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RESEARCH ARTICLE

Available iron and copper status and their relationship with soil physico-chemical properties and its content in wheat crop of internal drainage dry zone of Rajasthan

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SUMMARY

Seventy surface soil and wheat plant samples were collected from seventy village of Sri Madhopur tehsil of Siker District (Rajasthan) India. The soils were analysed for textural, separates, physic-chemical properties and status of available iron and copper. Grain and straw of wheat plant were separately analysed for determination iron and copper content. The majority of soils were found sandy in nature and their textural classes are sandy, loamy sand and sandy loam. Soils of the study area were found slightly calcareous in nature. Soils of study area have low organic carbon and cation exchange capacity. On the basis of pH_2 and EC_2 values, these soils were found slightly alkaline in nature. Majority of soils under study were found deficient in iron and adequate available in copper. The availability of iron and copper in soil significantly influenced by soil properties like textural separate, organic carbon, $CaCO_3$, CEC and pH_2 soils.

Key Words : Available iron, Available copper status, Physico-chemical properties of soil, Wheat crop

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Micronutrients are just as important in plant nutrition as the major nutrients, they simply occur in plants and soils in much smaller concentrations. Plants grown on micronutrient deficient soil can exhibit similar reductions in plant growth and yield as major nutrients. The deficiency of micronutrients has become a major constraints in production and sustainability.

The role of iron in the formation of chlorophyll in plants was discovered in late 19^{th} century. Since then, importance of iron in plant nutrition has been recognized worldwide. The deficiency of iron in plants may cause chlorosis which may reduce the growth and yield significantly. Beneficial effects of its application in our country have been reported from various states like: Punjab, Delhi, Rajasthan, Uttar Pradesh etc. The availability of iron depends upon chemical nature and reactivity of different forms of iron in soils; besides, its availability is also influenced by the physiological and morphological properties of plants, roots and soils. Copper on other hand is essentially required for oxidation reduction reactions, nitrogen fixation and for maintaining hormonal activities. It is an integral constituent of many enzymes like: plastocyanin, super oxide dismutase and amine oxidase, beside these, it acts as a activator for several enzymes.

In view of these, a need has increasingly been felt to search alternative practice of managing the fertilizer nutrients more judiciously, efficiently and in balanced proportions that would make agriculture more sustainable. The climate of the

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study area is semi-arid and soils of this area are characterized by sandy, sandy loam and loamy sand in texture, calcareous in nature, high pH and slightly alkaline. Hence, for any future planning on micronutrient research, it is necessary to find out the status of available iron and copper and their relationships with soil characteristics. Soils of internal drainage dry zone of Rajasthan have been consistently depleted their finite resource due to continuous cultivation for the years.

MATERIAL AND METHODS

Description of study area:

Srimadhopur tehsil comprising a part of Agro-Climatic zone IIa (Internal Drainage dry zone of Rajasthan situated between 27°21' north latitude and 74°44' east longitude and elevation 432.31 m from mean sea level). It is a part of semi-arid belt of Rajasthan having geographical area of 629.09 square kilometers.

Soil formation:

Soils of studied area is a member of Typic Ustipslamment family. Typically the soils are very deep, excessively drained with yellowish brown, sandy, slightly alkaline surface and sub-surface horizons. The soils are having pH 8.12 and EC 0.29 dS m^{-1} (1: 2, soil water suspension). The $CaCO_3$ and organic carbon contents are 5.27 and 0.26 per cent, respectively (0-30 cm soil depth).

Climate:

The climate of the area is typically semi-arid. Rainfall and temperature are the two main elements of the climate. The rainfall is seasonal and not properly distributed and it varies between 300 to 500 mm annually which is mostly received during the month of July to September. In summer maximum temperature ranges between 35^0C to 48^0C and in winter the minimum temperature varies from 1^0C to 10^0C and sometimes it falls below 0^0C. Weather hazards are also not uncommon in this region; like storms during summer, fog during winter, nights are frosty which provide a great variation in temperature.

