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EFFICIENCY AND CRITICAL LIMITS OF ZINC IN JHUM SOILS OF MANIPUR

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ABSTRACT

A pot culture experiment was conducted in sixty acid soils (India) to establish the critical limits of Zn for predicting response of chickpea (*Cicer arietinum*) to zinc application. The DTPA-extractable Zn in 60 acid soils ranged from 1.82 to 2.58 mg kg^{-1} and the total Zn in chickpea ranged from 12.50 to 20.47 mg kg^{-1}. The critical limits of zinc in soils and plants are 2.68 mg kg^{-1} and 12.26 mg kg^{-1} respectively. The soil available Zn was positively correlated with pH (r=0.68*), OC (r=0.243**), available N (r=0.236**), available P (r=0.364*) and also positive and significant correlations with sand (r=.085**), clay (r=.052**). The results revealed that, the mean distribution of zinc in surface soils of different villages recorded as 2.28 mg kg^{-1} which is deficient compared to critical limits in soils as 2.68 mg kg^{-1}. Application of Zinc (10 kg ha^{-1} recorded the highest yield in chickpea along with vermicompost 5 t ha^{-1}) shows significant results on chickpea.

INTRODUCTION

Chickpea (*Cicer arietinum*) is one of the important crops of the world and is consumed by people across the globe. In India, Madhya Pradesh ranks first in area (2.6Mha), production (2.4 m t) with a productivity of 930 kg/ha followed by Rajasthan. Zinc (Zn) is indispensable micro- nutrient for optimal plant growth. With their participation in a variety of enzymes and additional physiologically active molecules, these micronutrients are vital for gene expression, synthesis of proteins, nucleic acids, growth substances, chlorophyll, secondary metabolites, metabolism of carbohydrates and lipids, stress tolerance, *etc* Singh (2004), Rengel (2007), Gao *et al* (2008). Presence of micro- nutrient in plants can be ascertained in direct uptake investigations or anticipated with techniques that compare the amount of micro-nutrients taken out chemically from the soils Kabata-Pandias (2001). Micronutrient cycling is fairly dissimilar between diverse earthly ecological units, Han *et al.* (2007). Shifting cultivation (SC) is one of the main forms of crop husbandry in North Eastern Hill Region (NER) of India and it is called as jhuming and its cultivators are called as jhumias. Shifting cultivation (SC) in its customary and integrated outline is cost-effectively practicable system of agriculture as far as the population densities are low and jhum cycles are lengthy enough to uphold soil health together with fertility. In North east India about 2.7 million hectare are used for shifting cultivation. Currently, 48.1% of Indian soils are lacking diethylene-triaminepentaacetate (DTPA) extractable zinc, and are deficient to about 11.2% in iron, 7% in copper and 5.1% in manganese. Arable lands with multi-micronutrient deficiencies are restricted; therefore effortless normal fertilizers are adequate to make use of the potential of crops and cropping systems, Gupta (2005). The application of mineral fertilizers is the most advantageous and the fastest way to increase crop yields and their deficiency leads to various types of disorders in many commercially important crops, Duarah *et al*. Keeping in view the above importance of mineral fertilizers for crop growth and yield, this study on the status of soil micro nutrients was carried out with the following objectives (i) to estimate the critical limit of Zn in soils and crops and iii) to explore the relationships among Zinc and soil properties.

MATERIALS AND METHODS

The present investigation was carried out to assess zinc status of the soils of Churachandpur district, Manipur (India). Annual mean temperature surpasses 22˚C and temperature during summer ranges from 30 to 35˚C. There is a mean yearly rainfall altering from 2000 to 2400 mm. Soils of the study area fall under three major soil orders: ultisol, inceptisol and alfisol.

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Soil sampling and analytical methods

Sixty (60) soil samples in bulk from plough layer (0 to 15 cm) were collected from 12 villages of Churachandpur block, Churachandpur district. It lies on the south-western part of Manipur between 24.0 N and 24.3 N latitude and 93.15 E and 94.0 E longitude. The collected soil samples were separately air dried ground and passed through 2 mm size sieve for laboratory analysis. Particle size distribution was done by the standard Bouyoucos hydrometer method. Soil pH was determined by glass electrode (Jackson 1973). Electrical conductivity (EC) was determined by potentiometery and direct reading conductivity meter using 1:2.5 soil water suspensions, Jackson. (1973). Organic carbon was estimated by wet digestion method of Walkey and Black (Jackson, 1973). The cation exchange capacity was determined by leaching the soil with 1 N NH_4^+ OAC and subsequently displacing the adsorbed NH_4^+ methods (Gupta, 2007). Available N was analyzed by alkaline permanganate method (Subbiah and Asija 1956), available P using ammonium fluoride extraction by Bray and Kurtz (1945), available K using neutral ammonium acetate, Jackson (1973). Available zinc content of the soil samples was extracted with DTPA-TEA (pH 7.3) extractant following the method of Lindsay and Norvell (1978) and the concentration of Zn in the extracted solution was estimated with the help of Atomic Absorption Spectrophotometer (AAS). The relationship between various soil properties and zinc distribution were established by using simple correlation coefficient.

