Agric Res J **60** (3) : 371-378, *June* 2023
DOI No. 10.5958/2395-146X.2023.00055.8

SOIL MICRONUTRIENT INDEXATION UNDER COTTON-WHEAT AND RICE-WHEAT CROPPING SYSTEMS IN SANGAT BLOCK OF DISTRICT BATHINDA, PUNJAB

Pawandeep Kahlon[1], B K Yadav[2*], Sandeep Sharma[1] and S S Dhaliwal[1]

[1]Department of Soil Science, Punjab Agricultural University, Ludhiana-141004, Punjab
[2]Punjab Agricultural University Regional Research Station, Bathinda-151001, Punjab

ABSTRACT

Micronutrient deficiency is a major concern for sustainable cropping systems, leading to low micronutrient contents in edible plant parts and health problems in human beings as well as animals. For this investigation, the available (DTPA-extractable) micronutrient contents in 100 soil samples collected at 0-15 cm and 15-30 cm depths were studied in cotton-wheat and rice-wheat cropping systems in Sangat block of Bathinda district. Data showed a large variation in DTPA extractable Zn, Cu, Fe and Mn contents in soils under cotton-wheat and rice-wheat systems. Mean micronutrient contents were higher for Cu (2.19 mg kg^{-1}), Fe (3.59 mg kg^{-1}) and Mn (4.87 mg kg^{-1}) under cotton-wheat system compared to rice-wheat system with mean values of 3.13 mg Fe kg^{-1}, 2.11 mg Cu kg^{-1} and 4.37 mg Mn kg^{-1} at 0-15 cm soil depth. The soil nutrient index values (NIV) at 0-15 cm depth were 2.9 for Zn, 3.0 for Cu , 1.2 for Fe, and 1.9 for Mn under cotton-wheat system which indicated that soils were low in Fe, high in Cu, and Zn, and medium in Mn availability. However, at 15-30 cm soil depth NIV for Zn, Cu, Fe, and Mn were 2.7, 2.9, 1.1, and 1.7 respectively, which indicated that soils were high in Zn and Cu, low in Fe, and medium in Mn availability. Similarly, NIV for rice-wheat system at 0-15 cm and 15-30 cm for Zn (2.6, 2.4), Cu (2.8, 2.8), Fe (1.4, 1.3) and Mn (1.3,1.3) indicated that soils were high in Zn and Cu availability, low in Fe and Mn and at both 0-15 cm and 15-30 cm depths. The results clearly indicated soils (0-15 cm layer) under rice-wheat system are deficient in Fe and Mn, while Fe deficiency is more under cotton-wheat system, and highlights the need to apply these micronutrients to sustain the soil fertility and crop productivity.

Keywords: Cotton-wheat, Cropping system, Indexation, Rice-wheat, Soil micronutrient

The micronutrient deficiency has grown both in magnitude and extent because of increased use of high analysis fertilizers, limited use of organic manures, high yielding crop varieties and increased cropping intensity (Sharma *et al.,* 2004). According to Singh (2008) about 49 % of soils are potentially deficient in Zn, 12 % in Fe, 5 % in Mn, 3 % in Cu, 33 per cent in B and in India while, the extent of micronutrient deficiency in Punjab soils for Zn, Fe, Mn and Cu was 49, 17, 3 and 2%, respectively (Nayyar *et al.*,1990). Recently, a significant decrease (11.4%) in the Zn deficiency in soils of Punjab has been reported due to regular application of fertilizers, while Mn deficiency has increased to 26.9% in recent years (Dhaliwal *et al.,* 2020). In arid and semi-arid regions, soils are low in organic matter because of the prevailing climatic conditions and hence its contribution to available pools of Zn, Cu, Mn and Fe is limited (Dhaliwal *et al.,* 2009). A cropping system will be sustainable when it improves or at least maintains soil fertility and environment. A significant amount of soil nutrient mining is reported every year depending upon the cropping system, crop productivity and fertilizer application. The nutrient mining will cause multi nutrient deficiencies and reduce crop yields and quality. The imbalance nutrient and incorrect amounts of chemical fertilizer use is a serious threat to sustainable agricultural production (Dhaliwal *et al.,* 2011). In Punjab, majority of the farmers are following double or triple cropping systems per year and are using large quantities of high analysis fertilizers, insecticides, pesticides in order to get maximum gross returns without taking into consideration the soil fertility status. Bathinda district is lying in the south-western part of Punjab, popularly known as cotton belt, is progressively shifting towards rice-wheat system from the cotton-wheat system. Using satellite based remote sensing data along with spatial and non-spatial collateral data, Panigrahy *et al.* (2004) reported an increased in area under rice-wheat rotation. The area under rice has increased at the expanse of cotton as well as other minor crops, mainly because of clearing of sand dunes which were brought under cultivation with the expansion of irrigation facilities.

Soil test-based fertility management is an effective tool for increasing productivity of agricultural soils (Goovaerts, 1998), which helps in applying balanced amounts of different nutrients for profitable crop

*Corresponding author : bkyadav74@pau.edu
Date of receipt: 12.03.2022, Date of acceptance: 15.06.2022

production (Motsara, 2002). Although cotton-wheat and rice-wheat cropping systems are highly profitable in terms of economic yield, so far it has negative agro-ecological impacts. The information regarding micronutrient availability in soil under cotton-wheat and rice-wheat cropping system at block level in south-western region of Punjab is limited. Thus, there is an immediate need to study the effects of cropping system on micronutrient availability in soils. The present study was therefore, carried out with objective of soil micronutrient indexation under cotton-wheat and rice-wheat cropping systems in district Bathinda of Punjab.