Vegetation:

Vegetation is the main component of the organic matter which sustain soil fertility status and microbial population in soil and balancing to the natural environment. It is therefore essential to add information on natural vegetation of the study area. Bajra (*Pennisetum glaucum)*, guar (*Cyamopsis tetragonoloba*), moong (*Vigna radiat*a) and cowpea (*Vigna sinensis*) in *Kharif* season, wheat (*Triticum aestivum*), barley (*Hordeum vulgare*), mustard (*Brassica juncea*), gram (*Cicer arietinum*), and fenugreek (*Trigonella foenum-graecum*) in *Rabi* season and onion (*Allium cepa*), cauliflower (*Brassica oleracea* var, *botrytis*), cabbage (*Brassica oleracea* var. *capitata*), brinjal (*Solanum melongena*), ridge gourd (*Luffa acutangula*), bottle gourd (*Lagenaria riceraria*), pea (*Pisum sativum*), carrot (*Daucus carota*), tinda (*Citrullus vulgaris* var. *fistulosus*), tomato (*Lycopersicon esculentum*), radish (*Raphanus sativus)*, water melon (*Citrullus lanatus*), okra (*Abelmoschus esculentus*), musk melon (*Cucumis melo*), Indian spinach (*Beta vulgaris*) are main vegetables of the study area.

Collection of samples and analysis :

Seventy representative composite soil samples at a depth of 0– 30 cm were collected with the help of a wooden khurpi from 70 villages located at different locations of Srimadhopur tehsil (Table 5). Samples were completely air-dried and passed through 2 mm sieve and stored in properly labelled plastic bags for analysis. Samples of wheat plants at harvesting stage were also collected from each sampling site. Both straw and grain of plant samples were well processed separately in laboratory and analysed for available iron and copper cations. Standard methods used for the analysis of soil and plant samples are given in Table A.

Table A : Standard methods used for the analysis of soil and plant samples

Soil analysis		
Available Fe and Cu	DTPA extract estimated on AAS AA 6300	Lindsay and Norvell, (1978)
Plant analysis		
Fe and Cu	Di-acid digestion and estimated on AAS	Lindsay and Norvell (1978)

Statistical analysis:

The relationship between different soil characteristics and micronutrient contents in soils were determined by using standard statistical methods. The correlation co-efficient was determined by using the formula:

$$\mathbf{r} = \sqrt{\frac{\mathbf{SP\,(xy)}}{\mathbf{SS\,(x),\,SS\,(y)}}}$$

where:
r = Correlation co-efficient
SP (xy) = Sum product of x, y variables
SS (x) = Sum of square of x variable
SS (y) = Sum of square of y variable.

RESULTS AND DISCUSSION

The experimental findings obtained from the present study have been discussed in following heads:

Available iron in soil:

Data pertaining to available iron in soils have been presented in Table 1. The content of available iron in soils of the tract ranged between 1.65 to 6.00 mg kg^{-1} with a mean

Table 1 : Available iron and copper status of soils

Parameters	Iron (mg kg^{-1})	Copper (mg kg^{-1})
Minimum	1.65	0.10
Maximum	6.00	0.76
Average	3.63	0.38

value of 3.63 mg kg^{-1}. The minimum available iron (1.65 mg kg^{-1}) was recorded in soil sample P_{43}, while, maximum (6.00 mg kg^{-1}) iron content was recorded in soil sample P_{26}.

On the basis of critical limit of available iron suggested by Lindsay and Norvell (1978), the soils of Srimadhopur tehsil were found to be deficient in available iron content except P_1, P_{18}, P_{20}, P_{22}, P_{23}, P_{25}, P_{26}, P_{45}, P_{51}, P_{55} and P_{64}. The less availability of iron in these soils is probably due to their coarse texture, low organic matter content, high $CaCO_3$ content and low CEC values (Sakal *et al.*,1986 and 1990; Kameriya, 1995; Chatterjee and Khan, 1997 and Gupta, 2003). The area of sufficiency and deficiency of DTPA extractable iron has also been delineated in Fig 1.

