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Zinc Deficiency in the Wetlands of TNAU - Native or Induced?

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Zinc efficiency is the widespread nutritional disorder constraining rice production worldwide. Field experiment was conducted in the M7 block of the wetlands of Tamil Nadu Agricultural University, Coimbatore with six genotypes (Norungan, ASD 16, White Ponni, CO 47, ADT 38 and PMK 3) and eight zinc treatments viz., zinc control, soil application of $ZnSO_4$, foliar spray of $ZnSO_4$ and soil application combined with foliar spray to find out if zinc efficiency in the soil was native or induced due to external factors. The exorbitantly high phosphorus availability (26.4 kg ha^{-1}) in the wetland soil together with calcareousness are the reasons for poor availability of zinc in the soil. In such of those soils applying only maintainer dose of phosphorus, managing calcareousness and growing zinc efficient rice varieties can alleviate zinc stress without productivity decline.

Key words: Zinc deficiency, native, induced, genotypes, phosphorus, rice

In Tamil Nadu, rice cultivation spreads over an area of 20 lakh hectares with a total production of 52 lakh tonnes (Anon, 2006). Rice ecology is endowed with several yield depressing factors of which mineral related abiotic stresses paint a predominant picture. A plethora of evidences have accumulated stating that the resilience of rice production is very often put to acid test due to the prevalence of two major limiting nutrients viz., nitrogen and zinc.

Today, than ever before, the importance of zinc in crop production is felt. It is estimated that about 50 % of soils used for cereal production in the world have low levels of plant available Zn (Graham and Welch, 1996). Zinc deficiency sinks rice production to an extent of two million hectares in Asia (Ferno *et al.,* 1970), which is an economic and humanitarian problem. It is common in wide range of soil types including calcareous soils of high pH, sandy soils and high phosphorus containing soils (Marschner, 1995). Unlike the other micronutrients, zinc deficiency is a common feature of both cold and warm climates, acid and alkaline soils, heavy and light soils. In the endeavour to increase the food production to provide an adequate standard of nutrition for the exploding population, it is very important that any loss in production from a cause that can so easily be corrected as zinc deficiency is prevented. The chemistry of submerged soil well reflects the transformation reactions of the applied zinc fertilizers. The precipitation and adsorption reactions of zinc under submergence speak out the paramount importance for real time zinc management. Hence the current investigation was made to explore if zinc deficiency noticed in the wetlands of Tamil Nadu Agricultural University is native to the soil or induced due to other factors.

Materials and Methods

A field experiment was laid out in field M7 of the wetlands of Agricultural College and Research Institute, Coimbatore. The experiment was conducted during summer 2002 (February - May) dry season. The soil of the experimental site was deep, clay loam (Vertic Ustochrept) belonging to Noyyal series. The pH of the soil was 8.1, EC : 0.68 dSm^{-1}, CEC : 21.5 cmol (p+) kg^{-1} soil, organic carbon content : 6.2 g kg^{-1}, $KMnO_4$ – N : 320 kg ha^{-1}, Olsen - P : 26.4 kg ha^{-1} and NH_4OAc-K : 870 kg ha^{-1}, DTPA extractable Fe and Zn were

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32 and 0.90 mg kg^{-1} soil. Six genotypes, Norungan, ASD 16, White Ponni, CO 47, ADT 38 and PMK 3 were employed. The experiment was laid out in factorial randomized block design with three replications. Two factors were identified viz., varieties and levels of zinc. The treatments consisted of six varieties and eight levels of zinc. The treatment details are portrayed below.

Varieties

V_1 : Norungan, V_2 : ASD 16, V_3 : White Ponni,
V_4 : CO 47, V_5 : ADT 38, V_6 : PMK 3

Levels of zinc

T_1 : Control
T_2 : $ZnSO_4$ @ 12.5 kg ha^{-1}
T_3 : $ZnSO_4$ @ 12.5 kg ha^{-1} (basal) + 12.5 kg ha^{-1} (active tillering)
T_4 : $ZnSO_4$ @ 25 kg ha^{-1} (basal)
T_5 : $ZnSO_4$ @ 25 kg ha^{-1} (basal) + 12.5 kg ha^{-1} (active tillering)
T_6 : $ZnSO_4$ @ 37.5 kg ha^{-1} (basal)
T_7 : Foliar spray of 0.5 % $ZnSO_4$ at 20 and 40 DAT
T_8 : T_2 + Foliar spray of 0.5 % $ZnSO_4$ at 20 and 40 DAT

Rhizosphere and non rhizosphere soil samples were collected at all the physiological growth stages viz., active tillering (AT), panicle initiation (PI), 50% flowering (FF), grain filling (GF) and harvest (HT) stages. Olsen P and DTPA – Zn were analysed employing standard procedures.

