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Manganese Toxicity in Avocado (Persea americana Mill.)

Jonathan Edward Tracy
Candidate for degree of Master of Science in Soil Science from University of California at Riverside. This paper is an author-edited portion of his June 1983 thesis: "Manganese and Aluminum Toxicity in Avocado (Persea americana Mill).

SUMMARY

Avocado trees exposed to increasing concentrations of solution Mn suffered from increased leaf abscission. Tissue concentrations of Mn, K, and P were increased, while Fe decreased in response to solution Mn.

Approximately 1.1% of the avocado groves surveyed produced leaf samples with Mn concentrations greater than 1,000 mg/kg. Death of young, field grown avocado trees is associated with Mn concentrations of 2,000-2,500 mg/kg in six- to ten-month old leaves, and Mn in the saturation extract of 0.8-4.4 mg/l. Surviving trees were found to have Mn concentrations of 0.03-0.3 mg/l in the saturation extract. Toxic concentrations of soil Mn were associated with heavy fertilization-acidification of a manganiferous soil, or with the addition of a wood-product soil amendment high in soluble Mn.

Approximately 6.8% of the avocado groves surveyed produced leaf samples with P concentrations below 0.8 g/kg on a dry weight basis, which is less than optimum.

Introduction

Many of the virgin soils utilized for avocado production in San Diego County are slightly acidic and are acidified to very low pH values with the use of ammoniacal fertilizers. Most of the damage to plants grown in acid soils is attributed to high concentrations of soluble Al, Mn, or other toxic metals.

Mn has been observed to accumulate in avocado leaf tissue throughout the growing season under acid soil conditions, but stable leaf Mn values have been observed under more favorable soil conditions. Data from salt tolerance studies have demonstrated a wide variation in the ability of various avocado varieties to accumulate Mn.

Soil conditions favoring Mn solubility (and plant availability) are low pH and Eh (reducing conditions). Sulfate solubilizes more Mn than either chloride or nitrate, and Mn is displaced from cation exchange sites by cations in the order Mg > Ca > NH_4=Na > K.

Materials and Methods

Forty-eight avocado seedlings (*Persea americana,* variety Duke 7, grafted to Hass scions) were bare-rooted and transplanted into drain-equipped 10.4 liter buckets filled with No. 16 builder's sand. Four buckets (one seedling per bucket) were placed on each of twelve nutrient tanks (100 liter capacity) in the greenhouse.

The nutrient solutions were pumped continuously for 15 minutes four times daily onto the top of the plastic buckets. The nutrient solution contained the following concentrations of ions expressed in mg/l: 113 NO_3-N, 33 $P0_4$-P, 100 K, 100 Ca, 30 Mg, 67 SO_4-S, 5.0 Fe (chelate), 0.1 B, 0.1 Mn, 0.1 Zn, 0.05 Cu, 0.01 Mo. The SO_4-S concentration increased throughout the experiment due to adjustment of the solutions to pH 4.0 ± 0.5 with H_2SO_4.

Six weeks after transplanting, the nutrient solutions were amended with $MnSO_4$-$4H_2O$ to yield a metal concentration of either 0.0, 2.0, 4.0, or 10.0 mg/l in a specified tank. Thirteen weeks after transplanting, the nutrient solutions were renewed; and at sixteen weeks, the Mn concentrations were doubled to 0.0, 4.0, 8.0, or 20.0 mg/l.

Twenty-eight weeks after transplanting, the trees were harvested and divided into top leaves, bottom leaves, stems, and roots; and dry weights were determined (other growth parameters are reported elsewhere).

The top portions of the trees were analyzed for K, Ca, Mg, Zn, Fe, Mn, Cu, and Al by atomic absorption spectrophotometry; for N, P, and B by colorimetry; and for S by turbidity.

Field Data

Manganese was determined on 1,444 avocado tissue samples from commercial groves in northern San Diego County. The samples were collected in the fall of 1981 and analyzed as above.

Two additional groves were analyzed in detail by the above methods with N by microkjeldahl and soil analysis by CFA methods.