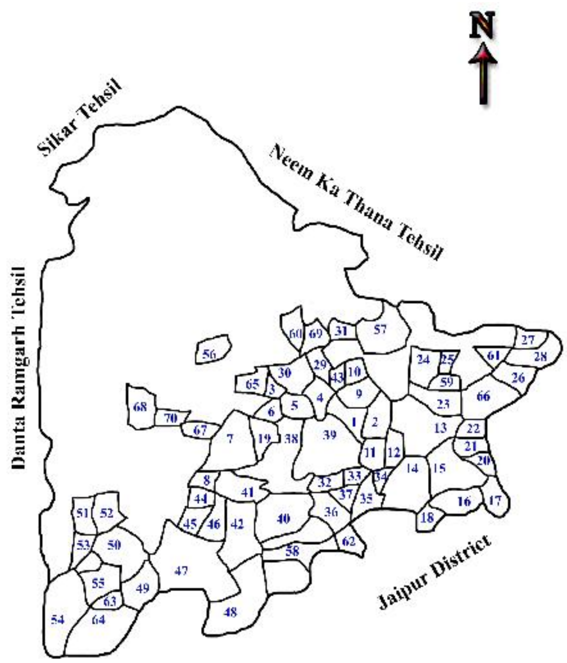

Fig. 1 : Soil and plant sampling site of Srimadhopur tehsil

Data presenting in Table 2 that availability of iron was found to increase significantly with increase in silt (r =+0.494*), clay (r =+0.440**), organic carbon (r =+0.663**) and CEC (r =+0.676**), whereas, its availability was found to decrease significantly with increase in sand (r = -0.515**), $CaCO_3$ (r = -0.554**), EC_2 (r = -0.314**) and pH_2 (r = -0.627**). Similar findings were also reported by Meena *et al.* (2006).

The availability of iron increased significantly with increase in finner fractions (silt and clay) because these fractions are helpful to improve soil structure and aeration which are favourable conditions for increasing its availability. The available iron was found to increase with increase in CEC of soils due to more availability of exchange sites on soil colloids. Similarly, the availability of iron enhanced significantly with increase in organic matter which is helpful in improving soil structure and aeration, protects the oxidation and precipitation of iron into unavailable forms and supply soluble chelating agents which increase the solubility of iron compounds.

On the other hand, its availability was found to be reduced with increase in pH_2 and $CaCO_3$ content of soils. High pH is responsible for its oxidation. Thus, most readily available form of iron is Fe^{2+} ions which convert into less soluble form (Fe^{3+} ions) after oxidation. Hence, the availability of iron is reduced at higher pH level. Besides, at high pH iron is also precipitated as insoluble Fe $(OH)_3$ which reduces its availability.

The $CaCO_3$ present in soils gets converted into bicarbonate ions which reduces the availability of iron and the chlorosis caused in these conditions is known as a "lime-induced chlorosis". The reduction in iron availability with increase in $CaCO_3$ content is because $CaCO_3$ favours the precipitation or oxidation of Fe^{2+} ions into Fe^{3+} ions and transformation of soluble iron compounds into less soluble iron carbonates or ions which may be retained by free $CaCO_3$ (Randhawa and Singh, 1996). Similar findings were also reported by Kameriya (1995), Chatterjee and Khan (1997), Nayak *et al.* (2000), Kumar (2003), Kumar (2005) and Yadav (2005). Furthermore, the availability of iron increased significantly with increase in contents of copper (r = +0.616**) contents in soils. These results are in close proximity with the findings of Kumar (2003), Kumar (2005), Yadav (2005), Singh (2006) and Mehra (2007).

Available copper in soil:

Data presented in Table 1 indicated that the content of available copper in soils varied from 0.10 to 0.76 mg kg^{-1} with mean value 0.38 mg kg^{-1}. The minimum (0.10 mg kg^{-1}) and maximum (0.76 mg kg^{-1}) contents of available copper were recorded in soil samples P_{61} and P_{21}, respectively.

The soils of Srimadhopur tehsil were found sufficient in available copper content as per critical limit suggested by Lindsay and Norvell (1978) (Fig. 2). Similar findings of soils of Nagaur and Jodhpur were also suggested by Joshi and Dhir (1983).

