

Critical Limit of DTPA Extractable Zn for Wheat in *Typic haplusterts* of Jabalpur District of Madhya Pradesh, India

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Abstract Field experiments were conducted during *rabi* 2012-13 at eleven farmer's field to find out the effect of Zn levels (0, 2, 4, 6 and 8 kg Zn ha⁻¹) on yield, nutrient content and uptake by wheat grown on *Typic haplusterts* of Jabalpur (MP). The soils of study sites varied in available Zn from 0.20 to 2.00 mg kg⁻¹ and classified in two groups i.e., zinc deficient (< 0.60 mg Zn kg⁻¹), marginal and adequate (> 0.60 mg Zn kg⁻¹). The results reflected that all the soils of deficient category, the application of 6 kg Zn ha⁻¹ significantly increased the wheat grain yield while little increased in sufficient category. The method of Cate and Nelson indicated the critical limit of available Zn to be 0.59

mg kg⁻¹ and gave a predictability value of 89%. The critical level of Zn in wheat grain was found to be 22.75 mg kg⁻¹. Based on these findings, it can be concluded that wheat crop will respond to Zn application when the soils content less than 0.59 ppm DTPA extractable Zn (Vertisol), hence, the application of 6 kg Zn ha⁻¹ through ZnSO₄·7H₂O fertilizer in these soil will enhance the wheat productivity.

Keywords Critical limit, Wheat, Zinc, Yield.

Introduction

Wheat (*Triticum aestivum* L.) is an important food grain crop in India ranking next to rice (*Oryza sativa* L.) contributing about 35% of the food grain production. India occupies second position next to China in the world with regard to area (27.7 million hectares) and production (77.6 million tonnes) of wheat. Besides its tremendous significance, average yield is far below than developed countries [1]. Amongst the micronutrients the deficiency zinc is common throughout the arid and semi-arid regions of the world due to low Zn solubility and high Zn fixation [2]. Almost 50% of the world soils used for cereal production is Zn deficient [3]. In India, analysis of 14,863 soil samples from all over the country showed that 49% of soils were potentially deficient in Zn [4] and in Madhya Pradesh 60.3% of 6713 soil samples analyzed indicated deficiency of Zn [5]. Crops grown under such deficient conditions have low yield and pro-

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Table 1. Initial soil properties.

Sites	Latitude	Longitude	pH	EC (dSm ⁻¹)	OC (g kg ⁻¹)	Ca CO ₃ (g kg ⁻¹)
1	23°19'20.97''	79°59'19.35''	7.4	0.12	9.5	30
2	23°15'15.67''	79°45'32.33''	6.9	0.15	5.1	20
3	23°18'21.92''	79°59'12.58''	7.5	0.13	7.1	20
4	23°15'06.01''	79°45'51.22''	7.2	0.25	4	45
5	23°18'10.33''	79°58'06.44''	7.4	0.23	3.8	20
6	23°19'53.23''	79°58'56.96''	7.5	0.18	6.2	30
7	23°18'55.65''	79°58'51.22''	7.6	0.17	1.6	20
8	23°15'07.36''	79°44'48.16''	7.6	0.11	6.2	25
9	23°19'29.48''	79°58'7.78''	7.9	0.19	6.4	20
10	23°16'52.74''	79°44'27.61''	7.6	0.16	4.8	25
11	23°15'19.43''	79°45'25.98''	7.3	0.14	3.4	25

Table 1. Continued.

Sites	N	Major Avail nutrients (kg ha)				Micronutrient (mg kg ⁻¹)				Avail S (mg kg ⁻¹)
		P	K	Zn	Cu	Fe	Mn	B		
1	308	34.12	397	0.2	4.1	16.4	5.1	1.2	9.5	
2	253	21.16	252	0.3	2.2	6.4	8.8	0.7	4.6	
3	318	39.79	398	0.4	2	9.6	7	0.7	4.6	
4	231	53.12	251	0.5	1.9	5	6	0.5	11.5	
5	306	22.46	426	0.5	2.2	10.4	9.9	1	4.6	
6	296	37.57	205	0.7	2.5	17.4	13.8	0.8	11.1	
7	261	17.8	357	0.9	2	8.4	4	1	9.5	
8	243	26.34	350	1.1	2.2	7	8.7	1	10.6	
9	318	22.69	223	1.4	2.7	13	7	0.7	12.8	
10	297	31.41	381	1.7	2.2	10	8.2	0.7	11.1	
11	307	31.76	391	2	2.1	6.2	4.4	0.6	3	

