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RESEARCH PAPER

Available zinc and manganese 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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Abstract : 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 zinc and manganese. Grain and straw of wheat plant were separately analysed for determination zinc and manganese 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 zinc and adequate available in manganese. The availability of zinc and manganese in soil significantly influenced by soil properties like textural separate, organic carbon, $CaCO_3$, CEC and pH_2 soils.

Key Words : Available zinc, Available manganese status, Physico-chemical properties of soil, Wheat crop

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INTRODUCTION

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.

Zinc is an integral part of many enzymes such as : carbonic anhydrase, alcohol dehydrogenase, superoxide dismutase, RNA polymerase etc. It actively participates in N-metabolism and also activates the hormonal activities (Indole acetic acid). Widespread zinc deficiency has been observed in arid and semi-arid regions.

Manganese is essentially needed in photosynthesis, particularly in hill reaction. It is an integral part of many enzymes and activators, particularly of deoxycarboxylase and dehydrogenase. The availability and supply of manganese to soil plant system is governed by oxidation and reduction processes that are influenced by number of factors. Thus, a knowledge dealing with the status of available manganese is of great importance to increase crop production.

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 study area is semi-arid and soils of this area are characterized

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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 zinc and manganese 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 7444’ 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 were having pH 8.12 and EC 0.29 dS m^{-1} (1: 2, soil water suspension). The $CaCO_3$ and organic carbon contents were 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 and Fig. A). 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.

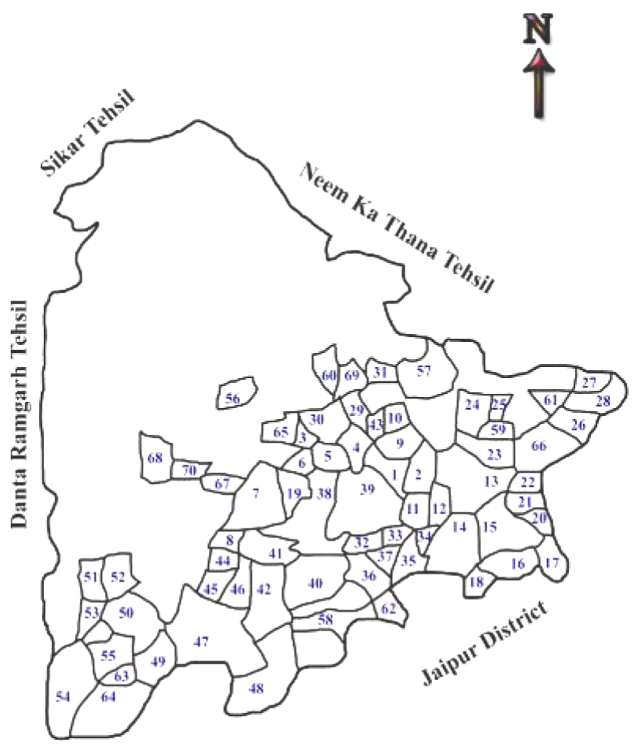

Fig. A : Soil and plant sampling site of Srimadhopur tehsil

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

Soil analysis		
Available zinc and manganese	DTPA extract estimated on AAS AA 6300	Lindsay and Norvell, (1978)
Plant analysis		
zinc and manganese	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:

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

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 results obtained from the present investigation as well as relevant discussion have been summarized under following heads :

Available zinc in soil :

Data related to available zinc have been presented in Table 1. The content of available zinc in soils varied between 0.28 to 3.24 mg kg^{-1} with mean value of 1.02 mg kg^{-1}. The minimum available zinc (0.28 mg kg^{-1}) was recorded in soil sample P_{11}, while, maximum (3.24 mg kg^{-1}) amount was recorded in soil sample P_{66}. On the basis of critical limits of available zinc suggested by Takkar and Mann (1975), 25.72 per cent soil samples were found deficient, 24.28 per cent samples were marginal and 50 per cent samples were sufficient in available zinc (Fig. 1).