A pot culture experiment was conducted during rabi season 2016-17 at the research farm of the College of Agriculture, Central Agricultural University, Imphal. Four kg of each soil was transferred into each pot. The treatment details are as follows: T_1= control, T_2= 2.5 ppm Zn, T_3= 5 ppm Zn, T_4= 10 ppm Zn, T_5= 0 ppm Zn+ vermicompost @ 5t/ha, T_6= 2.5 ppm Zn+ vermicompost @ 5t/ha, T_7= 5 ppm Zn+ vermicompost @ 5t/ha and T_8= 10 ppm Zn+ vermicompost @ 5t/ha soil as reagent grade of Zinc sulphate ($ZnSO_4$, $7H_2O$). The experiment was laid out in a factorial randomized block design with three replications.

Plant sampling and analytical methods

Three plant samples were harvested and rinsed with deionised water; dried at 65 ^{0} C in a hot air oven and dry-matter yield was recorded. The dried plant samples of each pot were separately powdered in a warring stainless steel grinder. The dry powdered plant samples were digested in a mixture of 10:4 of HNO_3: $HClO_4$ on a hot plate and filtered through Whatman No.42 for estimation of Zn with the help of Atomic Absorption Spectrophotometer (AAS). The critical limit of zinc in soil was determined by Bray's percent yield plotted against soil available zinc. Similarly, critical limits of zinc in Chickpea plant was determined by plotting Bray's percent yield of Chickpea against zinc concentration in plant, using the scattered diagram (Cate and Nelson 1965). Bray's percent yield was calculated using following formula:

Bray′s per cent yield = Yield without zinc application/Yield with optimum zinc level × 100

RESULTS AND DISCUSSION

Initial Soil properties

The results of soil pH, EC, organic carbon (OC), available N, P, K and DTPA-extractable Zn are presented in [Table 1]. Result shows that pH of the soils ranged from 6.01-7.04 (mean 6.64), EC varied from 0.11-0.24 dSm^{-1} (mean 0.16 dSm^1), organic carbon content ranged from 1.36-1.78 % with a mean value of 1.60 % and CEC ranged from 12.46-17.50 (C mol p^+ kg^{-1}) with a mean value of 14.87. The available N, P, K and Zn varied from 374.8-503.2 (mean 414.79), 11.20-16.90 (mean 14.25), 129.0-158.6 (mean 141.08) kg $ha^{-1}$and 1.82-2.58 (mean 2.28) mg ha^{-1}, respectively. The soils revealed a sturdily acidic to neutral reaction. The reason may be elevated precipitation resulting in the leaching losses of bases from the surface soils. In addition, the soil acidity was increased by addition of nitrogenous fertilizers and decomposition of organic residues. The broad disparity of EC of the soils may be because of the unlike concentration of basic cations in the soils. The high organic carbon content in the soil is due the luxuriant growth of grasses along with the seasonal decomposition of vegetative parts and roots.

Table 1 Some major chemical characteristics of the soils of Churachandpur District

Prameters	Mean	Range
pH	6.64	6.01-7.04
EC (dS m^{-1})	0.16	0.11-0.24
OC %	1.60	1.36-1.78
CEC (Cmol(p^+) kg^{-1})	14.87	12.46-17.50
Nitrogen (kg ha^{-1})	414.79	374.8-503.2
Phosphorus (kg ha^{-1})	14.25	11.20-16.90
Potassium (kg ha^{-1})	141.08	129.0-158.6
Zinc in soil (mg ha^{-1})	2.28	1.82-2.58

Effect of zinc with vemicompost application on zinc content and uptake by chickpea

Zinc content in plant (mg kg^{-1})

The concentration of zinc in crop at harvest was significantly influenced by different levels of zinc with vermicompost. The highest zinc concentration in crop was recorded in treatments T_8 (27.28 mg kg^{-1}) in Koite village followed by T_7, T_6 and T_5 (25.47, 23.02 and 21.38 mg kg^{-1}, respectively) in different villages of Churachandpur, which were on par with each other and these were significantly superior over all the other treatments. The lowest zinc concentration was recorded in treatments T_1 (8.44 mg kg^{-1}) in T. Champhai village followed by T_2, T_3 and T_4 (9.95, 10.75 and 11.64 mg kg^{-1}, respectively) in different villages of Churachandpur.

