trend was observed with respect to silt content in surface soils that varied from 14.1% in Bhaderwah Block to 49.2% in Ghatt Block with an overall mean value of 28.01%. However, in sub-surface soils, it ranged

between 14.1-49.4% in Ghatt Block having 29.61% as overall mean value. As far as clay is concerned, the distribution pattern observed was opposite to that of sand. Clay content in surface soils varied from a minimum of 5.6% in Ghatt Block to a maximum of 69.9% in Bhaderwah Block with an overall mean value of 29.47% whereas for sub-surface soils, it ranged between 2.8-42.6% in these respective blocks having an overall mean value of 27.57%. Accordingly, the texture of surface soils varied from loamy sand in Ghatt Block to clay in Bhaderwah Block and from loamy sand to silty clay in sub-surface soils of these respective blocks. Pal *et al.* (2024) attributed variations in soil texture to the difference in parent material and influence of pedogenesis.

The perusal of data presented in Table 2 revealed that soil reaction in surface layer varied from 4.71 in Bhalessa Block to 8.36 in Marmat Block and from 4.76-8.42 in sub-surface soils of the same blocks, in order, most of these being ideal for bioavailability of micronutrients. However, the low pH values encountered at one locality in Bhalessa Block might be the result of continuous addition of goat manure (containing high N amounts and hence, high nitrification rates contributing more H⁺ ions) and conifer (*Cedrus deodara* and *Pinus wallichiana*) needles. Coniferous litter (used locally as stall bedding) is known to be carbon-rich and macronutrient-deficient (Givinish, 2002; Carayugan, 2023) lacking in alkali elements (Bloomfield, 1953). Also, the use of recommended ammoniacal fertilizers like urea and DAP, that release H⁺ ions, and sub-humid temperate climate might have led to low pH of these soils. Values of pH for surface soils were recorded lower as compared to those in sub-surface soils. EC values in surface soils varied from a minimum of 0.03 d Sm⁻¹ in Ghatt Block to a maximum of 2.4 dS m⁻¹ in Bhalessa Block with a mean value of 0.14 dS m⁻¹ and from 0.03-2.0 dS m⁻¹ in sub-surface soils of these respective blocks with an overall mean value of 0.13 dS m⁻¹. Low mean EC values observed in Ghatt Block might be due to relatively less retention and more leaching of bases in these coarse textured soils. The soils of the study area were mostly in normal range of EC (<1 dS m⁻¹).

However, the soil with high EC value as found in Bhalessa Block may need appropriate ameliorative measures in view of apple plant being moderately sensitive/slightly tolerant to soil salinity (Galvani, 2007; Rosen *et al.*, 2008). The orchard was often used for grazing and temporary resting of goat herd. Consequently, the addition of goat urine might have contributed to high EC despite low pH. A solution with low pH but high salt content may have higher EC as the dissolved salts can contribute to EC independent of pH. Soil application of goat urine was found to increase extractable Al and decrease soil pH (Ritchey *et al.*, 2008). SOC content in surface soils varied from 0.49% in Ghatt Block to 2.17% in Bhalessa Block and from 0.30% again in Ghatt Block to 1.87% in Bhaderwah Block in sub-surface soils with respective overall mean values of 1.51 and 1.13%. For different blocks, the mean SOC content followed the order: Bhaderwah/ Bhalessa> Thathri> Marmat> Ghatt. SOC content was typically higher in surface soils as compared to that in sub-surface soils which could be due to the fact that organic inputs are generally

Table 1: Important physical characteristics of studied soils

Blocks	Locality	No. of orchards	*Soil depth	Sand	Silt	Clay	Soil texture
				(%)			
Bhaderwah	Dalaian, Atalgarh, Mathola, Sartangal, Sungali, Puneja, Seri, Drudhu, Neota, Bhallara, Dugga, Chhanni	30	a	14.5-69.5 (37.09±3.75)	14.1-44.7 (27.03±1.99)	15.5-69.9 (35.90±2.74)	Sl-C
			b	15.6-68.1 (38.5±3.57)	15.9-47.5 (31.70±2.10)	16.0-42.6 (29.8±1.59)	Sl-Sic
Ghatt	Troun, Shangru, Kotla, Droundi	25	a	15.8-74.4 (48.05±4.23)	15.2-49.2 (28.3±2.23)	5.6-40.0 (23.66±2.18)	Ls-Sicl
			b	15.8-75.2 (47.98±4.23)	14.1-49.4 (28.98±2.25)	2.8-40.0 (23.04±2.15)	Ls-Sicl
Marmat	Humbal, Kasal, Shalta, Roat, Malhori, Goa	10	a	30.4-49.7 (42.99±2.06)	20.1-39.6 (26.06±1.77)	23.2-39.6 (30.96±1.68)	Scl-CI
			b	33.5-49.2 (42.66±1.85)	22.3-38.7 (26.87±1.54)	23.2-38.1 (30.48±1.59)	Scl-CI
Thathri	Chiralla, Thalella, Bhella	12	a	25.7-54.8 (40.97±2.99)	24.1-35.5 (29.81±1.26)	16.1-40.0 (29.22±2.35)	Sl-CI
			b	21.8-54.2 (40.53±3.47)	23.9-39.4 (30.43±1.60)	16.2-40.2 (29.03±2.63)	Sl-CI
Bhalessa	Soti, Changa, Ichher, Chanti, Neeli, Bharati, Goelbad, Tandlah, Bhatyas, Jhakyas, Tilogra, Kilo tran, Kahljugasar	28	a	21.7-54.7 (43.91±2.08)	16.4-39.4 (28.73±1.11)	15.7-40.7 (27.36±1.46)	Sl-CI
			b	21.7-54.7 (43.85±2.07)	15.2-39.9 (28.56±1.11)	15.3-40.1 (27.55±1.47)	Sl-CI
Overall/ Total		105	a	14.5-74.4 (42.52±1.64)	14.1-49.2 (28.01±0.85)	5.6-69.9 (29.47±1.14)	Ls-C
			b	15.6-75.2 (42.81±1.61)	14.1-49.4 (29.61±0.89)	2.8-42.6 (27.57±0.88)	Ls-Sic
SD			a	16.86	8.76	11.70	
			b	16.49	9.11	9.07	
CV (%)			a	39.64	31.28	39.69	
			b	38.53	30.76	32.89	