A close examination of the data in Table 2 indicate that

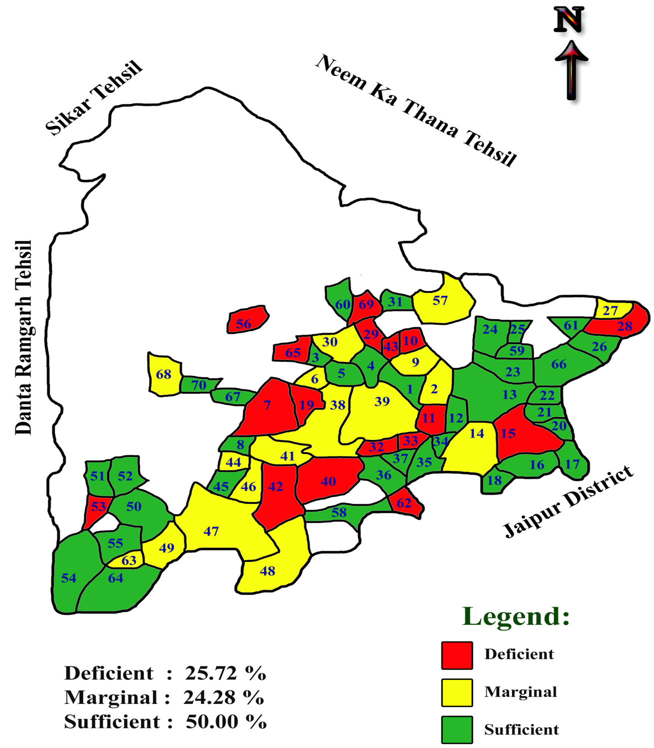

Fig. 1 : Status of available zinc in soil of Srimadhopur tehsil

the availability of zinc increased significantly with increase in silt (r=+0.439**), clay (r = +0.419**), organic carbon (r = +0.583**), EC_2 (r= +0.314**) and CEC (r = +0.649**) of soils. Since, silt and clay are the most active fractions of soil which provide more exchange sites for adsorption of cations. Most of the zinc bearing minerals such as : biotite, hornblande,

Table 1: Available zinc and manganese status of soils

Parameters	Zinc (mg kg^{-1})	Manganese (mg kg^{-1})
Minimum	0.28	2.00
Maximum	3.24	5.62
Average	1.02	3.53

Table 2 : Correlation matrix between soil characteristics

Sr. No.	Soil characteristics	Sand	Silt	Clay	$CaCO_3$	OC	pH_2	EC_2	CEC	Available manganese	Available zinc
1.	Sand	1.000	-0.944**	-0.934**	0.504**	-0.610**	0.542**	-0.044	-0.565**	-0.580**	-0.481**
2.	Silt		1.000	0.833**	-0.473**	0.556**	-0.517**	0.023	0.498**	0.568**	0.439**
3.	Clay			1.000	-0.472**	0.575**	-0.536**	0.047	0.546**	0.569**	0.419**
4.	$CaCO_3$				1.000	-0.583**	0.619**	-0.207	-0.728**	-0.604**	-0.563**
5.	OC					1.000	-0.579**	0.139	0.685**	0.508**	0.583**
6.	pH_2						1.000	-0.312**	-0.672**	-0.584**	-0.679**
7.	EC_2							1.000	-0.204	-0.060	0.314**
8.	CEC								1.000	0.595**	0.649**
9.	Available Mn									1.000	0.462**
10.	Available Zn										1.000

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

augite and others are easily weathered and thus released zinc is subjected to secondary soil forming processes such as : adsorption of Zn^{2+} ions by clay. Zinc (Zn^{2+}) ions adsorbed on soil complexes may easily be removed by leaching especially in sandy loam soils and adsorbed zinc is in equilibrium with the soil solution zinc. Thus, a soil having greater surface area will adsorb greater amount of zinc and vice versa. Since, DTPA is able to extract adsorbed zinc, which is easily released for plant use. The amount of extracted zinc is likely to increase with the increase in fineness of the soil texture. Similar results were also reported by Gupta (2003), Kumar (2003), Barala (2005), Yadav (2005) Singh (2006), Meena (2006), Mehra (2007) and Sharma and Chaudhary (2007). It has also been reported that organic matter plays an important role in controlling availability of zinc particularly in alkaline soils (Das, 2000)

