Pak. j. sci. ind. res., vol. 37, no. 10, October 1994

# SUITABILITY OF SOIL TEST PROCEDURES FOR PREDICTING RESPONSE OF FLOODED RICE TO ZINC APPLICATION ON CALCAREOUS SOILS

M. Sharif Zia, F. Hussain, Rahmatullah, M.B. Tahir and M. Inayat Khan

*Land Resources Section, National Agricultural Research Centre, Islamabad-45500, Pakistan*

(Received July 5, 1992; resvised January 13, 1994 )

Zinc (Zn) deficiency is wide-spread in agricultural crops produced on alkaline calcareous soils of Pakistan. A greenhouse study was, therefore, undertaken on six soil series of rice area for evaluating the suitability of different extractants for extracting available zinc and to determine the critical soil Zn values for predicting rice response to Zn application. Zinc treatments were nil and 10 mg Zn $kg^{-1}$ soil. Rice variety KS 282 was the test variety. Results revealed that DTPA extractable Zn in the soil had positive correlation with relative dry matter yield, tillers (in control pots), Zn concentration and its uptake in rice. Similarly, AB-DTPA extractable Zn was significantly correlated with the number of tillers/plants dry matter yield and Zn uptake in rice. Mehlich-3 extractable Zn had highly significant correlation with relative dry matter yield and Zn concentration in rice. Zinc extracted by HCl was significantly correlated with the number of tillers/plant and dry matter yield and it has highly significant correlation with Zn uptake in rice. Ammonium acetate extractable Zn was neither correlated with rice growth parameters nor with Zn concentration and its uptake in rice. Critical values of Zn determined were: DTPA, 0.99 mg Zn $kg^{-1}$; AB-DTPA, 1.22 mg Zn $kg^{-1}$; Mehlich-3, 2.47 mg Zn $(dm^3)^{-1}$ and HCl, 0.34 mg Zn $kg^{-1}$ soil. The AB-DTPA procedure of monitoring Zn availability in soils is preferred since it is a multielement soil test.

***Key words:*** Flooded, Lowland, Rice, Calcareous soils, Zinc extractant, Critical level, Zinc.

## Introduction

Zinc deficiency in Pakistan for rice was first recognised by Yoshida and Tanaka [1]. Later on, extensive survey in the country established its wide-spead and severe deficiency in rice soils, Chaudhry and Sharif [2], Kausar *et al.* [3], Tahir [4], Rahmatullah *et al.* [5] and Zia [6]. Rice in the country is grown in Northern areas, central Punjab and upper and lower Sindh. Soils in these areas are alluvial, calcareous and alkaline in nature, hence conducive to zinc deficiency especially in rice which is grown under flooded lowland ecosystem.

Scientific management of Zn deficiency problem in rice demands that the application of Zn fertilizer should be made on soil test basis. It will help to avoid the application of Zn where it is not required and fertilizer thus saved can be used where substantial responses are expected. Therefore, for judicious use of Zn fertilizers there is a pressing need to select a reliable, simple, rapid and inexpensive soil test method.

Soil tests have been mainly standardized for upland crops except some work scattered on soil test procedures for Zn in rice, Sillanpaa [7]. However, DTPA extractable Zn showed high correlation with its uptake by corn, Brown *et al.* [8]. Similarly other extractant such as dithiazone, Brown *et al.* [8]; HCl, Brown *et al.* [8] and EDTA, Trierweiler and Lindsay [9] adequately predicted Zn availability and its deficiency for several upland crops from various types of soils.

Since rice is grown in reduced flooded ecosystem which has chemical and electrochemical soil properties like concentration of soluble salts (EC), pH and Eh etc., entirely different than those of upland soils. Therefore, development of suitable Zn soil test in Pakistan had been tedious with little success, Chaudhry *et al.* [10] and Rahmatullah *et al.* [5]. Recently Ponnamperuma *et al.* [11] reported 0.05 M HCl to be an effective on a large variety and number of rice soils. Sakal *et al.* [12] reported 0.78 mg Zn $kg^{-1}$ soil as critical limit with DTPA extractant for growing rice. Universal soil tests, AB-DTPA, Soltanpour and Schwab [13] and Mehlich-3 [14] have also been developed recently which are quite suitable for determining overall fertility status of soils. But little information is available regarding their suitability for extracting Zn for lowland rice. Present study to find suitable Zn soil test and to determine critical Zn value using promising extractants for lowland rice soils is an endeavour in this direction.