MATERIALS AND METHODS

Location of study area

Bathinda district of Punjab is lying between 29º30' and 32º32' N latitudes, 73º55'and 76º55' E longitudes. The climate of the area is characterized by a large seasonal variation as well as fluctuations both in monthly rainfall and temperature. The annual normal rainfall of this region is about 436 mm, 80 percent of which is received during the south-western monsoon season (first week of July to mid- September) and the remaining during the winter season. The soil sampling sites in different villages of Sangat block (30°211′ latitude and 74°945′ longitude) are situated in Bathinda district of Punjab, India.

Collection of soil samples

GPS based 100 soil samples each were collected from surface (0-15 cm) and sub-surface (15-30 cm) layers from cotton-wheat and rice-wheat fields from different villages in Sangat block, Bathinda, Punjab.

Chemical analysis of soils

The soil samples were air dried, passed through 2 mm sieve and preserved in a polythene bag for laboratory analysis. Available micronutrients (Fe, Cu, Zn and Mn) in soil samples were determined using the procedure of Lindsay and Norvell (1978). The extracting solution consisted of 0.005 M DTPA (diethylene triamine penta-acetic acid), 0.01 M $CaCl_2$ and 0.1 M TEA (Tri ethanol amine) buffer adjusted to pH 7.3. Concentration of micronutrients in the extract was determined by atomic absorption spectrophotometer. Fertility status of zinc, iron, copper and manganese interpreted as deficient, sufficient and excess by the criteria given in Table 1.

Calculation of nutrient index value (NIV)

Nutrient Index in order to compare the levels of soil fertility of one area with those of another, it is necessary to obtain a single value for each nutrient. Here the Nutrient Index (NI) was calculated by following formula suggested by Parker *et al.* (1951).

Nutrient Index (NI) = ((Nl× 1) + (Nm × 2) + (Nh × 3))/ Nt

Where Nt =Total number of samples analyzed fora given soil depth.

Nl = Number of samples falling in low category of given nutrient.

Nm = Number of samples falling in medium category of given nutrient.

Nh= Number of samples falling in high category of given nutrient.

Nutrient index values below 1.5, in between 1.5 to 2.5 and above 2.5 are considered as low, medium and high, respectively (Motsara, 2002).

RESULTS AND DISCUSSION

Distribution of available zinc in soil

Available zinc (Zn) content under cotton-wheat system ranged from 0.2 to3.9 mg kg^{-1} at 0-15 cm and 0.4 to 3.5 mg kg^{-1} at 15-30 cm depth. At 0-15 cm depth, 37% of soil samples were recorded low, 47% medium and 16% high in Zn content, whereas 56% soil samples collected from sub-surface layer (15-30 cm depth) were low in Zn content, 35% were medium and 9% were high in Zn content (Table 2). The mean value for available Zn content was highest in soil samples collected from Paka Khurd (1.5 mg kg^{-1}) at 0-15 cm and (1.3 mg kg^{-1}) at 15-30 cm depth and it was lowest in village Shergarh at both 0-15 cm depth (0.8 mg kg^{-1}) and 15-30 cm depth (0.6 mg kg^{-1}) (Fig.1). The data on available Zn content in soil under rice-wheat system revealed that Zn content ranged from 0.3-6.3 mg kg^{-1}at 0-15 cm and 0.2-6.1 mg kg^{-1} at 15-30 cm depth across all the

Table 1. Criteria used to categorize available micronutrients into different soil fertility categories

Micronutrients (mg kg^{-1})	Fertility rating of nutrients		
	Low	Medium	High
DTPA extractable Zn	<0.6	0.6-1.2	>1.2
DTPA extractable Cu	<0.2	0.2-0.4	>0.4
DTPA extractable Fe	<4.5	4.5-9.0	>9.0
DTPA extractable Mn	<3.5	3.5-7.0	>7.0

Table 2. Range of soil micronutrients under cotton-wheat cropping system in different villages of Sangat block of district Bathinda