On the other hand, the availability of zinc reduced significantly with increase in sand (r = -0.481**), $CaCO_3$ (r = -0.563*) and pH_2 (r = -0.679*) of soil. The solubility of zinc mainly depends upon the H^+ ions activity and it decreases as pH is increased. The influence of pH is so intense that its each unit rise will decrease the solubility of divalent cations of zinc form zinc hydroxides and zinc carbonate which are sparingly soluble and less available. The findings of the present investigation are confirmed by the findings of Kameriya (1995), Gupta (2003), Kumar (2003), Kumar (2005), Barala (2005), Yadav (2005) Singh (2006), Meena (2006), Mathur *et al.* (2006), Mehra (2007) and Balpanda *et al.* (2007). Further, the availability of zinc increased significantly with increase in contents of available manganese (+0.462**) in soils. Similar results were also reported by Kumar (2003), Kumar (2005), Barala (2005), Yadav (2005), Singh (2006), Meena (2006) and Mehra (2007).

Available manganese in soil :

A close study of data pertaining to available manganese (Table 1) reveals that the available manganese content in soils ranged from 2.00 to 5.62 mg kg^{-1} with mean value 3.53 mg kg^{-1}. The minimum available manganese (2.00 mg kg^{-1}) was recorded in soil sample P_{14} and maximum (5.62 mg kg^{-1}) in soil sample P_4. In general, soils of Srimadhopur tehsil are sufficient in available manganese (as per critical limit suggested by Lindsay and Norvell, 1978). The status of available manganese in soils of study area have been shown in Fig. 2.

A close examination of data in Table 2 indicates that the availability of manganese in soils was significantly enhanced by silt (r = +0.568**), clay (r = +0.569**), organic carbon (r=+0.508**) and CEC (r =+0.595**) content of soils. Further, the availability of manganese was found to decrease significantly with increase in sand (r = -0.580**), $CaCO_3$ (r= -0.604**) and pH_2 (r = -0.582**) of soil. Further, the availability of manganese was non significantly correlated with EC_2 of soils. The increase in availability of manganese with increase in finer fractions in soil might be due to the improvement in soil structure and aeration conditions. Similarly, the availability of manganese increased with increase in organic carbon content because it protects Mn from oxidation and precipitation and provides chelating agents for solubilizing manganese compounds.

The reduction in availability of Mn with sand content might be due to less adsorption of its ions on exchange sites. Similarly, the reduction in availability of manganese with increase in $CaCO_3$ and pH_2 of soils might be due to the formation of less soluble compounds like; $MnCO_3$ or Mn $(OH)_2$. Besides, high pH favours the formation of less soluble

Table 3 : Zinc and manganese contents in wheat plants (μg g^{-1})

Parameters	Zinc (mg kg^{-1})		Mn (mg kg^{-1})	
	Grain	Straw	Grain	Straw
Minimum	16.20	11.00	47.40	21.70
Maximum	24.10	17.80	68.90	55.90
Average	20.41	14.32	58.63	46.13

Table 4 : Correlation matrix between soil characteristics, zinc and manganese content in wheat plants

Sr. No.	Soil characteristics	Zn contents in wheat plants		Mn contents in wheat plants	
		Grain	Straw	Grain	Straw
1.	Sand	-0.437**	-0.526**	-0.432**	-0.459**
2.	Silt	0.394**	0.526**	0.383**	0.466**
3.	Clay	0.349**	0.374**	0.389**	0.458**
4.	$CaCO_3$	-0.374**	-0.266*	-0.562**	-0.558**
5.	OC	0.245*	0.280*	0.517**	0.425**
6.	pH_2	-0.228	-0.146	-0.481**	-0.550**
7.	EC_2	0.066	0.070	0.029	-0.081
8.	CEC	0.355**	0.323**	0.584**	0.546**
9.	Zn contents in wheat plants	0.228	0.169	0.436**	0.318**
10.	Mn contents in wheat plants	0.199	0.265*	0.583**	0.532**