duce seeds with a low Zn content in India. In the past, the focus of agronomists and policy makers has been on crop production, rather than crop nutritional quality. This phenomenon contributed to Zn malnutrition in humans.

Zinc plays a major role in wheat production [6] but its deficiency is so widespread that it ranks next to N and P and continues to be a limiting factor of wheat production in India. Critical levels of a nutrient in soils refer to a level below which the crops will readily respond to its application. The general critical limit of Zn in soil and crops fall in the range of 0.6–1.0 mg kg⁻¹ (DTPA-extractant) and 10–20 mg kg⁻¹ in dry matter respectively [7] but it vary with soils and crops. For clear prediction of possible deficiencies, their critical limits must be refined with reference to the soil and crop characteristics respectively as they

vary in their nutrient supplying capacity and utilization efficiency. Most of the studies have been in pot culture under greenhouse conditions which are quite different from the field. Therefore, the present investigation undertaken under field condition to judge the response of wheat to Zn fertilization and the critical limit of (DTPA extractable) zinc in soil (Vertisol) and plant (grain) of wheat.

Materials and Methods

An field experiments was conducted during *rabi* 2012-13 in wheat crop in eleven farmer's field on *Typic haplusterts* of Jabalpur (MP) to study the effect of Zn levels (0, 2, 4, 6 and 8 kg Zn ha⁻¹) on yield, nutrient content and uptake by wheat. The soils selected for the study range from 0.20 to 2.00 mg kg⁻¹ DTPA extractable Zn (Table 1) belonged to deficient to two

Table 2. Effect of different levels of zinc application on grain and straw yield of wheat (t ha⁻¹).

Treat- ments (soil)	Zinc levels (kg ha ⁻¹)											
	0		2		4		6		8		Mean	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
1	3.5	5.83	3.53	5.9	3.73	5.96	4.1	6	3.6	6.4	3.69	6.02
2	3.6	6	3.73	6	3.97	6.2	4.13	6.22	4.13	6.77	3.91	6.24
3	3.7	6	3.73	6.5	3.78	6.6	4.4	6.93	4.63	6.63	4.05	6.53
4	3.73	5.33	4	5.57	4.04	5.9	4.37	6.43	3.93	6.53	4.02	5.95
5	3.75	5.19	4.18	5.33	4.2	5.77	4.4	5.9	4.09	6.5	4.12	5.74
6	4.35	5.6	4.43	5.98	4.45	6.47	4.55	5.73	4.1	5.53	4.38	5.86
7	4.47	6.3	4.5	6.37	4.57	6.5	4.8	6.8	4.5	5.47	4.57	6.29
8	4.5	6.25	4.53	6.26	4.6	6.37	4.85	7	4.53	7.07	4.6	6.59
9	4.6	4.53	4.63	4.67	4.67	5.37	4.73	5.48	4.63	5.47	4.65	5.1
10	4.65	5.73	4.77	6.1	4.8	6.17	5.05	6.77	4.83	6.02	4.82	6.16
11	4.7	6.45	4.79	6.6	4.93	7.18	5	7.01	4.93	6.96	4.87	6.84
Mean	4.14	5.27	4.26	5.61	4.34	6.04	4.58	6.36	4.36	6.44		
			Zn	Zn	Soil*	Soil*						
	Soil	Soil	doses	doses	Zn	Zn						
SEm±	0.11	0.13	0.08	0.09	0.26	0.28						
LSD (p=	0.32	0.35	0.22	0.24	NS	NS						
0.05)												

