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Effect of Inorganic and Integrated Long-term Nutrient Management on DTPA-extractable Micronutrients in a *Vertisol* under Soybean-wheat Cropping System across the Soil Depth

Vivek Singh [a*], Hitendra K. Rai [a], Priyanka Jain [a], B. S. Dwivedi [a], A. K. Upadhyay [a], S. B. Agrawal [a], Sanjib Kumar Behera [b] and R. B. Singh [a]

[a] *Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, India.*
[b] *ICAR-Indian Institute of Soil Science, Bhopal, India.*

Authors' contributions

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

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ABSTRACT

The status of DTPA extractable micronutrient (Zn, Cu, Fe and Mn) in response of continuous application of different inorganic and organic fertilizer combination in a 48 years old ongoing long-term fertilizer experiment (AICRP-LTFE) were investigated in *Vertisol* at Department of Soil Science, and Agricultural Chemistry, JNKVV, Jabalpur under intensive cultivation of soybean-wheat cropping system in 2021. The treatments selected for the study were: control (T1); 100% NP(T2); 100% NPK (T3); 100% NPK+FYM (T4); 100% N(T5); 50% NPK (T6); 150% NPK (T7).

**Corresponding author: E-mail: vivekofficial03@gmail.com;*

Application of FYM along with balance fertilizer (100% NPK) significantly increased the micronutrients availability in soil. On contrast, Imbalance fertilization caused a lower level of micronutrients in soil even below to the critical limit in case of zinc. A decreasing trend with increase in soil depth irrespective of type of nutrient management and micronutrient type was evident in the study. Findings of the present study emphasized the application of balance fertilization along with organic sources like FYM for sustaining micronutrients availability in *Vertisol* under soybean-wheat cropping system.

Keywords: Balance fertilization; DTPA-extractable micronutrient; INM; LTFE; soybean-wheat; Vertisol.

1. INTRODUCTION

Micronutrients are vital to plants and human health. Micronutrients like, Zn, Cu, Fe, and Mn play an important role in increasing the productivity of crop as well as maintaining its quality (Uprety et al., 2009; Tavakoli et al, 2014). When soil micronutrient concentrations are insufficient, plants cannot get enough of them to meet their demands. On the other hand, they may be toxic if their levels in the soil are too high. More than 50% of soils nowadays are deficient in micronutrients, which directly affects crop production and the nutrient value of farm products. The lack of micronutrients has an adverse impact on human well-being, and more than 2 billion people worldwide are malnourished. The deficiency of micronutrient to plant is the main contributor to this shortage [1]. Injudicious or imbalanced use of inorganic fertilizers for crop production over a long period results in low nutrient availability [2]. Availability of micronutrients in soil depends on various factors like, parent material, climatic and topographic conditions, cropping systems, management practices [3] and soil properties, such as pH, organic matter contents and available forms of macronutrients that are significantly affected by the use of mineral fertilizers and organic manures [4]. It is also evident that intensive cultivation for a longer period results in decrement in nutrient availability [5].

Long-term application of fertilizers affects the availability in several ways. Several research findings revealed that the continuous application of organic sources (FYM or Manure) with inorganic fertilizers enhance the status of micronutrient in soil. Long-term studies offer the chance to monitor changes in crop yields and nutrient balances, as well as the identification of factors linked to such changes, which can be used to assess the viability of agricultural management systems [6]. However, the depth wise scenario of DTPA-extractable micronutrient (Zn, Cu, Fe and Mn) in *Vertisol* under soybean-wheat system is still insufficient. Considering these research lacuna, present study has been conducted to quantify the distribution of DTPA-extractable Zn, Cu, Fe and Mn along the soil depth (0-60 cm) under soybean-wheat system in *Vertisol*.

