Rice Grain Yield and Tissue Response to Zinc Fertilizer Source and Rate

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Abstract

Greater incidences of Zn-deficient rice in Mississippi can be partly attributed to acreage expansion onto more coarse textured soils and cultural practices such as irrigation and land-leveling. Currently, the Mississippi State University Soil Testing Lab uses the “Mississippi Soil Test Method,” also known as the “Lancaster method.” This method was developed because of the wide-range of soils, and especially soil pHs used for row crop production in Mississippi. Soil test-Zn is categorized from very low (VL) to very high (VH) based on a combination of soil pH and extractable Zn.

The objective of this research was two-fold. First, Zn sources and rates were tested to determine their effectiveness on grain yield. Secondly, Zn extraction methods were correlated to grain yield and tissue concentration as a means of determining the validity of the Lancaster extractant for Zn recommendations in rice.

Averaged over treatment means, a significant yield response to Zn was obtained at one location (Sunflower N). The average yield in the non-treated was 86% of the greatest yielding treatment (5.6 kg Zn ha^{-1} as $ZnSO_4$). Lancaster Zn was neither correlated with whole plant Zn concentration nor grain yield; however, DTPA can be related to grain yield by $\%RY = -82.32(DTPA\text{-}ZN)^2 + 76.95(DTPA\text{-}Zn) + 82.24$ ($R^2 = 0.35$ $P = 0.0600$).

DTPA-Zn can also be related to whole plant Zn concentration by the following equation $Zn\ conc = -186.27(DTPA\text{-}ZN)^2 + 159.48(DTPA\text{-}Zn) + 24.91$ ($R^2 = 0.34$ $P = 0.0656$). Mehlich 3 and DTPA-Zn showed strong linear correlation that can be expressed as $DTPA\text{-}Zn = 0.4225(M3\text{-}Zn) - 0.2213$ ($R^2 = 0.64$, $P=<0.0001$), which suggests that Mehlich-3 potentially can be utilized as a multi-element extraction method for rice soils in Mississippi.

Introduction

Zinc (Zn) is the most limiting micronutrient in U.S. rice production. Deficiencies associated with Zn were officially documented in the 1960s, and since that time, observations have led to the following description of visual symptoms: 1) basal chlorosis of new leaves; 2) midrib of oldest leaves becoming yellow or white; 3) loss of leaf turgidity; 4) bronzing of older leaves; 5) inhibition of tillering; 6) stand loss after flood establishment; 7) stacked leaf collars; and 8) delay in maturity. Depending upon the severity of the deficiency, yield loss can approach 100%; however, typical yield loss associated with Zn-deficiencies range from 10 to 60%. Symptoms typically express themselves after flood establishment and corrective measures are difficult to employ without compromising sufficient areas of the field (Norman et al., 2003).

Rice acreage expansion onto more coarse-textured soils, the adoption of precision land-leveling, and soil pH increases due to irrigation water high in bicarbonates have caused greater incidences of Zn deficiencies in rice. Currently, the Mississippi State University Soil Testing Lab uses the “Lancaster method” to approximate plant-available Zn. This method was developed because of the wide range of soils and especially soil pHs used for row crop production in Mississippi. Soil Zn is categorized from very low (VL) to very high (VH) based on a combination of soil pH and extractable Zn. As soil pH increases, the critical level of Lancaster-Zn increases. A search of the published literature revealed no findings of this method being compared to other acceptable methods such as Mehlich 3 and DTPA for Zn extraction.

Zinc fertilizer sources have increased dramatically in recent years, and growers need sound methods to determine where Zn-fertilizer is needed and the appropriate rate and source. Hence, the objective of this research was two-fold. First, Zn sources and rates were tested to determine their effectiveness on grain yield. Secondly, Zn extraction methods were correlated to grain yield and tissue concentration as a means of determining the validity of the Lancaster extractant for Zn recommendations in rice.

Materials and Methods

Four locations were selected in the spring of 2007 based on a combination of historical Zn deficiencies and soil test Zn levels as determined by the Lancaster method (Table 1). The common Zn treatment at all locations was $ZnSO_4$ applied to 1-leaf rice at rates of 2.8, 5.6, and 11.2 kg Zn ha^{-1}. In addition, Zn-EDTA was applied to the foliage of 4- to 5-leaf rice at least 3 days prior to permanent flood establishment. Various other Zn sources were applied depending upon the location; however, grain yield data are only presented for Sunflower N, as this was the only location where visual Zn deficiencies were observed, and treatments affected grain yield (Figure 1a and 1b).

Soil samples were collected from the top 15 cm of each untreated plot and analyzed for soil pH (1:2 water), P, K, Ca, Mg, CEC, OM, Lancaster-Zn, Mehlich 3-Zn, and DTPA-Zn. Whole plant samples were collected from 0.9 m of row from each plot at the panicle differentiation growth stage, dried at 60°C for 72 hours, ground, and analyzed for Zn. Rice plots were harvested with a small plot combine and grain yields were adjusted to 12% moisture. Grain yield from each untreated plot was divided by grain yield from the 5.6 kg Zn ha^{-1} as $ZnSO_4$ treatment and multiplied by 100 to determine the percent relative yield (%RY).

