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EFFECTIVENESS OF ZINC SOIL TESTS FOR FLOODED RICE

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Abstract. The DTPA [(carboxy methyl) imino] bis(ethylene nitrilo) tetraacetic acid, EDTA (ethylene diaminetetraacetic acid), dithizone (dithiocarbazone) and HCl methods successfully measuring available Zn for upland crops, failed to predict its availability for lowland rice *(Oryza sativa* L.*)*. This discrepancy appears to be explained by the reported strong inhibition of Zn absorption in rice by flooding induced increased Fe and Mn contents of soil solution. Their contents in flooded soils are not related with those of air dried soils approximating field moisture conditions of upland crops.

Soil tests have played an important role in Zn fertilization of several crops. They have, however, been mainly standardized for upland crops. For example, DTPA extractable Zn showed high correlation with its uptake by corn,[3] sorghum, potato, beans and asparagus.[2] Similarly other reagents such as dithizone,[3,14] HCl,[3] and EDTA[17] adequately predicted Zn availability and its deficiency for several upland crops from various types of soils. Such studies were rarely conducted for flooded rice especially on alkaline calcareous soils.

Rice is grown in reduced flooded soils with chemical and electrochemical properties different from those of dry soils.[13] Since these properties strongly influence Zn absorption by rice,[13] its determination on air-dried soil samples may have little value for flooded rice. The present studies on 20 calcareous soils of Pakistan were undertaken to test this hypothesis and to evaluate its mechanism.

Materials and Methods

Twenty surface soils representing Satgarah. Pindorian, Gajiana, Missan, Gujranwala, Kotli, Shahpur, Miranpur, Pacca, Bhalwal, Lyallpur and Hafizabad soils series were collected from rice area of Lyallpur, Gujranwala, Lahore, and Sheikhupura districts. The fields were plain and needed no levelling for irrigation. The samples were air-dried, crushed in a wooden mortar to pass through 22-mm seive and analysed for various physico-chemical characteristics (Table 1). Soil texture was determined by Hydrometer, $CaCO_3$ by acid neutralization and organic matter by dichromate oxidation.[10] The pH, EC, Ca+Mg, and HCO_3 contents were assessed by usual methods on 1:2 soil/water extracts.[10]

Zinc from air-dried soil samples was determined by the following methods:

(a) *EDTA Method* The extraction solution contained 0.01*M* EDTA and 1.0*M* $(NH_4)_2CO_3$ at pH 8.6. Ten g soil was shaken with 20 ml solution for 30 min and Zn in the filterate was determined with atomic absorption spectrophotometer.[17]

(b) *DTPA Method.* The extraction solution contained 0.005*M* DTPA, 0.1*M* triethanolamine and 00.1*M* $CaCl_2$ at pH 7.3. Ten g soil was shaken with 20 ml of solution for 2 hr. Zinc in the filterate was determined with atomic absorption spectrophotometer.[11]

(c) *HCl Method.* Two g soil was mixed with 50 ml 0.1*M* HCl solution. After standing overnight, the mixture was shaken for 30 min. Zinc in the filterate was determined with atomic absorption spectrophotometer.[17]

(d) *Dithizone Method.* This method is almost similar to that of Shah and Dean.[14] A 2.5 g soil sample was shaken for 2 hr with 25 ml of CCl_4 containing 0.01% dithizone and 25 ml of 1.0M CH_3COONH_4 adjusted to pH 7.0. The aqueous phase was discarded. Zinc was extracted in a separatory funnel by shaking 20 ml aliquet of organic phase with 5 ml of 0.1*N* HCl. Zinc in the extract was determined with atomic absorption spectrophotometer.

Zinc uptake by plants was determined by growing them on 3.5 kg soil portions in polythene lined plastic pots receiving basal doses of N as $CO(NH_2)_2$ and P as KH_2PO_4 at 75 and 13 ppm respectively and of Zn as $ZnSO_4$ at 0 and 5 ppm. The fertilizers

TABLE 1. RANGES AND MEANS OF CHARACTERISTICS OF 20 SOILS SAMPLES USED FOR RICE GROWTH AND ZINC EXTRACTION.

Soil characteristics	Range	Mean
pH	9.15—7.48	8.38
Organic matter (%)	1.23—0.62	0.93
$NaHCO_3$ extract P (ppm)	33.33—4.44	14.58
DTPA extract, Zn (ppm)	3.44—0.94	2.03
$CaCO_3$ equivalent (%)	3.98—0.25	1.33
HCO_3 (meq/l)	6.10—2.15	3.49
Ca+Mg (meq/l)	3.55—1.30	2.26
EC (mmhos/cm)	11.70—0.50	0.80
Texture	clay loam	clay

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TABLE 2. ZINC CONTENTS OF RICE PLANTS AND OF SOILS EXTRACTED BY FOUR METHODS.