Zinc uptake (µg pot^{-1})

The zinc uptake at harvest by chickpea crop was significantly influenced by different treatments zinc and zinc with vermicompost application. The zinc uptake of chickpea crop varied from 162.68-289.17 (µg pot^{-1}) (Table 3) with an average of 237.40 µg/pot. The lowest available zinc content (162.68 µg pot^{-1}) was observed in the soils of village K. Sulbung. Whereas, highest available zinc content (289.17 µg pot^{-1}) was obtained in the soils of village Khawmawi.

Table 2 Zinc content in plant (mg kg^{-1})

Villages	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	Mean	C.D values
Tollen	11.58	13.76	17.20	18.71	16.12	19.81	22.62	25.13	18.12	0.713
Gamphajang	15.01	17.58	19.79	22.04	18.02	21.28	24.65	25.38	20.47	0.571
Leijang Kopi	13.24	16.29	18.47	21.20	16.97	20.01	21.91	24.90	19.12	0.586
Lajangphai	10.53	13.36	17.09	20.10	16.14	18.53	21.37	24.75	17.73	0.722
Molnom	11.22	13.26	16.02	18.24	14.73	17.53	19.87	23.93	16.85	0.638
Boljol	11.96	14.38	17.13	19.30	16.26	18.68	21.39	23.74	17.86	0.604
Koite	10.65	12.98	16.19	18.52	21.24	23.02	25.47	27.28	19.42	0.945
Khangjang	14.85	17.35	18.02	21.20	15.83	19.00	21.85	23.60	18.96	0.487
Yanglenphai	11.58	14.64	18.75	20.86	17.10	20.11	23.31	25.46	18.98	0.722
Khawmawi	12.92	15.02	17.00	19.51	21.38	22.55	23.98	25.21	19.70	0.701
K.Sulbung	9.27	10.86	11.74	12.75	13.54	15.70	16.80	17.40	13.51	0.746
T. Champhai	8.44	9.95	10.75	11.64	12.38	14.60	15.40	16.80	12.50	0.692
Mean	11.77	14.12	16.51	18.67	16.64	19.24	21.55	23.63	17.77	

Table 3 Zinc uptake and zinc content in chickpea

S. No	Villages	Zinc uptake (µg pot^{-1})	Zinc in plant (mg kg^{-1})
1	Tollen	237.10	18.12
2	Gamphajang	270.72	20.47
3	Leijang Kopi	244.20	19.12
4	Lajangphai	210.90	17.73
5	Molnom	191.38	16.85
6	Boljol	269.92	17.86
7	Koite	244.32	19.42
8	Khengjang	271.05	18.96
9	Janglenphai	273.49	18.98
10	Khawmawi	289.17	19.70
11	K.Sulbung	162.68	13.51
12	T. Champhai	183.93	12.50
	Mean	237.40	17.77
	Range	162.68-289.17	12.50-20.47

Effect of Zinc with vermicompost application on Dry matter of chickpea

Dry matter weight was significantly influenced by different treatments like zinc and zinc with vermicompost. Whereas factor 1 treatment T_4 ($ZnSO_4$ 10 kg ha^{-1}) recorded the highest dry matter weight (14.61 g pot^{-1}) (Table 4) village Tollen is significantly superior over the treatments, rest of the all treatments were on par with each other like T_3, T_2, T_1 and over all villages of Churachandpur. Whereas factor 2 treatment T_8 ($ZnSO_4$ 10 kg ha^{-1} + 5 t ha^{-1} vermicompost) recorded the highest dry matter weight (19.60 g pot^{-1}) in village T. Champhai is significantly superior over the treatments rest of the all treatments were on par with each other like T_7, T_6, T_5 in all villages of Churachandpur.

The highest mean average dry matter weight (14.63 g pot^{-1}) recorded in Boljol followed by Khawmawi and Khengjang with the corresponding values of 14.15, 13.90 g pot^{-1} respectively.

Critical limits of zinc in jhum soils and chickpea plants

The critical limit of zinc concentration in soil at harvest with the graphical procedure was found to be 2.60 mg kg^{-1} (Fig. 1). Zinc concentration of soil samples from most of the responsive (i.e., deficient) soils lied 1^{st} lower left quadrant containing less than 2.60 mg kg^{-1} zinc which may be considered as critical limit in chickpea plant, below which economic response to zinc application can be expected. These values are close to critical level of Zn (0.83 mg kg^{-1}) as observed by Rahman *et al.* (2007), Muthukumararaja *et al.* (2012) and Gangwar and Chandra (1975).

