Table 1. Comparison of growth for *Angophora costata* planted in Osburn Street, Wodonga, September 1999.

Date	Pot type	Height (m)	Calliper (mm)	Stability
Sept. 99	HW	1.6	na	Staked
	AP	1.8	na	Unstaked
Mar. 01	HW	3.7	65	Unstable
	AP	5.2	90	Stable
Mar. 02	HW	4.0	90	Unstable
	AP	7.0	150	Stable

Acknowledgments. The RocketPot Tree Growing System has been created with help from many dedicated growers, horticultural professionals, landscape professionals, and their clients. Thank you all.

The Role of Micronutrients and How They Affect Plant Growth©

David Nichols and Yibing Ma
Debco P/L, 12 McKirdys Road, TYABB VIC 3913

THE MICRONUTRIENTS

It is generally recognised that there are 16 nutrients that are essential to plant growth. Three of them carbon, hydrogen, and oxygen are obtained from water and the atmosphere and comprise most of the dry matter of the plant. The remaining nutrients are classed as fertiliser nutrients, which are chiefly obtained from the growing medium but can be supplied by foliage application. Six of these are categorised as major or macro-nutrients and the remaining seven as minor, micro- or trace nutrients. The essentiality of micronutrients was established in hydroponic studies over a period of 94 years beginning with iron in 1860 to chlorine in 1954. The remainder were proven to be essential in a period from 1922 to 1939.

Other nutrients that may have benefits for some plants but are not, at this stage, regarded as essential, are silicon, cobalt for soil-grown legumes, nickel, sodium, and vanadium.

The term "micro" refers to the fact that they are needed by plants in much lower concentrations than the major nutrients. The least needed of the major nutrients, magnesium and phosphorus, appear in the dry matter of plants at approximately 20 times the levels of the most needed micronutrient, iron.

Even amongst the micronutrients there are differences in regard to the amount required. In Nutritional Disorders of Plants (1992), adequate ranges in the dry matter of nursery plants show molybdenum to appear in the least amount 0.15 to 1 ppm, followed by copper 4 to 15 ppm, zinc and boron 15 to 80 ppm, and manganese 25 to 120 ppm. The adequacy range for iron is not clearly established.

Micronutrients have a wide range of functions in plant metabolism but these are of less interest to the average nursery grower than what happens when they are deficient, and how they interact with one another and with the major nutrients.

On the other hand to over-focus on the potential for deficiency can lead to toxicity and this is where the grower should be wary. Fertiliser companies will often use statements such as "contains trace elements" as a selling point without considering how the trace elements are balanced and whether they are needed at all.

Early researchers, while studying their importance, used acid-washed sand and distilled water to establish deficiencies. You can imagine then that there might already be sufficient quantities in potting mixtures derived from organic matter as well as impurities in water and fertilisers (Table 1) and as components of commonly used fungicide sprays. All of this on top of the fact that they will already be present in the seed, cutting or potted-on seedling, or tube stock.

A catalogue of over 200 analyses of ornamental plants growing in Victoria (Nichols, 1997) shows some of the micronutrients to be present in plant tissue at levels within or above adequate ranges rather than below (Fig. 1).

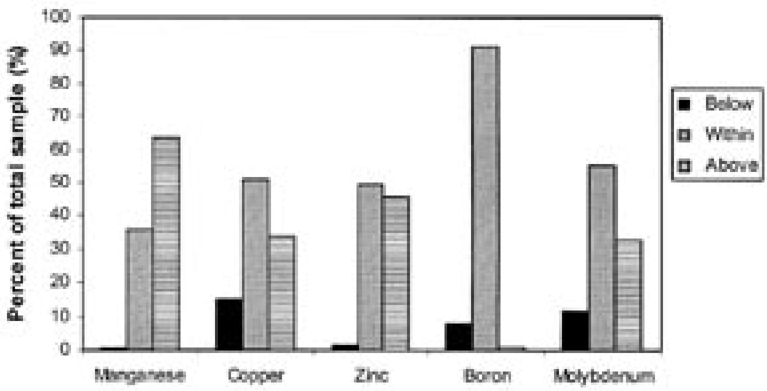

Figure 1. Leaf trace element levels below, within, and above normal range as found in Victorian nursey plants.