## Materials and Methods

Investigations were carried out during summer 1991 in the greenhouse of National Agricultural Research Centre, Islamabad. Six rice soils namely Mansehra (*Typic eutrochrepts*), Kamoke (*Typic ustrochrepts*), Gujranwala (*Typic ustrochrepts*), Shahpur (*Fluventic camborthids*), Jhatpat (*Torrertic camborthids*) and Gajiana (*Halic camborthids*) were examined. Soils were air dried, crushed and sieved through 1 cm sieve and homogenized.Three kg of each prepared soil taken in opaque brown coloured plastic pots (21 cm at the base, 19 cm tall and 22 cm diameter at the top) was flooded with distilled deionized water. Flooding was done 10 days before transplanting of rice crop. The soil in the pots was stirred twice at an interval of three days to induce puddled condition. Zinc treatments under investigation were: $T_1$=0 mg and $T_2$=10mg Zn $kg^{-1}$ soil as a reagent grade $ZnSO_4$. In these treatments a uniform basal application of N, P, K, S. Cu and B was made just before transplanting @ 100, 35, 150, 123, 5 and 1 mg $kg^{-1}$ soil, respectively. The treatments were imposed in triplicate.Two weeks old seedlings of rice cultivar KS-282 grown in sand culture (free from Zn) were transplanted. Three plants were grown upto panicle initiation stage and was harvested 50 days after transplanting. Tillers and dry matter yield were recorded. Relative tillering (%) and dry matter (D.M.) yield (%) were determined according to the following formula:

$$\text{Relative tillers/Relative D.M. yield (\%)} = \frac{\text{Tillers/D.M. yield without Zn}}{\text{Tillers/D.M. yield with Zn}} \times 100$$

After drying to constant weight at 65°C in hot air oven and grinding, Zn concentration in dry matter was determined after its digestion with diacid ($HNO_3$ : $HClO_4$, 2:1) mixture by using Perkin Elmer 4000 atomic absorption spectrometer, Allan [15]. Zinc in the soil was determined using various extractants (Table 1 and 4). Soils were also analyzed for other physico-chemical characteristics (Table 2). Zinc extracted by various soil Zn test methods was correlated with each other. Zinc soil test values were also correlated with rice growth parameters and Zn uptake in rice. Zinc critical concentration in soil was determined by constructing Mitscherlich curves of relative yield and Zn soil test values.

## Results and Discussion

Physico-chemical characteristics of the soils under investigation are given in Table 2 and 4. Soils ranged in texture from loam to clay with clay content varying from 21.8 to 49.0% having CEC values of 7.42 to 19.80 me/100 g soil. Organic matter in the soils ranged from 0.35 to 1.59%. Soils were calcareous in nature with free lime varying from 1.35 to 16.7%. Electrical conductivity values ranged from 0.58 to 2.0 mS/cm and all the soils except Mansehra were alkaline in nature (Table 2).

Rice growth parameters and its Zn uptake are given in Table 3. Soil Zn values extracted by different extractants are presented in Table 4. The DTPA extractable Zn in soils had highly significant correlation with the AB-DTPA extractable Zn and it was significantly correlated with Zn extracted by the Mehlich-3 and HCl (Table 5). The AB-DTPA extractable Zn had also highly significant correlation with HCl extractable Zn. Ammonium acetate extractable Zn was not correlated with Zn extracted either by DTPA, AB-DTPA, Mehlich-3 or HCl (Table 5).

