Chapter 10

ESSENTIAL PINEAPPLE NUTRIENTS

Version 1, 1 Feb 2006

Figure 1. Plant with nitrogen deficiency, normal leaf in hand

Figure 2. Phosphorus deficiency in older leaves

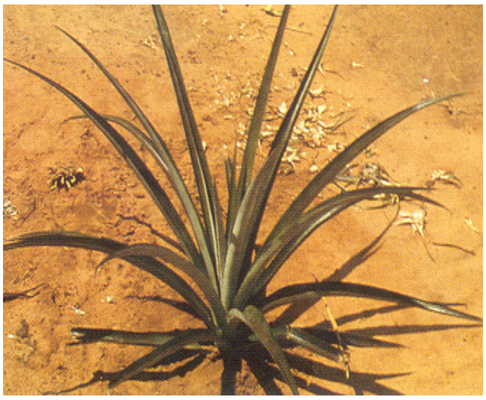
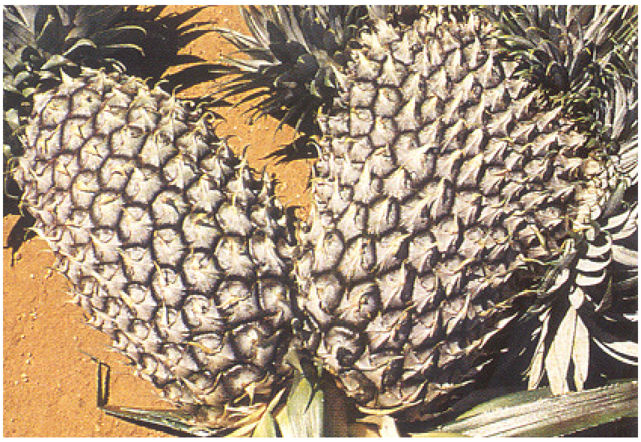


Figure 3. Potassium deficiency - erect, narrow, dark green leaves

Figure 4. Leaves of magnesium deficient leaves are yellow where exposed to sunlight



Figures 5a & 5b. Twin fruit and holes in leaves are symptoms of calcium deficiency

This section discusses the mineral nutrients required by pineapples, the soil and leaf levels needed and the disorders that can be seen when they are significantly under- or over-supplied. Nitrogen, phosphorus, potassium, calcium and magnesium are needed in large amounts by pineapples; they are referred to as macro-elements. Iron, zinc, copper and boron are required only in small amounts; they are referred to as micro-elements or trace elements. Many soils in Queensland are unable to supply these satisfactorily so fertilisers are commonly applied to make up natural shortages.

Identifying disorders related to nutritional problems is a critical part of good farming. Recognising symptoms early and taking proper corrective action is important.

However, by the time visual symptoms appear the nutrient is significantly below the optimum level (see Appendix I) and losses have already occurred. In most cases (nitrogen and iron are exceptions) soil and leaf analyses can pick up deficiencies and excesses much earlier than symptoms develop so corrective action can be taken before losses occur. Soil and leaf analyses are recommended as an essential component of good farm management. Using soil and leaf analyses to adjust your fertiliser program reduces the chances of under- and over-fertilisation.

This chapter should be read in conjunction with the chapter on pre- and post-plant nutrition.

Note 1: The recommended optimum levels and rates in this chapter apply specifically to Smooth Cayenne; they may vary for fresh fruit hybrids and may even differ from hybrid to hybrid. For fresh fruit hybrids use the information for Smooth Cayenne as a starting point and make adjustments based on knowledge as it becomes available.

Note 2: In this chapter leaf nutrient levels are expressed on a fresh weight basis (what the Golden Circle Ltd laboratory used). The outsourced commercial laboratory now used expresses results on a dry weight basis; optimum levels for both are listed in the chapter on pre- and post-plant nutrition.

Nitrogen

Function

Nitrogen (N) is required in large amounts by all plants and has a number of roles in plant metabolism. It is a constituent of plant proteins, enzymes, and cell membranes. It is also a part of other compounds such as plant growth hormones and chlorophyll.

Symptoms

The major symptom of nitrogen deficiency is a general yellowing of plant tissue. Older leaves show symptoms first. Crop colour will vary from very yellow in severely deficient plants to black-green in plants with excessive nitrogen.

