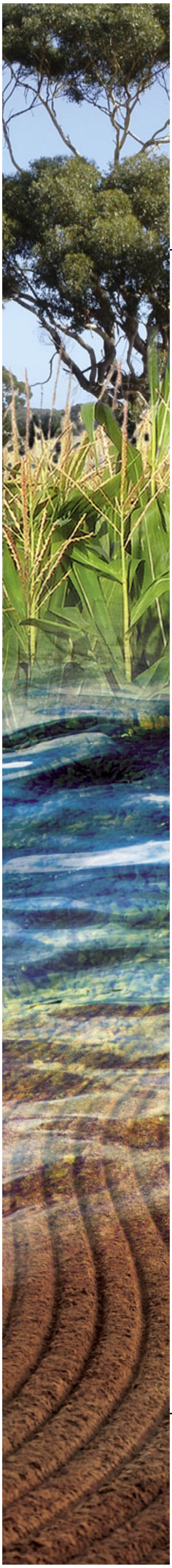

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Specialists in Soil Chemistry, Agronomy and Contamination Assessments

Soil Conditions & Fertilisers for P Sensitive Plants

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Soil Conditions and Fertilisers for P sensitive Plants.

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It has been apparent for some years to growers of mostly Proteaceous plants that while responding to some fertilisers a specific toxicity is seen when these plants are supplied with excessive soil phosphorus. Symptoms of this toxicity are various but include lack of growth, apparent iron deficiency (interveinal chlorosis of youngest leaves), red colours starting in oldest leaves but progressing to the whole plant, drop of oldest leaves, tip necrosis, and a susceptibility to root rot fungi such as phytophthora. The onset of P toxicity is actually an iron deficiency and thus chlorosis is an early symptom. If the high available phosphorus levels continue a true toxicity is seen with red foliage colours and leaf drop as well. Figure 1 shows the classical symptoms of iron deficiency (yellowing between the veins), and P toxicity (interveinal redness).

The condition can occur in pot culture and in soils and is often a compounding factor in transplant and environmental shock. Goodwin (1981) showed that plants not exhibiting symptoms could be made to produce symptoms under temperature or moisture stress.

The problem is not as simple as an excess of P and research has firmly established that this effect is influenced by other nutrient availability. A number of early workers (Nichols 1988, Goodwin 1981) showed a variety of interactions with other nutrients, none of which were very clear or consistent. Goodwin (1981), showed iron (Fe) supply to influence the onset of symptoms and subsequent work by Handreck (1991a and 1991b), showed iron supply to be the most important interaction. Thanks to Handreck's work it is now well understood in pot culture that the levels of Fe and P supply can be precisely measured and used to predict P problems in sensitive plants.

Nearly all this work has been done in artificial media and the precise prediction of problem in soil is yet to be fully researched. Our own experience is that P toxicity can occur in soils especially on old orchard soil improved over many years by "traditional" fertiliser programs such as superphosphate and fowl manure additions. An example of clear cut P problems for a Proteas grower in old orchard land is presented and the means used to control this toxicity by influencing iron supply and improving the availability of other nutrients is illustrated.

The factors reducing iron supply in soils and growing media are worth examination. They include-

- low total soil iron levels, a beach sand is low in iron, a lateritic soil very high
- alkalinity, acid soils supply iron better, alkaline conditions lock up iron
- high soil organic matter can lock up iron
- high soil P levels render iron insoluble
- poor soil to root contact reduces iron supply.

Soils naturally low in iron, and alkaline, such as a calcareous beach sand will be particularly prone to iron deficiency. Bright red acidic soils are likley to be less of a problem.

Addition of high levels of phosphate to a soil results in an insoluble phosphate being formed, the basic reaction being-

$$Fe^{3+} + PO_4^{3-} \text{ --------------> } FePO_4 \text{(insoluble solid)}$$

This is the same reaction resulting from rust converter being painted on rusty metal, phosphoric acid being the active ingredient and black inert iron phosphate forming. The same reaction of phosphate with iron can occur in the soil and inside the plant. Where a P sensitive plant is exposed to high P the reaction occurs inside the plant resulting in a depletion of iron reserves in the plant as iron phosphate is laid down mostly in the stem tissue and at the margins of leaves. The first symptom then is a depletion of iron leading to the chlorotic symptoms of iron deficiency. Where the plants in question are "iron inefficient", that is they are adapted to abundant iron supply (see Handreck 1991a), the problem is often worse and Australian and South African proteaceae are the most susceptible groups of plant being both P sensitive and iron inefficient.

Research (Jenny 1980) has also showed the importance of direct and firm contact of the root with the soil. Where roots get close to iron surfaces they can collect iron which is not soluble. Plants poorly rooted in loose soil can thus show iron deficiency.