Soil No.	Zn uptake by rice		Zn extracted by four methods			
	Zn Concn in plants (ppm)	Total Zn contents in plants μg/(pot)	EDTA (ppm)	DTPA (ppm)	Dithizone (ppm)	HCl (ppm)
1	13.8	1.68	2.44	2.52	2.75	15.00
2	28.4	45.0	2.08	2.48	2.48	12.50
3	23.0	86.3	1.08	1.58	1.38	14.25
4	15.5	23.7	1.02	2.16	1.10	10.00
5	10.2	18.6	0.70	1.84	0.69	6.00
6	16.3	32.8	0.60	1.08	0.69	6.00
7	17.0	29.9	0.72	1.46	1.10	5.50
8	32.1	140.5	0.68	1.72	0.69	8.00
9	22.0	123.2	0.76	1.76	0.83	7.50
10	16.4	41.1	3.66	3.22	2.20	9.00
11	9.5	20.9	0.90	1.98	0.83	8.00
12	9.4	7.0	0.62	1.58	0.83	6.75
13	19.9	67.4	0.86	0.94	0.83	7.00
14	24.6	131.7	1.01	2.66	1.10	6.25
15	15.4	35.2	1.18	2.36	1 65	6.90
16	11.4	15.6	0.90	3.44	1.38	7.00
17	7.5	12.2	0.56	2.22	1.10	4.75
18	7.0	24.2	0.60	2.06	1.38	5.00
19	4.3	8.5	0.44	1.06	0.55	4.50
20	9.0	17.2	0.66	1.44	0.69	6.00

were applied in triplicate and well mixed in soils before sowing of plants. Four Basmati-370 rice seedlings were grown for 50 days in 5 ml standing water, after which time, they were harvested at ground level, rinsed in deionized water, dried, weighed to evaluate Zn response, and their one g ground portions digested with 25 ml redistilled HNO_3 and $HClO_4$ (4:1) mixture. Zinc in the diluted digest was determined by atomic absorption spectroscopy. Correlation coefficients between soil and plant Zn were calculated using standard statistical procedures.

Results and Discussion

Zinc contents of rice plants and of 20 soils extracted by four methods are shown in Table 2. The amount of extractable Zn in the current soils was[3] almost similar to those of Colorado,[17] California and of other similar calcareous regions[2]. The relative efficiency of these methods for Zn extraction in the present and the earlier studies[3,17] was also identical and varied in the order of HCl > DTPA >dithizine > EDTA. Their extractable Zn contents highly correlated with each other ($P < 0.01$, calculated from Table 2). It is, however, surprising that whereas all the four methods successfully predicted Zn availability and its deficiency for wheat on the same 20 calcareous soils of Pakistan[1] and for several other crops in various regions.[18] None of them measured available Zn for flooded rice. Even EDTA and DTPA methods which are developed especially for calcareous soils[10,17] showed little correlation either with concentration or total Zn contents of rice plants (Table 3). The HCl method, though significantly correlated with Zn concentration in plants ($P < 0.05$), but exhibited a correlation coefficient of only 0,45 which was too small for the method to be reliable.

All four methods also failed to meet the criterion of distinguishing Zn-deficient from Zn-sufficient soils.[17] Thus when Zn extracted by HCl method (showing the highest correlation coefficient) was plotted against plant dry matter response ($P < 0.05$) to added Zn (Fig. 1), several nonresponsive soils scattered among the responsive ones rendering critical Zn level determination impossible. The other three methods similarly failed to distinguish Zn-deficient from non-deficient soils (Figures not shown). The present studies, thus, support the earlier results of Stewart *et al.*[15] indicating EDTA, DTPA, $MgCl_2$ and NH_4OAC methods to exhibit little relationship with Zn contents of 37-day old flooded rice plants. Correlation coefficient was significant for 27 days growth but was too small to be meaningful. Other researches[7] similarly failed to predict Zn deficiency in paddy soils by its extraction from air-dried soil samples. A recent IRRI report[6] indicating EDTA - $(NH_4)_2CO_3$ method to measure available Zn for flooded rice is inconclusive since the number of soils involved were too small for such correlation studies to be reliable. Another report[12] showing DTPA method to measure plant available Zn on California soils may have little relevance to the current studies since

TABLE 3. CORRELATION BETWEEN CONCENTRATION AND TOTAL ZN CONTENTS OF RICE PLANTS AND THOSE EXTRACTED BY FOUR METHODS FROM 20 SOILS.

Method of Zn extraction	Correlation Coefficient with	
	Zn Concn in rice	Total Zn contents in rice
EDTA	0.24	— 0.10
DTPA	0.12	0.10
Dithizone	0.21	— 0.12
HCl	0.45*	0.15

Significant at $P < 0.05$

rice, in California, is grown by direct seed broadcasting rather than from nursery seedlings. Its critical concentration of 0.5 ppm also appears of little significance since several soils of current studies with higher Zn concentration strongly responded to Zn fertilization (Fig. 1).