Study of data mentioned in Table 2 elucidates that the availability of copper increased significantly with increase in silt (r =+0.566**), clay (r = +0.503**), organic carbon (r = +0.618**) and CEC (r = +0.648**). Similar findings were also reported by Meena *et al.* (2006). On the other hand, the availability of copper decreased significantly with increase in sand (r = -0.571**), $CaCO_3$ (r= -0.581**), EC_2 (r = -0.241*)

Table 2 : Correlation matrix between soil characteristics

Sr. No.	Soil characteristics	Sand	Silt	Clay	$CaCO_3$	OC	pH_2	EC_2	CEC	Available Fe	Available Cu
1.	Sand	1.000	-0.944**	-0.934**	0.504**	-0.610**	0.542**	-0.044	-0.565**	-0.515**	-0.571**
2.	Silt		1.000	0.833**	-0.473**	0.556**	-0.517**	0.023	0.498**	0.494**	0.566**
3.	Clay			1.000	-0.472**	0.575**	-0.536**	0.047	0.546**	0.440**	0.503**
4.	$CaCO_3$				1.000	-0.583**	0.619**	-0.207	-0.728**	-0.554**	-0.581**
5.	OC					1.000	-0.579**	0.139	0.685**	0.663**	0.618**
6.	pH_2						1.000	-0.312**	-0.672**	-0.627**	-0.688**
7.	EC_2							1.000	-0.204	-0.314**	-0.241*
8.	CEC								1.000	0.676**	0.648**
9.	Available Fe									1.000	0.616**
10.	Available Cu										1.000

* and ** indicate significance of values at P=0.05 and P=0.01, respectively

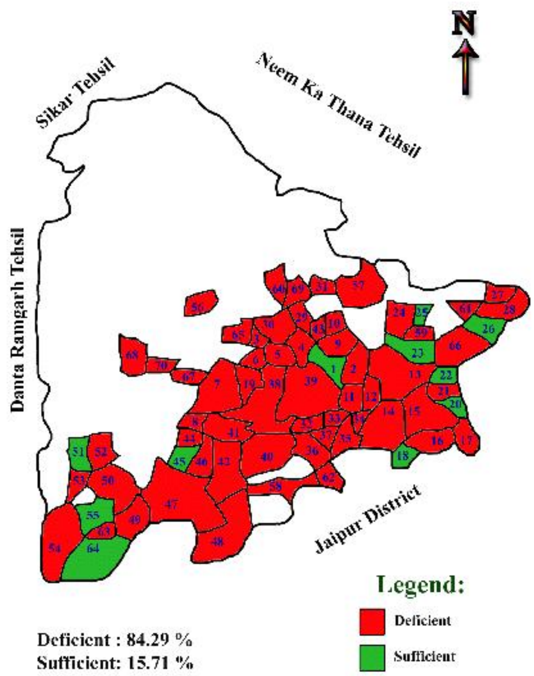

Fig. 2 : Status of available iron in soil of Srimadhopur tehsil

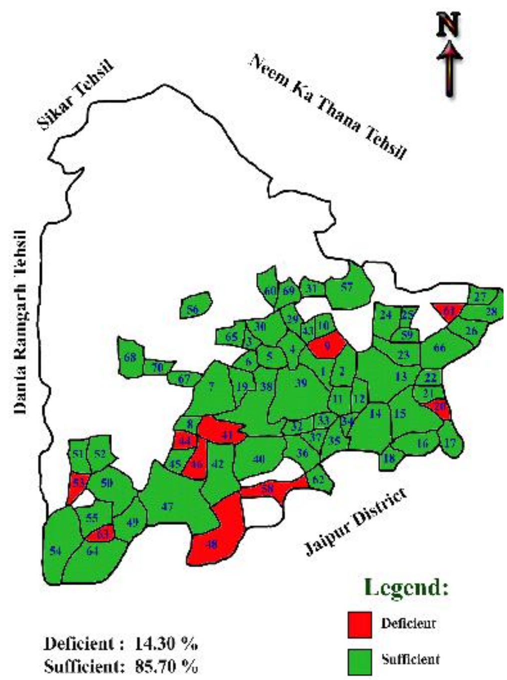

Fig. 3 : Status of available copper in soil of Srimadhopur tehsil

and pH_2 (r = -0.688**) of soils.