Theory should suggest then, that supplying the symptomatic plant with abundant iron may help to overcome some of the physiological problems associated with excessive P levels.

In an early case of severe phosphate toxicity documented by ourselves Proteas were grown on old orchard land showing very elevated soil P availability. Plants exhibited classic P toxicity symptoms of redness in margins of young and old foliage, poor vigour and flowering, and interveinal chlorosis on young foliage. Figures 1, 2, and 3 show the classic progressive nature of the problem from iron chlorosis to redness (Fig 1), terminating in intense redness and leaf deformity (undulating leaf margins, Fig 2) and eventually progressing to tip necrosis (Fig 3). The grower was not getting any production and things were becoming critical.

Table 1 shows the soil test results associated with the symptomatic plants and recommendations made. In the second column of results the soil conditions 4 years later are shown.

<u>Table 1. Soil test results, P toxic Protea plantations</u>

Test	Results		Desirable Range
	1990	1995	
pH	5.4	6.1	4.5 - 6.0
Exchangeable Cations (% of CEC)			
Potassium	1.7	6.4	5-10
Calcium	89.2	70.5	60-70
Magnesium	1.1	19.2	20-30
Phosphorus mg/kg (Bray No1)	87	43	<15
Iron (NH_4Acetate pH 5.0)	4.6	32	20-50
Nitrate N	2.9	3.0	15
Sulphate S	5.0	7.0	25

Recommendations: Acute P toxicity made worse by high Ca/Mg ratio, low iron, potassium, nitrogen, and sulphur. Apply-

Sulphate of iron 150g/bush
IBDU or similar 100g/bush
Sulphate of potash 50g/bush
Magnesium Carbonate 100g/sqm.
Chelated iron foliar sprays

The very high P level and low iron level was immediately picked as a problem but other nutrients such as K and Mg were also very low and needed correction. The use of iron sulphate is acidifying in soil so magnesium carbonate was included to counteract this effect and supply some Mg. The chelated iron is like an intraveinous drip to get iron straight into the plant quickly.

The first use of iron both as a foliar chelate application and soil application of ferrous sulphate reduced symptoms rapidly and with regular use improved the plants to the point where production occurred. The use of iron as a soil drench has gradually resulted in lowered soil P availability (dropping from 87 to 43) as the P is locked up by the iron. With time it appears that less and less frequent application of the iron may be needed to obtain control, and this offers the hope that eventually the condition will be fully cured.

Incidently the Ca/Mg ratio and K deficiency has also been markedly improved by the program. pH is now getting a little high and the Mg carbonate additions will cease.

This may be one of the first instances of a seriously high P level in soil being actually controlled and partially corrected in practice. I have heard other advisors give opinion that there is no hope and the plantation should be destroyed and another property found.

It is of course better if high P conditions are avoided and the following program is suggested for screening and selecting properties and management programs for growers of P sensitive plants.

1. Have the soil tested before purchasing the property of planting. Knowledge on desirable levels of P in soil is limited but 15mg/kg of Bray extractable P is suggested as a general cut off. We have seen Acacia baileyana suffering at 8mg/kg. Once P is added to soil it sticks for a very long time. Our laboratory has seen 100mg/kg persist for 30 years in a sandy soil and Heddle and Specht (1975) noted applied P being retained in the ecosystem for two decades. Once it is in you cannot get it out again.

2. Use what is known about the P sensitivity of various species to decide what fertiliser programs to use. Plants differ in P sensitivity and managing the system for the most sensitive can result in P deficiency in the other more tolerant species.

Various lists of plants including Australian natives and exotic Proteacea are published. The best list of P sensitivity in the cultivated Proteacea is that of Nichols (1981) shown as Table 2.

Table 2. P susceptibility of selected Cultivated Proteacea

(After Nichols 1981).

Highly Susceptible.	
	Protea compata, P. harmeri, P nerifolia, Leucadendron uliginosum, L salicifolium Leucospermum cordifolium.
Moderately Susceptible	
	Protea cyanoides, P. longifolia, P. coronata. Leucadendron coniferum, Dryandra formosa.
Slightly susceptible	
	Protea eximia, P. speciosa, P. grandiceps, P. macrocephala, P. punctata, Leucadendron linifolium, L. orientale L. rubrum, L. elimense, L. teratifolium, L. strobilinium, Serruria florida Aulax pinifolia
Tolerant	
	Protea repens, P. roupelliae, P. mundii, P. nana, P. obtusifolia, P. longifolia, Leucadendron salignum, L. procerum, L. gandogeri.