2. MATERIALS AND METHODS

An ongoing, All India Co-ordinated Research Project on long-term field experiment (AICRP-LTFE) on the soybean-wheat cropping system was established in 1972 at Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, M.P (29°01'N, 77°45'E, 393m above mean sea level), India was chosen for the investigation during 2021. It represents the semi-arid and sub-tropical zone of central India with average annual rainfall of 1274 mm mostly received by south-west monsoon during June to October, experiences hot dry summers and cool winters with mean maximum temperature 32ºC and mean minimum temperature 18ºC. The soil is known as medium-deep black soil and it is basically clayey *V*ertisol belongs to Kheri series of fine montmorillonitic hyperthermic family of *Typic* Haplustert. Seven treatments each with three replication, comprising combination of sub-optimal (50% of recommended rate) to super-optimal (150% of recommended rate) level of nutrient application with or without FYM (5 t ha^{-1} only in kharif crop) in randomized block design were chosen for study. Collection of soil sample were accomplished after harvest of *Rabi* season (wheat crop) in April, 2020. Soil sample were collected with the help of screw augar at four distinct depth with interval of 15 cm (0-15, 15-30, 30-45, and 45-60cm) from each replication belonging to the following treatments: Control, 100% NP, 100% NPK, 100% NPK+FYM, 100% N, 50% NPK, and 100% NPK. Soil sample were ground with wooden mortar-pestle, sieved through 2 mm sieve to get it ready for analysis, and stored in separate poly-ethylene bags. Analysis of micronutrients (Zn, Cu,Fe, and Mn) were accomplished by following DTPA method suggested by Lindsay and Norvell (1978) employing Atomic Absorption Spectrophotometer. (AAS). For testing the differences among means of various treatments, critical differences (CD) were calculated at 5% level of significance by carrying out Analysis of Variance (ANOVA) using randomized block design (RBD).

3. RESULTS AND DISCUSSION

3.1 DTPA-extractable Zinc (Zn)

Data pertaining to DTPA-extractable zinc (Zn) availability in soil at different depths under various nutrient management is presented in Table 1. Zn availability at all soil depths (0-15, 15-30, 30-45, and 45-60cm), was found significantly (*p=0.05*) highest in 100% NPK+FYM (0.83, 0.71, 0.54, and 0.42 mg kg^{-1}) and lowest in control (0.46, 0.39, 0.32, and 0.26 mg kg^{-1}). Zn availability reported in 100% NPK+FYM was at par to 100% NPK (69 mg kg^{-1}) and 150% NPK (76 mg kg^{-1}) at depth 0-15 cm, While value of 100% NPK+FYM was found only at par to 150% NPK (48 and 41 mg kg^{-1}) for deep layers (30-45 and 45-60 cm). In all soil depths except 45-60 cm, the value of control treatment was found at par to treatments receiving imbalance fertilization (100% N, 100% NP, and 50% NPK). Furthermore, it was observed that increase in soil depth resulted decrease in Zn availability irrespective of nutrient management applied for a long period (Fig. 1). A complete nutrient (100% NPK) application along with FYM (surface and sub-surface depth) and without FYM (at surface layer) confirmed Zn availability in soil more than its critical limit (0.6 mg kg^{-1}). The higher value found associated with 100% NPK + FYM and lower value in control treatment might be due to higher organic matter addition of Zn through FYM and release of chelating agents that prevent Zn from precipitation and leaching [3]. However, Shambhavi et al. [7] reasoned mineralization of organically bound forms of Zn in the FYM for higher DTPA-extractable zinc in 100% NPK + FYM. The results further elucidated that the DTPA-extractable zinc in treatment receiving balanced (150% NPK, 100% NPK, 50% NPK) fertilizer application had more values than treatment receiving imbalanced (100% N, 100% NP) fertilizer application and control could be because of higher crop residues incorporation that leads to increase in organic matter [8]. Presence of organic matter in particular soil depth may be attributed to the decrease in DTPA-extractable zinc with increase in soil depth. Similar results were reported by Meshram et al. [9] in soybean crop and of Patil et al. [10] in wheat crop on *Vertisols*. The increase of soil pH along with increase in soil depth may might be the reason behind the decreasing trend of Zn availability in soil [11].