Results

Olsen – P

The Olsen P content as observed at different stages of sampling varied between 15.7 kg ha^{-1} ($V_2T_6R_1$) and 39.1 kg ha^{-1} ($V_6T_2R_2$). The genotypes exhibited their varied influence on Olsen-P content at active tillering, panicle initiation and harvest stages (Table 1). The genotypes Norungan and ASD 16 were equally effective in registering a substantially higher P content at active tillering and panicle initiation stages but in the above said stages ADT 38 displayed a reverse trend. At harvest stage, PMK 3 exerted a significant positive influence on Olsen-P content (26.1 kg ha^{-1}) while ASD 16 registered a lower content (23.7 kg ha^{-1}).

The rhizosphere soil differed markedly from the non rhizosphere soil in recording a significantly lower Olsen P content at all the stages of sampling. The 'P' content of the rhizosphere soil showed a progressive and steep decline with the advancement of crop growth stages whilst in the non-rhizosphere region a gradual increase was noted till 50% flowering stage with a decline observed thereafter. The treatments imposed exerted significant variation at all the crop growth stages except at grain filling stage. At all the crop growth stages, T_6 ($ZnSO_4$ @ 37.5 kg ha^{-1}) registered significantly lower P content whilst T_3 and T_4 did record markedly higher P content.

DTPA Zn content

The DTPA zinc content of rhizosphere and non rhizosphere soil ranged from 0.62 mg kg^{-1} ($V_3T_1R_1$) to 2.18 mg kg^{-1} ($V_1T_5R_2$) as observed at harvest and active tillering stages respectively. (Table 2) The DTPA zinc content showed a progressive decline with the advancement of crop growth stages. A marked difference was evident with varieties for their influence on DTPA Zn content. At all the stages of sampling Norungan witnessed higher DTPA Zn content and ADT 38 followed by PMK 3, a lower Zn content.

The non rhizosphere soil had substantially higher DTPA Zn content than the rhizosphere region at all the crop growth stages. As a natural corollary, the plots which received higher dose of $ZnSO_4$ viz., T_5 ($ZnSO_4$ @ 37.5 kg ha^{1}) recorded higher DTPA zinc content and zinc control plots (T_1) showed significantly lower Zn content, however T_1 showed statistical parlance with T_7 (foliar spray of 0.5% $ZnSO_4$, twice at 20 and 40 DAT). The two factor interactions were significant at the early stages of sampling only. No zinc (control) plots recorded lower DTPA Zn content more diagnostic under White Ponni, ADT 38 and PMK 3.

Table 1. **Olsen P content (kg ha^{-1}) of the rhizosphere and non rhizosphere soil at different crop growth stages of rice as influenced by genotypic divergence and zinc treatments**

