ENSURING AN ADEQUATE SUPPLY OF SULPHUR TO PLANTS IN CONTAINERS

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Preliminary results of an experiment on the supply of sulphur (S) to plants in containers were reported in my IPPS paper in 1985. (1). I stated that if a liquid feed is the sole source of S for plants in containers then that feed needs to contain at least 15 ppm S for some species and at least 25 ppm S for others.

Those figures were used before an adequate statistical analysis was made on the data. This has now been done and the results of a number of other experiments analyzed, as well.

This paper summarizes these results and offers some guidelines for ensuring that your plants are never short of sulphur.

Sulphur—an essential element. Sulphur is an essential nutrient which plants take up mainly through their roots as sulphate ions (SO_4 =). Other forms of sulphur such as elemental sulphur (yellow powder), or sulphur present as part of soil organic matter must first be converted by microorganisms into sulphate ions. Inside the plant, the sulphur of these sulphate ions is used in making proteins and many other compounds. Plant tops typically contain about the same concentration of sulphur as they do of phosphorus—0.2 to 0.4% in the dry matter. Sulphur has been aptly named "the fourth major element."

Severe sulphur deficiency shows up first in the youngest leaves, which tend to be small, erect, and yellow all over. Mild deficiency, which comes on slowly, tends first to make all leaves a pale green colour. The youngest leaves may remain greener than the oldest leaves, which gradually die from the base of the plant upwards. The symptoms are very similar to nitrogen deficiency.

Sources of sulphur. In most soils the main source of sulphur is organic matter. Sulphur is released as sulphate ions from organic matter as it is decomposed by microorganisms. Gypsum (calcium sulphate) is another major source of sulphur, and some sulphate ions may be held on the surfaces of minerals in exchangeable form.

The wood wastes and peat used in potting mixes contain very little sulphur and little sulphate-sulphur is released from them as they decompose. An additional source of sulphur must be provided for plants in containers when these mixes are used.

Superphosphate, gypsum, sulphates of trace elements (eg. as in iron sulphate and Micromax) and such slow-release products as Osmocote and the sulphur-coated products all provide sulphur to plants. Liquid feeds may contain sulphates of ammonium, potassium, magnesium, iron, and other trace elements but some are formulated without them. All irrigation water contains some sulphate-sulphur, but the concentration varies widely. Thus, Melbourne tap water may contain as little as 0.3 ppm sulphur, while Perth water may contain 40 ppm or more. Air also contains some sulphur dioxide (SO_2) and various other sulphur compounds. Plants can take up sulphur from sulphur dioxide. In areas where the air is polluted with sulphur dioxide, plants can get part of their sulphur from this source.

Why is more sulphur needed? Sulphur has frequently been ignored in fertilization programs in nurseries, perhaps mainly on the assumption that the fertilizers used or the water supply should be providing enough. Many commonly available fertilizers do not even list their contents of S. Such assumptions are valid in some situations but they are certainly not universally valid. Feedback I have received from growers as a result of my paper at Rockhampton (1) and from others at various meetings has convinced me that mild sulphur deficiency is widespread in nurseries in areas where the water supply contains little sulphur, and where the air contains little sulphur dioxide. It is very widespread in homes where rainwater is used for watering plants in pots.

A main reason for deficiencies is that the materials used in soil-less potting mixes have almost no ability to retain sulphate ions against leaching. Almost all of the sulphur from very soluble sources such as the sulphates of ammonium, magnesium, potassium and iron is lost in the drainage water in a couple of weeks. The sulphur of the less soluble gypsum and superphosphate is almost totally lost in 4 to 7 weeks under typical nursery conditions. Whether these losses cause deficiency to develop depends on the concentration of sulphur in the water supply and on whether there is a slow-release source in the mix.

Ensuring an adequate supply of sulphur. Rather than go through the results of all of my experiments, I now summarize the conclusions I have drawn from them and other observations. I stress that these conclusions have been reached on the basis of experiments with a limited range of plant species. Some adaption will be needed for other species and growing conditions.

The maximum amounts of sulphur I specify should be adequate for all plants likely to be grown, but I don't know how much less than the maximum will be adequate for the bulk of the wide range of plants grown in Australian nurseries.