3.2 DTPA-extractable Copper (Cu)

Overall effect of different long-term nutrient management practices on DTPA-extractable copper (Cu) was significant across 0-60 cm soil depth after 48 years of intensive cultivation of soybean-wheat cropping system (Table 1). At all soil depths (0-15, 15-30, 30-45, and 45-60cm), a significantly (*p=0.05*) highest value of DTPA-extractable copper was observed treatment in 100% NPK+FYM (1.55, 1.48, 1.25, and 1.08 mg kg^{-1}) and the lowest values were found in untreated control (1.08,1.02, 0.84, and 0.78 mg kg^{-1}). DTPA- extractable Cu found in 150% NPK (1.46 mg kg^{-1}) was at par to 100% NPK+FYM at depth 0-15 cm only. However, DTPA- extractable Cu found in control treatment was found at par to 100% N (1.05, 0.88, 0.84 mg kg^{-1}) treatment at all soil depth except 0-15 cm). In all treatments a decreasing trend was observed in DTPA-extractable Cu as heading towards deep in soil. DTPA- extractable Cu across 0-60 cm soil depth (Fig. 2) ranged 0.78-1.55 mg kg^{-1}, which was more that its critical limit (0.2 mg kg^{-1}) in soil indicated it's sufficiency for plant uptake. Higher value observed in 100% NPK + FYM and lower value in control treatment could be because of organic matter (FYM) that contains a variety of nutrients, including micronutrients (815, 181, 14 and 74 mg/kg of Fe, Mn, Cu, and Zn, respectively, on a dry weight basis). Additionally, organic matter provides a number of complexing agents that keep the balanced nutrient supply to crop [12]. Due to FYM's richness in micronutrients, copper cation may have been increased in the soil as a result. Furthermore, due to FYM mineralization, well-decomposed FYM may have contributed to the formation of chelates with organic ligands, reducing copper's susceptibility to adsorption, fixation, and precipitation in the soil as well as the subsequent release of micronutrients [13]. A decrease in DTPA-extractable Cu across the soil depth was also reported by Jayaraman et al. (2020) in *Vertisol*.

3.3 DTPA-extractable Iron (Fe)

Continuous application of inorganic fertilizer in combination with FYM or alone significantly (*p=0.05*) influenced the DTPA-extractable Iron (Table 1). At the end of 48 years of intensive cultivation of soybean-wheat cropping system the highest DTPA-extractable Fe was found under treatment receiving combined application of 100% NPK along with FYM at soil depth 0-15, 15-30, 30-45, and 45-60 cm respectively 23.33, 21.32, 17.87, and 16.06 mg kg^{-1}. On contrast, the lowest value of DTPA-extractable Fe was observed in the untreated control in all respective soil depth (17.32, 16.72, 14.57, and 13.27 mg kg^{-1}). Treatment 100% NPK+FYM was found at par to 100% NPK (19.93 mg kg^{-1}) at 0-15 cm and 150% NPK (20.28, 16.96, 15.60 mg kg^{-1}) at soil depth 15-30, 30-45, and 45-60 cm. Whereas, control treatment was found at par to 100% N (17.95 mg kg^{-1}) and 50% NPK (18.55 mg kg^{-1}) at soil depth 15-30 cm. From surface to deep soil layer (up to 60 cm), DTPA-extractable Fe varied from 13.27-23.33 mg kg^{-1} implied its sufficiency in soil among all treatments. However, a decreasing trend in DTPA-extractable Fe was also observed with increase in soil depth irrespective of nutrient management applied (Fig. 3). Maximum value of DTPA-extractable iron found in treatment receiving combination of organic (FYM) and inorganic nutrient sources may be ascribed to reduction in the redox-potential of the soil with the addition of organic sources, which led to more release of iron in an available form in the soil as compared treatment receiving the application of inorganic fertilizers and control [14]. Decrease in DTPA-extractable iron with increase in soil depth could be attributed to decrease of organic matter across the soil depth, similar trend of DTPA-extractable iron across soil depth (0-150 cm) were also reported by Dhaliwali et al. (2015). Study of Thakur et al. [15] and Sireesha et al. [16] were found in agreement with findings of present study.

3.4 DTPA-extractable Manganese (Mn)

Perusal of the data presented in Table 1 showed a significant effect of long-term differential nutrient management practices on DTPA-extractable Mn in soil. The value of DTPA-extractable Mn varied from 14.24 to 7.45 mg kg^{-1} in all the treatments across 0-60 cm. At all soil depths (0-15, 15-30, 30-45, and 45-60 cm), significantly the highest value of DTPA-extractable Mn found in 100% NPK+FYM (14.24, 13.68, 10.32, and 10.17mg kg^{-1}) and that was at par to 100% NP, 100% NPK, and 150% NPK at surface and sub-surface. DTPA-extractable Mn in 100% NPK+FYM observed at par to 100% NPK and 150% NPK at 30-45 cm and at par to 150% NPK at 45-60 cm. Significantly the lowest value of DTPA-extractable Mn was reported in untreated control (11.60, 11.20, 7.87, and 7.45 mg kg^{-1}) for all respective soil depths. Overall a decreasing trend among all the treatments were observed across 0-60 cm soil depth (Fig. 4). The increase of organic matter in soil enhanced the activity of microbes, which helps in the release of trace elements [17] might be the possible reason behind maximum value of DTPA-extractable manganese found in 100% NPK + FYM. However, Application of superphosphate in long-term might caused the high DTPA-extractable Mn in treatment like 150% NPK, 100% NPK, 100% NP, and 50% NPK (Li et al., 2010). Similar results were reported by Meshram et al. [9] in *Vertisol* and Parven et al. [14] in alluvial soil [18-23].