Village	Zn (mg kg^{-1})		Cu (mg kg^{-1})		Fe (mg kg^{-1})		Mn (mg kg^{-1})	
	Range		Range		Range		Range	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
GurusarSaniwala	0.2-3.3	0.2-2.6	1.8-2.7	1.7-2.6	2.3-2.9	1.5-2.2	2.9-5.0	4.0-6.5
Mehta	0.5-2.6	0.4-2.1	0.3-2.9	0.3-2.7	2.3-9.3	1.0-8.3	3.4-11.0	3.2-5.3
Shergarh	1.1-1.6	0.8-1.1	1.3-2.0	1.3-2.4	1.1-5.4	0.8-3.1	0.4-6.4	1.2-5.5
Bhagwangarh	0.4-2.7	0.6-1.6	2.3-2.6	2.1-2.5	2.5-6.0	2.1-5.1	4.5-7.7	3.4-7.6
Malwala	1.3-2.5	1.1-2.1	2.3-3.4	2.0-2.5	2.0-4.7	3.5-4.5	3.4-7.8	2.1-5.5
Dunewala	1.1-1.8	0.9-1.4	0.3-2.4	0.3-2.1	1.3-2.5	1.2-2.1	2.6-5.3	3.8-5.7
Machhana	0.6-2.1	1.0-1.8	1.3-2.6	0.1-2.1	1.0-4.8	1.0-3.0	3.5-9.0	3.2-21.7
Gurthari	0.4-2.8	0.4-2.2	1.5-2.6	1.5-2.1	0.6-5.9	0.7-4.7	1.8-5.4	2.7-3.9
GehriButtar	0.8-1.8	0.5-1.4	0.3-2.3	0.3-2.2	1.4-6.9	1.4-5.6	3.1-9.6	3.6-6.9
Sangat	1.0-2.0	0.8-1.9	1.6-2.7	1.4-2.5	1.8-5.9	1.7-4.3	3.5-6.1	3.2-4.2
Koth Guru	0.4-2.6	0.1-1.9	2.0-2.9	2.1-2.8	2.1-6.0	1.4-5.9	3.2-7.0	2.1-8.8
Mohlan	1.0-3.5	0.9-2.6	1.4-3.1	1.3-2.3	2.0-6.2	1.6-3.6	3.7-6.2	3.1-5.8
JassiBaghi	0.6-2.3	0.4-1.6	1.7-2.5	1.3-2.5	2.2-6.9	1.4-7.2	2.8-4.4	2.9-4.5
Paka Kala	1.4-3.1	1.2-2.3	1.8-2.5	1.2-2.4	2.8-9.9	2.3-9.4	4.4-6.9	3.4-7.0
PakaKhurd	0.4-3.9	0.3-3.5	1.4-2.7	1.2-2.4	1.5-4.3	1.8-5.0	4.3-7.2	4.3-8.8
Sakhu	0.8-2.6	0.3-1.9	2.3-2.9	2.1-2.7	5.5-6.3	5.1-6.1	5.9-8.2	4.8-6.7
Phallar	0.3-1.8	0.6-1.7	1.7-2.8	1.8-2.5	1.5-2.6	1.4-2.4	3.2-6.5	3.1-4.5
Ruldhu Singh Wala	0.7-2.7	0.7-2.3	2.0-2.4	1.8-2.6	1.3-4.4	1.5-3.0	3.4-7.0	6.0-11.4

villages. In the samples collected from 0-15 cm soil layer, 43%, 45% and 12% were recorded low, medium and high in Zn content, respectively. In the sub-surface soil layer (15-30 cm depth), 64%, 29% and 7% samples were low, medium and high in Zn content, respectively (Fig. 3). The mean value for Zn content was highest in village Ghudda at 0-15 cm (3.6 mg kg^{-1}) and at 15-30 cm depth (3.3 mg kg^{-1}) and it was lowest in village Jassi Bagwali at both the soil depths (1.1 mg kg^{-1}at 0-15 cm and 0.9 mg kg^{-1} at 15-30 cm) (Fig. 2). In general, Zn content was reported low to medium in area under study, might be due to low organic matter, because of the prevailing climatic conditions, light soil texture and hence its contribution to available pools of Zn is limited (Dhaliwal *et al.,* 2009). The high doses of application of phosphate fertilizer (~ 104 kg DAP acre^{-1} year^{-1}) there is formation of Zn-phosphate complex of low solubility thus reducing Zn availability (Amara Denis *et al.,* 2016). Sadana *et al.* (2010) reported that 22% of Punjab soils were deficient in zinc. Zinc content was observed to be higher in surface soil than sub-surface soil. Begum *et al.*(2016) reported that total Zn gradually decreased in the lower layers, and as soil pH increased, the solubility and availability of Zn decreased. Yadav *et al.* (2016) studied the Soil fertility status of Punjab Agricultural University seed farm, Chak Ruldu Singh Wala, Sangat, Bathinda, Punjab and reported 3.10 and 1.51 mg kg^{-1} mean Zn at surface (0-15 cm) and sub surface (15-30 cm) soils, respectively. Similarly, higher Zn availability in surface than sub-surface soil under ber orchard under semi aridregion (Yadav *et al.*, 2018) and rice-wheat system (Yadav, 2020)was reported in Bathinda district.

Distribution of available Cu in soil

The copper (Cu) content of soils ranged from 0.3-3.4 mg kg^{-1} at 0-15 cm and 0.1-2.8 mg kg^{-1} at 15-30 cm depth (Table 2). In the cotton-wheat system from 0-15 cm no soil sample was recorded low in Cu, 3% soil samples were recorded as medium and 97% soil samples were higher in Cu content, whereas samples collected from sub-surface soil (15-30 cm) 1% soil sample was low, 3% soil samples were medium and 96% soil samples were recorded highest in Cu content. The mean value for Cu was higher in Malwala (2.7 mg kg^{-1}) at 0-15 cm depth and in Koth Guru (2.4 mg kg^{-1}) at 15-30 cm depth and was lowest in Dunewala (1.6 mg kg^{-1}) at 0-15 cm depth and in Machhana (1.3 mg kg^{-1}) at 15-30 cm depth (Fig. 1). The data on Cu under rice-wheat cropping system (Table 3) revealed that Cu content ranged from 0.3-3.8 mg kg^{-1} at 0-15 cm and 0.2-4.5 mg kg^{-1} at 15-30 cm depth. Similar to cotton-wheat system no soil sample was low in Cu content , 13% samples were recorded