Results and Discussion

Sand Culture Experiment:

Reduced measurements of leaves and roots were obtained in response to Mn in solution, although only leaf area and dry weight of bottom leaves were significantly reduced at the 0.05 level of probability. The relationship between total dry weight and Mn in solution is presented in Fig. 1. The increased statistical error at higher Mn concentrations is the result of individual trees largely defoliating, while stronger individuals in the same treatments continued to maintain most of their leaves. Leaves suffering from Mn toxicity were not observed to be smaller than comparable leaves from untreated trees.

The appearance of Mn toxicity symptoms on the lower surface of avocado leaves is shown in Fig. 2, along with the concentration of Mn in the respective nutrient solutions. The blackening of the blade surface immediately adjacent to the midrib and larger veins is evident. Occasionally, the symptoms are expressed on only part of an affected leaf; but the black color in relation to the veins has been characteristic in every case observed to date. This symptom is easily confused with normal leaf senescence in which the identical tissue turns dark brown. Average chemical composition of the bottom leaves from trees grown with Mn-amended nutrient solutions are presented in Table 1.

At harvest, an internal blackening of cambium tissue was noted in the trunks of some of the trees exposed to the higher concentrations of Mn.

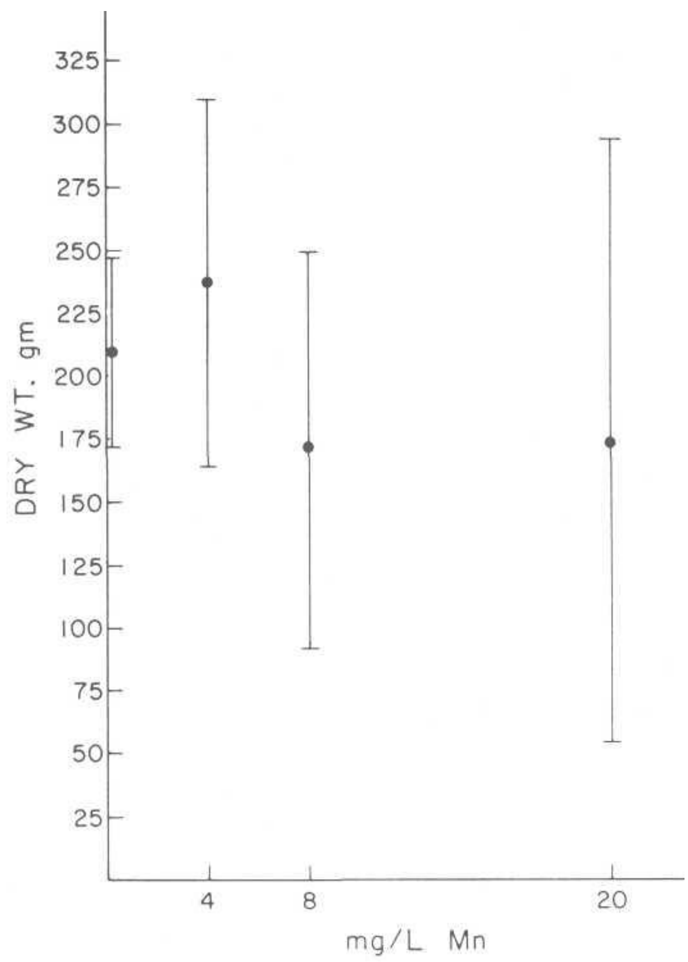

Fig. 1*. Total plant dry weight as a function of solution Mn.*

Survey Data

The distribution of Mn in 1,444 samples from commercial avocado groves in northern San Diego County is presented in Fig. 3. Approximately 1.1% of these groves have Mn concentrations in excess of 1000 mg/kg in their leaves on a dry weight basis, and are geographically centered in an area south of Fallbrook, where soils are derived from volcanic rocks rich in Mn.

Fig. 2. *The appearance of Mn toxicity symptoms on the bottom surface of avocado (eaves as a /unction of solution Mn concentration.*

Table 1. Average composition of six to ten month old avocado leaves with respect to solution Mn.