groups i.e. zinc deficient (<0.60 mg Zn kg⁻¹), marginal and adequate (>0.60 mg Zn kg⁻¹). The soils are clayey, alkaline in reaction and low in organic carbon. The Zn treatments (0, 2, 4, 6 and 8 kg ha⁻¹ Zn kg⁻¹) through ZnSO₄·7H₂O were applied thrice at the time of sowing in a randomized block design. The basal dose of 60 kg N, 60 kg P₂O₅ and 40 kg K₂O were applied through urea, single super phosphate (SSP) and muriate of potash respectively at the time of sowing and 60 kg N ha⁻¹ was applied at crown root sown initiation stage. The wheat seed was sown @ 120 kg ha⁻¹ at 22.5 cm row to row spacing.

Chemical analysis of soil and plant

From each experimental site, representative soil

samples were collected before and after harvest of wheat crop. The experimental soil (0–15 cm depth) was analyzed for initial soil physico-chemical properties. The initial soil sample were analyzed for available zinc (0.005 M DTPA) as given in Table 1. The crop was harvested at maturity (120 days after sowing). Grain and straw yield from each plot were recorded at the time of threshing and grain and straw samples were collected for analysis of Zn content. The plant samples were digested in a tri-acid mixture of nitric, sulfuric acid and perchloric acid (9:2:1) and Zn content in digestate was determined using Atomic Absorption Spectrophotometer. The uptake was estimated by multiplying the Zn content in grain and straw with their yield.

Table 3. Influence of zinc application on grain and straw yield.

Status of soil zinc (mg kg ⁻¹)	No. of soil	Parame- ter	Zn levels (kg ha ⁻¹)			
			0	6	6	6
			Range	Mean	Range	Mean
<0.59	5	Grain	3.5–3.75	3.66	4.1–4.4	4.28
		Straw	5.1–6.0	5.67	5.9–6.93	6.30
>0.59	6	Grain	4.35–4.70	4.55	4.55–5.05	4.83
		Straw	4.53–6.45	5.81	5.48–7.01	6.46

Table 4. Effect of zinc application on zinc content in grain and straw of wheat (mg kg⁻¹).

Treatments (soil)	Zinc levels (kg ha ⁻¹)											
	0		2		4		6		8		Mean	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
1	18.79	10.27	23.86	11.54	27.01	12.65	31.40	11.75	31.75	11.35	26.56	11.51
2	21.62	10.36	24.66	10.45	26.56	11.10	28.49	11.70	29.37	12.54	26.14	11.23
3	21.94	10.27	22.00	10.68	22.47	11.20	23.56	11.84	31.97	11.81	24.39	11.16
4	22.51	11.87	28.02	12.47	29.02	12.93	32.65	12.92	33.26	14.67	29.09	12.97
5	23.00	9.53	23.99	9.83	28.01	10.62	29.85	12.07	31.91	11.30	27.35	10.67
6	23.17	11.05	25.66	11.21	28.30	11.27	29.59	12.76	30.33	11.89	27.41	11.64
7	25.22	8.78	25.38	10.74	25.53	11.25	26.39	11.35	30.53	11.67	26.61	10.76
8	26.20	10.88	30.22	11.23	30.92	11.33	31.98	11.61	32.88	12.34	30.44	11.48
9	27.23	9.68	28.67	11.72	29.64	11.74	29.67	11.84	30.53	11.67	29.15	11.33
10	28.14	9.33	28.40	9.94	29.17	12.24	29.24	12.43	31.76	12.21	29.34	11.23
11	26.28	10.39	27.64	10.62	28.16	12.35	29.64	12.37	31.81	12.45	28.71	11.64
Mean	22.01	9.37	24.21	10.2	25.73	11.06	27.4	11.55	29.51	11.82		
		Soil	Soil	Zn doses	Zn doses	Soil* Zn	Soil* Zn					
SEm±		0.67	0.51	0.45	0.34	1.51	1.14					
LSD												
(<i>p</i> =0.05)		1.89	1.43	1.27	0.96	NS	NS					

Critical limit estimation

The Bray's per cent yield was calculated as per the following formula: Bray's percent yield = Yield without zinc / Optimum yield with zinc × 100. In the graphical version, horizontal and vertical lines were positioned to maximise number of points in the first and third quadrant to obtain the critical value. This was verified statistically from the total variance (R^2) of observed values with postulated critical values, where the R^2 peaks at the critical value.