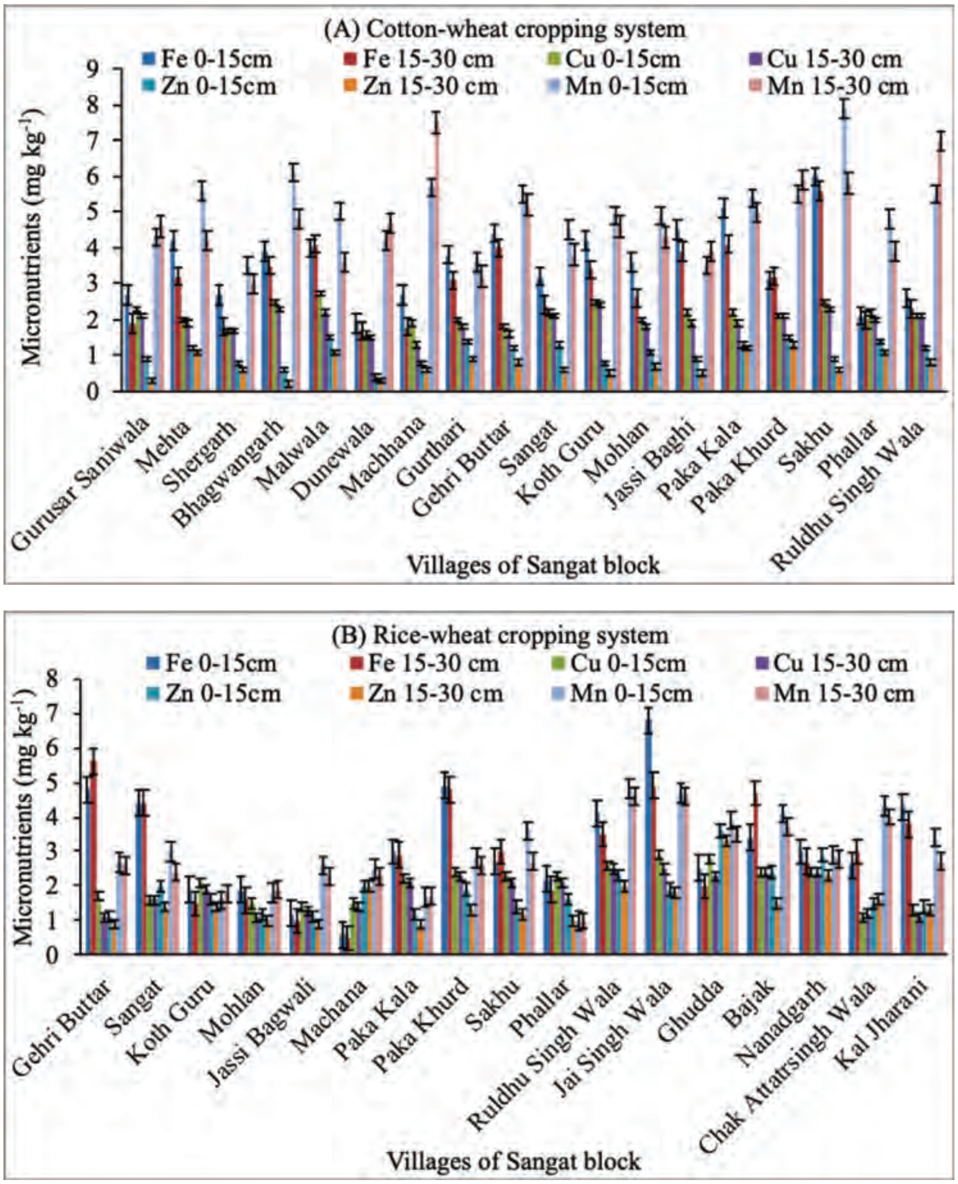

Fig. 1. Mean soil micronutrient availability under (A) cotton-wheat and (B) rice-wheat cropping system in different villages of Sangat block of district Bathinda

medium and 87% samples were highest in Cu content in rice-wheat system in 0-15 cm, whereas samples collected from sub-surface soil (15-30 cm depth) no soil sample was low, 17% soil samples were medium and 83% soil samples were recorded highest in Cu content. The mean value for Cu was highest in Jai Singh Wala (2.9 mg kg^{-1}) at 0-15 cm depth and (2.5 mg kg^{-1}) at 15-30 cm depth and was lowest in Chak Attar Singh Wala (1.1 mg kg^{-1}) at 0-15 cm depth and in Kaljharani (1.1 mg kg^{-1}) at 15-30 cm depth (Fig. 2). In soils of all the villages Cu was observed to be higher due to higher pH, as copper (Cu) availability was positively correlated with soil pH (Yadav, 2011) and frequently use of Cu containing fungicides/ pesticides as their application either to soil or in crops raising their content. Relatively higher Cu in 0-15cm soils than 15-30 cm soils were reported might be due to higher level of organic matter in surface than sub surface soils. The finding are in line with the study of Yadav *et al.* (2016), who reported higher Cu (0.99 mg kg^{-1}) in surface soil than (0.44 mg kg^{-1}) Cu in sub-surface soil under cotton-wheat system. Further, Yadav *et al.* (2018) and Yadav (2020) reported higher DTPA-Cu in surface soils than sub-surface soils under ber orchard and rice-wheat system.