*a=0-20 cm, b=20-40 cm; Figures in parentheses are mean±SE values; Sl=Sandy loam, C=Clay, Sic= Silty clay, Ls=Loamy sand, Sicl=Silty clay loam, Scl= Sandy clay loam, CI=Clay loam; n=105

highest on the surface. High levels of SOC in these soils are attributable to accumulation of organic matter (OM) under prevailing temperate conditions conducive for its preservation. Similar observations were recorded in apple orchards (Nabi *et al.*, 2020) and agri-horticultural land use in Kashmir (Bangroo *et al.*, 2023). Wide variations observed in physico-chemical characteristics of studied soils as depicted by high CV values (Table 1, 2) might be due to variations in nature and type of parent material, physiographic features (slope, aspect, relief and altitude) and environmental conditions of these hilly soils. Landscape position significantly affects soil characteristics under hilly topography (Betela and Wolka, 2021).

Data pertaining to available micronutrients content (Table 3) revealed that available Zn in surface soils ranged from a minimum of 0.50 mg kg⁻¹ in Ghatt Block to a maximum of 3.60 mg kg⁻¹ in Bhaderwah Block with an overall mean value of 0.97 mg kg⁻¹, whereas for sub-surface soils, it ranged between 0.40-2.90 mg kg⁻¹ in these respective blocks having an overall mean value of 0.76 mg kg⁻¹. Considering 0.6 mg kg⁻¹ as critical level for available

Zn (Takkur and Mann, 1975), 24.76% of the studied surface soils contained low available Zn, mostly in Ghatt Block. Majority of Zn deficient orchards were found in the neglected state as a consequence of absentee farming prevalent in the area. Available Fe in surface soils ranged from a minimum of 4.92 mg kg⁻¹ in Marmat to a maximum of 41.55 mg kg⁻¹ in Bhaderwah Block with an overall mean value of 19.77 mg kg⁻¹.

The corresponding range for sub-surface soils was 4.84-39.20 mg kg⁻¹ for these respective blocks with an overall mean value of 17.35 mg kg⁻¹. Available Cu in surface soils ranged from 0.70 mg kg⁻¹ in Ghatt to 2.86 mg kg⁻¹ in Bhaderwah Block with an overall mean value of 1.17 mg kg⁻¹ whereas for sub-surface soils, it ranged from 0.64 to 2.50 mg kg⁻¹ in these respective blocks with 1.0 mg kg⁻¹ as the overall mean value across the blocks. Available Mn ranged between 11.99-38.57 and 11.20-36.30 mg kg⁻¹ in surface and sub-surface soils of Bhaderwah Block with respective overall mean values of 20.70 and 19.10 mg kg⁻¹. The mean available micronutrient contents observed in the present study were comparable with those reported by Wani *et al.* (2023)

Table 2: Important chemical characteristics of studied soils

Blocks	*Soil depth	pH (1:2)	EC (dSm ⁻¹)	OC (%)
Bhaderwah	a	5.21-7.85	0.04-0.43 (0.13±0.016)	0.69-2.15 (1.59±0.07)
	b	5.30-7.87	0.04-0.36 (0.12±0.015)	0.65-1.87 (1.36±0.06)
Ghatt	a	6.23-7.35	0.03-0.15 (0.08±0.007)	0.49-1.99 (1.15±0.08)
	b	6.25-7.38	0.03-0.12 (0.07±0.005)	0.30-1.54 (0.70±0.05)
Marmat	a	5.92-8.36	0.04-0.22 (0.14±0.02)	0.87-1.83 (1.42±0.11)
	b	5.96-8.42	0.04-0.20 (0.13±0.02)	0.62-1.30 (0.88±0.08)
Thathri	a	6.10-7.65	0.04-0.25 (0.14±0.02)	0.67-1.90 (1.48±0.12)
	b	6.14-7.72	0.03-0.23 (0.14±0.02)	0.59-1.62 (1.19±0.10)
Bhalessa	a	4.71-8.06	0.04-2.4 (0.21±0.08)	1.47-2.17 (1.77±0.04)
	b	4.76-8.10	0.04-2.0 (0.18±0.07)	1.20-1.80 (1.33±0.03)
Overall	a	4.71-8.36	0.03-2.4 (0.14±0.02)	0.49-2.17 (1.51±0.04)
	b	4.76-8.42	0.03-2.0 (0.13±0.02)	0.30-1.87 (1.13±0.03)
SD	a	0.58	0.23	0.41
	b	0.57	0.20	0.39
CV (%)	a	8.49	163.59	27.56
	b	8.37	151.74	34.51