Nitrogen levels in the plant can fluctuate quite quickly and leaf tissue analyses have not been found to be a reliable measure of long-term plant nitrogen status. Visible symptoms of nitrogen deficiency are used to monitor plant requirements in the field.

See Figure 1, page 2

Optimum levels

Soil

The optimum level of nitrogen in soil at planting is 120+ ppm nitrate (N03), which is equivalent to 27 ppm nitrogen.

Table 1. Pre-plant nitrogen requirements for soils

Soil analysis (ppm N03)	Level	Pre-plant application of nitrogen (kg N/ha)
150+	high	Nr
125		Nr
100	good	20
75		45
50	low	70
25		95
0		120

Nr… not required

Note that the nitrogen fertiliser requirements of the crop cycle should be based on soil levels.

Leaf

As mentioned above leaf tissue is not normally analysed for nitrogen content as it is not a reliable indicator.

Plant nitrogen requirements are determined visually by leaf greenness, see Table 2.

Table 2. Appropriate degree of leaf greenness for different stages of plant growth in Smooth Cayenne (Note: fresh fruit hybrids often have a different colour scale)

Degree of green	Months
Light	0-8
Medium	8-12
Olive	12-flower initiation

Management of disorder
Nitrogen can be applied directly to the soil or as a foliar spray. Foliar sprays of nitrogen are very efficient, being absorbed by white tissue at the base of leaves and axillary roots. Frequent applications are required during periods of rapid growth.

Total plant crop requirements are in the range of 400 to 600 kg of nitrogen/ha. This includes N already in the soil as well as pre-plant N applications. Total ratoon crop N requirements range from 300 to 330 kg N/ha. Urea is the major source of foliar-applied nitrogen. Concentrations of up to 10% urea can be sprayed over plants. Ammonium nitrate can also be used, but concentrations in high volume sprays should never exceed 3% or severe burn will occur.

For soil applications, nitrate or ammonium forms of nitrogen are suitable. These can be used straight or in commercially available blends. Larger amounts of nitrogen can be applied to soil at less frequent intervals than with foliar applications but the risks are greater this way. Urea is not generally used as a soil-applied nitrogen source.

Applying excessive amounts of nitrogen fertiliser is wasteful. It can also cause environmental problems and cause high nitrate levels in canned fruit. *Refer to the chapter on fruit nitrate management.*

Table 3. Common nitrogen fertilisers

Application	Standard sources	% Nitrogen
Soil	Ammonium sulphate	21
Foliar	Ammonium nitrate*	34
	Urea	46
	Potassium nitrate	13
	Urea	46

*Requires a permit to purchase

Before planting, apply enough fertiliser to make the amount of N in the soil (after incubation) up to 120 kg/ha. For instance, if the soil test shows 80 kg N/ha present, then an additional 40 kg N/ha will be needed. After adjusting the preplant levels as suggested, there will be 600 - 120 = 480 kg N/ha left to be put on for the plant crop.

Inducing the crop with 2 rounds of ethrel plus urea @ 50 kg/1000 L in a spray volume of 2500 L/ha will apply 115 kg N. This leaves 480 - 115 = 365 kg N/ha left to apply after planting and prior to induction.

Young plants do not need large amounts of N, and slowly growing plants do not need much either, so although applications may be made in any month, the major amounts should be applied in the warmer months and when plants are large.

Nitrogen sprays can cause damage to pineapple leaves and fruit. Urea sprays up to 10% may be used, but there is a risk above 5% of urea spray burn and urea heart rot especially if dirty water is used and temperatures are hot. If these conditions exist then use a registered bactericide to prevent urea heart rot. A bactericide is not recommended for use with nitram or nitrate fertilisers. *Refer to the chapter on other disorders for more information.*

Nitram is much more likely to cause damage and should not be used at concentrations greater than 3%. Potassium nitrate is also a source of nitrogen which can burn - do not use at more than 3%.

Phosphorus

Function

Phosphorus (P) is an essential component of some fats, proteins and sugars. It also has a role in energy transfer and chromosome structure.

