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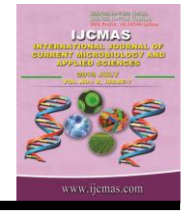

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To Assess the Response of Zn Application in Soils of Variable Available P and Zn and Comparison of Different Extraction Methods for Bioavailability of Zinc: A Case Study

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A B S T R A C T

Positive responses to Zn addition on numerous crops have been documented. In this study, we field tested no Zn (0 kg $ZnSO_4.7\ H_2O$/acre) and Zn treatment (25 kg $ZnSO_4.7\ H_2O$/acre) in zinc deficient sites and their effect on grain yield of Pusa Basmati 1121. Surface soil samples (0-15cm) were collected from 16 sites from basmati rice grown soils in Gurdaspur district of Punjab. Findings of the study revealed that soils had variable available phosphorus and zinc status. The grain yield ranged from 20.8 to 29.8 q/ha in control with mean value of 25.3 q/ha and in zinc treated plots grain yield ranged from 26.8 to 33.5 q/ha with mean value of 30.1 q/ha. A maximum response of (0.5-10.8 q/ha) was recorded with an increase of 29.3 per cent over control. Soil samples were also analyzed to assess the bioavailability of zinc using different extractants. The amount of Zn extracted using different chemical extractants was in the following order: AB-EDTA (ammonium bicarbonate-ethylene diamine tetra acetic acid)> Mehlich-3> AB-DTPA (ammonium bicarbonate- diethylene triamine penta acetic acid) > DTPA-HCl (diethylene triamine penta acetic acid- hydrochloric acid)> 0.1N HCl (hydrochloric acid)> DTPA (diethylene triamine penta acetic acid). The amount of Zn extracted by 0.005M DTPA+1M NH_4HCO_3 (pH 7.6), 0.01M EDTA+1M NH_4HCO_3 (pH 8.6), 0.005M DTPA+ 0.1N HCl, 0.005M DTPA (pH 7.3), 0.1N HCl and Mehlich-3 was well correlated with each other. Most commonly used 0.005M DTPA solution for extracting available Zn in soils was highly and significantly correlated with all the other extractants.

Introduction

Zinc (Zn) is one of the essential and the most important micronutrient limiting rice growth and yield (Dong *et al.,* 2006). Intensive cultivation of high yielding varieties has aggravated the depletion of soil Zn leading to its deficiency. On an average, 36.5 percent of the soils in India are deficient in Zinc (Shukla and Behera, 2018). Inadequate amount of zinc in soils reduces crop yield and quality. Phosphorus and zinc are two essential nutrients which are required for normal plant growth. These nutrients are mutually antagonistic in certain circumstances which can cause yield reductions in many crops due to either P or Zn deficiencies. Zinc absorption capacity is reduced by high phosphorus utilization and zinc in plant. The Zn induced P deficiency occurs because growers commonly apply large amounts of P fertilizer as compared to Zn fertilizer. The P induced Zn deficiency is related to the application of phosphatic fertilizers at high dose to the soils that are low or marginal in available Zn. For better and high crop production, proper recommendations of fertilizers are required. Extraction of zinc by DTPA method has been universally accepted irrespective of soil and climatic conditions (Lindsay and Norvell, 1978) but the suitability of extractants varies with crops, soils and the extractants used. Different soils possess different chemical and physical characteristics; therefore same extractants may not prove useful. Keeping this in view, in the present study different extractants were also evaluated to assess the available zinc status in the soil

Materials and Methods

Soil sampling and soil analysis

A study at cultivator's field was conducted by selecting sixteen sites in three villages of Gurdaspur. The district lies between 32° 02' latitude to 75° 25' N longitude. All plots were managed as usual by the farmer including fertilization of N, P and K. The treatments consisted of no Zn and Zn treatment. Zinc was applied as $ZnSO_4.7H_2O$ by broadcasting at the time of transplanting. The processed soil samples were analysed for important characteristics (Table 1) by following standard procedures. Available zinc content of the soil samples was determined using following six different chemical extractants:

1) 0.005M DTPA (diethylene triamine penta acetic acid) (pH 7.3)
2) 1M NH_4HCO_3 + 0.005M DTPA (pH 7.6)
3) 0.005M DTPA + 0.1N HCl
4) 0.1N HCl
5) 0.01M EDTA +1M NH_4HCO_3 (pH 8.6)
6) Mehlich-3 (0.2M CH_3COOH+0.25MNH_4NO_3+0.15M NH_4F+0.01M HNO_3+0.0005M EDTA)

Zinc concentration in the extracts was determined using atomic absorption spectrophotometer (AAS) (model Varian AA240FS). Grain yields were measured from a 1m^2area harvested in the centers of the plots at maturity. Recommended NPK fertilizers on soil test basis for Basmati rice was applied. All P, K were applied at sowing while urea was applied in two equal splits at 3 weeks and 6 weeks after transplanting The crop was harvested at maturity and soil samples were collected for chemical analysis.

Results and Discussion

On the basis of variability of zinc in soil samples collected from 16 locations at cultivator's field was grouped into three categories: I- (Zn-0.32-0.66 mg/kg), II- (Zn-0.70-0.88 mg/kg) and III- (Zn- 1.12-1.24 mg/kg). In the soil samples, where available Zn and P varied from 0.32-0.66 mg/kg and 19.1-48.7 kg/ha, the grain yield ranged from 4.16 to 5.38 t/ha in control and 5.36 to 6.70 t/ha where 12.5 kg Zn/ha was applied. A maximum response of (0.92-2.16 t/ha) and mean per cent increase of 35.9 per cent over control was noticed. In the sites, where zinc varied from 0.70-0.88 mg/kg and available P varied from 22.9-63.0 kg/ha, grain yield was 4.18 to 5.34 t/ha in control and 5.12 to 5.87 t/ha where 12.5 kg Zn/ha was applied. In this category, an increase of 14.3 per cent was recorded over control. In the soil samples where zinc varied from 1.12 to 1.24 mg/kg and available P varied from 30.0-50.0 kg/ha the grain yield ranged from 5.02 to 5.98 t/ha in control and from 5.26 to 6.32 t/ha where 12.5kg Zn/ha was applied. Findings of the study revealed differential response of basmati rice to Zn application in soils of variable available P and Zn status at cultivators fields, which may be due to the reason that these nutrients are mutually antagonistic and in certain circumstances it can cause yield reductions in many crops due to either P or Zn deficiencies (Table 2). Takkar *et al.*, (1976) and Norvell *et al.*, (1987) reported that addition of P only slightly reduced extractable Zn. Saeed (1979) observed that prior heavy P application in five Hawaiian soils had no influence on DTPA extractable Zn and concluded that Zn deficiency could not be due to precipitation of Zn as insoluble Zn- P compounds.

Estimation of available Zn using different chemical extractants

The amount of Zn extracted from soils by different extractants ranged markedly (Table 3). The highest Zn was extracted with 0.01M EDTA+1M NH_4HCO_3 which was about two times the amount extracted by 0.005M DTPA and it varied from 0.65 mg kg^{-1} to 1.81 mg kg^{-1} with a mean value of 1.14 mg kg^{-1} of soil

Table.1 Initial soil physico-chemical properties of soil samples from cultivator's field of basmati rice grown soils