Stages	AT		PI		FF		GF		HT	
Site of sampling	R	NR	R	NR	R	NR	R	NR	R	NR
Treatments										
V_1T_1	32.6	36.8	30.5	37.1	26.5	37.9	20.9	32.4	18.3	31.1
V_1T_2	34.1	36.2	30.1	36.8	26.2	36.9	21.2	32.2	18.0	30.0
V_1T_3	34.4	34.5	32.5	35.8	28.4	36.4	22.3	31.9	19.2	30.0
V_1T_4	33.1	35.1	30.1	36.3	26.5	36.9	20.2	32.4	16.4	31.1
V_1T_5	32.2	35.0	29.0	36.2	24.6	36.1	19.7	32.5	16.9	29.3
V_1T_6	31.9	34.4	28.2	34.2	24.0	35.4	19.4	31.9	15.7	29.0
V_1T_7	33.2	37.2	29.7	37.3	25.7	37.1	20.3	32.7	16.9	30.3
V_1T_8	36.0	36.5	33.2	36.7	29.3	33.5	24.0	31.5	21.7	29.6
V_2T_1	33.4	35.9	30.4	36.3	26.6	37.4	22.8	32.5	17.7	28.8
V_2T_2	32.8	36.2	29.9	37.2	25.8	38.6	21.8	33.2	17.6	30.4
V_2T_3	36.2	34.9	33.6	35.4	29.9	36.3	25.7	31.8	21.4	30.5
V_2T_4	32.4	35.8	29.3	36.3	26.2	37.4	23.1	32.2	20.9	29.8
V_2T_5	33.8	34.9	30.2	35.4	27.0	36.5	22.9	31.2	18.1	25.9
V_2T_6	32.0	33.6	28.3	34.2	25.0	35.8	21.0	30.1	15.7	25.2
V_2T_7	34.1	36.4	31.3	37.6	27.5	38.4	24.5	32.7	20.5	28.4
V_2T_8	34.9	36.0	31.8	36.5	27.8	37.2	25.1	32.1	20.2	27.2
V_3T_1	33.2	34.8	30.4	35.9	36.4	26.5	25.4	32.6	23.2	28.5
V_3T_2	34.6	35.1	32.1	36.9	37.8	25.8	24.2	33.2	22.3	28.7
V_3T_3	32.8	34.9	29.8	37.1	37.4	26.4	23.3	33.8	21.1	28.6
V_3T_4	31.4	35.3	28.6	36.4	37.5	27.2	24.3	32.2	22.8	27.8
V_3T_5	31.6	33.8	27.4	35.1	34.2	24.2	22.1	31.8	21.9	26.5
V_3T_6	30.8	31.2	26.2	32.9	32.8	25.4	20.4	30.2	20.8	26.1
V_3T_7	32.4	34.2	29.4	35.1	36.4	24.8	24.6	33.4	23.1	28.6
V_3T_8	33.7	35.3	28.7	37.2	38.0	27.3	22.9	31.7	21.9	27.0
V_4T_1	30.1	36.2	28.7	37.4	25.9	38.1	23.0	32.6	21.8	31.4
V_4T_2	29.8	35.9	27.4	36.8	23.4	37.2	22.8	32.4	22.0	30.8
V_4T_3	31.1	36.4	28.6	37.2	23.2	38.3	23.7	33.2	21.2	29.1
V_4T_4	30.1	37.2	28.4	38.4	21.8	39.2	24.8	33.2	22.0	28.2
V_4T_5	30.0	33.8	26.1	34.9	24.8	35.6	22.8	32.9	19.8	28.4
V_4T_6	29.1	32.4	27.2	33.8	23.2	34.4	24.0	31.8	20.7	30.1
V_4T_7	28.7	34.9	26.4	35.8	25.8	36.4	23.0	33.2	20.2	32.2
V_4T_8	32.5	35.3	29.4	36.4	23.4	37.3	24.5	33.9	21.5	28.5
V_5T_1	31.4	37.8	27.9	37.9	25.9	38.9	22.9	33.3	20.4	29.5
V_5T_2	28.6	36.3	24.2	36.4	23.4	38.3	22.3	34.4	19.4	29.6
V_5T_3	30.4	37.9	25.4	37.2	23.2	38.9	20.6	32.8	20.8	30.4
V_5T_4	27.8	38.4	23.6	38.8	21.8	39.7	18.9	31.9	19.9	31.4
V_5T_5	30.8	34.9	26.3	34.9	24.8	35.8	21.4	30.3	20.3	28.3
V_5T_6	28.6	33.8	24.4	33.8	23.2	35.3	21.3	32.8	19.2	27.8
V_5T_7	31.2	35.6	27.2	35.2	25.8	36.8	23.3	33.1	21.5	31.0
V_5T_8	29.5	31.6	24.4	36.5	23.5	38.3	21.5	32.5	20.7	30.7
V_6T_1	31.9	35.1	27.9	36.4	25.4	37.8	21.2	32.0	20.5	29.7
V_6T_2	30.8	36.2	28.1	38.4	26.1	39.1	22.7	33.3	21.1	30.4
V_6T_3	31.4	34.8	30.8	37.9	27.3	38.4	23.2	34.0	20.1	31.6
V_6T_4	29.9	35.7	28.4	37.8	25.2	39.1	21.7	33.8	21.9	30.2
V_6T_5	29.8	33.6	27.4	35.2	26.2	37.4	23.8	31.5	22.1	30.6
V_6T_6	30.8	32.8	27.6	34.1	25.2	36.6	22.1	30.8	20.7	30.9
V_6T_7	32.4	35.2	29.4	36.9	27.6	37.2	24.4	31.3	23.1	29.6
V_6T_8	33.7	36.7	31.3	37.5	28.5	38.2	25.4	32.2	23.9	30.1
Mean	**31.8**	**35.3**	**28.7**	**36.3**	**26.1**	**37.1**	**22.7**	**32.4**	**20.4**	**29.4**
CD P(= 0.05)	**NS**		**NS**		**NS**		**NS**		**4.149**	

Table 2. **DTPA Zn content (mg kg^{-1}) of the rhizosphere and non rhizosphere soil at different crop growth stages of rice as influenced by genotypic divergence and zinc treatments**