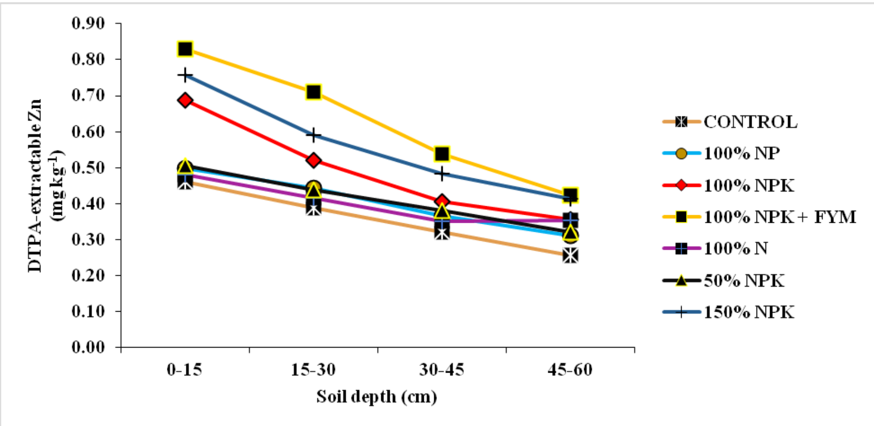

Fig. 1. Effect of different long-term nutrient management practices on DTPA-extractable Zn across 0-60 cm soil depth

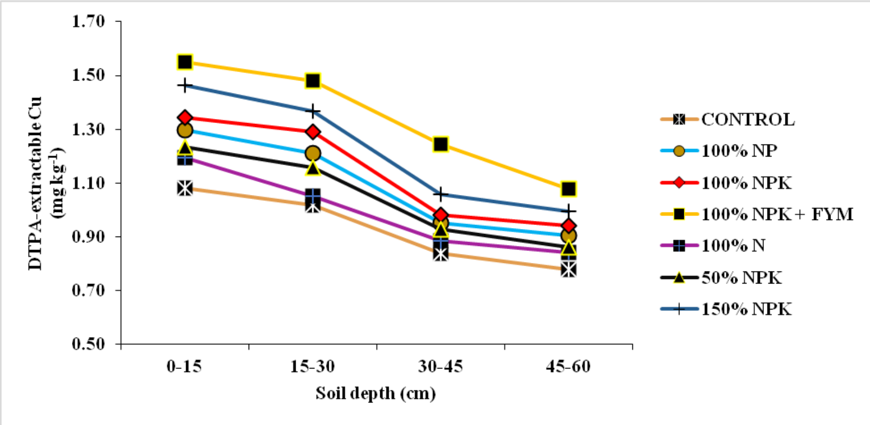

Fig. 2. Effect of different long-term nutrient management practices on DTPA-extractable Cu across 0-60 cm soil depth

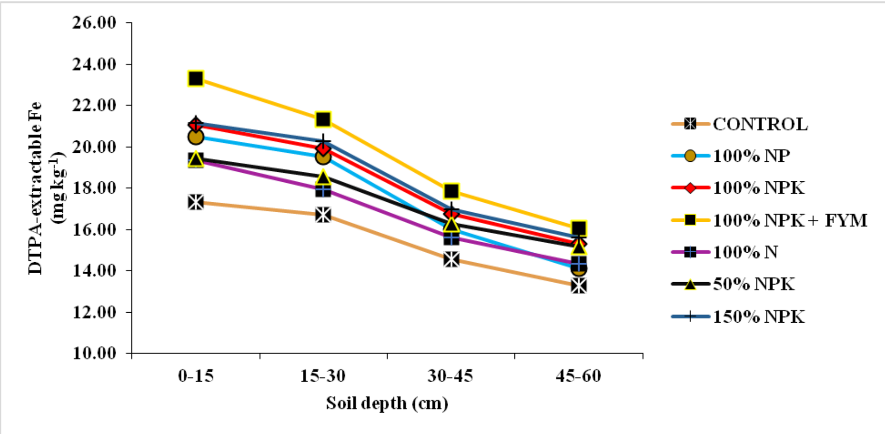

Fig. 3. Effect of different long-term nutrient management practices on DTPA-extractable Fe across 0-60 cm soil depth