Distribution of Fe in soil

The data on micronutrients under cotton-wheat cropping system represented in Table 2 revealed that

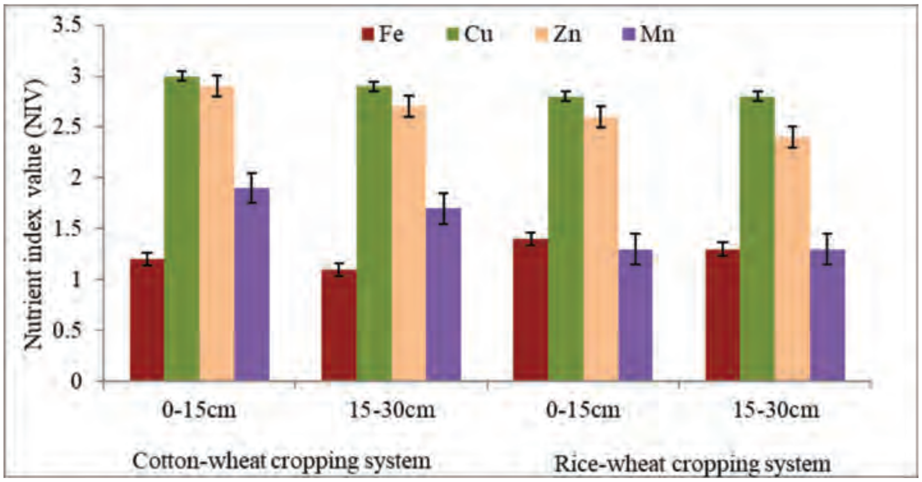

Fig. 2. Mean nutrient index value (NIV) of micronutrients under cotton-wheat and rice-wheat cropping system in Sangat block of district Bathinda

Fe content of soils ranged in all villages from 0.6-9.9 mg kg^{-1} at 0-15 cm and from 0.7-9.4 mg kg^{-1} at 15-30 cm. Samples collected from 0-15 cm, 73% soil samples were recorded low, 25% soil samples were medium and 2% soil samples were high in Fe content, whereas samples collected from sub-surface soil (15-30 cm) 82% soil samples were under low category, 17% soil samples under medium category and 1% soil sample under high category in Fe content. The high mean value for Fe was observed in Sakhu (6.0 mg kg^{-1}) at 0-15 cm and (5.6 mg kg^{-1}) at 15-30 cm and low mean value for Fe was observed in Dunewala (1.9 mg kg^{-1}) at 0-15 cm and (1.7) at 15-30 cm depth (Fig. 1A) . Likewise, the data on Fe under rice-wheat cropping system (Table 3) exposed that Fe content of soils ranged from 0.1-9.9 mg kg^{-1} at 0-15 cm and 0.1-17.5 mg kg^{-1} at 15-30 cm depth. Samples collected from 0-15 cm, 61% soil samples were recorded low, 35% soil samples were medium and 4% soil samples were high in Fe content, while samples collected from sub-surface (15-30 cm) 68% soil samples were under low category, 28% soil samples under medium category and 4% soil samples under high category in Fe content. The high mean value for Fe was observed in Jai Singh Wala (6.8 mg kg^{-1}) at 0-15 cm and in Gehri Buttar (5.6 mg kg^{-1}) at 15-30 cm and low mean value for Fe was observed in Machana (0.6 mg kg^{-1}) at 0-15 cm and (0.5 mg kg^{-1}) at 15-30 cm depth (Fig. 1B). The Fe content was observed low to medium in area under study because of alkaline nature of the soil. For every unit increase in pH, the solubility of cationic micronutrients may decrease from 100-fold for divalent Mn, Cu, and Zn to 1000-fold for trivalent Fe (Rengel, 2001), low to medium organic carbon content and also because of light textured soil (Dhaliwal *et al.,* 2009). Similar results were obtained by Malik *et al.* (2017) where low Fe content was observed because of sandy soil, low organic matter and alkaline pH. According to Sadana *et al.* (2010) 12% Punjab soils were reported to be deficient in Fe. The Fe content was observed to be higher in 0-15 cm soil than 15-30 cm soils, might be due to higher level of organic matter and low pH of 0-15cm soils as compared to 15-30 cm soils. Khan *et al.*(2002) reported higher concentration of total Fe in surface (0–15 cm) as compared to the subsurface layers under rice-wheat system. Yadav *et al.* (2016) reported 11.9 and 5.8mg kg^{-1} mean Fe at surface (0-15 cm) and sub surface (15-30 cm) soils of Punjab Agricultural University seed farm, Chak Ruldu Singh Wala, Sangat, Bathinda. Further, Yadav *et al.* (2018) and Yadav (2020) reported higher Fe in surface (0-15 cm) than sub-surface (15-30 cm) soil of ber orchard and rice-wheat cropping system.

Distribution of Mn in soil

However, Mn under cotton-wheat cropping system represented in Table 2 revealed that Mn content of soils from all the villages ranges from (0.4-11.0 mg kg^{-1}) at 0-15 cm and (1.2-21.7 mg kg^{-1}) at 15-30 cm depth. Samples collected from (0-15 cm) 16% soil samples were recorded low in Mn content, 78% soil samples were medium and 6% soil samples were higher in Mn content whereas samples collected from sub-surface soil (15-30 cm depth) 25%, 74% and 1% soil samples were low, medium and high in Mn content respectively. The mean value for Mn was highest in Sakhu (7.9 mg kg^{-1}) at 0-15 cm depth and in Ruldhu Singh Wala (7.0 mg kg^{-1}) at 15-30 cm depth and the mean value for Mn was lowest in Shergarh and Jassi Baghi (3.5 mg kg^{-1}) and (3.0 mg kg^{-1}) at 0-15 cm and 15-30 cm depth respectively (Fig. 1). The data on Mn under rice-wheat cropping system represented in Table 4 revealed that Mn content of soils from all the villages ranges from (0.1-7.5 mg kg^{-1}) at 0-15 cm and (0.2-7.8 mg kg^{-1}) at 15-30 cm depth. Samples collected from (0-15 cm)