*a=0-20 cm, b=20-40 cm; Figures in parentheses are mean±SE values; n=105

Table 3: Available micronutrients content (mg kg⁻¹) of studied soils

Blocks	*Soil depth	Zn	Fe	Cu	Mn
Bhaderwah	a	0.52-3.60 (1.08±0.15)	6.50-41.55 (18.90±1.61)	0.80-2.86 (1.21±0.09)	11.99-38.57 (22.7±1.14)
	b	0.43-2.90 (0.92±0.12)	6.44-39.20 (17.06±1.52)	0.78-2.50 (1.07±0.07)	11.20-36.30 (19.5±0.94)
Ghatt	a	0.50-1.30 (0.76±0.05)	6.14-27.60 (19.6±0.93)	0.70-1.50 (1.06±0.04)	12.75-15.20 (13.9±0.13)
	b	0.40-1.20 (0.54±0.04)	6.10-26.40 (16.6±0.82)	0.64-1.30 (0.89±0.03)	12.50-14.30 (13.5±0.11)
Marmat	a	0.60-2.00 (1.16±0.17)	4.92-31.40 (18.6±2.86)	0.72-1.90 (1.14±0.13)	19.16-28.07 (23.83±0.96)
	b	0.50-1.68 (0.72±0.11)	4.84-29.70 (16.1±2.71)	0.70-1.82 (1.02±0.12)	20.80-27.30 (23.30±0.79)
Thathri	a	0.62-1.40 (0.96±0.06)	5.15-28.40 (16.6±2.20)	0.72-1.82 (1.32±0.11)	18.73-26.81 (23.16±0.72)
	b	0.58-1.32 (0.84±0.05)	5.0-26.30 (13.8±1.91)	0.68-1.78 (1.03±0.10)	16.52-25.70 (19.98±0.86)
Bhalessa	a	0.81-1.25 (0.96±0.02)	12.50-32.40 (20.64±1.23)	0.75-1.92 (1.15±0.07)	20.64-25.11 (22.38±0.30)
	b	0.65-1.12 (0.78±0.02)	11.92-30.40 (20.25±1.16)	0.71-1.90 (1.0±0.06)	19.50-23.70 (21.58±0.26)
Overall	a	0.50-3.60 (0.97±0.05)	4.92-41.55 (19.77±0.72)	0.70-2.86 (1.17±0.04)	11.99-38.57 (20.70±0.05)
	b	0.40-2.90 (0.76±0.04)	4.84-39.20 (17.35±0.68)	0.64-2.50 (1.0±0.03)	11.20-36.30 (19.10±0.46)
SD	a	0.50	7.40	0.38	5.24
	b	0.40	6.91	0.33	4.69
CV (%)	a	52.26	37.43	32.78	25.31
	b	53.12	39.81	33.21	24.55

*a=0-20 cm, b=20-40 cm; Figures in parentheses are mean±SE values; n=105

for the soils of adjoining district Ramban. Considering 4.5-9.0 mg kg⁻¹ as sufficiency range for available Fe, 0.2 and 1.0 mg kg⁻¹ as respective threshold values for available Cu and Mn (Lindsay and Norvell, 1978), the soils under study contained high amount of these micronutrients, which may be ascribed to the positive effect of high SOC content, favourable pH and the parent material being rich in these minerals. Higher concentration of available micronutrients was recorded in surface soils as compared to sub-surface soils as reported by Dhaliwal *et al.* (2023).

In general, soils of Bhaderwah, Thathri, Marmat and Bhalessa Blocks contained higher mean available Zn, Cu and Mn contents as compared to those in Ghatt Block probably due to better management practices being followed in these blocks. Also, soils in Ghatt Block were relatively coarser in texture with lowest OC content. Sandy soils are characteristically known to be deficient in micronutrients. Soils of Bhalessa Block contained highest mean available Fe (20.64 mg kg⁻¹ in surface and 20.25 mg kg⁻¹ in sub-surface soils), while those of Thathri Block had the least (16.6 mg kg⁻¹ in surface and 13.8 mg kg⁻¹ in sub-surface soils). All available micronutrients showed high CV values both in surface and

sub-surface soils. Variations observed in available micronutrients content might be due to the variations existing in soil physico-chemical characteristics and management practices followed across these hilly blocks. Micronutrients availability is greatly affected by landscape position and land use (Debroy *et al.*, 2020). The perusal of data given in Table 4 revealed that the leaf Zn, Fe, Cu and Mn contents in apple orchards across the blocks ranged from a minimum of 12 mg kg⁻¹ in Thathri to a maximum of 37.5 mg kg⁻¹ in Bhaderwah, 32.3 mg kg⁻¹ in Marmat to 120 mg kg⁻¹ in Bhaderwah, 4.5 mg kg⁻¹ in Ghatt to 16.0 mg kg⁻¹ in Bhaderwah and 26 mg kg⁻¹ in Thathri to 108 mg kg⁻¹ in Bhalessa Block, respectively, with the corresponding mean values of 22.9, 71.8, 8.7 and 61.2 mg kg⁻¹. Orchards in Bhaderwah Block recorded the highest mean leaf Fe (84.4 mg kg⁻¹), Cu (11.1 mg kg⁻¹) and Mn (73.1 mg kg⁻¹) contents whereas Bhalessa Block had the highest mean leaf Zn (24.6 mg kg⁻¹) content. Ghatt Block recorded the lowest mean leaf Zn (20.8 mg kg⁻¹) and Cu (7.4 mg kg⁻¹) contents, while Marmat and Thathri Blocks had the lowest respective leaf Fe (52.5 mg kg⁻¹) and Mn (39.1 mg kg⁻¹) contents. The micronutrient content in leaf varied in accordance with that in soil. Also, the use of micronutrients based agrochemicals by the orchardists might have