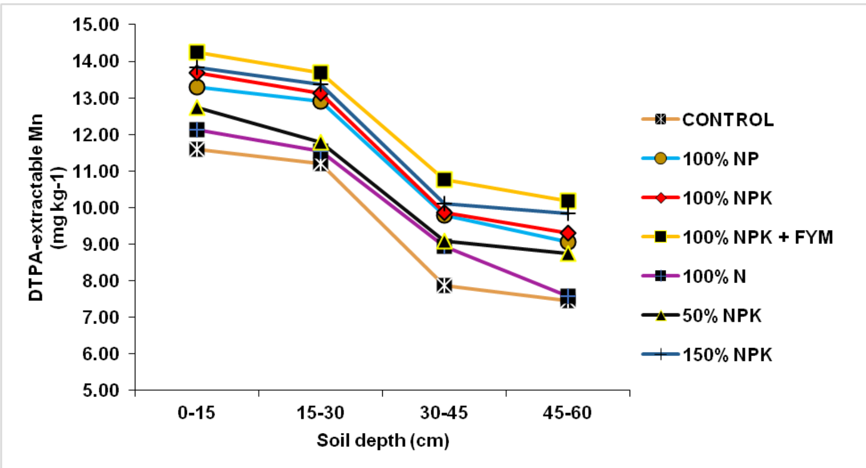

Fig. 4. Effect of different long-term nutrient management practices on DTPA-extractable Mn across 0-60 cm soil depth

Table 1. Depth-wise distribution of DTPA-extractable micronutrients (Zn, Cu, Fe, and Mn) in soil under INM practices after 48 years of intensive cultivation

Soil Depth (cm) / Treatment	DTPA-extractable Zinc (mg kg^{-1})				DTPA-extractable Copper (mg kg^{-1})			
	0-15	**15-30**	**30-45**	**45-60**	**0-15**	**15-30**	**30-45**	**45-60**
Control	0.46	0.39	0.32	0.26	1.08	1.02	0.84	0.78
100% NP	0.50	0.44	0.36	0.31	1.30	1.21	0.95	0.91
100% NPK	0.69	0.52	0.40	0.36	1.34	1.29	0.98	0.94
100% NPK + FYM	0.83	0.71	0.54	0.42	1.55	1.48	1.25	1.08
100% N	0.48	0.42	0.35	0.35	1.19	1.05	0.88	0.84
50% NPK	0.51	0.44	0.38	0.32	1.23	1.16	0.93	0.86
150% NPK	0.76	0.59	0.48	0.41	1.46	1.37	1.06	0.99
SEm±	0.043	0.027	0.023	0.010	0.030	0.032	0.019	0.022
C.D. (*p=0.05*)	0.132	0.084	0.070	0.032	0.093	0.099	0.057	0.067
Soil Depth(cm) / Treatment	**DTPA-extractable Iron (mg kg^{-1})**				**DTPA-extractable Manganese (mg kg^{-1})**			
	0-15	**15-30**	**30-45**	**45-60**	**0-15**	**15-30**	**30-45**	**45-60**
Control	17.32	16.72	14.57	13.27	11.60	11.20	7.87	7.45
100% NP	20.51	19.55	15.99	14.11	13.29	12.90	9.79	9.07
100% NPK	21.08	19.93	16.76	15.33	13.68	13.13	9.85	9.31
100% NPK + FYM	23.33	21.32	17.87	16.06	14.24	13.68	10.75	10.17
100% N	19.36	17.95	15.64	14.35	12.12	11.53	8.94	7.58
50% NPK	19.45	18.55	16.28	15.20	12.72	11.79	9.09	8.74
150% NPK	21.15	20.28	16.96	15.60	13.84	13.38	10.10	9.83
SEm±	0.481	0.657	0.306	0.197	0.408	0.343	0.305	0.247
C.D. (*p=0.05*)	1.483	2.025	0.942	0.607	1.258	1.058	0.940	0.760

4. CONCLUSION

From the present study it can be concluded that status of micronutrient availability (DTPA-extractable Zn, Fe, Cu, and Mn) in soil at varying depth was altered by different nutrient management practices in long-term. Balance fertilization with inclusion of organic sources (FYM) in *Vertisol* under soybean-wheat cropping system resulted sufficient availability of micronutrient for plant uptake. On contrast, long-term imbalance nutrient application may cause a deficiency of micronutrient in soil and can be a potential reason for severe reduction in yield.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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