Table 3. Range of soil micronutrients under rice-wheat cropping system in different villages of Sangat block of district Bathinda

Villages	Zn ($mgkg^{-1}$)		Cu ($mgkg^{-1}$)		Fe ($mgkg^{-1}$)		Mn ($mgkg^{-1}$)	
	Range		Range		Range		Range	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
GehriButtar	0.3-3.1	0.2-2.7	0.3-3.8	0.2-2.7	0.2-7.5	0.3-17.5	1.7-4.1	0.7-4.3
Sangat	0.5-2.7	0.5-2.1	0.4-3.0	0.3-3.4	0.2-7.8	0.2-7.6	3.8-5.3	3.6-4.6
Koth Guru	0.5-2.8	0.5-2.3	0.3-3.1	0.3-3.4	0.1-7.9	0.1-6.3	0.1-5.8	0.3-6.5
Mohlan	0.4-1.4	0.3-1.4	0.3-2.0	0.3-1.5	1.3-3.0	1.2-2.5	1.4-2.4	0.9-2.4
JassiBagwali	0.3-1.9	0.2-1.6	0.3-2.4	0.3-2.0	0.4-3.0	0.1-2.9	4.2-7.8	3.9-7.2
Machana	1.2-4.5	1.1-3.3	0.3-1.8	0.3-1.9	0.2-0.9	0.2-0.8	5.5-7.1	5.2-7.0
Paka Kala	0.5-2.2	0.4-1.9	0.3-3.4	0.3-3.1	0.3-6.7	0.2-6.8	0.3-3.0	0.4-3.4
PakaKhurd	0.6-1.8	0.4-1.4	1.8-2.8	2.0-2.5	0.3-9.7	0.2-9.4	4.4-6.7	4.2-5.5
Sakhu	0.4-2.5	0.2-1.9	1.9-3.2	1.2-3.0	0.1-7.4	0.2-10.4	0.3-6.5	0.5-5.1
Phallar	0.5-1.9	0.5-1.3	1.7-3.0	1.6-2.9	0.3-6.4	0.2-5.7	0.3-2.5	0.2-2.7
Ruldhu Singh Wala	0.9-6.1	0.7-6.1	1.7-3.4	1.0-4.5	0.3-8.7	0.2-7.8	5.5-7.4	5.3-6.0
Jai Singh Wala	1.2-2.6	0.5-2.3	1.9-3.6	2.0-4.0	3.5-8.1	2.3-7.3	2.4-7.5	2.3-6.7
Ghudda	0.8-6.3	0.3-6.1	2.2-3.3	2.0-2.8	0.5-9.9	0.2-8.1	5.4-5.6	4.6-5.4
Bajak	1.0-3.8	0.5-3.4	1.8-2.9	2.1-3.3	0.4-9.6	0.3-17.0	4.5-4.8	4.0-7.8
Nanadgarh	1.3-4.0	2.1-2.8	0.3-3.7	0.3-3.9	0.3-6.5	0.3-5.5	0.7-4.6	0.4-4.5
ChakAttatr Singh Wala	0.5-2.4	0.4-1.4	0.3-2.2	0.3-2.5	0.4-4.9	0.2-8.0	4.8-5.5	4.4-4.6
KalJharani	1.0-2.5	0.8-2.3	0.3-2.9	0.3-2.3	0.2-7.0	0.2-6.4	0.3-4.8	0.3-3.6

32% soil samples were recorded low, 64% samples were medium and 4% soil sample was higher in Mn content whereas samples collected from sub-surface soil (15-30 cm) 34%, 64% and 2% soil samples were low, medium and high in Mn content respectively (Table 3). The mean value for Mn was higher in Ruldhu Singh Wala (4.8 mg kg^{-1}) at 0-15 cm depth and (4.6 mg kg^{-1}) at 15-30 cm depth and the mean value for Mn was lowest in Phallar (1.0 mg kg^{-1}) at 0-15 cm and (1.0 mg kg^{-1}) at 15-30 cm depth respectively (Fig. 2).Considering 3.5 ppm as critical limit for DTPA-extractable Mn, 16% and 32% surface (0-15 cm) soil samples were found Mn deficient under cotton-wheat and rice-wheat cropping system. The soils cultivated under rice-wheat cropping system showed more Mn deficiency than soils under cotton-wheat cropping system, due to high Mn uptake by rice plant than cotton plant. Use of micronutrient containing pesticides over the years and addition of micronutrient containing fertilizers could bea reason for high content of these nutrients in soil. Similarly, Sharma *et al.* (2017) studied the status of micronutrients in intensively cultivated potato growing soils of Punjab and reported that majority of the soils contained high to very high contents of micronutrients (Dhaliwal *et al.,* 2012). In surface (0-15cm) soil higher Mn were reported as compared to sub-surface (15-30 cm) soils, as soil pH increase with increase in soil depth, and with increase in pH, divalent form of Mn^{2+} may convert into tri or tetravalent forms (Mn^{3+} or Mn^{4+}), which are water insoluble and hence not readily available to

Table 4. Micronutrient availability under cotton-wheat and rice-wheat cropping systems in Sangat block of district Bathinda

