



Impact of Various Cropping Systems on the Status and Distribution of Selected Micronutrients in Subtropical Region of Himachal Pradesh, India

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Globally, the majority of farmers use various cropping systems. In order to increase the production of food grains, the adaptation of these cropping systems necessitates intensive cultivation, which eventually calls for a greater quantity of macronutrients as well as micronutrients. The availability of micronutrients is greatly influenced by cropping practices, their distribution by profile and chemical pools, and their accessibility to plants. Many crops can reach beneath the soil layers and access the micronutrients with their deep roots, which they require to grow. The present study was conducted to quantify the impact of different cropping systems on DTPA extractable micronutrients viz., Zn, Fe, Cu, and Mn over time. Soil samples were collected from the surface layer (0-15 cm) of four cropping systems *i.e.*, cereal-cereal (CC), cereal-oilseed (CO), vegetable-vegetable (VV), and fodder-fodder (FF). The micronutrient cations were found highest under the VV cropping system

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when compared with all four cropping systems. The results illustrate that availability of micronutrients is affected by the presence of high organic carbon content and favourable soil reaction.

Keywords: Cropping system; micronutrients; soil organic carbon.

1. INTRODUCTION

Micronutrients play a crucial role in preventing micronutrient deficiencies in humans and improving crop yields and sustainability of crop production. Due to the global soil micronutrient deficiency, harvested grains lacking in Zn, Fe, Mn, and Cu have a negative impact on both animal and human health. Micronutrient deficiencies also limit sustainable crop yields. According to Welch and Graham [1], the high consumption of cereals deficient in micronutrients has an impact on roughly half of the world's population who live in developing nations. The status of DTPA-extractable micronutrients in soil varies significantly under various nutrient management techniques along with changes in the fundamental chemical characteristics of the soil, including pH, cation exchange capacity, and soil organic carbon [2]. For instance, iron deficiency causes about 800,000 deaths annually and zinc deficiency affects over two billion people worldwide [3].

Cropping systems and fertilization have an impact on micronutrients in the soil and as well as on crops [4]. Micronutrients accumulate along with macronutrients as a result of crop practices like incorporation of crop residue in soil. On the other hand, when crop residues are burned, some nutrient losses happen via volatilization [5]. Micronutrient addition through commercial fertilizer is not well documented and is frequently ignored, whereas micronutrients are primarily added to the soil through organic amendments like manure and green manures. Farmyard manure (FYM), according to numerous studies, boosts the availability of soil micronutrients [4]. On the other hand, excessive FYM application may cause Zn to precipitate with PO_4^{2-} , H_2PO_4^- , or HPO_4^{2-} anions and reduce the mobility of Zn in soil. The dynamics of micronutrient availability to crops change with pH changes, changes in soil organic matter (SOM), nutrient interactions, and nutrient responses to long-term fertilization [6]. As an illustration, increased soil pH reduces the availability of Cu, Zn, and Fe as a result of precipitation [7]. Application of organic matter increases the amount of micronutrients in available and exchangeable form. The

redistribution of micronutrients within soil systems is caused by differences in the concentrations of micronutrients in the horizontal and vertical directions [8].

Naturally, nutrient status in soil varies significantly over time and space due to management (uneven fertilizer application, natural deposition or occurrences), environmental factors (temperature and precipitation), and their availability is dependent on interactions with other soil nutrients [9]. Despite the crucial roles that micronutrients play in agriculture and human nutrition, little is known about how agricultural practices affect the dynamics of micronutrients in soil and plant system [10]. Therefore, it is crucial to investigate how agricultural management practices affect the availability of micronutrients and their accumulation in commonly consumed food crops.

After taking into the account of the aforementioned contexts, the current study has been conducted to address the goal: to investigate the impact of prevailing cropping systems on the availability of soil micronutrient cations (Zn, Cu, Fe, and Mn) and their relationships with pH and electrical conductivity of soil.

2. MATERIALS AND METHODS

2.1 Site Description

The geographical setting of Hamirpur district lies between latitudes $31^\circ 52'$ and $31^\circ 58'$ North and longitudes $76^\circ 13'$ and $76^\circ 44'$ East with an elevation range of 400 to 1,232 metres above mean sea level in subtropical region of the state representing a typical slopy and undulating topography, and surrounded by the middle and upper Shivalik ranges, which have the most delicate ecosystems [2]. The district covers 1,118 km^2 of land. Its neighboring districts are Mandi to the east, Bilaspur to the south, Una to the west, and Kangra to the north. Hamirpur and Kangra are separated by the River Beas, which is the parent river of the two tributaries Maan and Kunah that run along either side of the Hamirpur district [11].