Cultivator's name	DTPA- Zn (mg/kg)	pH (1:2)	EC (dS/m)	OC (%)	P_2O_5 (kg/ha)	K_2O (kg/ha)
Manjit Kumar	0.32	8.05	0.37	0.70	29.60	453.60
Ashok Kumar	0.34	8.16	0.33	0.74	19.10	431.20
Raghbir Singh	0.34	8.45	0.59	0.49	41.80	526.40
Bashan Singh	0.39	8.40	0.55	0.61	45.60	526.40
Kashmir Kumar	0.57	8.21	0.96	0.63	41.80	532.00
Ranjit Singh	0.59	8.17	0.54	0.41	47.40	509.60
Baljit Kumar	0.60	8.10	0.56	0.65	48.00	537.60
Kamaldeep Singh	0.62	8.15	0.35	0.70	33.20	476.00
Balbir Singh	0.62	7.94	0.28	0.41	48.70	476.00
Kulwinder Singh	0.66	7.16	0.52	0.72	28.40	537.60
Gurdial Singh	0.69	7.01	0.32	0.65	30.90	442.40
Ranjit Singh	0.69	7.93	0.32	0.55	63.30	386.40
Hardev Singh	0.72	7.52	0.38	0.64	40.40	543.20
Sarbjit Singh	0.88	7.05	0.52	0.53	22.90	515.20
Veer Singh	1.12	7.98	0.60	0.69	30.10	498.40
Joginderpal Singh	1.24	7.20	0.30	0.30	49.00	201.60
Mean	0.65	7.84	0.47	0.59	38.70	474.60

Table.2 Effect of zinc application on grain yield of basmati rice in soils of variable available P and Zn status at cultivators fields

Categories	DTPA-Zn (mg/kg soil)	Available P (kg/ha)	Grain yield (t/ha)		Response over control (t/ha)	Mean per cent increase in yield over control
			Levels of Zn (kg/ha)			
			0	12.5		
I	0.32-0.66 (0.48)	19.1-48.7 (38.5)	4.16-5.38 (4.48)	5.36-6.70 (6.06)	0.92-2.16 (1.57)	35.9
II	0.70-0.88 (0.70)	22.9-63.0 (39.0)	4.18-5.34 (4.70)	5.12-5.87 (5.4)	0.48-1.16 (0.65)	14.3
III	1.12-1.24 (1.18)	30.0-50.0 (39.5)	5.02-5.98 (5.50)	5.26-6.32 (5.79)	0.24-0.34 (0.29)	5.25

Table.3 Range and mean values of micronutrient zinc in soil using different extractants

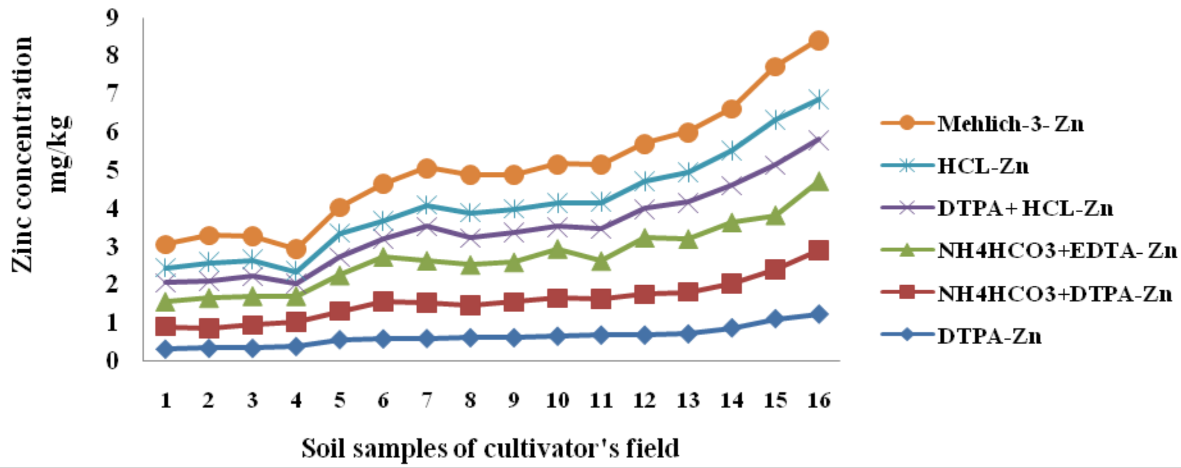
Category		Available zinc(mg/kg soil)					
		DTPA	NH_4HCO_3+DTPA -Zn	NH_4HCO_3 +EDTA-Zn	DTPA+ HCL-Zn	HCL-Zn	Mehlich-3- Zn
I	Range	0.32-0.66	0.52-0.99	0.65-1.29	0.32-0.90	0.32-0.65	0.58-1.02
	Mean	0.48	0.76	0.97	0.61	0.49	0.80
II	Range	0.69-0.88	0.95-1.16	0.98-1.59	0.76-0.98	0.70-0.90	0.98-1.10
	Mean	0.78	1.05	1.28	0.87	0.80	1.04
III	Range	1.12-1.24	1.28-1.66	1.42-1.81	1.1-1.32	1.05-1.18	1.4-1.56
	Mean	1.18	1.47	1.61	1.21	1.11	1.48