Results and Discussion

Initial soil characteristic

The soils of experimental sites varied in pH 6.9–7.9,

EC 0.11–0.25 dSm⁻¹, organic carbon 1.6–9.5 g kg⁻¹, CaCO₃ 20–45 g kg⁻¹. The primary available nutrient N 231–318 kg ha⁻¹, P 17–54 kg ha⁻¹ and K 205–426 kg ha⁻¹. The DTPA-extractable Zn 0.20–2.0 mg kg⁻¹, Cu 1.9–4.1 mg kg⁻¹, Fe 5.0–17.4 mg kg⁻¹, Mn 4.0–13.8 mg kg⁻¹, B 0.5–1.2 mg kg⁻¹ and S 3–12.8 mg kg⁻¹ and soil texture clay loam clay (Table 1). Variations in soil pH, lime, organic matter, clay, amount of phosphorus and zinc can significantly affect the Zn bioavailability [8].

The data presented in Table 2 indicated that the mean grain yield of wheat significantly increased with the application of 6 kg Zn ha⁻¹ over control. The application of 2, 4 and 6 kg Zn ha⁻¹ successively and significantly increased the straw yield over control but the Zn level @ kg ha⁻¹ was found at par with 6

Table 5. Influence of zinc application on zinc content in grain and straw (mg kg⁻¹).

Status of soil zinc (mg kg ⁻¹)	No. of soils	Parameter	Zn levels (kg ha ⁻¹)			
			0		8	
			Range	Mean	Range	Mean
<0.59	5	Grain	18.79–23.00	21.57	29.26–33.37	26.38
		Straw	9.53–11.87	10.46	11.30–14.67	12.33
>0.59	6	Grain	23.17–28.14	26.04	30.33–32.88	31.31
		Straw	8.78–11.05	10.02	11.67–12.45	12.04

Table 6. Influence of zinc application on total Zn uptake by wheat (g ha⁻¹).

Treatments (soils)	Zn level (kg ha ⁻¹)					Mean
	0	2	4	6	8	
1	124.79	151.49	175.07	198.69	185.82	167.17
2	140.03	154.82	174.68	190.74	206.22	173.30
3	142.23	151.87	159.34	186.64	226.34	173.29
4	146.23	180.97	194.14	225.20	225.53	194.41
5	136.04	153.35	178.75	201.96	202.91	174.60
6	163.06	180.09	197.93	207.19	190.40	187.73
7	167.40	181.97	189.60	203.87	223.76	193.32
8	185.79	207.51	214.83	235.33	235.27	215.75
9	168.20	186.85	198.85	205.22	205.11	192.85
10	184.62	196.12	215.67	231.66	227.05	211.02
11	190.89	202.69	227.57	235.21	242.64	219.80
Mean	159.02	177.07	193.31	211.06	235.55	
	Soil	Zn doses	Soil* Zn			
SEm ±	5.11	3.45	11.43			
LSD (<i>p</i> = 0.05)	14.32	9.65	32.01			

kg ha⁻¹. The soil no. 3 to 11 were found significant over soil no. 1 but soil no. 1 and 2 were found at par for grain yield of wheat. The mean grain yield in soil no.3, 4 and 5 were found at par with soil no. 2. However, the soil no 10 and 11 were found significant over all other for grain yield (Table 3). The mean maximum yield of grain 4.58 t ha⁻¹ with the application of 6 kg Zn ha⁻¹ and the mean maximum yield of straw 6.44 t ha⁻¹ was observed with 8 kg zinc ha⁻¹ application. The mean maximum grain yield 4.87 t ha⁻¹ was observed with soil no 11. The interaction between soil and Zn levels for grain and straw yield was found non-significant. The soil-applied Zn increased wheat grain yield up to 12% over control (zero-Zn) in alkaline Zn-deficient “*Typic haplustalfs*” reported by earlier [9].