2.2 Sample Collection and Analysis

One hundred and ninety two surface (0 – 15 cm) soil samples were collected from different cropping systems of Bamson, Bijhari, Bhoranj, Hamirpur, Nadaun and Sujampur block of Hamirpur district of Himachal Pradesh, India during 2021. Four cropping systems *i.e.*, cereal-cereal (CC), cereal-oilseed (CO), vegetable-vegetable (VV), and fodder-fodder (FF) cropping systems were selected on the basis of preliminary survey of the study area. Eight farmers per cropping system per block who were following the same system in more than 400 m² area and have completed three to five years of same cropping system were selected randomly for this study. Soil pH and electrical conductivity (EC) were determined by the standard procedure given by Jackson (1973). Soil organic carbon (SOC) content was estimated using wet digestion method [12]. DTPA extractable micronutrient cations (Zn, Cu, Fe and Mn) were extracted by using the method suggested by Lindsay and Norvell [13] and determined using atomic absorption spectrophotometer. Descriptive statistic was performed to compare different sites. Correlation study was conducted among different parameters of soil to compare their relativeness using ORIGIN, 2018 window version.

3. RESULTS AND DISCUSSION

3.1 General Soil Properties

Data on soil pH, EC and organic carbon are presented in Table 1. Soil pH under different cropping system varied from 6.55 to 7.48, 6.50 to 7.48, 6.65 to 7.51 and 6.50 to 7.46 with mean values of 7.03, 6.93, 7.13 and 6.91 under cereal – cereal, cereal – oilseed, vegetable - vegetable and fodder - fodder cropping system, respectively. Mean soil pH value was found little higher under vegetable – vegetable cropping system as compared to other cropping systems of the district, this could be due to less base leaching and the moderating impact of organic matter, which reduces the activity of exchangeable Al³⁺ ions in soil solution via chelation [14] and the production of aluminophosphate complexes. Similar results on the moderating influence of farm yard manure on soil pH were also reported by Pathak et al. [15] and Urkurkar et al. [16]. Coefficient of variation for all the cropping systems was recorded as 4.55, 4.47, 4.06 and 4.48 per cent under cereal – cereal, cereal – oilseed, vegetable – vegetable

and fodder – fodder cropping systems, respectively which signifies that the soil pH varied spatially. The soils of Hamirpur district under different cropping systems were found to be neutral in reaction. Similar findings of soil reaction in Central Himalayas of Himachal Pradesh were also reported by Chandel et al. [17] and Suri (2018) also reported similar soil pH ranges in different areas of Himachal Pradesh.

Mean electrical conductivity was found to be comparatively higher (0.225 dS m⁻¹) under vegetable – vegetable cropping system over other cropping systems of the Hamirpur district. High variability in EC was found in fodder – fodder (13.6%) followed by vegetable – vegetable (13.3%), cereal – oilseed (11.6%) and cereal – cereal (10.2%) and showed that electrical conductivity varied spatially. The data on electrical conductivity of the examined soils revealed that none of the cropping systems have a salinity problem. Electrical conductivity values were under normal range may be ascribed to leaching of salts to lower horizons of soil due to light texture. According to Richard [18], an EC value of less than 0.8 dS m⁻¹ is considered normal and suitable for all crops, and in this present study, the EC ranges from 0.102 to 0.292 dS m⁻¹, which is relatively safe for cultivation. A little higher salt buildup, as demonstrated by EC values (0.225 dS m⁻¹) was seen under vegetable - vegetable cropping systems, which could be attributed due to frequent fertilizer applications. The results clearly showed that there was no salinity risk. Shi et al. [19] and Ammari et al. [20] found similar results for soil electrical conductivity. Similar values for electrical conductivity were observed in different areas of Himachal Pradesh by Kyandiah [21], Chandel et al. [17].

Mean organic carbon content of soil was found comparatively higher in vegetable - vegetable cropping system as compared to the other cropping systems. Cropping system affects organic carbon content of soil due to changes in inputs of nutrients, water, biomass addition and tillage [22,23]. Higher organic carbon content in vegetable – vegetable cropping system may be attributable to more frequent additions of FYM and more biomass addition [24,25]. Comparatively lower organic carbon content in other cropping systems might be due to less amount of biomass addition [26]. Pal et al. [27] and Biswas et al. [28]. Similar values of organic carbon were also reported by Kumar [29] under different cropping systems of Himachal Pradesh.