Nutrient (mg kg^{-1})	Cotton-wheat cropping system				Rice-wheat cropping system			
	0-15 cm		15-30 cm		0-15 cm		15-30 cm	
	Range	Mean± SEM	Range	Mean± SEM	Range	Mean± SEM	Range	Mean ± SEM
Zn	0.2-3.9	1.89±0.06	0.4-3.5	1.56±0.05	0.3-6.3	1.87±0.11	0.2-6.1	1.58±0.10
Cu	0.3-3.4	2.19±0.05	0.1-2.8	2.00±0.05	0.3-3.8	2.11±0.06	0.2-4.5	1.95±0.07
Fe	0.6-9.9	3.59±0.17	0.7-9.4	3.04±0.16	0.1-9.9	3.13±0.44	0.1-17.5	3.06±0.57
Mn	0.4-11.0	4.87±0.15	1.2-21.7	4.37±0.13	0.1-6.5	2.54±0.16	0.2-7.8	2.40±0.18

plants. The results are in line with the findings of Yadav *et al.* (2016), who reported higher Mn (7.78 mg kg^{-1}) in surface soil (4.09 mg Mn kg^{-1}) in sub-surface soil under cotton-wheat system. Similarly, higher DTPA-Mn in surface than sub-surface soil of ber orchard under semi-arid region (Yadav *et al.*, 2018) and rice-wheat system (Yadav, 2020) was reported in Bathinda district.

Soil micronutrient availability

The available micronutrient status under cotton-wheat and rice-wheat systems was presented in Table 4. Data showed that available Zn content was at par under cotton-wheat cropping system (1.89 mg kg^{-1}) and rice-wheat cropping system (1.87 mg kg^{-1}) at 0-15 cm depth and also at 15-30 cm depth (1.56 mg kg^{-1} and 1.58 mg kg^{-1}) in cotton-wheat and rice wheat cropping system respectively. Zn content is slightly low in rice-wheat cropping system because of high Na level in this system that lead to Zn leaching as the exchange sites were occupied by Na ions (Alloway, 2008). Available Cu was maximum under cotton-wheat cropping system (2.19 mg kg^{-1}) at 0-15 cm depth and (2.0 mg kg^{-1}) at 15-30 cm depth than rice-wheat cropping system (2.11 mg kg^{-1}) at 0-15 cm depth (1.95 mg kg^{-1}) at 15-30 cm depth because of more use of Cu containing pesticides against diseases and pest thus accumulating more Cu in cotton-wheat cropping system (Sharma *et al.,* 2006). Available Fe was higher under cotton-wheat cropping system (3.59 mg kg^{-1}) than rice-wheat cropping system (3.13 mg kg^{-1}) at 0-15 cm depth but it was at par (3.04 mg kg^{-1} and 3.06 mg kg^{-1}) at 15-30 cm depth respectively. Fe was low under rice-wheat system due to inadequate degree of reduction of Fe oxides under flooding conditions (Nayyar *et al.,* 2001). Available Mn was maximum under cotton-wheat cropping system (4.87 mg kg^{-1}) at 0-15 cm depth and (4.37 mg kg^{-1}) at 15-30 cm depth than rice-wheat cropping system (2.54 mg kg^{-1}) at 0-15 cm depth (2.40 mg kg^{-1}) at 15-30 cm depth. Mn content was reported lowest in rice-wheat cropping system due to leaching of Mn under this system (Lu *et al.,* 2004). Higher DTPA-Mn content was observed in cotton-wheat cropping system followed by sugarcane-sugarcane > pearl millet-wheat > pearl millet-mustard > fallow-mustard > rice-wheat by Narender *et al.* (2016) in Haryana.

Nutrient index value of micronutrients

Nutrient index value (NIV) for micronutrients for cotton-wheat cropping system and rice-wheat cropping system were presented in Fig. 2. Under cotton- wheat cropping system NIV for Zn Cu, Fe, and Mn was 2.9, 3.0, 1.2, and 1.9, which indicated that soils were high in Zn, and Cu, low in Fe, and medium in Mn availability at 0-15 cm. At 15-30 cm depth NIV for Zn, Cu, Fe, and Mn was 2.7, 2.9, 1.1, and 1.7 which indicated that soils were low in Fe, high Cu and Zn and medium in Mn availability. Similarly, NIV for rice-wheat cropping system at 0-15 cm for Zn, Cu, Fe, and Mn2.6, 2.8, 1.3and1.4 which indicated that soils were high in Zn, Cu and low in Fe and Mn availability. Similarly, NIV for Zn, Cu, Fe and Mn was 2.4, 2.8, 1.3and 1.3 showed that soils were medium in Zn, high in Cu, low in Fe and Mn availability at 15-30 cm soil depth. In conclusion, content and distribution of available micronutrients in the soils were affected by cropping system and soil depth.

Authors' contribution

Conceptualization of research work and designing of experiments (PK, BKY, SS); Execution of field/lab experiments and data collection (PK, BKY, SS, SSD); Analysis of data and interpretation (PK, BKY, SS, SSD); Preparation of manuscript (PK, BKY, SS, SSD)

LITERATURE CITED

Alloway B J 2008. *Zinc in soils and crop nutrition* (2nd Ed.). International Zinc Association, Brussels, Belgium, p. 1–139.

Amara Denis M K, Patil P L, Kamara A M and Saidu D H 2016. Assessment of soil fertility status using nutrient index approach. *Int J Food Agric Vet Sci* **6**: 1-15.

Begum K, Hossain M F and Parveen Z 2016. Distribution of zinc fractions in relation to properties of some soils of Bangladesh. *Dhaka Univ J Biol Sci* **25**:19–25.