Symptoms

Visual symptoms are rare and occur only if deficiency is severe. Lack of phosphorus causes poor root growth and stunts the plants. A phosphorus-deficient crop looks dark green. On closer inspection, younger leaves are dark green while older leaves are purple-red with yellow margins. Older leaves die back as symptoms become more severe.

Fruit set is poor if the deficiency occurs at initiation, and subsequent sucker growth is slow and erratic.

See Figure 2, page 2

Occurrence

Phosphorus is required only in small amounts by pineapple, but Queensland soils are inherently low in phosphorus and phosphorus fixation occurs in podzolic, red krasnozem and red earth soils. Applications are therefore required in previously uncultivated soils and maintenance dressings are required on soils where fixation occurs. On replant land deficiency is less likely because phosphorus levels build up quickly with fertilisation and leach very little. Old replant ground often has higher phosphorus levels than required so have the soil analysed for available phosphorus to be sure the pre-plant application of phosphorus is really necessary. Excessive levels of phosphorus can induce deficiencies of trace elements such as zinc and iron.

Leaf analysis is used to find out if phosphorus uptake is adequate. Roots take up phosphorus slowly, so temporary reductions in leaf levels can be associated with sudden growth surges brought on by rain in warm seasons.

Optimum levels

Soil

Soil phosphorus is difficult to address after planting so it is better to aim for 25+ ppm in the soil prior to planting. However in soils where high phosphorus fixation occurs it may be difficult to reach 25 ppm so an adequate supply is achieved by banding the P fertiliser just below and to the side of the planting material at planting time, or applying regular maintenance dressings during growth. Symptoms of phosphorus deficiency develop where levels of available soil phosphorus are below 5 ppm.

Table 4. Pre-plant phosphorus requirements for soils

Soil analysis (ppm)	Level	Pre-plant application of phosphorus (kg P/ha)
100+	High	Nr
25	Good	Nr
15	May be inadequate	20
10	Low	40
5	Very low	60
0	Absent	80

Nr… not required

Leaf

The optimum level for leaves at flower initiation is 200 ppm (fresh weight of D-leaf basal white tissue). Phosphorus deficiency symptoms develop when the white tissue at the base of the D-leaf contains less than 90 ppm.

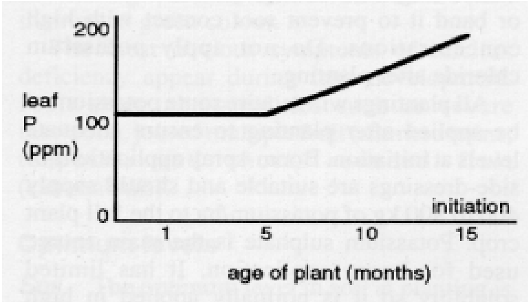


Figure 6. Optimal leaf phosphorus levels during plant growth

Plants grown in soils well supplied with phosphorus should show D-leaf levels of not less than 100 ppm during the first four to five months. This level should increase naturally as the plants age, to 200 ppm or above at flower initiation.

Management of disorder

If soil analysis is carried out before planting and phosphorus levels are adjusted accordingly, further applications are usually unnecessary.

If deficiency is suspected in growing plants then a side dressing is usually successful, but foliar sprays may also be used. For foliar sprays use technical grade MAP because most supplies of standard MAP and DAP comprise waxed granules which do not dissolve. Technical grade MAP is more expensive, but contains more P than ordinary MAP and is fully soluble. "Starter Fos", and "Liquifert P" are suitable substitutes. Approximately 12 to 15 kg of phosphorus/ha is required to raise leaf levels by 50 ppm.

Table 5. Common phosphorus fertilisers

Application	Standard sources	% Phosphorus
Soil	Single superphosphate	9
	Double superphosphate	20
Foliar & soil	MAP	22
	DAP	20

Ideally phosphorus should all be applied as a pre-plant dressing - this is cheapest too. The soil analysis reports will show how much should be applied. P is easily fixed in the soil, and is only slowly released for plant needs, so there is almost no leaching. One way of looking at it is that we need to establish a "bank" of phosphorus in the soil by regular applications (deposits). This bank slowly releases P into the soil (interest), and if the deposit is large enough the released amount will satisfy plant needs.