The zinc extracted with DTPA correlated significantly ($P < 0.01$) with tillers and dry matter yield produced in control

TABLE 1. DESCRIPTION OF ZINC SOIL TEST METHODS.

| Zn Soil test | Extractant | pH | Soil/solution ratio | Shaking time | Reference |
|---|---|---|---|---|---|
| DTPA | 0.005<u>M</u> DTPA + 0.01<u>M</u> $CaCl_2$ + 0.1<u>M</u> TEA | 7.3 | 1 : 2 | 2 hr. | Lindsay & Norvel (1978) |
| AB-DTPA | 0.005<u>M</u> DTPA + 1.0<u>M</u> $NH_4HCO_3$ | 7.6 | 1 : 2 | 15 min. | Soltanpour & Schwab (1977) |
| Mehlich 3 | 0.2<u>N</u> $CH_3COOH$ + 0.25<u>N</u> $NH_4NO_3$ + 0.015<u>N</u> $NH_4F$ + 0.013<u>N</u> $HNO_3$ + 0.001<u>M</u> EDTA | 2.5 | 1 : 10 v/v | 5 min. | Mehlich (1984) |
| Hydrochloric acid | .05<u>M</u> HCl | - | 1 : 2 | 5 min. | Ponnamperuma *et al.* (1981) |
| Ammonium acetate | 1.0<u>M</u> $CH_3COONH_4$ | 7.0 | 1 : 2 | 1 hr. | Viets and Boawn (1965) |

TABLE 2. PHYSICO-CHEMICAL CHARACTERISTICS OF THE SOILS.

| Soil | Texture | Clay (%) | O.M. (%) | $CaCO_3$ (%) | CEC (me/100g) | pH | EC dS/m |
|---|---|---|---|---|---|---|---|
| Mansehra | Silty clay loam | 29.0 | 1.35 | 1.60 | 14.60 | 5.6 | 1.36 |
| Kamoke | Silty clay loam | 37.0 | 1.59 | 1.60 | 19.80 | 8.2 | 2.0 |
| Gujranwala | Silty loam | 21.8 | 0.90 | 1.35 | 7.80 | 8.0 | 1.0 |
| Shahpur | Silty clay loam | 30.4 | 1.17 | 4.1 | 15.20 | 8.2 | 0.96 |
| Jhatpat | Clay | 49.0 | 0.35 | 16.7 | 16.80 | 8.4 | 0.58 |
| Gajiana | Loam | 25.8 | 0.86 | 4.4 | 7.42 | 8.9 | 2.00 |

TABLE 3. EFFECT OF ADDED ZINC ON GROWTH AND ZINC UPTAKE BY RICE.

| Soil | Tiller/plant (no./plant) | | Relative tiller | Dry matter yield (g/pot) | | Relative D.M.yield | Plant Zn conc. (mg/kg) | | Plant Zn uptake (mg/pot) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $Zn_{10}$ | $Zn_0$ | (%) | $Zn_{10}$ | $Zn_0$ | (%) | $Zn_{10}$ | $Zn_0$ | $Zn_{10}$ | $Zn_0$ |
| Mansehra | 15.33 | 15.00 | 97.90 | 36.0 | 36.0 | 100.0 | 44.0 | 41.4 | 1.61 | 1.52 |
| Kamoke | 12.33 | 11.56 | 93.73 | 21.5 | 21.0 | 97.7 | 39.8 | 35.0 | 0.86 | 0.74 |
| Gujranwala | 9.00 | 7.89 | 87.67 | 18.5 | 17.2 | 93.0 | 37.1 | 32.0 | 0.67 | 0.55 |
| Shahpur | 9.88 | 9.00 | 91.09 | 20.9 | 17.6 | 84.4 | 32.3 | 26.5 | 0.68 | 0.47 |
| Jhatpat | 9.78 | 9.11 | 93.15 | 23.1 | 17.2 | 74.2 | 28.5 | 22.3 | 0.69 | 0.38 |
| Gajiana | 9.33 | 6.89 | 82.70 | 16.5 | 10.1 | 61.2 | 25.5 | 20.0 | 0.42 | 0.20 |

