J. Soils and Crops 34 (1) 64-68, June 2024

ISSN 0971-2836 (Print)
ISSN 2582-2756 (Online)

ASSESSING MICRONUTRIENT LEVELS AND THEIR CORRELATION WITH SOIL PHYSICO-CHEMICAL PROPERTIES IN DRYLAND FARMING, ANANTAPUR DISTRICT, ANDHRA PRADESH

Sri Likhitha Gudla[1], Lakshmi Sravya Puligadda[2] and Santanu Kumar Moharana[3]

ABSTRACT

An investigation was carried at Agricultural Research Station, Anantapur in the year of 2022 aimed to assess micronutrient levels and their correlation with soil properties in three villages of Roddammandal, Anantapur district, Andhra Pradesh. A total 42 samples were collected, which included 14 from each village. Kanchisamudram and Bucharla had mean pH values of 7.59 and 7.79 which showed slightly alkaline respectively, while Kogira had a mean pH of 7.94 which showed more alkaline condition. Electrical conductivity (EC) values were 0.19 dS/m for Kanchisamudram, 0.21 dS/m for Bucharla, and 0.26 dS/m for Kogira showed low to moderately saline condition. Organic carbon content remained consistently low across the villages with average of 0.28% in Kanchisamudram, 0.31% in Bucharla, and 0.55% in Kogira. Micronutrient concentrations in ppm were: Fe - 1.88 in Kanchisamudram, 1.19 in Bucharla, and 0.57 in Kogira; Mn - 1.66 in Kanchisamudram, 2.22 in Bucharla, and 0.44 in Kogira; Zn - 0.11 in Kanchisamudram, 0.08 in Bucharla, and 0.18 in Kogira; Cu - 0.34 in Kanchisamudram, 0.31 in Bucharla, and 0.20 in Kogira. In Kanchisamudram, pH correlated with Fe (r = 0.029) and Mn (r = -0.001), EC correlated negatively with Fe (r = -0.646) and Mn (r = -0.648**), and OC correlated weakly with Fe (r = -0.203) and Mn (r = -0.26). In Bucharla, pH had negative correlations with Fe (r = -0.006) and Cu (r = -0.117) but positive with Zn (r = 0.328). In Kogira, pH negatively correlated with Fe (r = -0.4) and Cu (r = -0.402) but positively with Zn (r = 0.37). EC showed positive correlation with Fe (r = 0.313) and Cu (r = 0.147) in Kogira, while OC exhibited strong positive correlations with Fe (r = 0.794**) and moderate correlation with Cu (r = 0.491*). Based on the findings, it is recommended that composting and cover cropping enhanced organic matter, correcting pH imbalances with lime or sulfur, and regulate salinity with increased irrigation and drainage. Iron chelates and manganese sulphate are recommended in Kogira, while zinc oxide and copper sulphate are adviseded in all three villages. These measures will improve soil fertility, nutrient availability, and agricultural sustainability in this dryland area.**

(Key words: Micronutrients, organic carbon, correlation, alkaline reaction, electrical conductivity)

INTRODUCTION

About 20% of the total cultivable land in world is reported with low soil fertility levels and this is major concern of one fourth population of the world to meet livelihood needs from these eroding soils (Thombe *et al.*, 2020).Physicochemical properties of soil are important in determining nutrient retention and availability. The level of organic matter, the degree of microbial activity, pH changes, the types and amount of clay and the status of soil moisture influences nutrient retentics and supply in soils. Soil physicochemical properties such as pH, calcium carbonate (C_aCO_3) and organic carbon are important because they influence nutrient availability in soil and thus affects crop growth and production (Mane *et al.*, 2002).

Micronutrients are indispensable for the success of dryland agriculture, even though they are required in smaller quantities compared to macronutrients. These vital elements are crucial for plant growth and development, facilitating enzymatic reactions, photosynthesis, and hormone synthesis (Marschner, 2012). They play a pivotal role in nutrient balance within soils and enhance plant resilience against environmental stresses such as drought, high temperatures, and salinity, thus improving crop productivity in arid conditions (Hafeez *et al*., 2013).