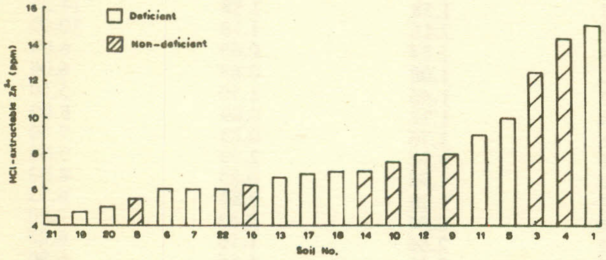

Fig. 1. Response of rise to soil applied $ZnSO_4$ in relation to HC1—extractable Zn^{2+} on 20 soils.

The reasons of failure of soil Zn tests for predicting Zn availability for flooded rice are not known. A series of our soil and solution culture studies indicate that Zn is not the only factor controlling Zn nutrition of rice on flooded soils. Soluble Fe and Mn contents also exhibit strong effect.[13] Thus increasing their concentration in solution from 0 to 0.12 ppm inhibited Zn absorption by 25 and 35% respectively in two local rice varieties.[13] Similarly, on several calcareous soils of Pakistan, Fe application or its higher supplies decreased Zn absorption by IR-6 rice plants,[4] competitively inhibited its translocation from roots to shoots[5] and induced higher Zn requirement within plants resulting in severe Zn deficiency in flooded rice.[4] These factors may also explain rice response to Zn application on several current soils inspite of their Zn contents being higher than critical levels of upland crops.[2,17] Our kinetic studies[13] have shown flooding to strongly enhance Fe and Mn solubility in soils. Their increase, however, does not depend on their original contents in air-dried soils or those at field capacity. Thus on two soils with identical Fe and Mn contents, flooding enhanced them to 1.9, 0.6 and 1.5, 2.1 ppm respectively. Similar poor correlation between Zn contents of air-dried and flooded soils were reported on calcareous soils of Bangladesh[8] and of other regions. Thus by contrast of upland crops, Zn measured on air-dried soils may have little relationship with Zn contents of flooded rice. The problem will be still greater if submergence also influences Zn solubility in calcareous soils.[13]

Concentration of Zn whole shoots[9] or in topmost leaves[4] during active rice growth is a reliable measure of its availability and deficiency for flooded rice. It can, thus, help in Zn fertilization of rice even of the ongoing crop since Zn spray effectively controls its deficiency in plant.[16] Plant tests cannot, however, completely replace soil tests which have added advantage especially for a broader fertility programme. Further studies on evaluating a reliable soil Zn test should, therefore, be conducted. At least two approaches can be adopted. Zinc determined on samples from flooded fields may prove a better measure of its availability to plants, but such a sampling will be tedious and probably impracticable for a routine procedure. Alternatively, small amounts of soil samples (say 10 g, depending upon the method used) may be submerged (say in 20 ml H_2O) for a few days in appropriate sized polythene tubes prior of their Zn determination by various procedures. Iron and Mn contents must also be considered since they strongly influence Zn absorption and its utilisation in rice plants. All the three cations can simultaneously be extracted by suitable routine extractants[18] and can be rapidly determined from a fairly dilute soil extract directly by the latest technique of atomic absorption spectroscopy.

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References

1. S.M. Alam, M A. Kausar, F.M. Chaudhry and A. Rashid, Agri. Pakistan, in press.
2. L.C. Boawn, Annual Pacific NW Fort Calf., Proceeding 22nd (Bozeman, Mont.), 143 Pacific NW Plant Assoc., Portland, Orc (1971).
3. A.L. Brown, J. Quick and J.L. Eddings, Soil Sci. Soc. Am. Proc., **35**, 105 (1971).
4. F.M. Chaudhry, S.M. Alam, A. Rashid and A. Latif, Plant Soil, submitted.
5. F.M. Chaudhry and A. Wallance, Plant Soil, in press.
6. Annual Report, 1969, International Rice Research Institute, Los Danos, Philippines.
7. Annual Report, 1968, International Rice Research Institute, Los Banes, Philippines.
8. A. Islam and W. Islam, Plant Soil, **39**, 555 (1973).
9. M.A. Kausar, F. M. Chaudhry, A. Rashid, A. Latif and S.M. Alam, Plant Soil, in press.
10. M.L. Jackson, *Soil Chemical Analysis*, Academic, New York, 1966).
11. W.L. Lindsay and W.A. Norvell, Agron. Abstr., 84 (1969).
12. D.S. Mikkelson and D.S. Brandon, Calif. Agri., **29**, 9 (1975).
13. Rahmatullah, F.M. Chaudhry and A. Rashid, Plant Soil, in press.
14. E. Shaw and D A. Dean, Soil Sci., **73**, 341 (1952).
15. J.W.B. Stewart, B.V. Fraize, and F.M. Lapid, Proc. Symp. IAEA, Vienna, 539 (1972).
16. A. Tanaka and S. Yoshida, Intern. Rice Res. Inst. Tech. Bull. No. 10 (1970).
17. J.F. Trierweiler and W.L. Lindsay, Soil Sci. Soc. Am. Proc., **3**, 49 (1969).
18. F.G. Viets Jr. and W.L. Lindsay, in *Soil Testing and Plant Analysis*, Soil Science Society of America, Madison, 1973, p. 153.