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

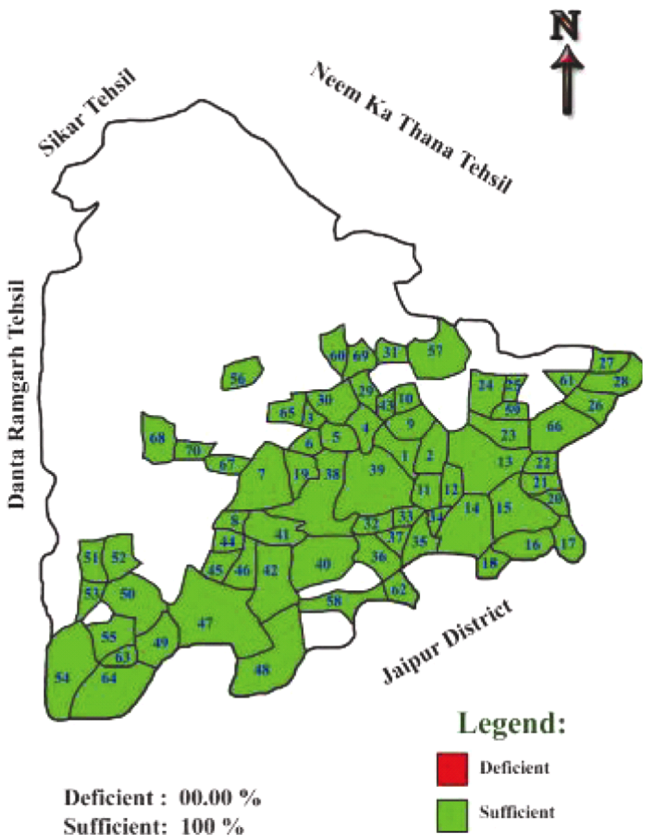

Fig. 2 : Status of available manganese in soil of Srimadhopur tehsil

organic complexes of manganese, which reduces the availability of manganese. The results of present investigation are in accordance with the findings of previous workers like : Kameriya (1995), Saha *et al.* (1998), Siddamalai (1999), Gupta (2003) and Balpande *et al.* (2007). The data explicited in Table 3 further indicate that the availability of Mn was significantly enhanced by the contents of zinc (r = + 0.462**). These results have been confirmed by the findings of Kumar (2003), Barala (2005), Yadav (2005) Singh (2006), Meena (2006) and Mehra (2007).

Zinc contents in wheat plants :

A perusal of data present in Table 3 revealed that zinc content in straw varied between 11.00 to 17.80 mg g^{-1} with a mean value of 14.32 mg g^{-1}, whereas, its content in grain ranged between 16.20 to 24.10 mg g^{-1} with a mean value of 20.41 mg g^{-1}. The lowest zinc content (11.00 mg g^{-1}) in straw was obtained in sample P_{39} and P_{70}, while, highest zinc content (17.80 mg g^{-1}) in straw was noticed in sample P_1. Furthermore, the lowest zinc content (16.20 mg g^{-1}) in grain of wheat was obtained in sample P_{65} and P_{70} and highest zinc content (24.10 mg g^{-1}) in grain was recorded in sample P_{66}.

A close study of data mentioned in Table 3 indicates that the contents of zinc in both grain and straw of wheat significantly increased with increase in silt, clay and organic carbon contents of soil. Its contents in both grain and straws of wheat decreased significantly with increase in sand and $CaCO_3$ of soils. Further, the correlation between amount of available zinc present in soils and its contents in straw and

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			

grain were also computed and it was observed that zinc contents in both grain (r = +0.228) and straw (r = +0.169) increased with increase in available zinc content in soil.

Manganese contents in wheat plants :

Data mentioned in Table 4 indicate that the content of manganese in both grain and straw significantly increased with silt, clay and organic carbon of soils. Its content in both grain and straw decreased significantly with increase in sand, $CaCO_3$ and pH_2 of soil. Similar to the iron contents, the manganese content in both straw (r = +0.532*) and grain (r = +0.583**) increased significantly with increase in available manganese content in soil.

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