Additionally, they optimize nutrient use efficiency by working synergistically with macronutrients, ultimately

1 & 2. Sr. Research Fellows, Sustainability India Finance Facility (SIFF- INDIA), Research unit, Guntur, 522034, Andhra Pradesh, India

3. Organic Inspector, Odisha State Seed & Organic Product Certification Agency OSOCA), 751003, Bhubaneswar, Odisha, India

influencing crop yield and quality (Cakmak, 2008). Certain micronutrients also act as natural defenses against crop diseases, reducing the need for chemical interventions, promoting sustainable agricultural practices, and preventing environmental harm from nutrient runoff (White and Brown, 2010).

Dryland agriculture, characterized by its susceptibility to water scarcity and soil nutrient limitations, poses significant challenges to global food security. Micronutrients, essential for plant growth and development, have gained prominence in efforts to enhance crop productivity in these arid and semi-arid regions (Smith *et al*., 2019).

Anantapur, the southernmost district of the Rayalaseema region in Andhra Pradesh, relies heavily on agriculture as its primary economic activity. However, the micro-nutrient status of Anantapur district is generally characterized as poor to moderate, as it is situated in an arid region. Factors such as low organic matter content, moderately acidic to alkaline soils, and limited microbial activity often lead to micronutrient deficiencies, particularly in zinc (Zn), iron (Fe), copper (Cu), and manganese (Mn) (Hafeez *et al*., 2013). To address these challenges and enhance crop health and yield, maintaining proper soil fertility through soil testing and judicious micronutrient application is essential for dryland farmers. This approach not only contributes to economic sustainability but also underscores the indispensability of micronutrients in successful dryland agriculture (Smith *et al*., 2019; Marschner, 2012; Cakmak, 2008).

MATERIALS AND METHODS

Study area

The district was situated between 76º 472 and 78º 26'E, of the eastern longitudes and 13º 412 and 15º 14'N, of northern latitudes. The district is bounded on the north by the Kurnool District, on the southeast by Chittoor District, on the east by YSR District, and on the west and southwest by Karnataka state. The average minimum and maximum temperatures are 22.9 and 34°c, respectively, and the average rainfall is 556 mm.

Soil sample collection

Soil samples were collected from three villages *viz*., Kanchisamudram, Bhucharla and Kogira in Roddam Mandal of the Anantapur district. With the help of Khurpi, Spade and metre scale the soil samples were collected randomly from 10 to 30 cm depth. 14 samples were collected from each village and a total of 42 samples were collected and air-dried and then ground (>2 mm) for the analysis of soil fertility.

Soil analysis

The pH (measured at a 1:2.5 soil-to-water ratio) and electrical conductivity (EC, measured at a 1:2.5 soil-to-water ratio) of the soil were determined using a glass electrode pH meter and a Systronics Digital Electrical Conductivity meter, respectively. These measurements were carried out in accordance with the procedures outlined in Jackson (1973). To determine organic carbon (OC) content, the Walkley-Black's titrimetric determination method (Nelson and Sommers, 1996) was employed. The extraction of micronutrients (iron, zinc, copper, and manganese) was carried out using DTPA (DiethyleneTriamine Penta Acetic Acid) method by using Atomic Absorption Spectrophotometer, following the methodology described by Lindsay and Norvell (1978). Pearson's correlation was applied to analyse the associations among different soil properties.