1. *If your water supply contains at least 25 ppm sulphur.*

You are fortunate. Your plants will be getting enough sulphur so long as all watering is with this water. Sulphur deficiency could show up in plants grown outside and watered by rain alone for extended periods, if there was no other source of sulphur in the mix.

2. *If your water supply contains 15 to 25 ppm sulphur.*

Plants of many species will grow quite well when all of the water contains a concentration of sulphur in this range. As in 1 (above), a sulphur deficiency is most likely to show up during extended periods of watering by rain, if all other sources of sulphur are inadequately provided. So far as I know, the only plants needing sulphur at concentrations at the upper end of this range are the crucifers—brassicas, stocks, *Cheiranthus*, etc. Many fast-growing broad-leaved plants may need concentrations of sulphur in the middle to upper end of this range.

My guess is that most plants will be well-supplied with 15 to 20 ppm sulphur in the water supply as the sole source of sulphur.

3. *If your water supply contains 10 to 15 ppm sulphur.*

This is where we get into uncertain territory. Some plants will grow well at 10 to 15 ppm sulphur, but they are likely to be slow-growing species. There is probably little in the way of reserves in the plant when water with this sulphur concentration is the sole source of sulphur. Any sudden decrease in supply, as would be brought on by prolonged rainy weather, could easily lead to deficiency.

4. *If your water supply contains less than 10 ppm sulphur.*

Many plants will be struggling if the water supply contains much less than 10 ppm sulphur and there is no other source of sulphur in the mix. Some may look healthy enough near 10 ppm, but if it was possible to compare them with adequately fed plants it would be obvious that they were somewhat stunted and pale. In this range it is essential, for many species, to provide some other source of sulphur. However, the grasses, and perhaps other monocotyledenous plants (including orchids?) and species which grow slowly may manage quite well on 10 ppm sulphur or even less.

Providing More Sulphur

a. *Liquid feed*

If you normally fertilize by means of a liquid feed, all that is needed is to ensure that the feed contains enough sulphur to give the desired 15 to 25 ppm. This is easy enough if you make your own feed. Just include some ammonium, potassium or magnesium sulphate in it. A feed containing 20 ppm sulphur is given by dissolving, respectively, 8.2, 10.9 and 15.4 g of these sulphates per 100 litres of actual feed. You need to multiply this up to take account of the dilution setting on your injector. The requirement for 15 to 25 ppm sulphur refers to the situation where all irrigation water is to be liquid feed. If you apply liquid feed only once a week or less frequently you should increase the concentration of sulphur in that feed to 30 to 60 ppm to allow for use and leaching during the periods when irrigation is with water only. There is no benefit to be gained from higher concentrations, and some harm may by done if the extra sulphate increases salinity to a toxic level.

If you use a proprietary feed, calculate from the label the concentration of S to be expected in a liquid feed made from it. If there is no information about S on the label, try to find out from the manufacturer or switch to a brand which does give this information.

b. *Single superphosphate or gypsum.*

Most of the sulphur in a typical granulated superphosphate will be taken up by plants or lost from soilless media in drainage water within 6 to 7 weeks when watering is from overhead. Using very coarsely granulated superphosphate will somewhat prolong the period of release. Most of a 1 or 2 g per litre addition of phosphogypsum or fine dune gypsum will be gone in about 40 days. Crushed rock gypsum of 1 to 4 or 5 mm size, added at about 2 g (½ standard teaspoon/litre), will provide a steady supply for several months.

The point at which superphosphate or gypsum needs to be reapplied to pots depends on the concentration of sulphur in the water supply and liquid feed and on whether there is another slow-release source of S in the mix. Clearly, the poorer the supply from other sources, the sooner extra superphosphate or gypsum, or another source of sulphur needs to be added.

c. *Slow-release fertilizers*

Fertilizers such as Nutricote, Osmocote, Osmocote Plus, Biocote, and the sulphur-coated products all contain sulphur, but they vary in the amount released in a given time, and in the time until all the sulphur has been released. I have only tested the first three products.

The sulphur in Nutricote is very poorly available. One Nutricote formulation (13:5.7:9.1; 8 to 9 month) released little sulphur and is an ineffective source of sulphur. When added at 9 g/litre, two 3 to 4 month formulations were unable to supply enough sulphur for adequate growth of at least one species of test plant. The symptoms of a sulphur deficiency were made worse if a dilute liquid feed containing a very low concentration of sulphur (0.01 ppm sulphur) was also supplied.

