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J. A. Silva and R. Uchida, eds. College of Tropical Agriculture and Human Resources, University of Hawaii at Manoa, ©2000

Chapter 11

Plant Tolerance of Low Soil pH, Soil Aluminum, and Soil Manganese

R. S. Yost

Some plants are more able than others to grow on soils with low pH. This interesting ability was not well recognized until the past 20 years or so, and it still is not fully understood. Crop tolerance of low soil pH has become extremely important in the agricultural development of the humid tropics because so many of those soils have low pH (Kamprath and Foy 1985, Salinas and Sanchez 1981, Maranville 1992). In Hawaii, this tolerance can be important because there are extensive areas of soils with low calcium (Ca) and considerable areas with soil toxicity due to high levels of aluminum (Al) and manganese (Mn) (reviewed in Yost and Evensen 1994).

One reason sugarcane was successful in Hawaii may be related to its considerable tolerance of low Ca and high Al (ibid.). Pineapple is notable for its tolerance of and, indeed, requirement for low soil pH. Hawaii is an example of a place where crops have been selected to fit soil conditions rather than amending soils to fit crops, which is the traditional method of soil management in many temperate climates.

This chapter describes some examples of crop tolerance of factors related to low soil pH—primarily, high levels of toxic Al and Mn. These examples illustrate the impressive differences among plants in adapting to and tolerating low pH in soils of the humid tropics.

Some of the first research identifying and quantifying crop tolerance of soils with low pH has come from the tropics (Spain et al. 1975, Silva 1976; see Figure 11-1). Identifying and understanding crop tolerance of soils with low pH has been the subject of a series of scientific symposiums (Silva 1976, Marschner 1991, Edwards 1993, Maranville et al. 1994). Several authors have pointed out that tolerance of toxic conditions of Al or Mn in soils of low pH has the components of both tolerance (of the presence of the toxic element within the plant) and of avoidance (prevention of the toxic element from entering the plant; e.g., Marschner 1991). However, the physiology of tolerance and avoidance is much less clear and separable than this distinction might suggest. Nonetheless, we will consider factors that are involved in the two aspects of successful growth in soils with low pH.

Aluminum tolerance

High concentrations of Al are found in various plants including tea, azalea, rye, cranberry, weeping lovegrass, bermudagrass, star grass, buckwheat, peanut, and members of the *Proteaceae* family. Other plants with known ability to tolerate soils with high Al content (called "Al saturation") include pangolagrass, rubber, blueberry, and Norway spruce (Kamprath and Foy 1985).

Of particular interest has been the finding that varieties within species of plants also vary in tolerance of acidity factors. Foy (in Kamprath and Foy 1985) pointed out that varietal differences in tolerance of Al have been identified in rice, alfalfa, tomato, soybean, ryegrass, snap bean, cotton, corn, sunflower, pea, sweetpotato, green algae, and even among pathogens. Studies are suggesting that there also are differences in Al toler-

Figure 11-1. Two varieties of wheat had differing tolerances of soil aluminum in southern Brazil (Silva 1976).

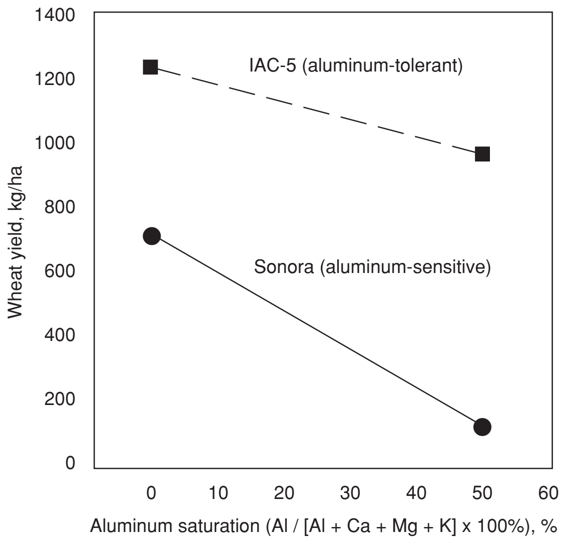


Table 11-1. Critical manganese ranges for selected crops[z].