The Pearson correlation coefficient can take values between -1 and 1. *i.e.,* r = 1, it indicates a perfect positive linear relationship, r = -1, it indicates a perfect negative linear relationship, r = 0, it suggests no linear relationship between the two variables.

$$r = \frac{n\,[(\sum xy) - (\sum x) - (\sum Y)]}{\sqrt{[n\sum x2 - (\sum x)2]\ [n\sum y2) - (\sum y)2]}}$$

Where:

Ø n is the number of data points (observations)

Ø x and y are the values of the two variables for each data point

RESULTS AND DISCUSSION

Physico – chemical properties of soil

pH

The pH of soil samples collected from Kanchisamudram and Bucharla shared relatively similar mean values of 7.59 and 7.79, respectively, indicating slightly alkaline to neutral conditions. On the other hand, Kogira had the highest mean pH of 7.94, reflecting a more alkaline condition. The range of pH values spanned from 7.02 to 8.32, indicating notable variability. The standard deviation (SD) values for pH were 0.43, 0.52, and 0.50 for Kanchisamudram, Bucharla, and Kogira, respectively (Table 1). Kanchisamudram had no acidity (pH 6.0 - 6.5) but had 6 samples in the neutral range (pH 6.5 - 7.5) and 8 samples in the alkaline range (pH 7.5 - 9.0). Bucharla showed a similar pattern with 4 neutral and 10 alkaline samples. Kogira had 3 neutral and 11 alkaline samples. This consistent pattern of elevated pH levels observed in Aridisols can be attributed to reduced moisture levels and the accumulation of salts, a phenomenon previously reported by Randhawa *et al*. (2021).

Electrical Conductivity (EC)

In the study area, electrical conductivity (EC), a measure of soil salinity, revealed that Kogira had the highest average EC at 0.26, followed by Bucharla with 0.21, and Kanchisamudram with 0.19. The range of EC values extended from 0.05 to 0.83 and the standard deviation (SD) values for EC were 0.12, 0.17, and 0.23 for Kanchisamudram, Bucharla, and Kogira, respectively (Table 1). In the non-saline category (0 - 0.1), Kanchisamudram had 4 samples, while Bucharla and Kogira had 5 samples each. In the very slightly saline category (0.1 - 0.3), Kanchisamudram had 7 samples, Bucharla had 6, and Kogira had 4. In the moderately saline category (0.3 - 0.5), Kanchisamudram had 3 samples, Bucharla had 2, and Kogira had 4. In the strongly saline category (0.5 - 1.0), only Bucharla and Kogira had samples, each with 1. There were no samples that fell into the very strongly saline category (>1.0) in any village. This finding aligns with the observations of Kumar *et al.* (2019) and Shirgire *et al.* (2018), who similarly reported non-saline to moderately saline characteristics in soils within the hot arid regions of Rajasthan and Gujarat.

Organic Carbon (OC)

Kogira boasted the highest average OC percentage at 0.55, while Bucharla followed with 0.31, and Kanchisamudram with 0.28. The OC values ranged from 0.07 to 0.46, indicating significant differences. The standard deviation (SD) values for OC were 0.13, 0.13, and 0.22 for Kanchisamudram, Bucharla, and Kogira, respectively (Table-1). For organic carbon content, Kanchisamudram predominantly fell into the low category (<0.50) with 14 samples. Bucharla also had a majority in the low category with 13 samples. In contrast, Kogira had 7 samples in the low category, 1 in the medium category (0.50 - 0.75), and 1 in the high category (>0.75). The reduced levels of organic carbon in these soils can be attributed to the combination of elevated temperatures and limited moisture content prevalent in the study area. These climatic conditions accelerate the oxidation process of organic carbon found within organic matter, as demonstrated in the study conducted by Witzgall *et al.* (2021).

Available Micronutrients

Available Iron (Fe)

The available iron (Fe) concentrations in Kanchisamudram averaged the highest at 1.88 ppm, followed by Bucharla with 1.19 ppm, and Kogira with 0.57 ppm. The range of iron concentrations extended from 0.1 to 4.86 ppm, indicating a substantial difference in availability. The standard deviation (SD) values for iron were 1.46, 0.85, and 1.05 for Kanchisamudram, Bucharla, and Kogira, respectively (Table 1). In terms of iron concentration, Kanchisamudram, Bucharla, and Kogira mostly exhibited low levels (<4 ppm) with 12, 14, and 13 samples, respectively. Kanchisamudram had 2 samples in the medium category (4 to 8 ppm), while Bucharla and Kogira had none in this category. None of the villages had samples in the high category (>8 ppm) (Figure – 5). The relatively low availability of iron (Fe) in Aridisols soils observed in this study could be attributed to a higher fixation of iron due to the elevated calcium carbonate content in the soils, as noted in the research conducted by Sharma *et al*. (2006).