TABLE 4. EXTRACTABLE ZINC IN SOIL USING DIFFERENT ZINC SOIL TESTS.

| Soil | DTPA | AB-DTPA | 0.05N HCl | 1M $CH_3COONH_4$ | Mehlich 3 |
|---|---|---|---|---|---|
| | | | mg/kg | | ($mg/dm^3$) |
| Mansehra | 1.40 | 2.50 | 1.04 | 0.08 | 2.75 |
| Kamoke | 1.05 | 1.30 | 0.12 | 0.04 | 2.60 |
| Gujranwala | 0.95 | 1.20 | 0.25 | 0.02 | 2.75 |
| Shahpur | 0.90 | 1.10 | 0.07 | 0.24 | 2.45 |
| Jhatpat | 0.79 | 0.96 | 0.06 | 0.06 | 1.85 |
| Gajiana | 0.64 | 0.90 | 0.06 | 0.06 | 1.80 |

TABLE 5. CORRELATION COEFFICIENT AMONG ZINC VALUES DETERMINED BY DIFFERENT SOIL TESTS [ n = 6 ].

| | Zn Soil tests | | | |
|---|---|---|---|---|
| | AB-DTPA | Mehlich 3 | HCl | $CH_3COONH_4$ |
| DTPA | 0.95** | 0.80* | 0.88* | –0.03 |
| AB-DTPA | – | 0.63 | 0.98** | –0.05 |
| Mehlich 3 | – | – | 0.55 | –0.02 |
| HCl | – | – | – | –0.11 |

* and ** indicate the correlation coefficients significant at 5 and 1% level of probability, respectively.

pots (Table 6). It was also significantly correlated with relative tillers and relative dry matter yield (Table 6). Zinc extracted by AB-DTPA was highly significantly correlated with tillers and dry matter yield in control and treated pots. Zinc extracted by Mehlich-3 had highly significant correlation with relative dry matter yield. Correlation between HCl extractable Zn and dry matter in control and treated pots was highly significant. The AB-DTPA extractable Zn had highly significant correlation with the number of tillers in control as well as treated pots. Ammonium acetate extractable Zn was neither correlated with tillers nor with dry matter yield (Table 6).

Zinc extracted by DTPA had highly significant correlation with Zn concentration in rice shoots and with Zn uptake by rice plants in control and treated pots (Table 7). Zinc extracted by AB-DTPA had also highly significant correlation with Zn uptake in rice both in control as well as in treated pots.

TABLE 6. CORRELATION COEFFICIENT BETWEEN ZINC VALUES DETERMINED BY DIFFERENT SOIL TEST METHODS, RICE TILLERS AND DRY MATTER YIELD [ n = 6 ].

| Zn Soil test method | Tillers/plant | | [a]R.T. | Dry matter yield | | [b]R.D.M.yield |
|---|---|---|---|---|---|---|
| | $Zn_{10}$ | $Zn_0$ | (%) | $Zn_{10}$ | $Zn_0$ | (%) |
| DTPA | 0.90* | 0.93** | 0.82* | 0.87* | 0.97** | 0.88* |
| AB-DTPA | 0.92** | 0.91** | 0.71 | ·0.92** | 0.97** | 0.68 |
| Mehlich 3 | 0.50 | 0.57 | 0.49 | 0.43 | 0.65 | 0.94** |
| HCl | 0.85* | 0.83* | 0.61 | 0.91** | 0.92** | 0.58 |
| $CH_3COONH_4$ | –0.06 | –0.01 | 0.11 | 0.05 | 0.00 | –0.07 |

[a]R.T. = Relative tillers, [b]R.D.M. = Relative dry matter.
* and ** indicate the significant correlation coefficients at 5 and 1% level of probability, respectively.