Other evidence (Bottomley and Aroney 1986) suggests that Telopea speciosissima would be in the slightly susceptible category. There are some contradictions in various lists which suggests to me that iron was not controlled in some of the comparisons and may have interacted with the results.

Handreck (1991b) produced a table illustrating Fe requirements of a range of cultivated Australian natives in potting mix which also illustrates the effect of iron on reducing sensitivity. This is shown as Table 3.

Table 3. Maximum concentrations of P tolerated by species growing in a soil-less potting medium at two levels of extractable Fe. After: Handreck (1991a)

Fe (ppm)in the mix		**Species**
34	19	
3	<3	*Acacia merrallii, Grevillea leucopteris, Hakea bucculenta,*

		H. francisiana, H. petiolaris
5	<3	*A. imbricata, Banksia benthamiana, B. brownii, B. lemanniana, B. leptophylla, B. sphaerocarpa, G. banksii, H. salicifolia*
5	3	*A baileyana, A. decurrens, A. spectablis, H. sericea*
8	7	*A. dealbata, A. glaucoptera, A. ligulata, A. lineata, A. montana, A. myrtifolia, A. retinoides, H. laurina*
11	3	*B. tricuspis, H. rostrata*
11	10	*A. argyrophylla, A. baileyana purpurea, A. burkittii, A. calamifolia, A. florabunda, A. iteaphylla, A. menzelii, A. microcarpa, A. papyrocarpa, A. paradoxa, A. rigens, A. rivalis, A. rotundifolia, A. sclerophylla, B. aculeata, B. laricina, B. speciosa, G. intricata, G. robusta, H. suberea*
>20	14	*A. cyclops, A. fimbriata, A. hakeoides, A. longifolia sophorae, A. melanoxylon, A. nyssophylla, A. pendula, A. ramulosa, H. muelleriana*
>20	>25	*A. longifolia, A. saligna, A. truncata, A. victoriae, H. leucoptera*

While the results do not relate to soil the order of sensitivity is probably valid. We have noted a landscape where plants went down to P toxicity in the order Banksia ericifolia, Acacia longifolia, B. marginata, B. serrata, B. integrifolia while Acacia sophorae still persists with few symptoms. This suggest that A longifolia may be more sensitive than this list indicates.

3. Choose a fertiliser program.

The pH and cation relations of a soil should be corrected with lime, dolomite, or gypsum as needed, preferably before planting. In low fertility soils regular additions of nitrogen, potassium, sulphur, and some times phosphorus, will usually lead to better growth and flowering.

A zero, low, or in some cases moderate P level may be required for the soil and plant type. No P fertiliser at all should be needed even for insensitive plants if soil P levels show more than around 15 mg/kg in the Bray soil test. Below about 5 mg/kg of P, careful additions could be be made to low and moderately sensitive plants. At less than 1 mg/kg of soil P even sensitive plants could benefit from P additions in a fertiliser program.

It is difficult to make individual recommendations given the paucity of research on P fertiliser for these plants in soil and the following recommendations are made with the caution that a trial approach should be adopted and the advice that the soil must be checked for available P levels and pH regularly after planting following any fertiliser program.

Generally fertilisers low in water soluble P and low in total P are to be preferred. Avoid fowl manure, mushroom compost, superphosphate, ammonium phosphates, and mixtures containing these altogether. Fertilisers supplying P in the form of bone are routinely used by Protea growers with few ill effects however some caution should be used with regular long term use as the total P level in Blood and Bone is quite high (5%) and harmful levels may accumulate. Various native plant fertilisers are available and the analysis of these is usually something like 8:1:5 and they use blood and bone as the P source. P should be supplied as insoluble forms only in these formulations, such as blood and bone and rock phosphate. A suitable mixture for trails might be

Ammonium nitrate	1 part
Blood and bone	1 part
Sulphate of potash	1 part
Sulphate of iron	1 part

4. Monitor. Only by regular testing will early warning of high P levels be made. Remember, once it is in the soil you cannot get it out again.

Where soil Bray P levels are over about 15 mg/kg for sensitive plants, and 30 mg/kg for the more insensitive species, corrective programs will possibly be beneficial in an attempt to reverse iron deficiency and P toxicity. Use chelated foliar sprays of iron to mask or correct symptoms in the short term. On naturally limey (alkaline) and very sandy or organic soils continued use of foliar iron chelates may be needed to grow some plants. To correct high P levels in the long term use soil applications of sulphate of iron but remember that sulphate of iron is acidifying and dolomite may be needed to maintain the correct pH range.

Foliar syptoms symptoms of iron deficiency/P toxicity are usually fairly unambiguous and should be used in conjunction with soil tests to diagnose P problems.

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