This finding explains, among other things, the often poor performance of Nutricote in southern Victoria, where water supplies contain litle sulphur. Nutricote's limited ability to supply sulphur is, in my view, at least as much a reason for its poor performance as is its reputed inability to release N, P and K fast enough in cold weather.

In some nurseries the combination of Nutricote and Phostrogen has a proven track record. One supplies N, K and some P and the other supplies these and sulphur. If your water supply contains a suboptimal concentration of sulphur and you want to use Nutricote, you must add another source of sulphur as well.

Osmocote with a nominal release time of 3 to 4 months should be capable of supplying enough sulphur to keep pace with the release of other nutrients, so long as there is at least a few ppm sulphur in the water used. Whether the formulations with longer release times can do this too, is not clear from my work. Certainly the longer the nominal release time, the slower the rate of release of sulphur. The question really is whether, if this type of Osmocote is the main source of nutrients, the rate of release of sulphur is fast enough to allow full use of the other nutrients. My guess is that when the concentration of sulphur in the water supply is very low, some supplementation is desirable, but probably only some months down the track. Supplementation is probably unnecessary within the nominal release time if the water contains at least 4 to 5 ppm sulphur.

The Osmocote Plus formulation which I tested had a 3 to 4 months nominal release time. It certainly did not need any supplementation even when the water used contained less than 0.01 ppm sulphur. In fact the rate of release of all nutrients from this formulation of Osmocote Plus was such that growth produced by it when added at 6 g/litre was as good as that from a continuous liquid feed containing 175 ppm N, 20 ppm P, 140 ppm K, and 30 ppm S. The results also suggested that the nutrients might run out well before the end of the nominal release time in warm to hot conditions.

In summary then, of the slow-release fertilizers I have tested so far, Osmocote Plus needs no supplementing with extra sulphur, Osmocote might need a little extra if the water supply contains a particularly low concentration, and Nutricote certainly does need supplementation if the water supply contains less than perbaps 10 ppm sulphur.

Checking your situation.

A first step is to find out the concentration of sulphur in your water supply. Your water supply authority will be able to tell you. If your water is from a bore or dam there are laboratories which will analyze it. You can then take action on the basis of the information given above.

Another check is to sprinkle fine gypsum or ground superphosphate over some of the pots in a reasonably uniform batch. Your usual watering and fertilization program should continue for the whole batch. Any greening of the plants in the treated pots over a period of 7 to 10 days, but not in the other pots, indicates a need for extra sulphur. The rate of sprinkling can be equivalent to about 2 g (½ standard teaspoon) per litre of mix.

There is ample evidence that cuttings in propagation benches need nutrients as soon as roots start to form. An adequate supply of soluble sulphur is as necessary then as it is during later stages of production.

Full accounts of the experiments on which the statements in this paper are based are being published in *Scientia Horticulturae*.

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GREENHOUSES IN PLANT PROPAGATION: AN HISTORICAL PERSPECTIVE

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The growing of plants in covered houses, whether they be greenhouses, conservatories, or orangeries, is essentially a northern hemisphere phenomenon. It is not, however, a new phenomenon, and the first attempts at growing plants under artificial conditions go back to at least early classical times. For countless generations much use has also been made of "shade houses" or natural cover to allow the cultivation of many plants which were affected by excess sunlight.

The Greeks with their "gardens of Adonis" appeared to have had forcing houses in miniature. Plato says that "a grain, a seed or a branch of a tree placed in or introduced to these gardens acquired in eight days a development which could not be obtained in as many months in the open air." Columella, a Roman writer on rural matters, speaks of Rome possessing "within the precincts of her walls, fragrant trees, trees of precious perfumes such as grown in the open air in India or Arabia." The implication of this is that they were not grown in the open air in Rome. It was Caesar Tiberius, however, who, *introduced a utilitarian note to these early attempts at covered* gardening. Told by his doctor that he needed a cucumber a day to cure an illness, he instructed his gardener to produce a cucumber a day or else! The gardener succeeded in growing cucumbers by cultivating them in pits filled with fermenting dung and covered with frames or lights of talc or mica.

In later Roman times forcing was done my means of specularia, buildings covered with sheets of mica, thinly split. Mainly fruits, cucumbers, and peaches were grown in specularia. Among the ruins of Pompeii a building of this kind was discovered, with