When soil P levels are low, if the amounts of P added are too small, they will immediately be locked up in the fixed form and will be unavailable for the plant. However, be careful, as large injections of P into the crop can have adverse affects by interfering with the uptake of other nutrients (e.g. zinc and iron). Never apply more than 100 kg/ha total P as a single preplant treatment, and do not apply more than a total of 25 kg/ha P in post plant applications to any single crop.

P fertilisers are not compatible with iron, zinc, or copper salts in the fertiliser tank because complexes with P can be formed. These are insoluble, so will settle on the tank bottom.

Like calcium, phosphorus uptake is very reliant on having functional roots not just adequate soil levels.

Potassium

Function

Pineapple plants require large amounts of potassium (K). Plants need it to metabolise carbohydrate and nitrogen, and for stomata to function normally. Without enough potassium, plant growth is retarded and yield reduced.

Symptoms

Potassium deficiency symptoms shows as very narrow, deep-troughed leaves. In young, potassium-deficient plants, leaves are dark green and stiff. As deficient plants age, leaves become yellow, and leaf tips die back. In contrast, healthy young plants have wide, light-green leaves. Fruit produced on deficient plants are small, have reduced sugar and acid levels, and pale flesh. Fruit stalks are often weak and unusually few slips are produced at times of the year when slips are expected. Once the deficiency is seen, a serious problem exists. Leaf analysis is the only sure guide to plant potassium levels.

See Figure 3, page 2.

Optimum levels

Soil

The optimum level in soil at planting is 150+ ppm (0.4 milli-equivalents per 100 g). Potassium deficiency symptoms develop where soil levels are below 60 ppm.

Table 6. Pre-plant potassium requirements for soils

Soil analysis (ppm)	Level	Pre-plant application of potassium(kg K/ha)
150+	High	Nr
120		75
100	Medium	125
80		175
60	Low	225
40		275
20		325
0		375

Nr… not required

Leaf

The optimum level in leaves at initiation is 3000 ppm (fresh weight of D-leaf basal white tissue). Visual symptoms begin to appear at 2000 ppm and are obvious at 1000 ppm. In plants growing in soils well supplied with potassium, the leaf levels of four- to five-month-old plants should range between 3500 and 4000 ppm. Good fertiliser management will maintain or slightly increase these levels until the plant begins to mature at 10 to 12 months. The levels then naturally decline. Unless potassium levels in young plants are high, it is very difficult to ensure that 3000 ppm is achieved at flower initiation.

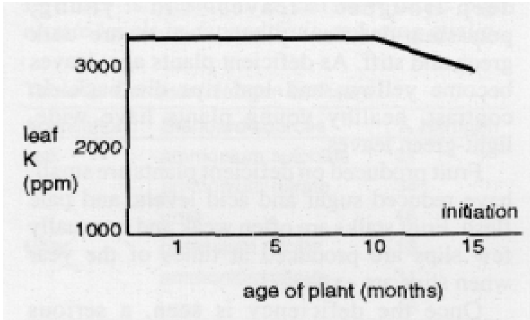


Figure 7. Optimal leaf potassium levels during plant growth (note that the K level goes up and down according to growth rate, induced crop stress and crop moisture status so leaf testing may need to be repeated 2 to 3 times over eight weeks under changeable conditions to get an average)

Management of disorder

Queensland pineapple soils vary widely in potassium levels. The heavy clay loams with good nutrient-holding capacity (Mary Valley) retain potassium, while the very sandy soils with poor nutrient-holding capacity (Sunshine Coast) do not. Some clays have high magnesium levels which suppress potassium and it can be difficult or almost impossible to reach the theoretical pre-induction potassium target. The importance of potassium to the crop and the highly variable nature of pineapple soils make pre-plant soil analysis necessary to determine potassium requirements.

Pre-plant

Potassium sulphate, straight or in blends, is the major source of pre-plant potassium.

Potassium chloride (muriate of potash) is a cheaper, more soluble form of potassium but has a high salt index and chloride content which will cause burning on plant parts including roots. However it can be used in limited quantities before planting. In light, sandy soils do not use more than 250 kg/ha and on heavy clay soils do not use more than 500 kg/Ha. Thoroughly mix it with the soil to prevent root contact with high concentrations. Never use it after planting.