Dhaliwal S S, Bijay-Singh and Sharma B D 2012. Soil quality and sustainability of cultivated land use system in different watersheds in rainfed region under submontaneous tract of Punjab, India. *Indian J Fertil* **8:**14-21.

Dhaliwal S S, Bijay-Singh, Sharma B D and Khera K L 2009. Soil quality and yield trends of different crops in low productive submontaneous tract and highly productive area in Punjab, India. *Indian J Dryland Agri Res Develop* **24**: 39-45.

Dhaliwal S S, Sadana U S, Sidhu S S and Gurpreet-Singh 2011. Role of cropping systems in amelioration of aggravated micronutrients deficiency in alluvial soils of Punjab. *J Pl Sci Res* **27**: 21-29.

Dhaliwal S S, Shukla A K, Sharma V, Behera S K, Choudhary O P, Chaudhari S K, Prakash C, Kumar A, Patra A K, Sikaniaya Y and Tripathi A 2020. Status of sulphur and micronutrients in soils of Punjab - Blockwise Atlas. Published by Department of Soil Science, Punjab Agricultural University, Ludhiana and ICAR-Indian Institute of Soil Science, Bhopal, India.pp.1-210.

Goovaerts, P 1998. Geo-statistical tools for characterizing the spatial variability of microbiological and physic-chemical soil properties. *Biol Fertil Soil* **27**: 315-34.

KhanMSH, MianMJ, Akhtar A, Hossain M F and Sikder M S I 2002. Effects of long term fertilization and cropping on micronutrient cations of soils in Bangladesh. *Pak J Biol Sci* **5**: 543-44.

Lindsay W L and Norvel W A 1978. Development of DTPA soil test for zinc, copper, iron and manganese. *Soil Sci Soc Am J* **42**: 421-28.

Lu S, Liu X, Li L, Zhang F, Zhang X and Tang C 2004. Effect of manganese spatial distribution in the soil profile on wheat growth in rice-wheat rotation. *Plant Soil* **261**: 39-46.

Malik R S, Yadav H K, Narender, Rajpaul and Sangwan P S 2017. Background levels of zinc, iron, manganese and copper in soil series of Haryana and their relationship with soil properties. *Int J Agric Sci* **87**: 1094-98.

Motsara MR 2002. Available nitrogen, phosphorus and potassium status of Indian soils as depicted by soil fertility maps. *Fertil News* **47**: 15-21.

Narender, Malik R S, Yadav K and Yadav H K 2016. Fractionation and distribution of manganese in different cropping system and their relationship with soil properties in Haryana. *Environ Ecol* **34**: 2533-40.

Nayyar V K, Arora C L and Kataki P K 2001. Management of soil micronutrient deficiencies in the rice-wheat cropping system. *J Crop Prod* **4**: 87-131.

Nayyar V K, Takkar P N, Bansal R L, Singh S P, Kaur N P, and Sadana U S 1990. Research Bulletin, *Department of Soils, Punjab Agricultural University*, Ludhiana, pp. 146 + xiv

Panigrahy S, Ray S S, Sood A, Patel L B, Sharma P K and Parihar J S 2004. Analysis of cropping pattern changes in Bathinda district, Punjab. *J Indian Soc Remote Sens* **32**: 209–16.

Parker F W, Nelson W L, Winters E and Miles J E 1951. The broad interpretation and application of soil test summaries. *Agron J* **43**: 103-12.

Rengel Z 2001. Genotypic differences in micronutrient use efficiency in crops. *Commun Soil Sci Plant Anal* **32**:1163–86.

Sadana U S, Manchanda J S, Khurana M P S, Dhaliwal S S and Singh H 2010. The current scenario and efficient management of zinc, iron and manganese deficiencies. *Better Crops- South Asia* **4**: 24-26.

Sharma B D, Arora H, Kumar R and Nayyar V K 2004. Relationships between soil characteristics and total and DTPA-extractable Zn, Cu, Mn and Fe in Indo-Gangetic plains. *Commun Soil Sci Plant Anal* **35**: 799– 18.

Sharma B D, Mukhopadhyay S S and Katyal J C 2006. Distribution of total and DTPA-extractable zinc, copper, manganese, and iron in vertisols of India. *Commun Soil Sci Plant Anal* **37**: 653-72.

Sharma J, Kumar P, Dua VK, Sharma V, Kumar D, Kumar S, Rawal S and Khan MA 2017. Status of micronutrients in intensively cultivated potato growing soils of Punjab. *Potato J* **44**: 58-64.

Singh M V 2008. Micronutrient deficiencies in crops in India. In: *Micronutrients in global crops*. (A. Brown Ed.) Springer, New York.

Yadav B K 2011**.** Micronutrient status of soils under legume crops in arid region of Western Rajasthan, India. *Academic J Plant Sci* **4**: 94-97.

Yadav B K 2020. Effect of crop residue burring on micronutrients availability in arid soils of Punjab, India. *J Soils Crops* **30:** 69-73.

Yadav B K, Gupta N and Kumar D 2018.Soil micro-nutrient availability and accumulation in ber (*ziziphus mauritiana* L.) under semiarid region. *Multilogic sci* **8**: 93-96.

Yadav B K, Sidhu A S and Thaman S 2016. Soil fertility status of Punjab Agricultural University seed farm, Chak Ruldu Singh Wala, Sangat, Bathinda, Punjab. *Annals Plant Soil Res* **18**: 226-31.