The organic matter may increase the availability of copper in soils due to the formation of soluble complexing agents which may decrease fixation of copper in soils. Copper also has higher affinity for complexation with organic matter, which may increase its solubility. Furthermore, the availability of copper enhanced with finer fractions of soils and this might be due to the improvement of soil structure and aeration conditions. Besides, more exchange sites are available for its adsorption in fine textured soils.

On the other hand, its availability was found to decrease significantly with increase in sand content because the coarseness of soil texture reduces the adsorption of Cu^{2+} ions on exchange sites (Fig. 3). On the same line, the availability of copper is significantly reduced at high pH_2. This might be due to precipitation of Cu^{2+} ions as relatively insoluble hydroxides. Thus, newly formed hydroxides, either would have become the part of lattice or occluded with the hydroxides of Fe (Lindsay and Norvell, 1978). Similarly, calcium carbonate has also been reported to decrease the availability of copper by bringing change in soluble Cu^{2+} ions to less soluble compounds like: $Cu(OH)_2$ and $CuCO_3$.

The results of present investigation were further confirmed from the results of previous researcher Kameriya (1995); Chatterjee and Khan (1997); Singh *et al.* (1999), Nayak *et al.* (2000), Meena *et al.* (2006) and Balpande *et al.* (2007). Furthermore, the data explicit in Table 2 indicated that the availability of copper was significantly enhanced by the content of Fe (r = +0.616**). Similar findings were also recorded by Kumar (2003), Barala (2005), Yadav (2005), Singh (2006).

Iron contents in wheat plants:

A close study of data mentioned in Table 3 indicates that the iron content in wheat grain varied between 93.44 to 108.40 µg g^{-1} with a mean value of 102.56 µg g^{-1}. The lowest iron content in grain (93.44 µg g^{-1}) was obtained in sample collected from village P_{10}, while, highest iron content (108.40 µg g^{-1}) in sample P_{26}. The iron content in wheat straw varied between 301.60 to 330.14 µg g^{-1} with a mean value of 316.97 µg g^{-1}. The lowest iron content (301.60 µg g^{-1}) obtained in straw of sample collected from villages P_{53}, while, highest iron content (330.14 µg g^{-1}) in samples no. P_5.

Table 3 : Iron and copper contents in wheat plants («g g^{-1})

Parameters	Iron (Fe)		Copper (Cu)	
	Grain	Straw	Grain	Straw
Minimum	93.44	301.60	6.50	4.70
Maximum	108.40	330.14	14.80	8.40
Average	102.56	316.97	11.10	6.46

Correlation between content of iron in wheat plants and soil characteristics were computed. Data elucidate that the content of iron in both grain and straw of wheat enhanced significantly with increase in silt, clay, organic carbon and CEC of soils. On the other hand, its content in both grain and straw of wheat decreased significantly with increase in sand,

Table 4 : Correlation matrix between soil characteristics, iron and copper content in wheat plants

Sr. No.	Soil characteristics	Iron contents in wheat plants		Cu contents in wheat plants	
		Grain	Straw	Grain	Straw
1.	Sand	-0.486**	-0.491**	-0.497**	-0.480**
2.	Silt	0.411**	0.484**	0.491**	0.421**
3.	Clay	0.444**	0.374**	0.377**	0.438**
4.	$CaCO_3$	-0.624**	-0.553**	-0.522**	-0.427**
5.	OC	0.563**	0.526**	0.449**	0.419**
6.	pH_2	-0.591**	-0.633**	-0.491**	-0.441**
7.	EC_2	0.178	0.120	0.211	0.096
8.	CEC	0.651**	0.523**	0.508**	0.518**
9.	Fe contents in wheat plants	0.651**	0.564**	0.519**	0.355**
10.	Cu contents in wheat plants	0.510**	0.550**	0.447**	0.300*

* and ** indicate significance of values at P=0.05 and P=0.01

Table 5 : Description of sampling sites located in Srimadhopur tehsil of Sikar district