Solution Mn, mg/L	N	P	K	Ca	Mg	*S*
			g/kg			
0.1	19.9	1.3	10.1	18.5	4.6	2.2
4	18.5	1.3	10.1	18.0	4.0	2.1
8	20.7	1.5	12.1	17.6	3.9	2.3
20	20.3	1.7	12.8	16.5	3.8	2.5
			mg/kg			
	Zn	Fe	Mn	Cu	B	Al
0.1	110	146	297	8.3	68	67
4	83	130	2025	6.7	58	77
8	90	123	3700	6.3	54	65
20	95	99	6300	7.7	60	51

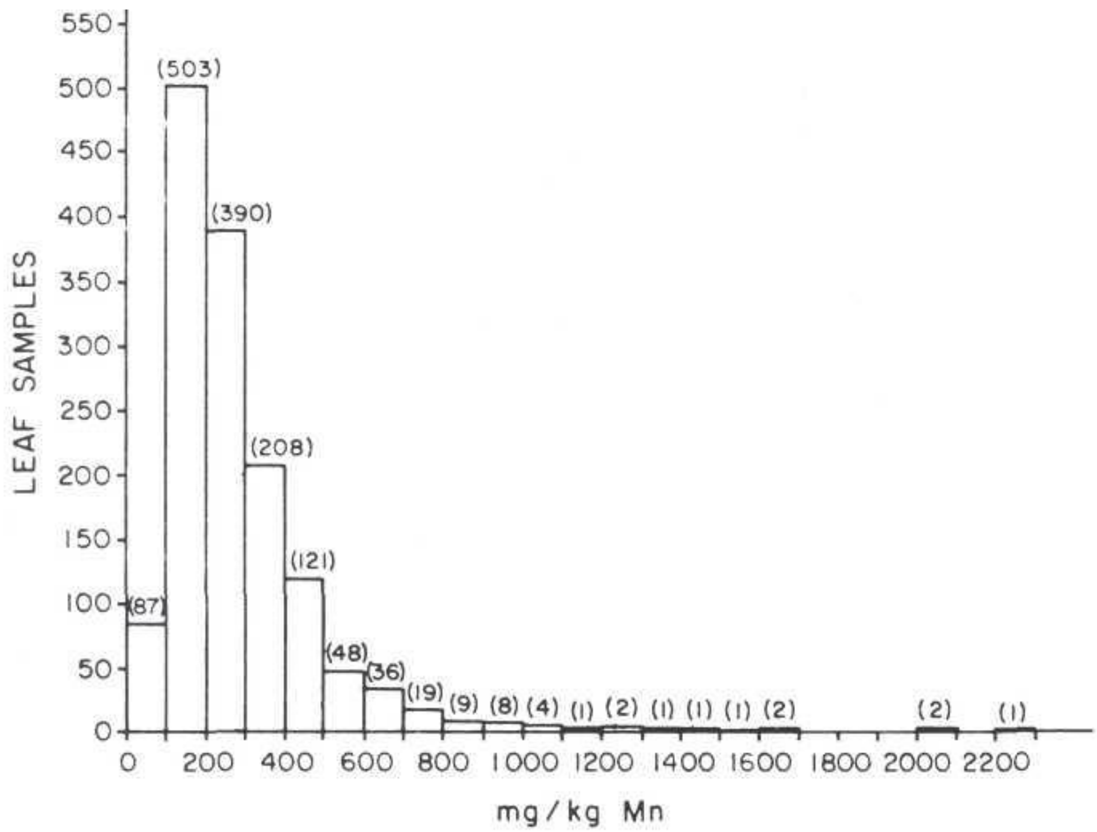

Fig. 3. *Frequency distribution of Mn concentrations (dry wt. basis) in leaf samples of commercial avocado groves in Riverside and San Diego Counties in 1981 (samples courtesy Fallbrook Ag-Lab).*

Mn Toxicity in Poorly-drained Mn-rich Soils

This particular grove is situated at the apex of a steep hill in San Diego County and has a shallow, rocky, heavy-textured soil which has been included in a unit mapped as Olivenhain cobbly loam (Bowman, 1973). The bedrock has been mapped as Tertiary volcanic-rhyolite (Rodgers, 1965), and field specimens are commonly stained with metal oxide minerals. These metal oxides are tentatively labeled as pyrolusite (Mn02> due to their dendritic form (Hamilton *et al.,* 1974).

The analytical data presented in Table 2 represent two separate samplings of the grove.