TABLE 7. CORRELATION COEFFICIENT BETWEEN ZINC VALUES DETERMINED BY DIFFERENT ZN SOIL TEST METHODS AND ZINC UPTAKE IN RICE [ n = 6 ].

| Zn Soil test method | Zn Concentration | | Zn Uptake | |
|---|---|---|---|---|
| | $Zn_{10}$ | $Zn_0$ | $Zn_{10}$ | $Zn_0$ |
| DTPA | 0.96** | 0.96** | 0.96** | 0.98** |
| AB-DTPA | 0.83* | 0.87* | 0.98** | 0.99** |
| Mehlich 3 | 0.91** | 0.89* | 0.61 | 0.69 |
| HCl | 0.74 | 0.79 | 0.94** | 0.94** |
| $CH_3COONH_4$ | -0.15 | -0.16 | -0.04 | -0.07 |

* and ** indicate the significant correlation coefficients at 5 and 1% level of probability, respectively.

Also it had significant correlation with Zn concentration in rice plants in control and in treated pots. Zinc extracted by Mehlich-3 had highly significant correlation with Zn concentration in rice plants whereas HCl extractable Zn was highly significantly correlated with Zn uptake by rice. Ammonium acetate extractable Zn again did not correlated with either concentration or uptake of Zn by rice (Table 7).

Mitscherlich curves of relative yield and soil Zn values of promising extractants were prepared for determining critical Zn values in soil (Fig. 1). Critical Zn value for DTPA method was found to be 0.99 mg Zn $kg^{-1}$ soil. For AB-DTPA ex-

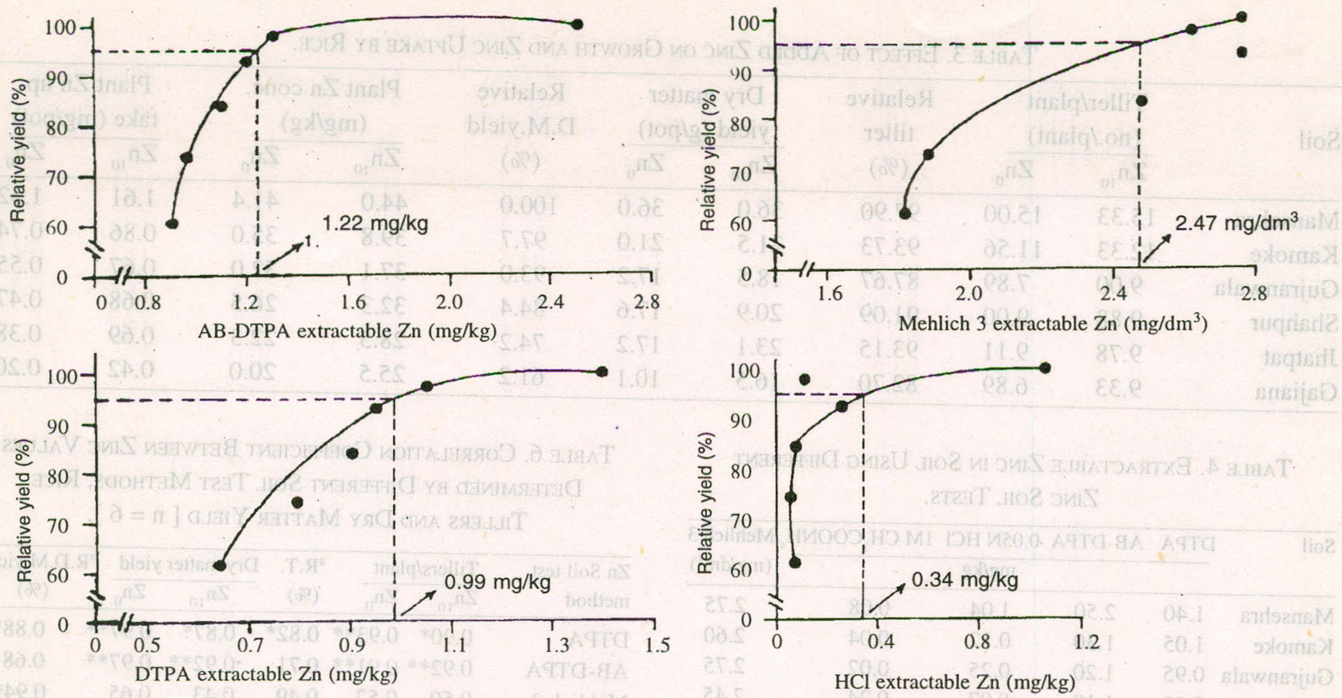


Fig. 1. Mitscherlich curves of relative dry matter yield and soil test zinc.