Table 1. Status of soil pH, EC and available micronutrients in various cropping systems

Soil parameters		Mean	Range	SD	CV%
pH	C-C	7.03	6.55 - 7.48	0.32	4.55
	C-O	6.93	6.50 - 7.48	0.31	4.47
	V-V	7.13	6.55 - 7.51	0.29	4.06
	F-F	6.91	6.50 - 7.46	0.31	4.48
EC (dS m ⁻¹)	C-C	0.195	0.13 - 0.25	0.02	10.20
	C-O	0.172	0.11 - 0.21	0.02	11.60
	V-V	0.225	0.13 - 0.29	0.03	13.30
	F-F	0.147	0.10 - 0.20	0.02	13.60
SOC (g kg ⁻¹)	C-C	11.10	8.40 - 14.70	1.59	14.32
	C-O	9.55	6.70 - 13.50	1.57	16.44
	V-V	14.05	9.50 - 19.20	2.08	14.80
	F-F	7.96	5.10 - 11.70	1.57	19.70
Available Zn (mg/kg)	C-C	1.84	1.24 - 3.23	0.45	24.45
	C-O	1.55	1.17 - 2.75	0.35	22.58
	V-V	2.05	1.32 - 3.51	0.52	25.36
	F-F	1.26	0.85 - 2.36	0.28	22.22
Available Fe (mg/kg)	C-C	10.04	7.52 - 12.32	1.05	10.45
	C-O	9.19	6.89 - 11.22	0.95	9.79
	V-V	10.84	8.60 - 12.74	1.07	9.87
	F-F	8.38	6.87 - 11.14	1.04	12.41
Available Cu (mg/kg)	C-C	1.17	0.68 - 2.18	0.37	31.62
	C-O	0.94	0.58 - 1.65	0.26	27.65
	V-V	1.39	0.91 - 2.32	0.34	24.46
	F-F	0.78	0.52 - 1.52	0.21	26.92
Available Mn (mg/kg)	C-C	2.25	1.39 - 3.16	0.39	17.33
	C-O	1.90	1.25 - 2.59	0.32	16.84
	V-V	2.64	1.68 - 3.52	0.40	15.15
	F-F	1.55	1.10 - 2.03	0.24	15.48

3.2 Distribution of Micronutrients

Descriptive statistics of DTPA-extractable Zn, Fe, Cu and Mn in soils is presented in Table 1. The content of Zn in soil varied widely from 1.24 – 3.23 mg kg⁻¹ (mean 1.84 mg kg⁻¹), 1.17 – 2.75 mg kg⁻¹ (1.55 mg kg⁻¹), 1.32 - 3.51 mg kg⁻¹ (2.05 mg kg⁻¹) and 0.85 - 2.36 mg kg⁻¹ (1.26 mg kg⁻¹) under cereal – cereal, cereal – oilseed, vegetable – vegetable and fodder – fodder cropping systems, respectively (Fig. 1). The highest zinc content in vegetable – vegetable cropping system might be the result of favorable soil pH which increased solubility due to high desorption and low adsorption [30]. The distribution showed wide variability among all cropping systems.

Percent distribution of DTPA – extractable zinc content under cereal – cereal cropping system most (95.83%) of the soil samples were in medium category and few (4.17%) fall under high category of zinc availability. In cereal – oilseed cropping system, all (100%) the samples reported to fall under medium category of availability. In vegetable – vegetable cropping

system, 91.67 per cent of soil samples were reported in medium category and 8.33 per cent soil samples under high category. In case of fodder – fodder cropping system 87.50 and 12.50 per cent fall under medium and high category, respectively. The coefficient of variation was found to be 24.45 for cereal – cereal, 22.58 for cereal – oilseed, 25.36 for vegetable – vegetable and 22.22 per cent for fodder – fodder cropping system indicating the spatial variability of DTPA extractable zinc in Hamirpur district.

Relatively high availability of Zn in vegetable – vegetable cropping systems may also be closely associated with SOC content and more favourable soil reaction. This is in agreement with the findings of Biswas et al. [28], Chandel et al. [17] in soils of Himachal Pradesh.

3.3 DTPA Extractable Iron

Average content of available iron was 10.04 mg kg⁻¹ (7.52 - 12.32 mg kg⁻¹), 9.19 mg kg⁻¹ (6.89 - 11.22 mg kg⁻¹), 10.84 mg kg⁻¹ (8.60 - 12.74 mg kg⁻¹) and 8.38 mg kg⁻¹ (6.87 - 11.14 mg kg⁻¹)

under cereal – cereal, cereal – oilseed, vegetable – vegetable and fodder – fodder cropping systems, respectively (Fig. 2).

The percent sample distribution under cereal – cereal cropping system shows that 54.17 per cent of the soil samples were in medium category and 45.83 per cent fall under high category. In cereal – oilseed cropping system,

79.17 per cent of the samples reported to fall under medium category and 20.83 per cent soil samples were in high category. In vegetable – vegetable cropping system, 68.75 and 31.25 per cent of soil samples reported under high and medium category, respectively. In case of fodder – fodder cropping system, 87.50 and 12.50 per cent fall under medium and high category, respectively.