Post-plant

All pineapples will require some potassium to be applied after planting to ensure adequate levels at initiation. Boom-spray applications or side-dressings are suitable for post-plant needs. Potassium sulphate is the main source used for boom application. It has limited solubility so it is normally applied in high volume sprays (2000 to 4000 L/Ha) at a concentration of 5%. Potassium nitrate, which supplies N as well as K is often used when solubility is an issue, but it can burn and should not be used at more than 3% concentration.

Approximately 40 to 80 kg K/ha are required to raise leaf levels by 500 ppm.

Potassium competes strongly with magnesium in soils and plants, so heavy applications of potassium can induce magnesium deficiency. If heavy applications of potassium are required, then supplementary magnesium should also be given. It is common to combine potassium and magnesium in boom-spray applications (10% potassium sulphate + 1% magnesium sulphate).

Table 7. Common potassium fertilisers

Application	Standard sources	% Potassium
Soil	Potassium sulphate	41
	Potassium chloride	50
Foliar	Potassium sulphate	41
	Potassium nitrate	38

It is important to make up the preplant levels of potassium to the level recommended in the soil analyses and keep levels up throughout the growth period. If potassium levels are not high in young plants (3,500 to 4,000 ppm 7 months before induction) it is very difficult to achieve optimum levels at induction because they tend to drop as the plants mature.

In addition, since potassium applications depress the level of calcium and magnesium in the plant tissue, if potassium levels are low and need boosting, you can often find yourself in a difficult situation if calcium is also low. Keeping potassium levels high throughout the growing period improves your options in fertilising.

Calcium

Function

Calcium (Ca) is essential to pineapples and is required in relatively small amounts. Development and maintenance of cell wall structure, quality and shelf life of fruit, and health of growing points depend on adequate supplies. Dramatic improvements in yield and quality have been reported where calcium deficiency has been corrected.

Symptoms

In severe calcium deficiencies, new heart leaves often have 'cut-off' tips, and scalloped margins. The deficiency resembles the damage caused by grasshoppers' chewing. Occasionally, the growing point will die and several high suckers will form. Plants retain their usual green colour. See Figure 5b, page 2.

The most obvious symptoms of calcium deficiency appear during fruit development. Fruit show abnormalities such as severe fasciation, joined multiple fruit (Siamese twins, teapots), and short, rounded fruit (cannonballs). See Figure 5a, page 2.

Optimum levels

Soil

The optimum level in soil at planting is in excess of 100 ppm (0.5 milliequivalents per 100 g). Calcium deficiency symptoms develop where soil levels fall below 25 ppm.

Table 8. Pre-plant calcium requirements for soils

Soil analysis (ppm)	Level	Pre-plant application of calcium (kg Ca/ha)
100	High	Nr
75	Medium	75
50	Low	175
25	Very low	275
0	Absent	375

Nr… not required

Leaf

The optimum level in leaves at initiation is 150 ppm (fresh weight of D-leaf white basal tissue). Calcium deficiency symptoms begin to develop where the white tissue at the base of the D-leaf falls below 40 ppm.

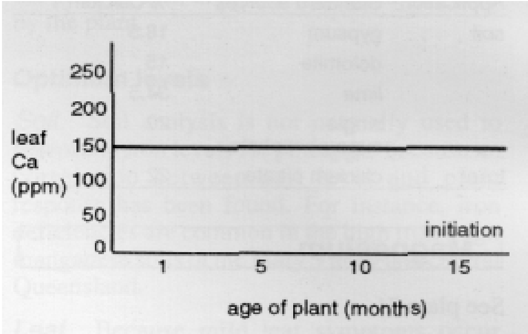


Figure 8. Optimal leaf calcium levels during plant growth

When soil calcium levels are adequate, leaf calcium levels start high and decrease with plant age to the critical level or above at flower initiation.

Calcium levels drop naturally during winter and will rise again in the spring.

Management of disorder

The recommended way to avoid calcium deficiency is by conducting a soil analysis and treating soil before planting if required. Gypsum, dolomite, lime and superphosphate are all good calcium sources. Use lime and dolomite cautiously because they increase soil pH and root rot problems increase as pH rises. Gypsum will not affect soil pH.

