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Effect of Manganese Source on Manganese Uptake by Pygmy Date Palms

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Manganese deficiency is a serious and widespread problem on many species of palms (Broschat, 1991). Recommended treatments for correction or prevention of the problem usually include soil or foliar applications of manganese sulfate (Dickey, 1977), but Broschat and Donselman (1985a) found that in a peat-based potting medium, other Mn sources provided equivalent levels of Mn.

Several additions to foliar Mn sprays have been been recommended for use on some plants, but this has never been shown to be effective for palms. These include urea (Labanauskas and Puffer, 1964; Yamada et al., 1965) and calcium hydroxide (Dickey 1977). Dimethylsulfoxide (DMSO) is a widely used penetrant-solvent that could potentially enhance foliar absorption of Mn from foliar sprays, but has never been tested. Similarly, soil acidification has been suggested as a means of alleviating deficiencies of micronutrients such as Mn, Fe, and Zn (Kidder et al., 1990; Messenger and Hruby, 1990), but this has not been tested on palms. The purpose of this study was to determine which of the commercially available soil and foliar applied Mn fertilizer materials are effective in supplying Mn to palms in both a field soil situation and a pine bark, peat and sand medium, and to determine if the addition of calcium hydroxide, urea, or DMSO enhanced the foliar absorption of Mn from foliar sprays.

Materials and Methods

Pygmy date palms (*Phoenix roebelenii*) 25 to 30 cm tall were planted into 10 liter plastic containers using a 4 pine bark: 2 Canadian peat: 1 sand (by vol.) medium amended with dolomite at 6 kg.m-3. Eight replicate pots were each treated with single media surface applications of the materials listed in Table 1 at rates equivalent to 3.2 g of Mn per container on 14 Oct. 1987 (= first year). Seven replicate plants were also sprayed to runoff with single foliar sprays of the materials shown in Table 1 at concentrations equivalent to 1.3 g Mn per liter. The experiment was repeated starting 4 Jan. 1989 using 10 replicate palms per treatment (= second year). All plants were grown under 63% shadecloth and received about 1 cm of water daily from overhead irrigation. All pots received surface applications of Osmocote 17N-3P-15K (Grace-Sierra Hort. Prod., Milpitas, CA) at 56 g per pot and a single micronutrient drench containing .6 mg Fe, .2 mg B, .06 mg Zn, .06 mg Cu, and .01 mg Mo and were arranged in a completely randomized design. Samples of central leaflets of recently matured leaves were collected from each plant at 1, 2, 4, and 6 months after fertilization the first year and at 2, 4, and 6 months after fertilization for the second year. All leaves sampled for analysis had emerged subsequent to any foliar spray treatment and therefore were not washed prior to analysis. Dried and ground leaf samples were digested in sulfuric acid and hydrogen peroxide (Allen, 1974) and were analyzed for total Mn content by atomic absorption spectrophotometry. Data were analyzed by analysis of variance with mean separations by the Waller-Duncan k-ratio method.

In order to determine if results from the container experiments would be valid for field-grown palms, a 2-year old field planting of 50 to 60 cm tall pygmy date palms was treated with single soil applications of the same materials used in the first container media experiment on 4 Jan. 1989. These palms were growing in a Margate fine sand soil and were planted 3 m apart in rows 4 m apart. Treatments were assigned on a completely randomized basis with 9 replicate palms per treatment. Rates were increased to 32 g Mn and 550 g of Osmocote 17N-3P-15K per plant. Sampling and analysis were carried out as in the first container experiment.

Results and Discussion

Media application-- first year. Only Mn sulfate plus ammonium sulfate significantly increased leaf Mn one month after media treatment, but both Mn sulfate plus ammonium sulfate and Mn citrate-treated palms had higher leaf Mn concentrations than control palms at 2, 4, and 6 months after treatment. Mn sulfate plus ammonium sulfate also increased leaf Mn concentrations signficantly more than Mn citrate after 2 and 4 months, but the differences were insignificant 6 months after treatment.

Media application--second year. All materials except Mn oxide increased leaf Mn concentrations after 2, 4, and 6 months, but Mn sulfate, Mn sulfate plus ammonium sulfate, and Mn citrate-treated palms had much higher Mn concentrations. Manganese concentrations of palms treated with most materials began decreasing at 6 months, but continued to increase for sulfur plus Mn sulfate-treated palms. All of the materials except Mn oxide are water soluble and some decrease in availability is expected over time due to microbial binding or precipitation. Elemental sulfur constitutes 80% of the sulfur plus Mn sulfate material and thus would be expected to gradually decrease media pH and increase Mn solubility (Kidder et al., 1990). The large differences in Mn uptake between years for similar materials can only be accounted for by the lower average ambient temperatures during the first year (x = 22.4 vs. 24.2C). Manganese uptake in palms is strongly temperature dependent (Broschat and Donselman, 1985b).