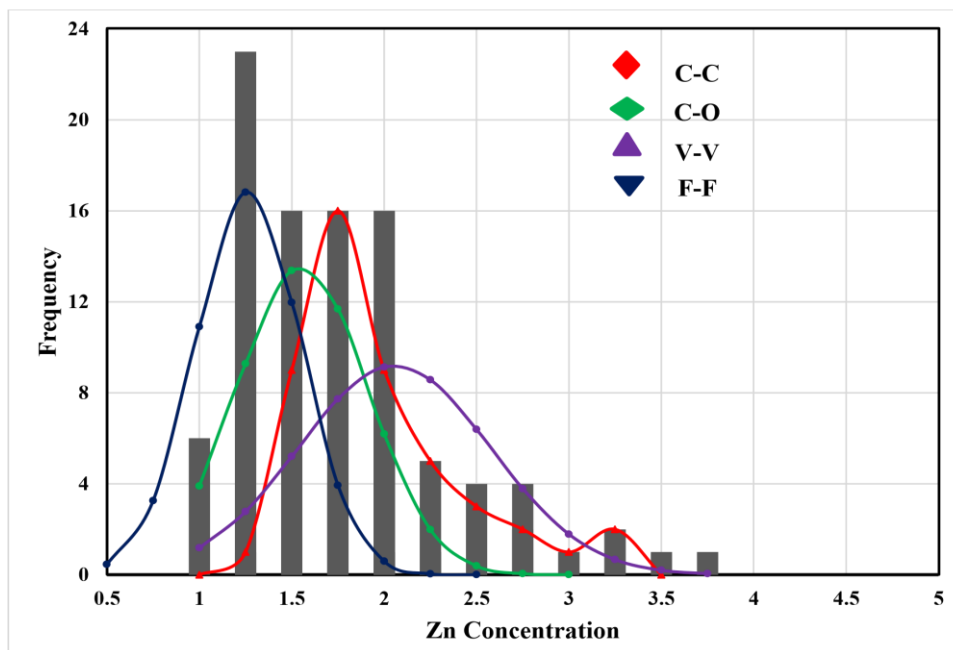


Fig. 1. Frequency distribution of Zinc under prevalent cropping system

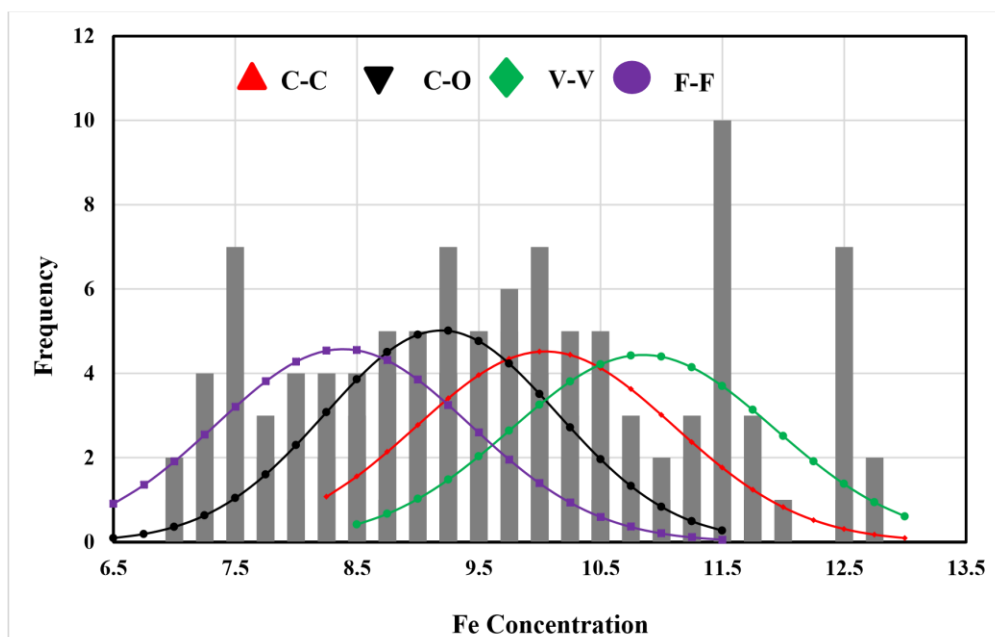


Fig. 2. Frequency distribution of Iron under prevalent cropping system

Coefficient of variation was observed as 10.45 for cereal – cereal, 9.79 for cereal – oilseed, 9.87 for vegetable – vegetable and 12.41 for fodder – fodder cropping systems indicating spatial variability of DTPA extractable iron content in the district. Higher mean extractable Fe content was recorded under vegetable – vegetable cropping systems which might be due to higher organic carbon content which might have resulted in higher production of complexing agents which promoted better extractability of Fe in these soils. Sidhu and Sharma [31] reported similar results in the soils of Indo-Gangetic plains of India. Similar results were also reported by Kumar [29] under different cropping systems of Himachal Pradesh.