Rice grain yields were subjected to analysis of variance procedures, and treatment means were separated using Fisher’s LSD at $P\leq 0.10$. Pearson correlation coefficients were determined for the three Zn extraction methods using PROC CORR in SAS. Multiple regression was used to relate %RY and Tissue Zn concentration to soil test Zn.

Results and Discussion

- ☐ Depending on the rate and source, foliar and soil applied Zn fertilizers produced yields greater than the non-treated (Table 2).
- ☐ A linear correlation existed between Mehlich 3-Zn and DTPA-Zn; however, Lancaster-Zn showed no correlation with either of the two solutions (Table 3 and Figure 2).
- ☐ Multiple regression analyses indicated that linear and quadratic terms for DTPA provided the best fit for % Relative Yield and Whole plant Zn concentration (Figure 3 and Figure 4).
- ☐ The data set presented is not sufficient to formulate recommendations; however, the Lancaster solution does not appear to be a sufficient method for Zn determination in rice.
- ☐ Because a strong linear correlation existed between DTPA and Mehlich 3, it is reasonable to expect that Mehlich 3 may potentially be the solution of choice for determining rice nutrition needs in Mississippi. In addition, it also has been proven effective for rice fields in AR (Slaton et al., 2000).

Table 1. Location, soil taxonomic description, and reactivity parameters for four study locations.

Location	Soil	Taxonomy	pH (1:2 water)	CEC ($cmol_c$ kg^{-1})
O’Reilly	Dundee sil	Fine-silty, mixed, active thermic, Typic Endoaqualfs	7.1	12
Drew	Forestdale sicl	Fine, smectitic, thermic Typic Endoaqualfs	6.9	30
Sunflower N	Forestdale sil		7.9	21
Sunflower S	Forestdale sicl		7.9	19

Table 2. Rice grain yield response to Zn fertilizer source and rate at Sunflower N.

Source	Rate kg ha^{-1}	Application Method	Yield kg ha^{-1}
Zinc Sulfate (36%)	2.8	Soil	9979a
	5.6		10332a
	11.2		9778ab
†Ruff-N-Tuff (10%)	2.8	Soil	10030a
	5.6		9929a
	11.2		10130a
Zn-EDTA (9%)	0.56	Foliar	10181a
	1.12		10332a
	2.24		9626abc
Zn-Citrate (10%)	0.56	Foliar	8820c
	1.12		9626abc
	2.24		9727ab
Non-treated	0	--	8921bc
LSD (P=0.10)			**832**
CV%			**7.12**
P>F			**0.0765**

†Ruffin-Tuff™ is manufactored by RSA-Microtech, LLC, St. Paul Minnesota. Zinc is derived from Zinc lignosulfonate

Table 3. Pearson correlation coefficients and (Prob > |r|) for extractable Zn concentrations using Mehlich 3, DTPA, and Lancaster solutions.

Solution	Mehlich 3	DTPA	Lancaster
Mehlich 3	1.0000	0.7988 (<0.0001)	-0.1976 (0.3548)
DTPA	0.7988 (<0.0001)	1.0000	-0.1132 (0.5985)
Lancaster	-0.1976 (0.3548)	-0.1132 (0.5985)	1.0000

Figure 1a. Zinc response plots located at Sunflower N. Picture was captured near the panicle differentiation growth stage.

Figure 1b. Close-up picture of non-treated plot shown in Figure 1a. Stunted plants, with bronzed leaves and white midrib, are symptoms of Zn deficiency.

Figure 2. Relationship between DTPA-Zn and Mehlich 3-Zn. DTPA-Zn = 0.4225(M3-Zn) -0.2213 R2 = 0.64, P=<0.0001, n = 24

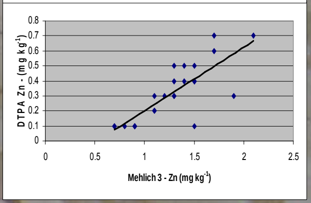


Figure 4. Relationship between Tisse Zn concentration and DTPA-Zn.

$Zn\ conc = -186.27(DTPA\text{-}ZN)^2 + 159.48(DTPA\text{-}Zn) + 24.91$ $R^2 = 0.34$ $P = 0.0656$ $n = 16$

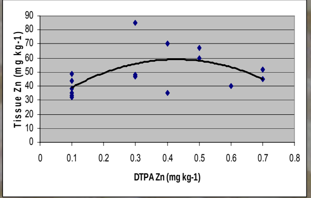
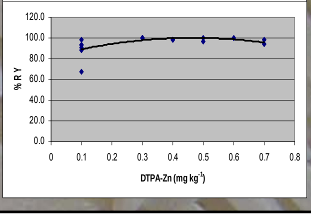


Figure 3. Relationship between % Relative Yield and DTPA-Zn.

$\%RY = -82.32(DTPA\text{-}ZN)2 + 76.95(DTPA\text{-}Zn) + 82.24$ $R^2 = 0.35$ $P = 0.0600$ $n = 16$



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