Available Manganese (Mn)

In this study, Kanchisamudram had the highest average manganese concentration at 1.66 ppm, followed by Bucharla with 2.22 ppm, and Kogira with 0.44 ppm. All three regions exhibited low manganese levels, with concentrations ranging from 0.06 to 4.08 ppm. The standard deviation (SD) values for manganese were 1.20, 1.52, and 0.44 for Kanchisamudram, Bucharla, and Kogira, respectively (Table 1). All three villages, Kanchisamudram, Bucharla, and Kogira, had low levels of manganese (<10 ppm) with 14 samples each. There were no samples falling into the medium (10 to 20 ppm) or high (>20 ppm) categories for manganese in any village. These findings align with the research conducted by Randhawa *et al.* (2021), which concluded that available manganese was generally low in Aridisols compared to Entisols and Inceptisols. The reduced manganese (Mn) content in these soils is likely linked to the limited presence of organic residues. This condition can lead to the accumulation of micronutrients in forms that are prone to oxidation and precipitation. Furthermore, it reduces the availability of soluble chelating agents necessary for the solubilization of micronutrients, as observed in the research conducted by Chandel *et al*. (2018), Yadav (2018), and Neha and Nisha *et al*. (2020).

Available Zinc (Zn)

Kogira had the highest mean zinc concentration at 0.18 ppm, indicating relatively better zinc availability for plant uptake. In contrast, Kanchisamudram had a mean zinc concentration of 0.11 ppm, while Bucharla had the lowest mean at 0.08 ppm. The range of zinc concentrations across all three villages spanned from 0.006 ppm to 0.48 ppm. The standard deviation (SD) values for zinc were as follows: Kanchisamudram - 0.07, Bucharla - 0.05, and Kogira - 0.06. Similar to manganese, all three villages had low zinc concentrations (<4 ppm) with 14 samples each. There were no samples in the medium (4 to 8 ppm) or high (>8 ppm) categories for zinc in any village. Several factors contributed to the accentuated zinc deficiency observed in the soils. These include coarse texture, parent material, high pH levels, poor organic carbon status, and specific management practices. This pattern is consistent with the findings of Kumar *et al.* (2019), who also reported similar trends of DTPA zinc status in arid and semi-arid soils within the country. The alkaline soil reaction in the particular area may contribute to this zinc deficiency.

Available Copper (Cu)

In the study, Kanchisamudram had the highest mean copper concentration at 0.34 ppm, followed closely by Bucharla with 0.31 ppm, and Kogira with 0.20 ppm. The wide range of copper concentrations ranged from 0.092 ppm to 0.74 ppm across all three villages, demonstrating significant variability in copper availability. The SD values for copper were as follows: Kanchisamudram - 0.13, Bucharla - 0.11, and Kogira - 0.33. In terms of copper concentration, Kanchisamudram had 1 sample in the low category (<4 ppm) and 12 samples in the medium category (4 to 8 ppm). Bucharla had 4 samples in the low category and 8 samples in the medium category. Kogira, on the other hand, had 11 samples in the low category, 1 sample in the medium category, and 2 samples in the high category (>8 ppm). The data suggest

Table 1. Statistical data of physico-chemical properties and micronutrient levels in three villages of Anantapur district, Andhra Pradesh, India