3.4 DTPA Extractable Copper

Wide variability of the copper content was found indicating differences in management practices adopted by farmers for different cropping systems. A range of from 0.68 to 2.18 mg kg⁻¹ with an average of 1.17 mg kg⁻¹, 0.58 to 1.65 mg kg⁻¹ with average value of 0.94 mg kg⁻¹, 0.91 to 2.32 with mean value 1.39 mg kg⁻¹ and 0.52 to 1.52 mg kg⁻¹ with average value 0.78 mg kg⁻¹ under cereal – cereal, cereal – oilseed, vegetable – vegetable and fodder – fodder cropping systems, respectively (Fig. 3).

Percent distribution of DTPA extractable copper in soil samples was medium to high in copper content in soil samples under all the cropping

systems. In cereal – cereal cropping system, 81.25 per cent of soil samples were in high category and 18.75 per cent were reported in medium category of copper availability. In case of cereal – oilseed cropping system, 64.58 per cent of soil samples recorded under high category and 35.42 per cent of soil samples fall under medium category of copper availability. All the soil samples (100%) under vegetable – vegetable cropping system reported high category of copper availability. In fodder – fodder cropping system, 68.75 and 31.25 per cent of soil samples reported medium and high category of copper availability, respectively.

The coefficient of variation was reported as 31.62 per cent for cereal – cereal, 27.65 per cent for cereal – oilseed, 24.46 per cent for vegetable – vegetable and 26.92 per cent for fodder – fodder cropping system which specifies the spatial variability of DTPA extractable copper in the Hamirpur district. Higher organic carbon may be the reason for higher DTPA extractable copper content in vegetable – vegetable cropping system, because copper forms copper-humus complex of relatively high stability with humus that decreases its susceptibility to fixation or precipitation in the soil. Chandel et al. [17] also observed application of Blitox (copper containing fungicide used for controlling diseases in vegetables) as one of the reasons for comparatively higher copper content.