IRON

Iron is usually supplied in potting mixtures at levels far higher than might be reflected in the plant tissue. For instance iron and manganese are found in plant tissue at approximately the same amounts but the recommended range for manganese in potting mixtures is 1 to 15 mg·litre^{-1} while a minimum of 25 mg·litre^{-1} is required for iron (Australian Standard AS 3743, 1996). This suggests that the iron has other functions in the media than simply as a source of the element itself. A common explanation is that iron acts as a buffer against excess of other nutrients such as phosphates and other cationic trace elements. A recent study on seedling geraniums by Lee et al. (1996) found increasing levels of iron to increase chlorophyll content while increased levels of other trace elements led to reduced chlorophyll with the leaves showing symptoms of interveinal chlorosis, not unlike those of iron deficiency. An ample supply of iron is also very important where alkaline irrigation water is used although acidification of the water might be a better prospect.

Toxicity of iron has been reported for a number of ornamental plants including marigolds, impatiens, zonal and seedling geraniums, gerbera, salvia, vinca, elatior begonias, larkspur, and chrysanthemum. Basil, lettuce, tomato, and cabbage have also been affected.

Iron toxicity shouldn't be expected if moderate rates of iron have been used in the media unless the pH has dropped to a level below 5, where iron is available in excess. The form of iron used can be a factor (Fig. 2). Iron chelates, especially FeEDTA applied in excess have been prominent in major bedding plant losses (Nichols, 2000).

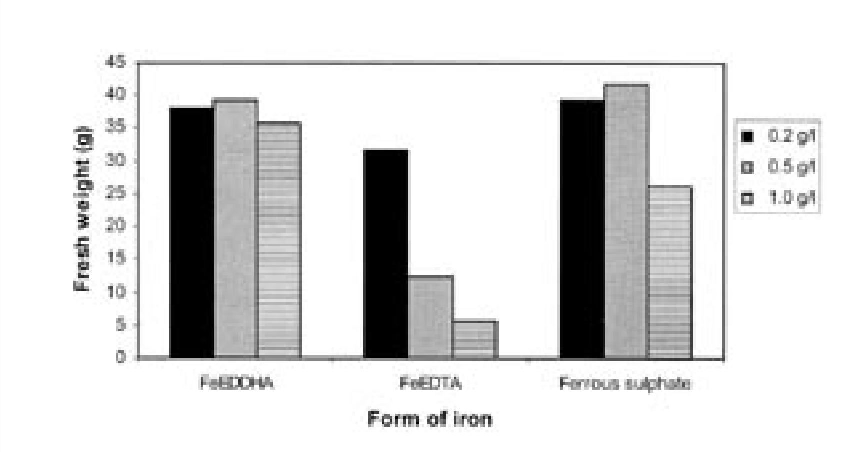

Figure 2. Growth of lettuce as affected by form and rate of iron added to a composted bark mixture already containing 15 ppm iron.

The symptoms of iron toxicity vary with different species and include: leaf margin and tip necrosis, lettuce; speckling of older leaves, gerbera and marigold; and chlorosis, induced manganese or zinc deficiency. These symptoms reflect extreme situations and growth reduction without symptoms may be a more insidious expression of the disorder.

MANGANESE

Manganese is an element that does cause problems with container plants, not so much from the point of deficiency but from toxicity. It is normally found in nursery plants at levels far above the plants requirements. One reason for this is that it is present in pine bark at levels where further addition may not be required (Handreck, 1995). It is also a component of commonly used fungicides such as Mancozeb. The availability of manganese is dependant to a large extent on pH and the potential for toxicity becomes worse as the pH drops. The symptoms resemble those of iron deficiency. There may also be speckling in the leaves and bark.