Sr. No.	Sample code No.	Village name	Sr. No.	Sample code No.	Village name	Sr. No.	Sample code No.	Village name	Sr. No.	Sample code No	Village name
1.	P_1	Ghatamdas	19.	P_{19}	Naangal Bhem	37.	P_{37}	Phutalaya	55.	P_{55}	Tapipalya
2.	P_2	Trilokpura	20.	P_{20}	Modyari	38.	P_{38}	Mau	56.	P_{56}	Ralvata
3.	P_3	Deravali	21.	P_{21}	Mandustha	39.	P_{39}	Bagriyavas	57.	P_{57}	Thoie
4.	P_4	Prithyipura	22.	P_{22}	Hathora	40.	P_{40}	Arniya	58.	P_{58}	Jalalpura
5.	P_5	Holy ka Bass	23.	P_{23}	Suranie	41.	P_{41}	Bharani	59.	P_{59}	Sherpura
6.	P_6	Haspur	24.	P_{24}	Jhadali	42.	P_{42}	Mahroli	60.	P_{60}	Jarvarnagar
7.	P_7	Srimadhopur	25.	P_{25}	Heripura	43.	P_{43}	Dhabavali	61.	P_{61}	Burja Ki Dhani
8.	P_8	Patwari Ka Bass	26.	P_{26}	Her Das Ka Bass	44.	P_{44}	Mala Kani	62.	P_{62}	Khurrampura
9.	P_9	Sihori	27.	P_{27}	Devipura	45.	P_{45}	Jaitusar	63.	P_{63}	Purohit Ka Bass
10.	P_{10}	Geedavala	28.	P_{28}	Hathi deh	46.	P_{46}	Gudha	64.	P_{64}	Dadia Rampura
11.	P_{11}	Naangal	29.	P_{29}	Simarala	47.	P_{47}	Reengus	65.	P_{65}	Kalyanpura
12.	P_{12}	Aspura	30.	P_{30}	Kotri	48.	P_{48}	Sargodh	66.	P_{66}	Nare
13.	P_{13}	Garhtakhet	31.	P_{31}	Garhbhopji	49.	P_{49}	Kotridhoyalan	67.	P_{67}	Charanvas
14.	P_{14}	Divrala	32.	P_{32}	Nathusar	50.	P_{50}	Lapuva	68.	P_{68}	Jajod
15.	P_{15}	Ajeetgarh	33.	P_{33}	Ratanpura	51.	P_{51}	Bhavanipura	69.	P_{69}	Nalot
16.	P_{16}	Mangarh	34.	P_{34}	Anatpura	52.	P_{52}	Dheerajpura	70.	P_{70}	Khedi
17.	P_{17}	Seepur	35.	P_{35}	Lasariya	53.	P_{53}	Santoshpura			
18.	P_{18}	Jugrajpura	36.	P_{36}	Mundru	54.	P_{54}	Aabavas			

pH_2 and $CaCO_3$ contents of soil (Table 4). Further, the iron content in both grain (r = +0.651**) and straw (r = +0.564**) of wheat enhanced significantly with increase in content of available iron in soils (Table 4). This shows the translocation of iron from soil to plants.

Copper contents in wheat plants:

Data related to copper content in wheat straw and grain presented in Table 3 elucidated that the copper content in wheat straw varied from 4.70 to 8.40 $\mu g\ g^{-1}$ with a mean value of 6.46 $\mu g\ g^{-1}$. The lowest copper content (4.70 $\mu g\ g^{-1}$) was recorded in straw sample P_{39} while, highest copper content (8.40 $\mu g\ g^{-1}$) was found in straw sample P_{70}. Data further indicate that the copper content in wheat grain ranged between 6.50 to 14.80 $\mu g\ g^{-1}$ with a mean value of 11.10 $\mu g\ g^{-1}$. The lowest copper content (6.50 $\mu g\ g^{-1}$) was obtained in grain sample P_{17} and highest copper content (14.80 $\mu g\ g^{-1}$) in grain sample P_{24}.

A close study of data mentioned clearly indicates that the content of copper in both grain and straw of wheat significantly increased with increase in silt, clay, organic carbon and CEC of soils, while, its contents in grain and straw of wheat decreased significantly with increase in sand, $CaCO_3$ and pH_2 of soils. Positive and significant correlations were recorded between copper content of soils and its content in straw (r = 0.447**) and grain (r = 0.300**) of wheat (Table 4).

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