Soil application-- field grown palms. No significant differences were observed among treatments after 1 month. However, Mn concentrations of palms treated with Mn sulfate plus ammonium sulfate were signficantly greater than that of all other treatments 2 to 6 months following treatment. Thus, results under field conditions confirm the superior effectiveness of Mn sulfate in providing Mn to palms compared to other commercially available Mn sources. Similar results were obtained for field crops on other soil types (Fiskel and Mourkides, 1955; Randall et al., 1975; Shuman et al., 1979; Wilcox and Cantliffe, 1969). The pH of the field soil was higher than that of the container medium (7.25 vs. 6.45), and this should decrease Mn availability (Lindsay, 1972). However, acidifying materials such as sulfur plus Mn sulfate did not improve palm Mn uptake under alkaline field soil conditions as predicted from Messenger and Hruby's (1990) work on Mn deficiency in red maple (*Acer rubrum* L.).

Foliar application--first year. Only Mn sulfate significantly increased leaf Mn concentrations over that of control plants after 1 month, but Mn citrate also did 2 months after application. Foliar Mn concentrations in palms sprayed with Mn sulfate treatments gradually decreased or stayed the same during the period between the first and sixth months, but no differences existed among treatments after 6 months. Plant uptake from foliar sprays was not enhanced by addition of calcium hydroxide or urea for any Mn source throughout the experiment.

Foliar application-- second year. Leaf Mn concentration after 2 months was not signficantly increased by foliar application of any Mn source, but all treatments except Mn glucoheptanate plus urea, Mn EDTA, and Mn citrate plus urea had higher leaf Mn concentrations after 4 months than the control palms. All treatments had higher foliar Mn concentrations than the controls after 6 months. The addition of urea enhanced Mn uptake only from Mn EDTA after 4 months and addition of both calcium hydroxide and urea or DMSO did not improve plant uptake of foliar-applied Mn sulfate at any time.

These results appear contrary to those reported by Yamada et al. (1965) and Labanauskas and Puffer (1964), but in those studies urea increased Mn uptake in leaves that had been sprayed. However, the latter study also examined the effects of urea on Mn concentrations in leaves produced subsequent to spraying and reported no significant increases in Mn concentration of the new leaves due to urea. This is consistent with the results from the current study in which only new leaves were sampled. Although foliar fertilization is generally considered to be a quicker, though short-term method of getting micronutrients into plants, this study suggests that uptake from soil applications is just as fast, even under slightly alkaline field soil conditions.

In conclusion, of the various commercially available Mn fertilizer sources, Mn sulfate plus ammonium sulfate (Tecmangam) was the most effective material for soil or foliar fertilization of pygmy date palms, both in container media and in slightly alkaline sandy field soils. Mn citrate is moderately effective for both container media and foliar applications, but all other materials tested were relatively ineffective as soil-applied fertilizers and produced inconsistent responses when applied to the foliage of palms. Also, there appears to be no advantage to adding calcium hydroxide, urea, or DMSO to Mn foliar sprays on palms.

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Table 1. Manganese fertilizer materials used for soil or foliar applications on pygmy date palms

Material	Trade Name	Manufacturer	% Mn
Soil application			
Mn oxide	Granusol	American Minerals	40
Mn sulfate[z]		Mallinckrodt	33
Mn sulfate + ammonium sulfate	Tecmangam	Eastman Chem. Co.	27
Mn EDTA	Sequestrene Mn	Ciba-Geigy	12

Sulfur + Mn	Disper-Sul+Mn	Chemical Enterprises	5
Mn citrate	Micro-Green	Liquid Ag Systems	5
Foliar application			
Mn sulfate		Mallinckrodt	32
Mn sulfate + urea[y]		Mallinckrodt	32
Mn sulfate + urea[y] + calcium hydroxidex		Mallinckrodt	32
Mn sulfate + calcium hydroxidex		Mallinckrodt	**32**
Mn sulfate + DMSO[w]		Mallinckrodt	**32**
Mn citrate		Mallinckrodt	**30**
Mn citrate + urea[y]		Mallinckrodt	**30**
Mn EDTA	Sequestrene Mn	Ciba-Geigy	**12**
Mn EDTA + urea[y]	Sequestrene Mn	Ciba-Geigy	**12**
Mn glucoheptanate	Keyplex 250		**1.1**
Mn glucoheptanate + urea[y]	Keyplex 250	Morse Enterprises	**1.1**

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[z]Used in second year container media experiment only.

[y]rate = 6 g per liter

[x]rate = .22 g per liter

[w]rate = 1 ml per liter; used only in second year experiment.