tractable Zn a critical value was 1.22 mg Zn $kg^{-1}$ soil. The critical values for Mehlich-3 was 2.47 mg Zn $(dm^3)^{-1}$ soil and for HCl 0.34 mg Zn $kg^{-1}$ soil.

Critical Zn value determined with HCl method was lower than the value reported by Ponnamperuma *et al.* [11]. This is perhaps due to alkaline and calcareous nature of Pakistani rice soils where part of weak acid is used for neutralizing the alkaline reaction, hence the values determined were rather low. In Mehlich-3, a large number of expensive chemicals are involved. Both DTPA and AB-DTPA extractants are multi-element procedures and can, therefore, be safely used for determining Zn requirements of lowland rice soils. However, AB-DTPA has an edge over DTPA because besides Zn it can be employed for determining micro as well as macro-nutrient status of soils. It permits the extraction of $NO_3^-$, N, P, K, Zn, Cu, Mn and Fe in a single extraction. However, these investigations need to be confirmed using a comparatively larger number of rice soils.

## References

1. S. Yoshida and A. Tanaka, Soil Sci. Plant Nutr.,**15**, 75 (1969).
2. F.M. Chaudhry and M. Sharif, Proc. Combined Panel and Res. Coords. Meeting, Vienna, IAEA- 172, P.I., Sept. 23-27 (1974).
3. M.A. Kausar, F.M. Chaudhry, A. Rashid, A. Latif and S.M. Alam, Plant Soil, **45**, 397 (1976).
4. M. Tahir, Final Tech. Report, PL-480 Project, NIAB, Faisalabad (1981), pp.124.
5. Rahmatullah, M. Salim and A. Rashid., Proceedings of the National Seminar and Micronutients in Soils and Crops in Pakistan, Peshawar, Dec.13-15, 1987 (1988), pp.118-122.
6. M.S. Zia, Ph.D. Dissertation, Fac. Agric., Kyoto Univ., Japan (1990).
7. M. Sillanpää, Micro and Macro-Nutrient Status of Soils, A Global Study, FAO Soil Bull., Rome **48** (1982).
8. A.L. Brown, J. Quick and J.L.A. Eddings., Soil Sci. Soc. Amer. Proc., **35**, 105 (1971).
9. J.F. Trierweiler and W.L. Lindsay, Soil Sci. Amer. Proc., **3**, 49 (1969).
10. F.M. Chaudhry, A. Latif, M. Sharif and A. Rashid, Pak. j. sci. ind. res., **19**, 94 (1976).
11. F.N. Ponnamperuma, M.T. Cayton and R.S. Lantin, Plant Soil, **61**, 297 (1981).
12. R. Sakal, B.P. Singh and A.P. Singh, Plant Soil, **66**, 129 (1982).
13. P.N. Soltanpour and A.P. Schwab, Commun. Soil Sci. Plant Anal., **8**, 195 (1977).
14. A. Mehlich, Commun. Soil Sci. and Plant Anal., **15**, 1409 (1984).
15. J.E. Allan, *Agricultural Analysis by Atomic Absroption* (Ruakura Soil Research Station, Hamilton, Newzealand, 1969).
16. W.L. Lindsay and W.A. Norvel, Soil Sci. Soc. Amer. J., **42**, 421 (1978).
17. F. G. Viets Jr. and L. C. Boawn, Zinc, in Methods of Soil Analysis Part-2, *Chemical and Microbiological Properties* (C.A. Black, ed. ), Agronomy Series No.9, (Amer. Soc. Agron., Madison, WI., USA 1965), pp. 1090-1101 .