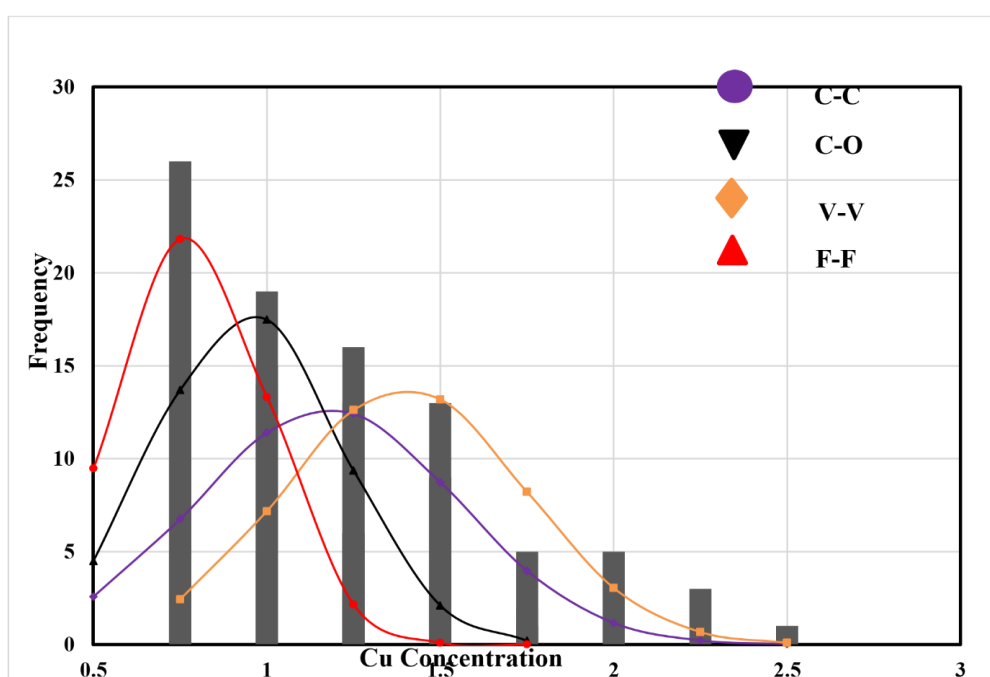


Fig. 3. Frequency distribution of Copper under prevalent cropping system

3.5 DTPA Extractable Manganese

The manganese content varied from 1.39 to 3.16 mg kg⁻¹ (2.25 mg kg⁻¹) 1.25 to 2.59 mg kg⁻¹ (1.90 mg kg⁻¹) 1.68 to 3.52 mg kg⁻¹ (2.64 mg kg⁻¹) and 1.10 to 2.03 mg kg⁻¹ (1.55 mg kg⁻¹) under cereal – cereal, cereal – oilseed, vegetable – vegetable and fodder – fodder cropping systems, respectively (Fig. 4). Higher mean manganese content was found in vegetable – vegetable cropping system which could be attributed to greater organic matter content accumulation as a result of root biomass integration and a large amount of leaf litter as soil organic matter is known for enhancing the Mn availability to the crop plants [32]. The coefficient of variation was recorded as 17.33 per cent for cereal – cereal, 16.84 per cent for cereal – oilseed, 15.15 per cent for vegetable – vegetable and 15.48 per cent for fodder – fodder cropping systems which

directs the spatial variability of DTPA extractable manganese content in soils of Hamirpur district under different cropping systems. All the soil samples under cereal – cereal and vegetable – vegetable cropping system reported high level of manganese availability however, 93.75 and 6.25 per cent of soil samples under cereal – oilseed cropping system had high and medium Mn availability, respectively. In fodder – fodder cropping system, 68.75 per cent of soil samples recorded under high category and 31.25 per cent of soil samples were in medium category of Mn availability. The critical observation of the data revealed that soils rich in organic carbon are less prone to Mn deficiency [33]. In the present investigation, most of the soil samples falls under medium availability of manganese. Similar values of DTPA extractable manganese were also observed by Behera and Shukla [34] and Kumar et al. [35] in soils of Himachal Pradesh.

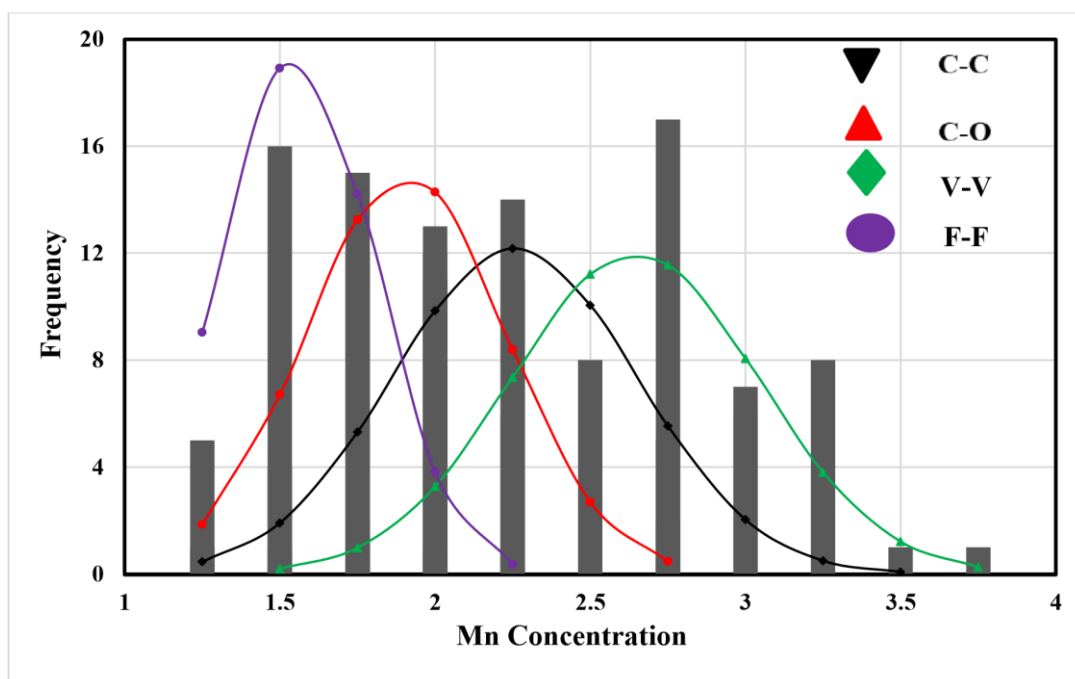


Fig. 4. Frequency distribution of Managense under prevalent cropping system

Table 2. Correlation of micronutrients

Parameters	pH	EC	OC	Zn	Fe	Cu	Mn
pH	1	0.213**	0.505**	0.138**	0.160**	0.232**	0.171**
EC		1	0.346**	0.377**	0.438**	0.413**	0.593**
OC			1	0.426**	0.555**	0.536**	0.598**
Zn				1	0.494**	0.448**	0.498**
Fe					1	0.433**	0.482**
Cu						1	0.554**
Mn							1

*. Significant at the 0.05 level; **. Significant at the 0.01 level

The statistical significance and Pearson's correlation coefficient amongst the soil factors presented in Table 2 indicated significant interaction among the soil micronutrients. Soil organic carbon also showed significant and positive correlation with the DTPA extractable zinc (0.426**), iron (0.555**), copper (0.536**), manganese (0.598**). Similar findings were also reported by Nath and Bhattachayya [36], Gyawali et al. [37], Annepu et al. [32] and Kumar et al. [38].