Table 4: Leaf micronutrients content (mg kg⁻¹) of studied orchards

Blocks	Zn	Fe	Cu	Mn
Bhaderwah	14.0-37.5 (22.8±1.31)	48.2-120.0 (84.4±4.05)	5.6-16.0 (11.1±0.6)	35.0-105.2 (73.1±4.1)
Ghatt	14.0-32.1 (20.8±1.13)	45.0-100.5 (69.8±3.38)	4.5-12.8 (7.4±0.41)	30.1-98.2 (66.5±4.33)
Marmat	12.9-30.1 (23.8±1.81)	32.3-82.0 (52.5±5.28)	4.9-10.7 (7.7±0.58)	28.2-60.0 (43.3±3.6)
Thathri	12.0-28.3 (22.3±1.38)	35.7-80.0 (59.4±4.02)	5.0-11.5 (8.8±0.59)	26.0-52.2 (39.1±2.57)
Bhalessa	12.7-36.2 (24.6±1.13)	46.4-98.4 (72.2±3.02)	5.1-10.9 (7.7±0.31)	29.8-108.0 (59.4±4.08)
Overall	12.0-37.5 (22.9±0.6)	32.3-120.0 (71.8±1.99)	4.5-16.0 (8.7±0.27)	26.0-108.0 (61.2±2.24)
SD	6.18	20.36	2.80	22.91
CV (%)	27.04	28.36	32.18	37.47

Figures in parentheses represent mean±SE values

contributed to their higher concentrations in leaf and soil as observed by Sharma *et al.* (2019).

Results of correlation analysis (Table 5) revealed that among the studied soil separates, sand showed significant negative correlations with SOC as well as with all micronutrients both in soil and leaf. Conversely, silt and clay fractions exhibited significant positive correlations with these parameters, except for surface silt with leaf Mn where the correlation observed was non-

significant. Higher amount of organic matter provides enhanced stability to soil aggregates thereby resulting in higher clay content (Paul *et al.*, 2018). The clay-humus complex protects the organic matter against oxidation and degradation. Further, surface soil pH exhibited significant negative correlations with all available micronutrients, except for Zn in surface and Mn in sub-surface soils where the observed correlations though negative, failed to achieve the level of significance. Similarly, sub-surface soil pH also had significant negative correlations with all available micronutrients, except of surface soil Zn. Low availability of micronutrients at higher pH may be attributed to the reduction in their solubility. Soil EC showed significant and positive correlations with SOC. Organic matter increases EC of the soil by releasing cations and anions and affects it by adsorption of ions (Kim and Park, 2024). However, it's correlation with soil pH was significant and negative. Low pH due to large number of H⁺ ions in the soil may encourage soil EC (Mohd-Aizat *et al.*, 2014; Adegoke *et al.*, 2022).

Further, significant positive correlations of SOC with all available micronutrients observed in the studied soils are in conformity with those reported by Naskar *et al.* (2021). Decomposition of organic matter releases nutrients, increases intensity of reduction in soil and lowers soil pH that increases the solubility of micronutrient cations. Also, chelating action of organic compounds released during organic matter decomposition helps to augment availability of micronutrients to plants through the prevention of fixation, oxidation, precipitation and leaching. Wani *et al.* (2016) made similar observations for pear orchards of Kashmir. The micronutrients content in leaf and soil were

Table 5: Correlation coefficients among studied soil and leaf parameters

Soil parameters		pH		OC		EC		Leaf parameters			
		a	b	a	b	a	b	Zn	Fe	Cu	Mn
Sand	a	0.22*	0.23*	-0.67**	-0.61**	-0.17	-0.17	-0.75**	-0.74**	-0.72**	-0.36**
	b	0.24*	0.25*	-0.64**	-0.58**	-0.17	-0.17	-0.74**	-0.71**	-0.69**	-0.33**
Silt	a	-0.17	-0.17	0.42**	0.32**	0.11	0.10	0.45**	0.43**	0.36**	0.14
	b	-0.17	-0.18	0.51**	0.45**	0.13	0.13	0.59**	0.63**	0.59**	0.30**
Clay	a	-0.19	-0.21*	0.64**	0.64**	0.16	0.17	0.75**	0.74**	0.77**	0.42**
	b	-0.27**	-0.28**	0.66**	0.59**	0.18	0.18	0.75**	0.67**	0.66**	0.30**
pH	a	1.0	0.99**	-0.06	-0.05	-0.32**	-0.28**	-0.33**	-0.39**	-0.31**	-0.34**
	b	0.99**	1.0	-0.06	-0.05	-0.32**	-0.28**	-0.33**	-0.41**	-0.32**	-0.36**
OC	a	-0.06	-0.06	1.0	0.91**	0.22*	0.23*	0.73**	0.62**	0.56**	0.39**
	b	-0.05	-0.05	0.91**	1.0	0.25*	0.26**	0.59**	0.60**	0.63**	0.37**
EC	a	-0.32**	-0.32**	0.22*	0.25*	1.0	0.99**	0.27**	0.17	0.16**	0.21*
	b	-0.28**	-0.28**	0.23*	0.26**	0.99**	1.0	0.27**	0.16	0.16**	0.20*
Available Zn	a	-0.18	-0.18	0.56**	0.52**	0.18	0.18	0.77**	0.63**	0.67**	0.41**
	b	-0.23*	-0.24*	0.58**	0.61**	0.22*	0.22*	0.75**	0.68**	0.74**	0.47**
Available Fe	a	-0.49**	-0.49**	0.56**	0.42**	0.17	0.17	0.65**	0.60**	0.41**	0.45**
	b	-0.49**	-0.49**	0.57**	0.45**	0.19	0.19	0.64**	0.60**	0.43**	0.46**
Available Cu	a	-0.45**	-0.45**	0.56**	0.52**	0.24*	0.24*	0.70**	0.63**	0.63**	0.46**
	b	-0.45**	-0.46**	0.54**	0.52**	0.31**	0.30**	0.65**	0.60**	0.59**	0.46**
Available Mn	a	-0.22*	-0.21*	0.59**	0.63**	0.17	0.18	0.49**	0.33**	0.48**	0.18
	b	-0.19	-0.21*	0.60**	0.58**	0.18	0.19	0.52**	0.28**	0.39**	0.16