Crop		Critical Mn range (mg/kg)
Bragg soybean	(leaves)	
(Mask and Wilson 1978; greenhouse)		171 – 181
(Jones and Nelson 1978; field)		320
Tomato	(young leaves)	450 – 500
	(old leaves)	900 – 1000
Sweet sorghum	(upper leaves)	445
	(lower leaves)	1440
Carnation		2600
Corn		2500 – 6500

[z]Data from Kamprath and Foy (1985), except for carnation and corn.

ance in taro cultivars (M. Calisay, personal communication, 1995). This identification of varietal tolerance of Al toxicity has led to the breeding of Al-tolerant varieties of soybean and maize in Brazil (Shaffert 1994). Two international agricultural research centers, CIAT (Colombia) and IRRI (Philippines), have collaborated in the development of modern rice varieties that tolerate Al saturation of 50–75 percent with scarcely any yield reduction. Success in identifying and introducing such tolerance in plant varieties has surpassed expectations.

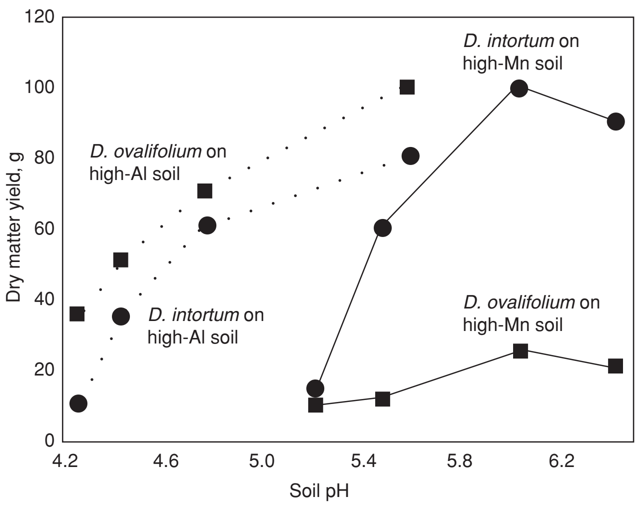
Indeed, there are so many examples of varietal tolerance of high soil Al that species without such tolerance have become the exception. *Leucaena leucocephala*, the useful forage and agroforestry species, seems to be one such exception, because despite intense breeding efforts, substantial Al tolerance remains to be found. Selection and breeding of acid-tolerant forage and pasture species have met with great success in the CIAT pasture and savannas program. In fact, they have identified so many species with high tolerance of acidity that it is no longer a bottleneck. All of CIAT's promising forage species are highly tolerant of Al toxicity.

Manganese tolerance

Plant species differ considerably in tolerance of high levels of soil Mn. A review by Kamprath and Foy suggests that maize and rice are more tolerant of high soil Mn than soybean and barley, and alsike clover and oats are more tolerant than cowpea, lespedeza, and sweetclover. Among flower crops, carnation, poinsettia, and rose were tolerant while snapdragon and calendula were sensitive. Vegetables were ranked in tolerance (from most tolerant to sensitive) as follows: tomato > lettuce > barley and bean > clover > potato. Many tropical legumes have been reported to be Mn-tolerant. Although critical levels of Mn depend widely on growth conditions, suggested levels for various crops have been established (Table 11-1).

As in the case of Al tolerance, there also appear to be differences in Mn tolerance within plant species. Varietal tolerance has been reported in soybean, wheat, apple, and cotton. Tolerance of Mn in forage legumes appears to be a combination of prevention of Mn entry into the plant and greater internal tolerance. Superior Mn tolerance in corn (compared to peanut) is believed to be due to reduced transport of Mn to the leaves. On

Figure 11-2. ***Desmodium ovalifolium*** **grew better than** ***D. intortum*** **on a soil high in aluminum (Paaloa series) but grew poorly on a soil high in manganese (Wahiawa series). This demonstrates that tolerance of these soil toxicities varies among plants, even closely related ones (R.S. Huang, unpublished data).**



the other hand, Brown and Devine (1980) found that Mn-tolerant and Mn-sensitive soybean cultivars both contained about the same amounts of Mn in their tops.

Foy also described differences among plants in their requirements for Ca, Mg, and P that can help confer tolerance when growing in acid soils, which are often low in these nutrients. The ability to grow well with low levels of Ca, Mg, and P is therefore another type of tolerance of (or ability to grow in) soils with low pH.

While there are species and varietal differences in tolerance of Al and Mn, it is often assumed that tolerance of high Al might be correlated with tolerance of high Mn. This does not always occur. An example of tolerance of high Al but sensitivity to high Mn is shown in Figure 11-2.

These results suggest that there are, indeed, many species with considerable tolerance of high soil Al and high soil Mn, and even within species there are often varieties that are tolerant of such adverse conditions. Tropical biodiversity has contributed to the development of this crop management alternative by contributing many of the tolerant species and cultivars.

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