Experimental work has shown that side-dressings of calcium fertilisers correct deficiency during growth - even as late as flower induction. Superphosphate (20% calcium) is probably the most suitable source of calcium to apply to deficient soils after planting, but incorporation is recommended and the difficulties of applying and incorporating a side dressing in a mature crop make this an unattractive option. The comments on leaf analysis reports will provide guidance in cases of deficiency.

Trying to correct calcium deficiency with foliar sprays is questionable, but they are sometimes applied (especially to fresh fruit hybrids) in an attempt to enhance fruit quality and shelf life. Calcium nitrate can be used but must be used alone or with urea only as it is not compatible with many other chemicals. Calcium is fairly immobile in plants so foliar applied calcium may not move to where it is needed.

Table 9. Common calcium fertilisers

Application	Standard sources	% Calcium
Soil	Gypsum	approx. 18.5
	Dolomite	approx. 15
	Lime	approx. 34.5
	Single superphosphate	20
Foliar	Calcium nitrate	22

Magnesium

Function

Magnesium (Mg) is a component of chlorophyll, the green pigment in leaves that uses sunlight energy to convert carbon dioxide to carbohydrates. It is critical in basic plant metabolism. Magnesium is also essential in the functions of some plant enzymes.

Symptoms

Visual symptoms of magnesium deficiency are not easily interpreted and should be confirmed with leaf analysis. Deficiency symptoms begin to develop when leaf levels fall below 150 ppm magnesium and are generally obvious once below 90ppm.

The leaves of magnesium-deficient plants are bright yellow where they are exposed to sunlight but keep their normal green colour where they are shaded (e.g. by other leaves or on southerly slopes in winter). Magnesium moves from older to younger leaves. When symptoms occur on the upper leaves, magnesium is probably required.

See Figure 4, page 2

Optimum levels

Soil

The optimum level of magnesium in soil at planting is in excess of 50 ppm (0.4 milliequivalents per 100 g). Magnesium deficiency occurs in soils with less than 10 ppm.

Magnesium leaches easily from many acid soils and will normally need to be supplemented by foliar sprays over the growing crop.

Table 10. Pre-plant magnesium requirements for soil

Soil analysis (ppm)	**Level**	**Pre-plant application of magnesium (kg Mg/ha)**
50+	High	Nr
40	Medium	50
30	Low	100
20	Very low	150
10	Extremely low	200

Nr… not required

Leaf

The optimum magnesium level in the white tissue at the base of the D-leaf at flower initiation is 250 ppm in low potassium soils and 270 ppm in high potassium soils.

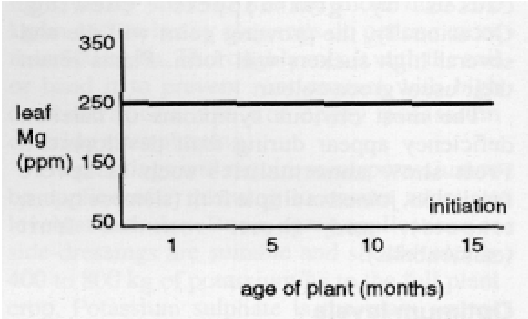


Figure 9. Optimal leaf magnesium levels during plant growth

Management of disorder

In Queensland's coastal, sandy soils, magnesium content is frequently low, while in clay loam soils, pre-plant magnesium is rarely required. However, only pre-plant analysis can establish the exact magnesium status of a soil.

Where necessary, adjust soil magnesium content by applying dolomite or magnesium oxide before planting.

Use regular boom spray applications of magnesium sulphate (Epsom salts, 10% Mg) on growing plants. Normally 10 kg/ha of Epsom salts applied with monthly fertiliser applications will keep plants well supplied with magnesium. Up to 30 kg/ha Epsom salts can be applied at one time to correct deficiency in growing plants.

A total of 100 to 120 kg/ha Epsom salts is normally needed up to flower initiation of plant crops, with half this amount required up to flower initiation of ratoon crops.

Soils with high potassium levels will tend to interfere with magnesium uptake, and foliar potassium sprays also tend to reduce magnesium levels. Use leaf analysis regularly to monitor magnesium levels, starting when plants are about 5 months old.