Stages	AT		PI		FF		GF		HT	
Site of sampling	R	NR	R	NR	R	NR	R	NR	R	NR
Treatments										
V_1T_1	0.99	1.01	0.90	0.95	0.85	0.92	0.82	0.88	0.75	0.87
V_1T_2	1.56	1.62	1.50	1.53	1.43	1.50	1.38	1.45	1.34	1.44
V_1T_3	1.87	1.98	1.75	1.93	1.58	1.88	1.53	1.85	1.49	1.83
V_1T_4	1.64	1.95	1.58	1.88	1.50	1.86	1.42	1.83	1.38	1.80
V_1T_5	2.01	2.18	1.93	2.13	1.87	2.11	1.82	2.08	1.78	2.06
V_1T_6	1.92	2.10	1.88	2.02	1.84	2.00	1.79	1.96	1.71	1.94
V_1T_7	0.91	1.02	0.89	0.98	0.85	0.94	0.8	0.91	0.76	0.88
V_1T_8	1.48	1.64	1.42	1.59	1.38	1.55	1.34	1.50	1.29	1.49
V_2T_1	0.97	0.99	0.94	0.97	0.91	0.95	0.87	0.90	0.79	0.87
V_2T_2	1.48	1.60	1.42	1.56	1.35	1.55	1.25	1.49	1.18	1.46
V_2T_3	1.79	1.96	1.73	1.92	1.65	1.84	1.57	1.80	1.51	1.77
V_2T_4	1.60	1.92	1.30	1.87	1.22	1.82	1.18	1.78	1.11	1.75
V_2T_5	1.98	2.16	1.92	2.12	1.84	2.10	1.72	2.00	1.68	1.97
V_2T_6	1.96	2.07	1.93	2.02	1.86	1.98	1.76	1.94	1.68	1.91
V_2T_7	1.00	1.00	0.98	0.97	0.93	0.95	0.89	0.92	0.82	0.89
V_2T_8	1.50	1.61	1.48	1.62	1.42	1.60	1.38	1.55	1.32	1.52
V_3T_1	0.86	0.97	0.83	0.95	0.79	0.94	0.70	0.92	0.62	0.89
V_3T_2	1.54	1.61	1.49	1.57	1.43	1.49	1.38	1.48	1.29	1.43
V_3T_3	1.81	1.97	1.78	1.94	1.72	1.85	1.42	1.83	1.33	1.79
V_3T_4	1.66	1.88	1.62	1.85	1.57	1.85	1.48	1.82	1.40	1.78
V_3T_5	1.94	2.14	1.90	2.11	1.86	2.10	1.80	2.07	1.70	2.02
V_3T_6	1.99	2.07	1.94	2.04	1.89	2.03	1.75	2.01	1.66	1.96
V_3T_7	0.95	0.98	0.92	0.96	0.88	0.96	0.87	0.95	0.84	0.91
V_3T_8	1.54	1.60	1.52	1.59	1.49	1.48	1.44	1.44	1.39	1.40
V_4T_1	0.90	0.99	0.87	0.96	0.82	0.93	0.78	0.88	0.72	0.86
V_4T_2	1.48	1.60	1.45	1.59	1.39	1.56	1.34	1.51	1.28	1.49
V_4T_3	1.74	1.98	1.69	1.95	1.64	1.90	1.60	1.85	1.53	1.78
V_4T_4	1.68	1.86	1.63	1.85	1.58	1.81	1.54	1.76	1.48	1.73
V_4T_5	1.90	2.10	1.86	2.07	1.82	2.02	1.73	1.97	1.63	1.92
V_4T_6	1.87	2.08	1.82	2.06	1.78	2.04	1.72	2.00	1.61	1.96
V_4T_7	0.92	1.00	0.85	0.97	0.83	0.95	0.78	0.90	0.73	0.85
V_4T_8	1.50	1.59	1.46	1.58	1.43	1.55	1.38	1.51	1.34	1.48
V_5T_1	0.87	0.99	0.82	0.96	0.76	0.93	0.69	0.88	0.65	0.86
V_5T_2	1.42	1.60	1.38	1.59	1.30	1.56	1.22	1.51	1.17	1.49
V_5T_3	1.66	1.98	1.62	1.95	1.57	1.90	1.50	1.85	1.43	1.78
V_5T_4	1.64	1.86	1.59	1.85	1.52	1.81	1.47	1.76	1.40	1.73
V_5T_5	1.83	2.10	1.78	2.07	1.75	2.02	1.68	1.97	1.60	1.92
V_5T_6	1.81	2.08	1.78	2.06	1.73	2.04	1.61	2.00	1.57	1.96
V_5T_7	0.91	1.00	0.87	0.97	0.82	0.95	0.79	0.90	0.70	0.85
V_5T_8	1.46	1.59	1.42	1.58	1.36	1.55	1.30	1.51	1.23	1.48
V_6T_1	0.94	0.97	0.92	0.94	0.87	0.92	0.82	0.89	0.74	0.84
V_6T_2	1.46	1.57	1.43	1.56	1.39	1.54	1.33	1.51	1.27	1.46
V_6T_3	1.54	1.90	1.50	1.85	1.44	1.82	1.38	1.80	1.30	1.62
V_6T_4	1.69	1.88	1.65	1.86	1.60	1.84	1.53	1.81	1.46	1.70
V_6T_5	1.87	2.12	1.83	2.10	1.78	2.08	1.72	2.04	1.66	1.88
V_6T_6	1.89	2.07	1.82	2.04	1.77	2.00	1.70	1.97	1.63	1.92
V_6T_7	0.97	0.98	0.94	0.96	0.89	0.94	0.86	0.91	0.84	0.87
V_6T_8	1.48	1.58	1.45	1.55	1.40	1.50	1.35	1.48	1.30	1.45
Mean	**1.51**	**1.66**	**1.46**	**1.62**	**1.40**	**1.59**	**1.34**	**1.55**	**1.27**	**1.51**
CD P(= 0.05)	**0.056**		**0.055**		**0.054**		**NS**		**NS**	