a=0-20 cm, b=20-40 cm; *Significant (p<0.05), **Significant (p<0.01) two tailed; n=105

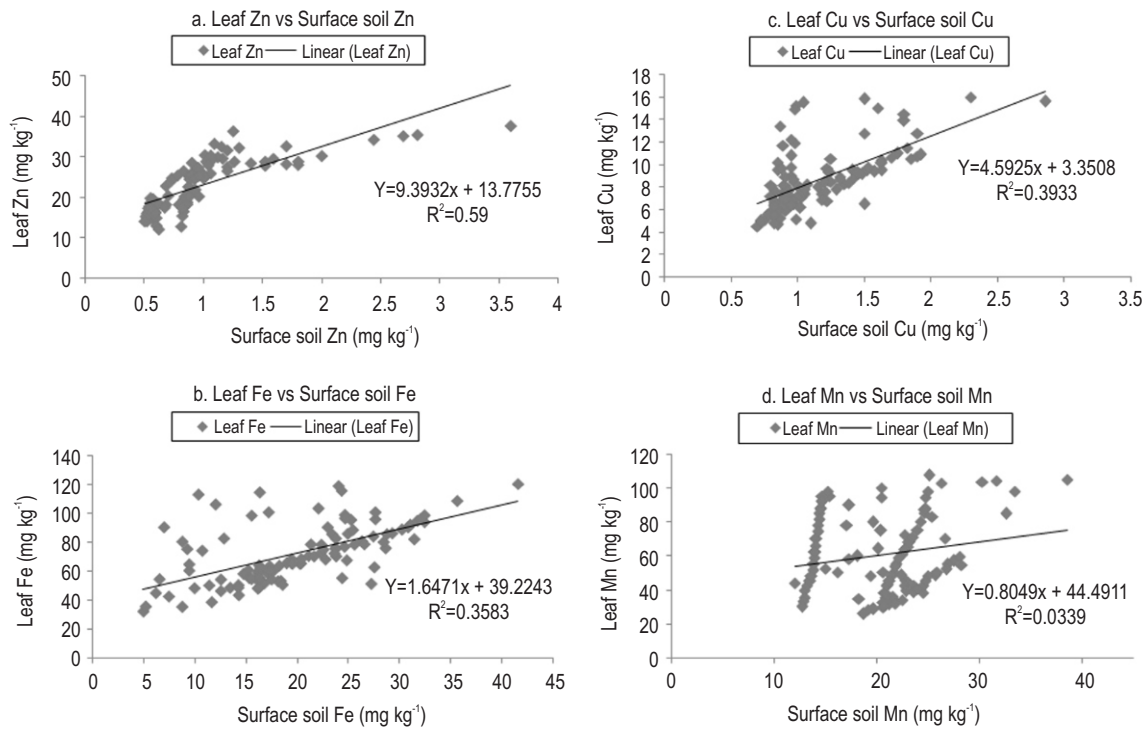


Fig. 1: Relationship between micronutrients content in leaf and surface soils.