4. CONCLUSION

The availability of DTPA-micronutrients was shown to be considerably varied among cropping systems in the order VV > CC > CO > FF. Management practices such as addition of FYM, fertiliser application, and other cultural practices used by farmers in vegetable - vegetable cropping systems may have contributed to higher micronutrient availability. The information obtained in this study about the micronutrient status of the soils of the Hamirpur district may be useful in developing an integrated nutrient management schedule for better agricultural practices and long-term soil health sustainability.

CONFERENCE DISCLAIMER

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Welch RM, Graham RD. Breeding for micronutrients in staple food crops from a human nutrition perspective. *Journal of Experimental Botany*. 2004;55(396):353–64.
2. Mehra R, Bala P. Estimation of annual effective dose due to Radon level in indoor air and soil gas in Hamirpur district of Himachal Pradesh. *Journal of Geochemical Exploration*. 2014;142:16-20.
3. Mayer JE, Pfeiffer WH, Beyer P. Biofortified crops to alleviate micronutrient malnutrition. *Current Opinion in Plant Biology*. 2008;11:166–170.
4. Wei X, Hao M, Shao M, Gale WJ. Changes in soil properties and the availability of soil micronutrients after 18 years of cropping and fertilization. *Soil Tillage Res.* 2006; 91:120–130.
5. Biederbeck VO, Campbell CA, Bowren KE, Schnitzer M, McIver RN. Effect of burning cereal straw on soil properties and grain yields in Saskatchewan. *Soil Science Society of America Journal*. 1980;44:103–111.
6. Li B Y, Huang SM, Wei MB, Zhang HL, Shen AL, Xu JM, Ruan, XL. Dynamics of soil and grain micronutrients as affected by long term fertilization in an aquic inceptisol. *Pedosphere*. 2010;20:725-735.
7. Li B Y, Zhou DM, Cang L, Zhang HL, Fan XH, Qin SW. Soil micronutrient availability to crops as affected by long-term inorganic and organic fertilizer applications. *Soil Tillage Research*. 2007;96:166–173.
8. Zu YQ, Gao HW, Fang JY, Yang WL, Li Y. Spatial distribution of Pb, Cu and Zn in periurban market garden soil in Chenggong County, Yunnan Province. *Journal of Agro-Environment Science*. 2010;29:299–307.
9. Bhrigvanshi SR, Adak T, Kumar K, Singh VK, Singh A and Singh V K. 2012. Soil moisture, organic carbon and micronutrient dynamics and their relationship in drip irrigated mango orchard. *Journal of soil and water conservation* 11(4): 316-322.
10. Kumar K, Adak T, Singh VK. Status and distribution of micronutrients in mango orchards under subtropical region of Uttar Pradesh. *Journal of Agricultural Physics*. 2015;15(2):127-139.
11. Kumar S. Environmental awareness among rural folks of Hamirpur district, H.P. *The International Journal of Engineering and Science*. 2013;2:81-84.
12. Walkley A, Black IA. Examination of the method for determining soil organic matter and a proposed modification of the chromic acid titration method. *Soil Science*. 1934;37:9-38.
13. Lindsay WH, Norvell WA. Development of DTPA soil test for zinc, iron, manganese and copper. *Soil Science Society of American Journal*. 1978;42:421-428.