Discussion

The critical limit for occurrence of zinc deficiency varies between 0.6 and 2.0 mg kg^{-1} depending upon the soil type and type of extractants used. As the DTPA Zn content of the experimental site was 0.90 mg kg^{-1} speculation of the causes for the occurrence of Zn deficiency may serve as a useful tool in effective Zn management. Extensive reviews and research go on highlighting the induction of Zn deficiency by excess P fertilization or by the high availability of soil phosphorus. High soil phosphate level is one of the most common causes of zinc deficiency in crops encountered around the world.

Robson and Pitman (1983) have brought out the fact that large application of phosphorus fertilizers to soils low in available zinc can induce zinc deficiency (P induced zinc deficiency) by altering either soil or plant factors. High levels of available soil phosphorus have been implicated as contributing to zinc deficiency. High phosphorus content in soils can decrease solubility of zinc in soils (Loneragan *et al*., 1979) although such effects do not always occur (Pasricha *et al*., 1987). High phosphorus supply is often associated with a reduction in root growth and a lesser degree of infection of roots with vesicular arbuscular mycorrhizae. Both these factors are important for the acquisition of zinc. Also Loneragan and Webb (1993) reported that the phosphorus can enhance the adsorption of zinc onto soil constituents. The field in which the experiment was conducted had exorbitantly high Olsen P content (23 kg ha^{-1}). The enhanced P content might have significantly reduced the availability of zinc in the soil. The negative correlation existing between Olsen P content and DTPA Zn content as influenced by different treatments is pictorially represented in Fig. 1.

High P supply can also induce Zn deficiency by decreasing the physiological availability of Zn at the cellular level (Cakmak and Marschner, 1987). Phosphorus has been implicated as interfering with the uptake, translocation or utilization of zinc (Thorne, 1957). An excessive concentration of phosphorus interferes with the metabolic function of zinc at certain sites within the plant cells; nevertheless zinc concentration *per se* is not the cause of the disorder.

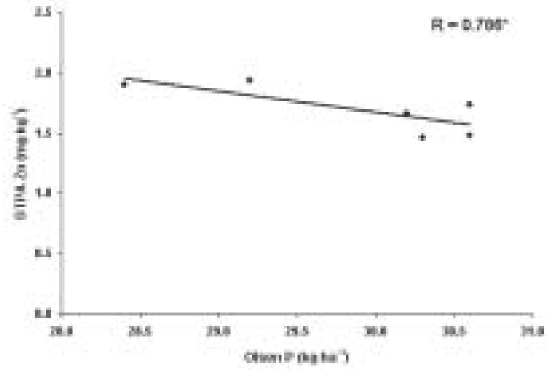

Fig. 1. Correlation between Olsen P and DTPA Zn content of the experimental site

Sillanpaa (1982) uses the term secondary deficiency for situations resulting in the low availability of zinc, sometimes referred to as induced deficiencies due to calcareousness with a soil pH> 7.4. The condition of the experimental field also simulates the above conditions with slight calcareousness and initial pH of > 7.5. Gangwar and Mann (1972) speculated that *Khaira* disease of rice may be because of Fe and Mn induced zinc deficiency. Thus Zn deficiency in the field was less a native and more an induced one due to the exorbitant availability of Fe and P.

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