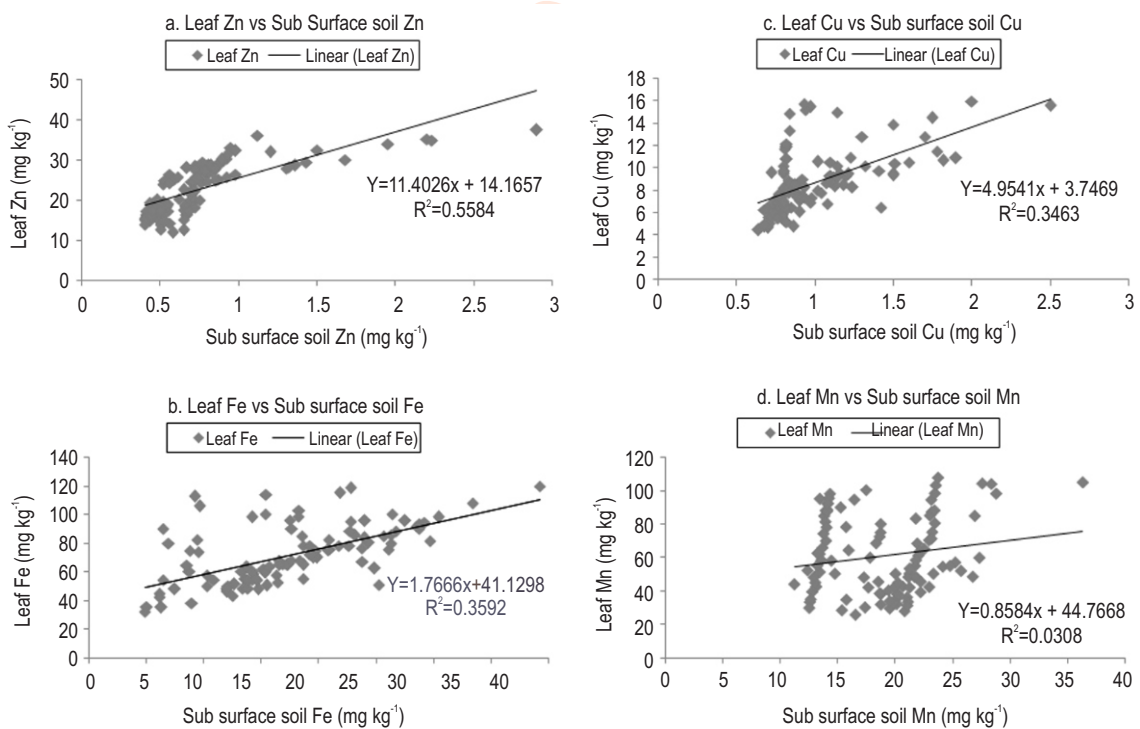


Fig. 2: Relationship between micronutrients content in leaf and sub-surface soils.

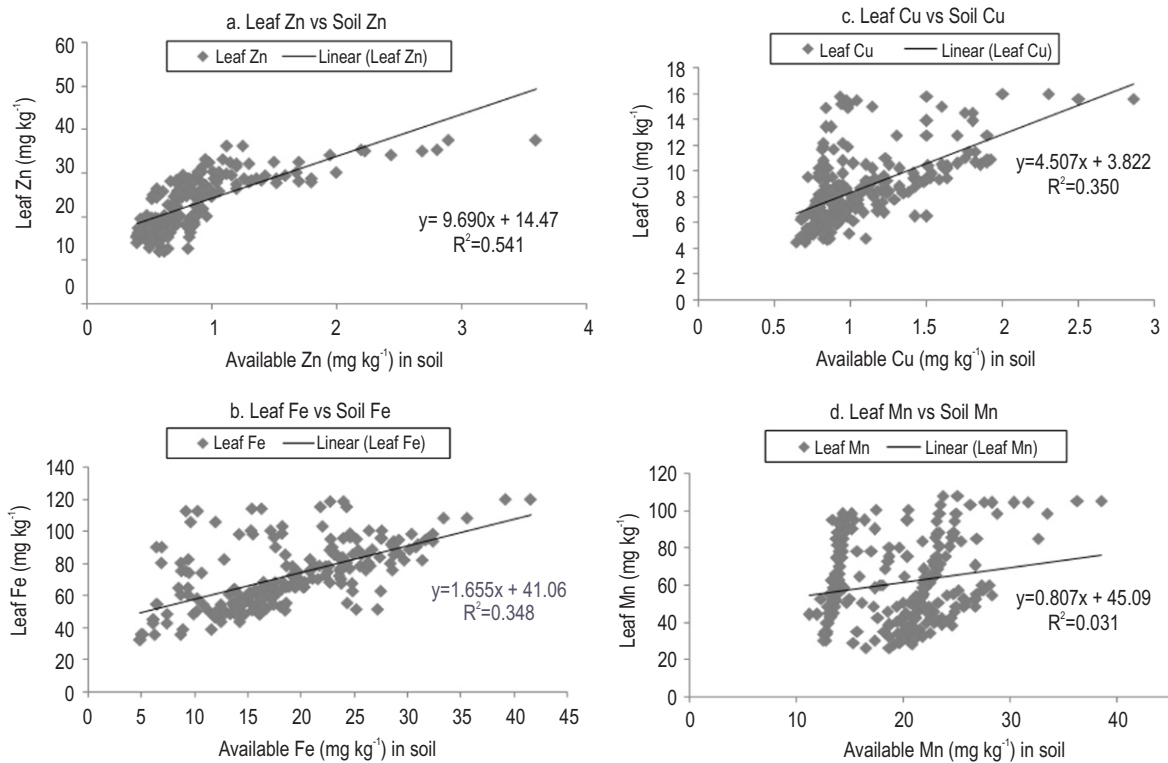


Fig. 3: Relationship between micronutrients content in leaf and soils (surface and sub-surface).