	Kanchisamudram							Bucharla							Kogira						
S.No.	pH	EC (ds/m)	OC (%)	Fe (ppm)	Mn (ppm)	Zn (ppm)	Cu (ppm)	pH	EC (ds/m)	OC (%)	Fe (ppm)	Mn (ppm)	Zn (ppm)	Cu (ppm)	pH	EC (ds/m)	OC (%)	Fe (ppm)	Mn (ppm)	Zn (ppm)	Cu (ppm)
1	7.02	0.28	0.46	0.69	0.31	0.08	0.09	7.41	0.06	0.15	3.22	3.16	0.006	0.22	7.97	0.38	0.69	2.54	1.80	0.02	0.66
2	7.15	0.1	0.07	1.2	1.12	0.14	0.32	7.56	0.07	0.23	1.85	2.88	0.04	0.18	7.38	0.29	0.68	0.58	1.12	0.10	1.22
3	7.32	0.14	0.18	1.94	2.04	0.14	0.42	7.61	0.33	0.33	0.60	2.22	0.04	0.30	7.18	0.48	1.15	4.00	1.44	0.03	0.5
4	7.53	0.37	0.23	0.54	0.34	0.22	0.4	8.55	0.24	0.38	0.48	1.30	0.006	0.232	8.36	0.06	0.65	0.10	0.50	0.48	0.096
5	8.12	0.21	0.42	0.1	0.06	0.1	0.2	7.27	0.18	0.11	0.86	2.34	0.10	0.30	7.84	0.09	0.43	0.10	0.44	0.10	0.1
6	8.32	0.13	0.43	1.22	1.34	0.2	0.28	7.84	0.73	0.23	0.50	1.22	0.084	0.30	8.42	0.05	0.36	0.10	0.28	0.10	0.12
7	7.49	0.27	0.17	0.48	0.76	0.12	0.36	8.7	0.07	0.44	1.14	1.96	0.02	0.21	7.65	0.06	0.43	0.04	0.06	0.20	0.02
8	7.52	0.12	0.11	4.86	4.08	0.24	0.74	6.79	0.33	0.39	0.58	1.66	0.22	0.326	7.83	0.41	0.24	0.014	0.16	0.20	0.006
9	7.04	0.42	0.33	1.26	1.12	0.08	0.3	7.4	0.17	0.35	1.34	2.48	0.008	0.64	8.85	0.29	0.54	0.05	0.012	0.22	0.02
10	8.1	0.33	0.32	0.94	1.16	0.04	0.32	7.62	0.28	0.14	0.64	1.62	0.10	0.18	7.94	0.10	0.47	0.06	0.02	0.22	0.02
11	8.3	0.06	0.46	4.16	2.08	0.1	0.42	7.93	0.12	0.39	2.88	6.1	0.08	1.08	7.71	0.08	0.36	0.08	0.16	0.22	0.02
12	7.54	0.05	0.27	2.24	3.78	0.1	0.36	8.41	0.06	0.44	2.50	3.94	0.08	0.30	7.33	0.47	0.65	0.08	0.018	0.22	0.02
13	7.65	0.08	0.38	3.04	3.1	0.02	0.28	8.24	0.23	0.21	0.01	0.14	0.16	0.02	8.74	0.11	0.42	0.12	0.02	0.22	0.02
14	7.13	0.07	0.12	3.66	1.98	0.02	0.22	7.74	0.09	0.58	0.07	0.06	0.208	0.02	7.90	0.83	0.68	0.06	0.10	0.22	0.02
Mean	**7.59**	**0.19**	**0.28**	**1.88**	**1.66**	**0.11**	**0.34**	**7.79**	**0.21**	**0.31**	**1.19**	**2.22**	**0.08**	**0.31**	**7.94**	**0.26**	**0.55**	**0.57**	**0.44**	**0.18**	**0.20**
Median	**7.53**	**0.14**	**0.30**	**1.24**	**1.25**	**0.10**	**0.32**	**7.68**	**0.18**	**0.34**	**0.75**	**2.09**	**0.08**	**0.27**	**7.87**	**0.20**	**0.51**	**0.09**	**0.16**	**0.21**	**0.02**
SD	**0.43**	**0.12**	**0.13**	**1.46**	**1.20**	**0.07**	**0.13**	**0.52**	**0.17**	**0.13**	**0.85**	**1.52**	**0.07**	**0.27**	**0.50**	**0.23**	**0.22**	**1.05**	**0.44**	**0.10**	**0.33**
Min	**7.02**	**0.05**	**0.07**	**0.1**	**0.06**	**0.02**	**0.09**	**6.79**	**0.06**	**0.11**	**0.01**	**0.06**	**0.006**	**0.22**	**7.18**	**0.05**	**0.24**	**0.014**	**0.02**	**0.02**	**0.006**
Max	**8.32**	**0.42**	**0.46**	**4.86**	**4.08**	**0.24**	**0.74**	**8.7**	**0.73**	**0.58**	**3.22**	**6.1**	**0.22**	**1.08**	**8.85**	**0.83**	**1.15**	**4.00**	**1.80**	**0.48**	**1.22**