Table.4 Linear coefficients of correlation between different soil test methods for available soil zinc

Extractants	DTPA	AB-DTPA	AB-EDTA	HCL-DTPA	HCL
AB-DTPA	0.966**				
AB-EDTA	0.894**	0.938**			
DTPA+HCL	0.869**	0.820**	0.755**		
HCL	0.961**	0.959**	0.899**	0.913**	
Mehlich-3	0.948**	0.863**	0.839**	0.867**	0.897**

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

Fig. 1. Amount of available Zn extracted by using different soil test methods



It may be due to the presence of NH_4^+ in AB-EDTA which rendered it to displace more of the exchangeable cations and thus makes it more efficient in extracting Zn from soils. Based on the amount of Zn extracted by different extractants, the relative efficiency was of the following order: AB-EDTA> Mehlich-3> AB-DTPA> DTPA-HCl> 0.1N HCl> DTPA. Because of acidity, Mehlich 3 (pH 2.5) could release part of the adsorbed Zn, particularly from the oxide surfaces (Vidal-Vazquez *et al.*, 2005) causing higher Zn extraction compared with the other extractants used. The least amount of mean available Zn was extracted by DTPA (pH 7.3) & 0.1 N HCL and the highest amount by using NH_4HCO_3+EDTA. The amount of Zn extracted by different methods using different extractants was in the following order: NH_4HCO_3+EDTA> Mehlich-3> NH_4HCO_3+DTPA> DTPA+HCL> 0.1N HCL=DTPA with Zn extraction of 1.14, 0.95, 0.94, 0.73, 0.65 and 0.65 mg/kg, respectively (Fig. 1).

Different extractants were highly and significantly correlated with each other indicating that they could extract zinc more or less from soil. DTPA-Zn and NH_4HCO_3+DTPA-Zn showed the highest correlation (0.966**) while NH_4HCO_3 + DTPA-Zn and DTPA+HCL-Zn showed the least (0.755**). Accordingly, DTPA and NH_4HCO_3+DTPA extractant could be used effectively for estimating Zn. The amount of Zn extracted by 0.005M DTPA+1M NH_4HCO_3 (pH 7.6), 0.01M EDTA+1M NH_4HCO_3 (pH 8.6), 0.005M DTPA+0.1N HCl, 0.005M DTPA (pH 7.3), 0.1N HCl and Mehlich-3 was well correlated with each other (Table 4).

In conclusions, field soil sample analysis results of cultivator's field demonstrated deficiencies of zinc and hence observed response of crops to the application of these nutrients. In general, post-harvest soil analysis of basmati rice grown soils showed that application of 12.5 kg zn/ha in zinc deficient soils improved grain yield. Therefore, it is clear that for sustained increase in productivity and to have quality produce and better soil health, applications of nutrients like Zn is required along with major nutrients. Secondly, assessment of soil samples of cultivator's field for available zinc with different chemical extractants showed that NH_4HCO_3+EDTA extractant was found superior over others. DTPA-Zn and NH_4HCO_3+DTPA-Zn showed the highest correlation (0.966**) while NH_4HCO_3+DTPA-Zn and DTPA+HCL-Zn showed the least (0.755**). Therefore, DTPA and NH_4HCO_3+DTPA extractant could be used effectively for estimating Zn.

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