Table 6: Leaf micronutrients content (dependent variable) as influenced by soil factors

Regression equation	Predictability ($R^2 \times 100$)
Surface soils (a=0-20 cm), n=105	
Leaf Zn=23.162-2.343 pH**+6.585 OC**+5.880 Av. Zn**	76.4
Leaf Fe=89.566-9.498 pH**+24.262 OC**+0.514 Av. Fe*	52.4
Leaf Cu=1.749+2.049 OC**+3.321 Av. Cu**	45.5
Leaf Mn=115.812-12.530 pH**+20.215 OC**	24.9
Sub-surface soils (b=20-40 cm), n=105	
Leaf Zn=25.961-2.032 pH**+3.935 OC**+8.404 Av. Zn**	62.3
Leaf Fe=92.200-8.971 pH**+24.635 OC**+0.770 Av. Fe**	54.7
Leaf Cu=2.136+3.160 OC**+3.007 Av. Cu**	48.9
Leaf Mn=130.250-13.434 pH**+20.493 OC**	24.9
Surface (a) and sub-surface (b) soils, n=210	
Leaf Zn=5.672+14.71 OC(a)**-10.286 OC(b)**+8.681 Zn(b)**	75.7
Leaf Fe=88.408-8.704 pH(b)**+24.703 OC(b)**+0.771 Fe(a)**	55.5
Leaf Cu=7.552-0.762 pH(b)**+3.251 OC(b)**+2.333 Cu(a)**	53.6
Leaf Mn=121.61-13.24 pH(b)**+20.188 OC(a)**	26.0

Zn, Fe, Cu, Mn (mg kg^{-1}), OC (%); *Significant ($p < 0.05$), **Significant ($p < 0.01$) two tailed

significantly and positively inter-correlated, except for Mn. Regression analysis revealed available Zn, Cu and Fe to be significant predictors of their respective contents in leaf with R^2 values of 0.59, 0.39, 0.36, in order, for surface soils (Fig. 1); 0.56,

0.35, 0.36 for sub-surface soils (Fig. 2); and 0.54, 0.35, 0.35 while considering both surface and sub-surface soil depths (Fig. 3). However, available Mn with R^2 value of 0.03 was found to be a poor indicator of leaf Mn content. Further, the step down

regression equations (Table 6) revealed that in surface soils, the contribution of pH and organic matter to the total variability in leaf Zn was about 76% along with available Zn and to that in leaf Fe was about 52% along with available Fe. About 45% of total variability in leaf Cu could be attributed to organic matter and available Cu together, while nearly 25% of that in leaf Mn could be attributed to pH and organic matter together in surface soils. For sub-surface soils, however, the corresponding values were about 62, 55, 49 and 25%. Soil pH and SOC directly affect the forms and availability of Zn, Fe, Cu and Mn in soils (Mohiuddin *et al.*, 2022). When considered irrespective of soil depth, the respective predictability values improved to about 76, 55, 54 and 26%. This showed the importance of sub-surface soil nutrition in addition to surface soils in case of perennial crops like apple having deep and ramified root system, drawing a part of its nutrient requirement from sub-surface layers of soil, as well.

Apple orchard soils of district Doda had wide variations in physico-chemical characteristics. Application of organic matter especially to soils with high pH, may prove beneficial in maintaining soil health by lowering pH towards 5.5-6.5, the optimum range for apple plant growth. These soils were sufficient in available Fe, Cu and Mn, about 25% being low in available Zn due to poor orchard management. SOC and pH along with respective available micronutrients (except Mn) were identified as significant predictors of leaf micronutrient content. The study also highlighted the significance of sub-surface soil nutrition in apple cultivation. Information generated may be helpful to the orchardists of the district for judicious micronutrient management to obtain higher yield and quality of apple crop.

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References

- Adegoke, T.O., Tae-il Moon and Hyun-Hwoi Ku: Ammonia emission from sandy loam soil amended with manure compost and urea. *App. Biol. Chem.*, **65**, 83 (2022).
- Alaie, T.A., R. Gupta and V. Sharma: Spatial distribution of available micronutrient status under different land use systems of district Doda, J&K. *J. Soil Water Cons.*, **19**, 317-321 (2020).
- Ali, J. and J. Kachroo: Marketing analysis of the commercial cultivars of apple in mountainous and inaccessible areas of Chenab valley. *Indian J. Econ. Dev.*, **16**, 239-246 (2020).
- Ali, J. and J. Kachroo: Bottlenecks in production and marketing of apple in mountainous and inaccessible areas of Chenab valley. *Agric. Sci. Dig.*, **43**, 675-680 (2023).
- Bailey, R.L., K.P. West Jr. and R.E. Black: The epidemiology of global micronutrient deficiencies. *Ann. Nutr. Metabol.*, **66**, 22-33 (2015).
- Bangroo, S.A., M.I. Bhat, J.A. Wani, R. Rasool, S.S. Madhi, O. Bashir and T.I. Shah: Mapping soil properties using geostatistical methods for mid to high altitude temperate zone of Kashmir Himalayas. *J. Indian Soc. Soil Sci.*, **71**, 1-12 (2023).
- Barker, A.V. and D.J. Pilbeam: Handbook of Plant Nutrition. 2nd Edn., CRC Press, USA, pp. 305-564 (2015).
- Betela, B. and K. Wolka: Evaluating soil erosion and factors determining farmers' adoption and management of physical soil and water conservation measures in Bachire watershed, southwest Ethiopia. *Environ. Challen.*, **5**, 100348 (2021).
- Bloomfield, C.: A study of podzolization part I- The mobilization of iron and aluminium by scots pine needles. *J. Soil Sci.*, **4**, 5-16 (1953).
- Carayugan, M.B., J.Y. An, S.H. Han and B.B. Park: Litterfall and element fluxes in secondary successional forests of South Korea. *Ecol. Indic.*, **156**, 111096 (2023).
- Debroy, P., R.K. Jena, P. Ray, S. Bandyopadhyay, S. Padua, S.K. Singh and S.K. Ray: Vertical distribution of cationic micronutrients across landscape positions on Meghalayan plateau in the North-Eastern region of India. *J. Environ. Biol.*, **41**, 1089-1098 (2020).
- Dhaliwal, S.S., V. Sharma, A.K. Shukla, J. Kaur, R.K. Gupta, V. Verma, M. Kaur, V.K. Singh and P. Singh: Interactive effect of land use systems on depth-wise soil properties and micronutrients minerals in North-Western India. *Heliyon*, **9**, e13591 (2023).
- Galvani, A.: The challenge of the food sufficiency through salt tolerant crops. *Rev. Environ. Sci. Biotechnol.*, **6**, 3-16 (2007).
- Givinish, T.J.: Adaptive significance of evergreen vs. deciduous leaves: Solving the triple paradox. *Silva Fenn.*, **36**, 703-743 (2002).
- Hesse, P.R.: A Text Book of Soil Chemical Analysis. John Murray Pub. Ltd., UK, 520 pages (1971).
- Kenworthy, A.L.: Fruit, Nut and Plantation Crops, Deciduous and Evergreen- A Guide for Collecting Foliar Samples for Nutrient Element Analysis. Horticulture Dept., Michigan State University, USA, pp. 1-39 (1964).
- Kim, H.N. and J.H. Park: Monitoring of soil EC for the prediction of soil nutrient regime under different soil water and organic matter contents. *Appl. Biol. Chem.*, **67**, 1 (2024).
- Lindsay, W.L. and W.A. Norvell: Development of DTPA soil test for zinc, iron, manganese and copper. *Soil Sci. Soc. Am. J.*, **42**, 421-428 (1978).
- Mohd-Aizat, A., M.K. Mohamad-Roslan, W.N.A. Sulaiman and D.S. Karam: The relationship between soil pH and selected soil properties in 48 years logged-over forest. *Int. J. Environ. Sci.*, **4**, 1129-1140 (2014).