Response of wheat to zinc

Taking 0.59 mg kg⁻¹ as the critical level derived in the present study using Cate and Nelson statistical procedure, the soils were classified i.e. into two categories deficient (5 soil) and sufficient (6 soils). The critical limits of Zn in plants indicates deficiency are : < 10 mg kg⁻¹ definite Zn deficiency, 10—15 mg kg⁻¹ very likely, 15—20 mg kg⁻¹ likely and > 20 mg kg⁻¹ unlikely (sufficient). In most crop species leaf sufficiency range for Zn 15 to 50 ppm in the dry matter of mature plants

and in most cases 15 ppm Zn is considered as critical value [10].

The application of 2, 4, 6 and 8 kg Zn ha⁻¹ successively and significantly increased the Zn content in wheat grain (Table 4). The concentration of Zn ranged from 18.79 mg kg⁻¹ to 23.00 mg kg⁻¹ (mean 21.57 mg kg⁻¹) at 0 kg Zn ha⁻¹ and 29.37 mg kg⁻¹ to 33.26 mg kg⁻¹ (mean 31.65 mg kg⁻¹) with 8 kg zinc ha⁻¹ in deficient category. In soils of sufficient category the Zn content in grain ranged from 23.17–28.14 mg kg⁻¹ (mean 26.04 mg kg⁻¹) at 0 kg Zn ha⁻¹ and 30.33–32.88 mg kg⁻¹ (mean 31.31 mg kg⁻¹) with 8 kg Zn ha⁻¹ (Table 5). Results indicated that the interaction between soil and Zn levels was found non-significant. The Zn content in mature grain is a good indicator of soil Zn availability status and plant tissue critical Zn concentration ranges appeared to be 16—20 mg Zn kg⁻¹ in young whole shoots, 12—16 mg Zn kg⁻¹ in flag leaves, and 20—24 mg Zn kg⁻¹ in mature grains of wheat in alkaline Zn-deficient “*Typic haplustalfs*” reported by earlier [9].

Zinc on total zinc uptake

The application of increasing levels of Zn successively and significantly increased the total uptake of Zn up to 6 mg Zn ha⁻¹ but higher than that Zn level i.e. @ 8 kg ha⁻¹ was found at par with 6 kg ha⁻¹ (Table

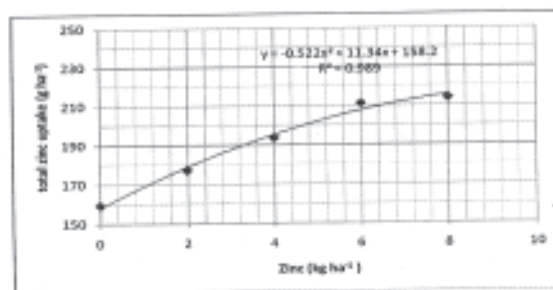


Fig -1

Fig.2a.

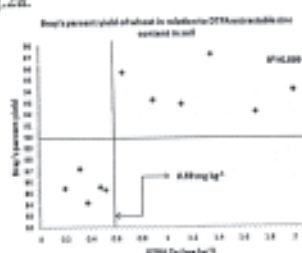


Fig.2b.

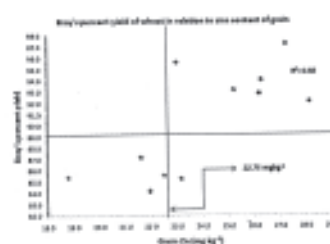


Fig. 1. Effect of different levels of zinc on total zinc uptake by wheat crop. **Fig. 2a.** Bray's percent yield of wheat in relation to DTPA extractable zinc content in soil. **Fig. 2b.** Bray's percent yield of wheat in relation to zinc content of grain.