The critical limit of zinc concentration in chickpea plant at harvest with the graphical procedure was found to be 12.20 mg kg^{-1} (Fig. 2). Zinc concentration of plant samples from most of the responsive (i.e., deficient) soils lied 1^{st} lower left quadrant containing less than 12.20 mg kg^{-1} zinc which may be considered as critical limit in chickpea plant, below which economic response to zinc application can be expected.

Correlation among soil properties and zinc

In this study, Available Zn showed significant and positive correlation coefficient with pH (r=0.68*), OC (r=0.243**), available N (r=0.236**), available P (r=0.364*) and also positive and significant correlations with sand (r=.085**), clay (r=.052**) (Table 6).

Table 4 Effect of Zinc and vermicompost on Dry matter (g pot^{-1})

S. No	Villages	Treatments								Mean	C.D value
		T1	T2	T3	T4	T5	T6	T7	T8		
1	Tollen	10.55	10.03	10.62	14.61	13.62	13.32	14.30	14.87	12.74	0.23
2	Gamphajang	8.56	9.49	12.19	13.32	13.17	14.59	14.53	16.93	12.85	0.34
3	Leijang Kopi	9.48	9.49	10.95	11.69	12.75	14.02	15.42	15.61	12.43	0.72
4	Lajangphai	8.69	10.20	9.46	11.32	12.42	10.65	14.36	14.77	11.48	0.65
5	Molnom	8.30	8.85	10.33	12.43	9.67	10.62	12.72	14.50	10.93	0.61
6	Boljol	10.09	12.73	12.71	14.44	14.91	15.96	17.33	18.87	14.63	0.89
7	Koite	8.40	9.14	10.41	10.74	12.77	12.67	13.17	17.62	11.87	0.69
8	Khengjang	10.05	9.23	12.91	13.58	13.90	14.26	17.94	19.30	13.90	0.89
9	Janglenphai	9.03	11.45	11.46	14.00	14.85	16.10	16.20	17.81	13.86	0.90
10	Khawmawi	9.20	11.73	13.44	14.11	14.34	15.43	17.78	17.20	14.15	0.83
11	K. Sulbung	8.31	8.70	9.79	9.81	12.46	13.07	14.93	15.24	11.54	0.68
12	T. Champhai	9.12	11.63	12.25	13.40	14.32	15.51	16.76	19.60	14.07	0.95
	Mean	8.30	9.45	10.55	11.62	12.20	12.80	14.34	15.70	11.87	
	Range	8.30-10.55	8.85-12.73	9.46-13.44	9.81-14.61	9.67-14.91	10.62-16.10	12.72-17.94	14.50-19.60		

Table 5 Bray's percent yield of Chickpea in Jhum soils of Churachandpur

Villages	Zinc in soil (mg/kg)(control)	Bray's % yield	Zinc in plant (mg/kg)(control)	Bray's % yield	zinc in plant (mg/kg)
Tollen	2.86	66.36	11.58	46.08	18.12
Gamphajang	3.01	61.05	15.01	59.14	20.47
Leijang Kopi	2.25	44.73	13.24	53.17	19.12
Lajangphai	2.51	49.8	10.53	42.55	17.73
Molnom	2.34	43.09	11.22	46.89	16.85
Boljol	2.17	42.55	11.96	50.38	17.86
Koite	2.51	43.88	10.65	39.04	19.42
Khengjang	3.36	56.76	14.85	62.92	18.96
Janglenphai	2.54	42.76	11.58	45.48	18.98
Khawmawi	3.11	64.12	12.92	51.25	19.70
K.Sulbung	1.8	57.88	9.27	53.28	13.51
T. Champhai	1.25	45.96	8.44	50.24	12.50
Mean	2.48	51.58	11.77	50.03	17.77