Table 2. Correlation analysis of Physico-chemical characteristics and micronutrient levels in three villages of Anantapur district, Andhra pradesh, India

	Kanchisamudram			Bucharla			Kongira		
	pH	EC	OC	pH	EC	OC	pH	EC	OC
Fe	0.029	-.646**	-0.203	-0.006	-0.494*	-0.083	-0.400	0.313	0.794**
Mn	-0.001	-.648**	-0.260	-0.020	-0.351	-0.007	-0.365	0.196	0.647**
Zn	0.122	0.052	-0.260	-0.328	0.162	0.223	0.370	-0.213	-0.253
Cu	0.11	-0.183	-0.47*	-0.117	-0.035	0.119	0.402	0.147	0.491*

that the adequacy of copper (Cu) in the soils could be attributed to the interactive influence of various soil properties, including pH, electrical conductivity (EC), and organic carbon (OC), which collectively impact copper availability. Copper availability tends to increase with higher organic matter content but decreases with soil pH and the presence of calcium carbonate ($CaCO_3$), as highlighted in the study conducted by Mahashabde and Patel (2012).

Correlation Coefficient (r) between physico - chemical properties with available micro nutrients in dry land agriculture of Anantapur district, Andhra Pradesh, India.

In Kanchisamudram, there was a positive correlation between pH and Fe (r = 0.029) and a negative correlation between pH and Mn (r = -0.001). The electrical conductivity (EC) showed a negative correlation with Fe (r = -0.646**) and Mn (r = -0.648**), while organic carbon (OC) had a weak negative correlation with Fe (r = -0.203) and Mn (r = -0.26). Additionally, there was a positive correlation between Fe and Mn (r = 0.26) (Table 2).

In Bucharla, pH was negatively correlated with Fe (r = -0.006) and Cu (r = -0.117), and positively correlated with Zn (r = 0.328). The EC had a negative correlation with Fe (r = -0.494*) and a weak positive correlation with Cu (r = 0.035). OC showed a weak negative correlation with Fe (r = -0.083) and a positive correlation with Cu (r = 0.119) (Table 2).

In Kogira, pH exhibited a negative correlation with Fe (r = -0.4) and Cu (r = -0.402), and a positive correlation with Zn (r = 0.37). EC had a positive correlation with Fe (r = 0.313) and Cu (r = 0.147), while OC had a strong positive correlation with Fe (r = 0.794**) and a moderate positive correlation with Cu (r = 0.491*) (Table 2).

In summary, the study identified varying soil conditions across the villages, with Kogira exhibiting notably higher alkalinity and salinity levels compared to the others. Organic carbon content was low in all three villages, but micronutrient concentrations varied, with Kanchisamudram having higher iron (Fe) and manganese (Mn) levels than Bucharla and Kogira. Zinc (Zn) and copper (Cu) levels fluctuated but remained low in all. To improve agricultural productivity, it is crucial to address pH issues in Kogira, implement salinity control measures, and enhance organic carbon content in all three villages. Based on the findings, it is advised to use composting and cover cropping to increase organic matter, rectify pH imbalances using lime or sulphur, and manage salinity with improved irrigation and drainage. Micronutrient supplements such as iron chelates and manganese sulphate are recommended in Kogira, while zinc oxide and copper sulphate are recommended in all three villages. These measures will promote soil fertility, nutrient availability, and agricultural sustainability in these dryland regions.