14. Hue NV. Correcting soil acidity of a highly weathered Ultisols with chicken manure and sewage sludge. *Communications in Soil Science and Plant Analysis*. 1992; 23:241-264.
15. Pathak H. Trend of fertility status of Indian soils. *Current Advances in Agricultural Sciences*. 2010;2:10-12.
16. Urkurkar JS, Tiwari A, Shrikant C, Bajpai RK. Influence of long-term use of inorganic and organic manures on soil fertility and sustainable productivity of rice (*Oryza sativa*) and wheat (*Triticum aestivum*) in Inceptisols. *Indian Journal of Agricultural Sciences*. 2010;80:208-212.
17. Chandel S, Tripathi D, Kakar R. Soil health assessment under protective cultivation in North West Himalayas. *Journal of Environmental Biology*. 2017;38:97-103.
18. Richard LA. Diagnosis and improvement of saline and alkali soils. *Agriculture Handbook 60*, US Department of Agriculture, Washington DC. 1954;160.
19. Shi WM, Yao J, Yan F. Vegetable cultivation under greenhouse conditions leads to rapid accumulation of nutrients, acidification and salinity of soils and groundwater contamination in south-eastern China. *Nutrient Cycling and Agroecosystems*. 2009;83:73-84.
20. Ammari TG, Tahhan R, Sulebi NA, Tahboub A, Taany RA, Abubaker S. Impact of intensive greenhouse production system on soil quality. *Pedosphere*. 2015; 25:282-293.
21. Kyandiah R. Impact of different land uses on runoff and nutrient losses in Ga₃ a micro watershed of Giri river in Solan district of Himachal Pradesh. M.Sc. Thesis. Department of Soil Science and Water Management, YSP University of Horticulture & Forestry, Solan. 2012;74 .
22. Mendes LW, Tsai SM, Navararrete AA, Hollander M, Van JA, Kuramae EE. Soil borne microbiome: linking diversity to function. *Microbial Ecology*. 2015;70:255-265.
23. Singh SR, Yadav P, Singh D, Tripathia MK, Bahadur L, Singh S, Mishra A, Kumara S. Cropping systems influence microbial diversity, soil quality and crop yields in Indo-Gangetic plains of India. *European Journal of Agronomy*. 2020;121: 126-512.
24. Chen L, Qi X, Zhang X, Li Q, Zhang Y. Effect of agricultural land use changes on soil nutrient efficiency in agricultural area, Beijing, China. *Chinese Geographical Science*. 2011;21:392.
25. Ryals R, Kaiser M, Torn MS, Berhe AA, Silver WL. Impact of organic matter amendments on carbon and nitrogen dynamics in grassland soils. *Soil Biology and Biochemistry*. 2014;68:52-61.
26. Hajduk E, Wlasniewskis S, Szpunar-Krok E. Influence of legume crops on content of organic carbon in sandy soil. *Soil Science Annual*. 2015;66:52-60.
27. Pal S, Panwar P, DR Bhardwaj. Studies on long term application of fertilizers and manure on yield of maize-wheat rotation and soil properties under rainfed conditions in Western Himalayas. *Journal of the Indian Society of Soil Science*. 2013;50:311-312.
28. Biswas D, Raina JN, Das KK. Assessment of soil health under protected cultivation by soil quality indexing and variability analysis. *International Journal of Current Microbiology and Applied Sciences*. 2017 ;6:2546-2556.
29. Kumar R. Assessment of soil quality under prevalent cropping systems in different agroclimatic zones of Himachal Pradesh. Ph.D. Thesis. Department of Soil Science. CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur, India. 2019; 212.
30. Bradl HB. Adsorption of heavy metal ions on soils and soils constituents. *Journal of Colloid and Interface Science*. 2004;277:1-18.
31. Sidhu GS, Sharma BD. Diethylene triamine penta acetic acid-extractable micronutrients status in soil under a rice-wheat system and their relationship with soil properties in different agroclimatic zones of Indo-Gangetic plains of India. *Communication in Soil Science and Plant Analysis*. 2010;41:29–51.
32. Reisenauer HM. Determination of plant-available soil manganese. In Graham, RD, Hannam R J and Uren N C. (eds.) *Manganese in Soils and Plants*. Kluwer Academic, Dordrecht, The Netherlands. 1988;87–98.
33. Annapu SK, Shirur M, Sharma VP. Assessment of soil fertility status of mid Himalayan region, Himachal Pradesh. *Indian Journal of Ecology*. 2017;44:226-231.
34. Behera SK, Shukla AK. Spatial distribution of surface soil acidity, electrical conductivity, soil organic carbon content

- and exchangeable potassium, calcium and magnesium in some cropped acid soils of India. Land Degradation. 2014;26:71-79.
35. Kumar A, Arshad M, Singh SP, Sepehya S. Macronutrient status and their relationship with leaf nutrient content of Cauliflower (*Brassica oleracea* var. botrytis) growing areas of Kunah river flood planis in Hamirpur, Himachal Pradesh. Journal of Soils and Crops. 2022;32:45-58.
36. Nath TN, Bhattachayya KG. Status of macronutrients (N, P and K) in some selected tea growing soils of Sivasagar district of Assam, India. International Research Journal of Chemistry. 2014;7:12-29.
37. Gyawali C, Dahiya DS, Devraj, Bhat MA, Bhandari RR. Spatial distribution of physico-chemical properties and macronutrients in rice growing soils of Haryana. The Ecoscan. 2016;10:365-370.
38. Kumar G, Mishra B, Kumar R, Agarwal BK, Singh BP. Long-term effect of manure, fertilizer and lime application on active and passive pools of soil organic carbon under maize-wheat cropping system in an Alfisol. Journal of the Indian Society of Soil Science. 2017;59:245-250.

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