6). The uptake of Zn was found maximum (215.75) in soil no. 8 which was found at par with no. 10 and 11. Further it was evident from the data, the uptake of zinc was found significantly higher in the soil no. 4, 7, 6 and 9 over soil no. 1 which was the lowest amongst the soils. Total Zn uptake in relation to different levels of zinc is depicted in Fig. 1. It is evident from the figure that a quadratic relation was obtained for total zinc uptake $Y = 0.522x^2 + 11.34x + 158.2$ ($R^2 = 0.989$) in relation to zinc applied in wheat. Fig. 1 further showed the zinc uptake follows increasing levels initially which increases towards higher levels of zinc application. The obtained present results could be attributed to the different uptake capacity of Zn and adaptability of wheat cultivars to Zn deficient soils due to their genotypic differences and study is supported by the study of [11].

Critical level of zinc

Fig. 2a and b scatter diagram showing relationship between Bray's percent yield with available zinc con-

centration in soil and grain zinc concentration in wheat. The variations in zinc concentration of grain and the yield of wheat in different soils were due to difference in ability of soils to supply zinc to the crop. This is confirmed by the significant correlation of DTPA extractable Zn with zinc concentration of grain ($r = 0.60$)** and yield of wheat ($r = 0.90$)**. Critical limit of available soil Zn 0.59 mg kg^{-1} was calculated using statistical procedure for wheat and critical level of Zn in wheat grain was found 22.75 mg kg^{-1} . These results are confirmed by [10]. For better Zn nutrition of human being, cereals grains should contain around $40\text{--}60 \text{ mg Zn kg}^{-1}$; however the current situation is 10 to 30 mg kg^{-1} Zn [6].

Conclusion

The study thus indicates that wheat crop will respond to Zn application when the soils contain less than 0.59 ppm DTPA extractable Zn (Vertisol) and wheat grain with Zn concentration less than 22.75 ppm , hence the application of Zn fertilizer in these

soil will enhance the wheat productivity with better economical returns.

References

1. FAO (2010) Scaling soil nutrient balances: Enabling meso-level applications for African realities fertilizer and plant nutrition bulletin 15 Rome.
2. Donner E, Broos K, Heemsbergen D, Warne, MSTJ, McLaughlin MJ, Hodson ME Nortcliff S (2010) Biological and chemical assessments of zinc ageing in field soils. *Environ Poll* 158 : 339—345.
3. Gibbson RS (2006) Zinc: The missing link in combating micronutrient malnutrition in developing countries. *Proc Nut Soc, Univ of East Anglia, Norwich*, Jun 28—Jul 1, 2005.
4. Singh MV (2008) Micronutrient deficiencies in crops and soils in India. In: Alloway B (ed). *Micronutrient deficiencies in global crop production*. Springer, Dordrecht, pp 93—126.
5. Shukla AK, Tiwari PK (2014) Progress report 2011-2013 on All India Coordinated Research Project on Micro and Secondary Nutrients and Pollutant elements in soils and plants, IISS, Bhopal.
6. Cakmak I, Pfeiffer W, Mc. Clafferty B (2010) Bio-fortification of durum wheat with zinc and Iron. *Cereal Chem* 87 : 10—20.
7. Katyal J, Rattan R (2003) Secondary and micronutrients research gaps and future needs. *Fert News* 48 : 9—20.
8. Adiloglu A, Adiloglu S (2006) The effect of boron (B) application on the growth and nutrient contents of maize in zinc deficient soils. *Res J Agric Bio Sci* 2 : 1—4.
9. Rafique E, Rashid A, Ryan J, Bhatti A (2006) Zinc deficiency in rainfed wheat in Pakistan : Magnitude, spatial variability, management, and plant analysis diagnostic norms. *Commun Soil Sci Pl Anal* 37 : 181—197.
10. Benton JJ (2003) *Agronomic handbook ; management of crops, soils and their fertility*. CRC press LLC, USA.
11. Imtiaz M, Alloway B, Khan P, Memon M, Siddiqui S, Asla M, Shah S (2006) Zinc deficiency in selected cultivars of wheat and barley as tested in solution culture. *Commun Soil Sci Pl Anal* 37 : 1703—1721.