REFERENCES

Cakmak, I. 2008. Enrichment of cereal grains with zinc: Agronomic or genetic biofortification, Plant Soil, **302**(1-2): 1-17.

Chandel, S., M.S. Hadda and A.K. Mahal, 2018. Soil Quality Assessment Through Minimum Data Set Under Different Land Uses of Submontane Punjab, Commun Soil Sci. Plant Anal. **49**(6): 658-674.

Hafeez, B., Y. M. Khanif and M. Saleem, 2013. Role of zinc in plant nutrition—a review, Am. J. Exp. Agric. **3**(2): 374-391.

Jackson, M. L. 1973. Soil chemical analysis. Prentice Hall India Pvt. Ltd., New Delhi, pp. 498.

Kumar, M., A. Kar, P. Raina, S.K. Singh, P.C. Moharana and J.C. Chauhan, 2019.Spatial variability of available nutrients in the Shekhawati region of Thar Desert, India. J. Indian Soc. Soil Sci. **67**: 21-33.

Lindsay, W. L. and W. A. Norvell, 1978. Development of a DTPA soil test for zinc, iron, manganese and copper. Soil Sci. Soc. Am. J. **42**: 421-428.

Mahashabde, J.P. and S.N. Patel, 2012.DTPA – Extractable Micronutrients and Fertility Status of Soil in Shirpur Tahasil Region. IJCRT, **4**(0974-4290), 1681-1685.

Marschner, H., 2012. Mineral Nutrition of Higher Plants (3rd ed.). Imprint of Elsevier Academic Press.

Neha, B.S. Bhople and S. Sharma, 2020. Seasonal variation of rhizospheric soil properties under different land use systems at lower Shivalik foothills of Punjab, India.Agrofor. Syst.**94**(5): 1959-1976.

Randhawa, M.K., S.S. Dhaliwal, V. Sharma, A.S. Toor, S. Sharma and M. Kaur, 2021. Impact of Integrated Nutrient Management on Transformations of Micronutrients and Uptake by Wheat Crop in North-Western India, J. Soil Sci. Plant Nutr.**21**(4): 2932–2945.

Mane, S. S. , K.T. Jadhav and S. P. Chakke, 2022.Appraisal of soil fertility status of somthana dam area of badnapur. J. Soils and Crops. **32** (2) 301-304.

Sharma, B.K., N. Singh and M. Kumar, 2006. Sandy soils of Jaisalmer district: Their morphogenesis and evaluation for sustainable land use, Ann. Arid Zone. **45**: 139-149.

Shirgire, S.T., S.G. Savalia and N.B. Misal, 2018.Assessment of available macro and micronutrient status of coastal Jamnagar district in Saurashtra region of Gujarat. J. Indian Soc. Soil Sci. **66**: 182-187.

Smith, A.P., J.A. Johnston and I.S. Cornforth, 2019.Advancing Micronutrient Research and Application in Dryland Agriculture. Front Plant Sci. **10**: 1224.

Thombe, Swati V., W. P. Badole, Shivani Kawade and R. M. Ghodpage, 2020. Assessment of soil fertility status in selected villages under Jalyukt Shivar in Nagpur District. J. Soils and Crops, **30** (1):132-138.

Walkley, A. and C.A. Black, 1934.An examination of digestion methods for determining soil organic matter and a proposed modification of the chromic acid titration method. Soil Sci. **37** (1): 29-38.

White, P.J. and P.H. Brown, 2010.Plant Nutrition for Sustainable Development and Global Health. Ann. Bot. **105**: 1073-1080.

Witzgall, K., A. Vidal, D.I. Schubert, C. Höschen, S.A. Schweizer, F. Buegger, V. Pouteau, C. Chenu and C.W. Mueller, 2021.Particulate organic matter as a functional soil component for persistent soil organic carbon, Nat. Commun.**12**(1): 1-10.

Yadav, R.K. and V. Nisha, 2019. Studies of some soil health parameters of district Bareilly, U.P. (INDIA). J. Soils and Crops, **29**(1): 68-73.

Rec. on 01.09.2023 & Acc. on 21.09.2023