- Mohiuddin, M., M. Irshad, S. Sher, F. Hayat, A. Ashraf, S. Masood, S. Bibi, J. Ali and M. Waseem: Relationship of selected soil properties with the micronutrients in salt-affected soils. *Land*, **11**, 845 (2022).
- Nabi, B.B., S. Chand, M.A. Dar and K. Farooq: Physico-chemical properties of apple orchard (Red Delicious) soils of Ganderbal district. *Chem. Sci. Rev. Lett.*, **9**, 1026-1032 (2020).
- Naskar, P., D.K. Das and D. Ghosh: Distribution of cationic micronutrients in relation to different soil properties and fractions of phosphorus in coastal soils of West Bengal. *J. Indian Soc. Soil Sci.*, **69**, 147-155 (2021).
- Pal, D., M.K. Sharma, R.S. Garhwal and Dinesh: The pedospheric variation in physico-chemical properties of guava growing soils in North-East Haryana. *J. Indian Soc. Soil Sci.*, **72**, 249-259 (2024).
- Panase, V.G. and P.V. Sukhatme: Statistical Methods for Agricultural Workers. 2nd Edn., ICAR, New Delhi, pp. 100-135 (1967).
- Paul, O.O., B.S. Sekhon and S. Sharma: Spatial variability and simulation of soil organic carbon under different land use systems: Geostatistical approach. *Agrofor. Syst.*, **92**, 1-10 (2018).
- Piper, C.S.: Soil and Plant Analysis. Hans Publishers, India, pp. 223-237 (1966).
- Ritchey, K.D., D.G. Boyer, K.E. Turner and J.D. Snuffer: Goat urine and limestone affect nitrogen and cation distribution in an acidic grassland. *Soil Sci. Soc. Am. J.*, **72**, 626-633 (2008).
- Rosen, C.J., P.M. Bierman and R.D. Eliason: Soil Test Interpretations and Fertilizer Management for Lawns, Turf, Gardens and Landscape Plants. University of Minnesota Extension, USA, 44 pages (2008).
- Sharma, P., M. Singh and S.K. Bhardwaj: Effect of management practices on soil nutrient status of apple orchards in Kullu district of Himachal Pradesh. *Int. J. Econ. Plants*, **6**, 150-155 (2019).
- Shukla, A.K., S.K. Behera, A. Pakhre and S.K. Chaudhari: Micronutrients in soils, plants, animals and humans. *Indian J. Fert.*, **14**, 30-54 (2018).
- Takkar, P.N. and M.S. Mann: Evaluation of analytical methods of estimation of available zinc and response of applied zinc in major soil series of Ludhiana, Punjab. *Agrochimica*, **19**, 420-430 (1975).
- Walkley, A. and I.A. Black: An examination of the degtjareff method for determining soil organic matter, and a proposed modification of the chromic acid titration method. *Soil Sci.*, **37**, 29-38 (1934).
- Wani, M.H., A. Bhat and S.H. Baba: Economic evaluation of high density apple (ex-ante) in Kashmir. *Int. J. Fruit Sci.*, **21**, 706-711 (2021).
- Wani, O.A., K.R. Sharma, V. Sharma, S.S. Kumar, S.S. Mahdi, S.A. Bangroo and A.R. Malik: Digital mapping of micronutrients in soils of Ramban district of J&K using Geographic Information System. *J. Soil Water Cons.*, **22**, 135-141 (2023).
- Wani, S.A., G.R. Najjar, F. Akhter, M.A. Wani, M. Sajad and R. Rasool: Micronutrient indexing of pear orchards of Pulwama district in Jammu and Kashmir, India. *Bio. Biotech. Res. Asia*, **13**, 2303-2306 (2016).