The April sampling consisted of parallel samples collected from the north and south sides of the hill. Leaves were selected on the basis of exhibiting toxicity symptoms from the healthiest looking trees. The concentrations of Mn, Al, and Mg are elevated in these leaves, while B and K are depressed. Symptoms of B or K deficiency were not observed.

The leaves from the May sampling were confined to the south slope and consisted of mature, normal looking leaves, except where younger leaves were the only choice available (95% defoliation). This has resulted in analyses which have been confounded by the effect of leaf age in addition to the effects of Mn. These analyses are still useful in that they suggest that K and B may be in adequate supply to the tree, even though they are depressed in the older leaves.

Table 2. Leaf analysis of Mn-affected avocado trees grown on a shallow, rocky, heavy-textured and poorly drained soil (Fallbrook Ag-Lab Inc., ICP data courtesy Dr. G. Bradford).

	g/kg						mg/kg					
Sample*	N	P	K	Ca	Mg	Na	Zn	Fe	Mn	Cu	B	Mn/Fe
NS 4/81	20	1.5	4.1	20	7.0		24	110	2000	2.5	20	18.2
SS 4/81	20	1.4	5.4	19	6.0		24	. 90	2500	2.5	20	27.8
Not D 5/81	27	2.5	12.0	10	3.8	0.3	26	55	1450	2.0	30	26.4
50% D 5/81	35	3.8	17.0	12	5.0	0.9	49	87	1150	2.0	130	13.2
95% D 5/81	40	4.0	17.0	11	4.8	1.5	48	110	530	2.5	60	4.8

	mg/kg				Less than 5 mg/kg
	Al	Si	Sr	Ba	Ag, Be, Cd, Co, Cr, Ga, Li, Mo, Ni, Pb, Sn, Ti
NS 4/81 ICP	250	138	14	77	

*. NS is the north slope, SS is the south slope, D is defoliated and ICP is Inductively coupled plasma spectroscopy.

N in the stem is indicated as having a nearly significant positive correlation with solution Mn (Table 2). Whether this represents N which has simply been displaced from the roots by Mn (i.e., facilitating translocation), or whether this is an active accumulation of N in response to excessive Mn, is not clear.

Nonsignificant negative correlations were obtained for Ca and Mg with Mn in solution. A significant negative correlation was obtained with Ca but not Mg in coffee trees (Pavan, 1979), and decreases in both Ca and Mg concentration with increasing Mn are discernible in the apple leaf data of Eggert and Hayden (1970). Mengel and Kirkby (1978) suggest that Mn-Ca-Mg effects are the result of competing ions being restricted by the overall ionic balance of the plant.

The mortality rate in this grove was approximately 80% of the avocado trees, two years after planting.

Mn Toxicity Related to the use of Soil Amendments

This one year old grove is situated on a gentle, south facing slope in San Diego County, and has a 2-3 foot deep, medium textured soil which has been included in a mapped unit of Vista coarse sandy loam (Bowman, 1973).

Mn toxicity symptoms were visible in this grove and were confirmed by leaf analysis (Table 3). Soil analysis showed a close correlation between soil pH and tree condition.

Large amounts of water soluble Mn were present in a wood product soil amendment applied to the grove at the time of planting (Table 3).

The mortality rate in this grove was approximately 25% of the avocado trees one year after planting.

Table 3. Leaf and soil analysis of a Mn affected avocado grove (courtesy Fallbrook Ag-Lab Inc.)

Sample	P	K	Na	Cl	Zn	Fe	Mn	Cu	Mn[1]	Mn_e	pH
	g/kg						mg/kg			mg/L	
Top Leaves											
Healthy trees	3.8	19.2	0.2	2.0	37	70	232	3			
Weak trees	3.2	24.0	0.4	5.0	49	97	785	3			
Bottom Leaves											
Healthy trees	1.2	6.4	0.2	4.0	17	85	950	2			
Weak trees	1.3	3.9	0.1	7.0	16	100	2285	1			
Soil Samples											
Native soil									182	0.03	6.2
Healthy trees											6.4
Weak trees											4.9
Wood product soil amendment									180	1.2	5.7

[1] Determined on a H_2O_2-H_2SO_4 digest.

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