COPPER

Copper is one element that might need to receive some attention (Handreck, 1995). The data shows copper to be partly in the above-adequate range and partly in the deficient range. Copper is of course a commonly used fungicide and this might explain the high levels. It can form insoluble complexes with organic matter and also interacts with other nutrients notably, phosphorus, iron, and zinc. Symptoms of copper deficiency may be no more than reduced growth but at extreme levels there will be distortion of young growing tip and leaves.

ZINC

Zinc is another element commonly found in excess. It is a component of many fungicides, and toxicity in the past was common when galvanised iron was used was used for greenhouse construction and in water tanks and piping. It is unlikely to be deficient in modern potting mixtures.

BORON

Of the trace elements boron is the one most likely to leach from the media. However, leaf analysis in Victorian nurseries (Fig. 1) doesn't indicate either under-use or over-use. There are circumstances where boron might receive special attention. One is where bore or spring water is used. Boron can sometimes occur at toxic levels in the water and analysis of boron is a pre-requisite before using saline irrigation water.

The second involves the relationship between boron and calcium. A common symptom of boron deficiency is die back of growing tips and twigs often in deciduous trees such as magnolias. This symptom also occurs with calcium deficiency and it is sometimes difficult to separate one from the other. It may be that both are needed. Certainly the efficient use of calcium has been shown to depend on appropriate supply of boron at the same time (Fig. 3). Other crops to consider in this regard are those with specialised storage structures such as bulbs, corms, tubers, rhizomes, and fruits of various kinds.

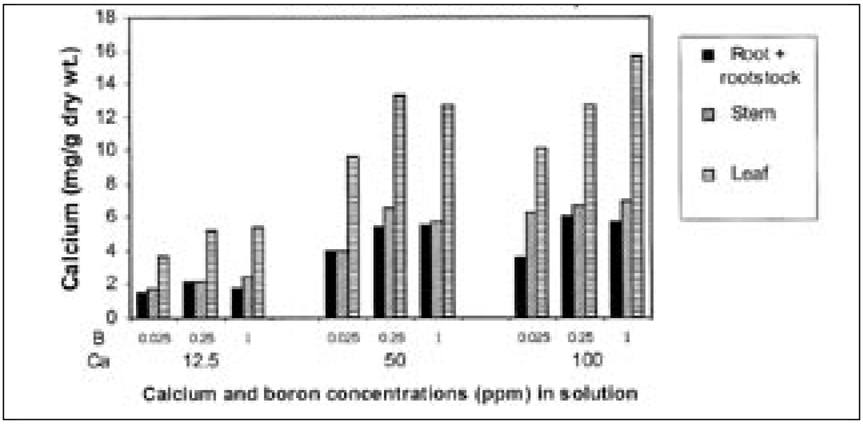

Figure 3. Effect of calcium (Ca) and boron (B) concentration in solution on Ca concentration in rose plant organs (drawn from Ganmore-Neumann and Davidov, 1993 with kind permission of Kluwer Academic Publishers).

Table 1. Trace elements found in Apex fertilisers not claiming trace element additions. Copyright Debco Pty Ltd.

Trace element (ppm)	14:6.1:11.6 Sample 1	14:6.1:11.6 Sample 2	18:2.1:10 Sample 1	18:2.1:10 Sample 2
Copper	37	37	46	51
Zinc	50	21	16	13
Manganese	62	70	31	25
Iron	1200	950	550	490
Boron	190	160	47	15

MOLYBDENUM

Because molybdenum is needed in such small quantities it is often omitted from leaf analyses. In most contexts it is unlikely to be deficient. It does, however, have a special relationship in the reduction of nitrate to amine in the plant. Plants such as poinsettias, which are given liquid fertiliser based on the nitrate forms of nitrogen, should certainly be considered as potentially liable to molybdenum deficiency.

CHLORINE

The potential for chlorine deficiency can almost be ignored. The levels found in the leaves of nursery plants are always well above those that would lead to deficiency. It is much more likely to be toxic. The symptom for toxicity is leaf necrosis usually associated with water stress in the plant.

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