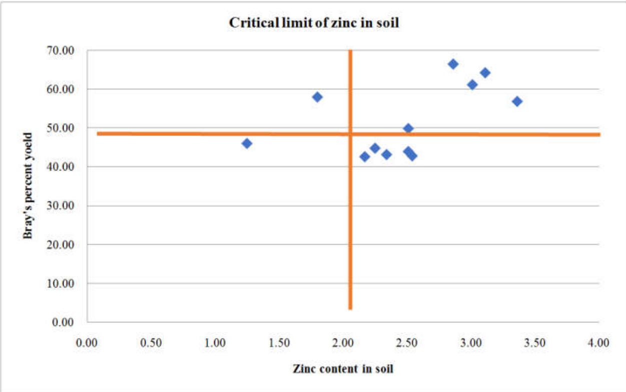

Fig 1 critical limits of zinc in Jhum soils of Churachandpur

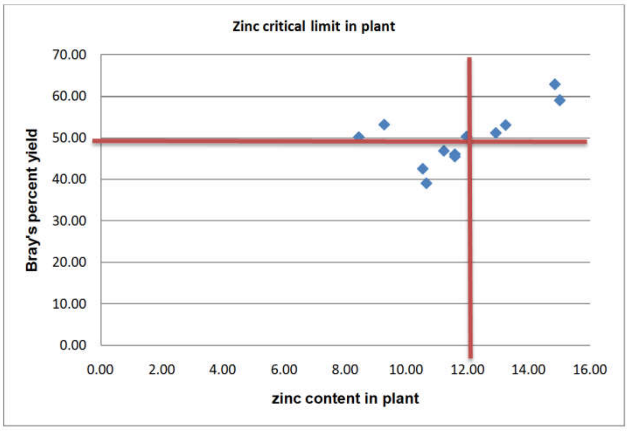

Fig 2 Critical limit of zinc in chickpea

This might be due to leaching losses of water soluble micronutrients with the high rainfall leading to the low content of zinc in the soils even though zinc most soluble and readily available under acidic condition. Available Zn in the studied surface soils varied from 1.82 to 2.58 mg kg^{-1} with a mean value of 2.28 mg kg^{-1}. Similar finding was also reported by Raina *et al.* (2003) in apple growing soils of Himachal Pradesh, India and Indira *et al.* (2014) in acid soils of Manipur. Considering 2.60 mg kg^{-1} as critical limit of available Zn as suggested by Takkar and Mann (1975). Organic matter and manure applications affect the immediate and potential availability of micronutrient cations, Rengel (2007). The micronutrient cations react with certain organic molecules to form organometallic complexes as chelates and soluble chelates can increase the availability of the zinc nutrient and protect it from precipitation reactions. These chelates may be synthesized by the plant roots and released to the surrounding soil. The chelate may also be present in the soil humus or may be synthetic compound added to the soil to enhance micronutrient availability, Brady and Weil (2002).

CONCLUSION

The content of available zinc in all the surface soils ranged between 1.82-2.58 mg kg^{-1} with a mean value of 2.28 mg kg^{-1}. Out of 60 surface soils, 11 soil samples (18.4%) were found to be above critical level of available Zn and 49 samples (81.6%) were below critical limit suggesting the need of application of zinc in soil.

Organic carbon, available nitrogen and potassium were found to be high and available phosphorus varies from very low to medium in status. Among the micronutrients, soils are low in Zn. Based on the analysis; farmers are advised on soil fertility management through rational use of manure, fertilizers and amendments to make agriculture more productive and sustainable. 81.6% of the studied soils were under deficient categories. Available Zn showed significant and positive correlation coefficient with pH (r=0.68*), EC (r=0.50*), OC (r=0.243**), available N (r=0.236**), available P (r=0.364*) and also positive and significant correlations with sand (r=.085**), clay (r=.052**). The critical limit of zinc concentration in soil and chickpea plant at harvest with the graphical procedure was found to be 2.60 and 12.20 mg kg^{-1} respectively.

Table 6 Correlation amongst the different soil parameters under study

Parameters	pH	EC	OC	CEC	N	P	K	Zn	Sand%	Silt%	Clay%
pH	1										
EC	0.242	1									
OC	-0.051	-0.396	1								
CEC	0.559*	0.338	-0.202*	1							
N	-0.217*	-0.129*	-0.064*	-0.142*	1						
P	0.066	0.394*	0.109*	0.430*	-0.073*	1					
K	-0.286*	-0.537*	0.346**	0.043*	0.034	-0.243*	1				
Zn	0.068*	-0.050*	00.243*	-0.032*	0.236**	0.364*	-0.415	1			
Sand%	0.579*	0.056*	-0.112*	0.470*	0.096**	0.049	-0.225	0.085**	1		
Silt%	-0.260	-0.182*	0.372*	-0.064*	0.044**	0.079*	0.642**	-0.106*	-0.730**	1	
Clay%	-0.311*	0.198*	-0.407*	-0.466*	-0.178*	-0.172	-0.664*	0.052**	-0.129*	-0.583*	1

*Correlation is significant at the 0.05 level (2-tailed).
**Correlation is significant at the 0.01 level (2-tailed).

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