Table 11. Common magnesium fertilisers

Application	**Standard sources**	**% Magnesium**
Soil	Dolomite	9
	Serpentine	18
	Magnesium carbonate	25
	Magnesium oxide (granomag)	53
Foliar	Magnesium sulphate (Epsom salts)	10

If soil analysis shows a requirement for magnesium it is best to correct the problem with pre-plant applications of the relatively cheap dolomite or granomag, rather than correct the problem post-plant with the expensive magnesium sulphate (Epsom salts).

In most crops, additional regular boom spray applications of magnesium sulphate are required to supply enough magnesium to the developing plant, and also to counteract the effect of potassium sprays depressing magnesium levels in the plant. Generally about 1 kg/ha of Epsom salts are required for each 10 kg/ha of potassium sulphate, but this will vary with soil types and some other factors.

Iron

Function

Iron (Fe) is necessary in chlorophyll formation and in energy transfer systems, so is essential to basic plant functions.

Symptoms

Pineapples are very susceptible to iron deficiencies and deficiency symptoms are often seen in southern Queensland.

Reduced root activity caused by nematodes and wet soils will often show up as iron deficiency symptoms on leaves. It can also occur as a result of poor root function as soil temperature declines in April and after any extended dry spell.

Iron deficiency symptoms always appear first on the youngest leaves of the plant. Mild deficiency causes the leaves to become yellow with green mottling, rather like the markings on a leopard skin. In more severely deficient plants, the main leaf colour is yellow with large, dark-green splotches of chlorophyll. If severe iron deficiency continues through harvest, the fruit is very small, hard and has a red skin. Many cracks develop between the fruitlets, and the crown is very yellow, sometimes almost white.

Visual symptoms are completely diagnostic and soil and leaf tissue analysis can be misleading. Plants can show severe deficiency symptoms when there are high levels of iron in the plant or soil, in a form that cannot be used by the plant.

See Figure 10, page 20

Optimum levels

Soil

Soil analysis is not normally used to determine iron levels for pineapple because no correlation between soil level and plant response has been found. For instance, iron deficiencies are common in the high iron-high manganese soils of the Mary Valley and central Queensland.

Leaf

Because mild leaf symptoms occur before any effect on yield is measurable, and because the iron content of leaves is not well related to deficiency symptoms, leaf analysis for iron is not used in Queensland's pineapple industry.

Management of disorder

- Iron is available in the organic matter of previously uncultivated soils, but deficiency symptoms can suddenly develop as this source is depleted.

- Leaf symptoms of iron deficiency are easily recognisable and can be corrected by iron sulphate foliar sprays. However, the cause of the deficiency needs to be investigated. Iron may be unavailable to pineapple plants in cold, wet soils, in high manganese soils, where roots are damaged, or where soil pH is high.

- Iron sulphate sprays can poison plants. Even when used carefully, hard, black burns may occur on the leaf. In severe cases, entire leaves may be cut off at the base. Sprays should never be applied between flower initiation and the end of petalling (dried flower) or severe fruit deformities will result.

- In areas with only occasional, mild plant symptoms, one or two applications of 2 kg iron/ha (10 kg/ha of iron sulphate) will correct the problem. The iron sulphate is applied either as a high volume spray (at least 2000 L/ha) or as a low volume spray (no more than 400 L/ha). This mild disorder is most commonly caused by reduced root activity in cold, wet soil.

- In high manganese soils, or where plant roots are damaged by nematodes or symphylids, symptoms will persist and regular monthly sprays are necessary to correct the iron deficiency. However, this will not correct nematode or other soil pest problems.

- Where plants are already severely iron deficient, it is necessary to apply iron twice a month at 2 kg/ha (10 kg/ha iron sulphate) in low volume sprays until leaf symptoms disappear. Regular monthly high volume sprays will then maintain good iron status in most cases.

- If severe iron deficiency symptoms do not respond to iron sprays in limited field areas, have a soil pH test done. Iron is less available in soils with high pH and it may be necessary to reduce pH with acid-forming materials like sulphate of ammonia or elemental sulphur. *Refer to the chapter on pre- and post-plant nutrition.*

- If iron symptoms appear during fruit development, iron sprays can be applied from dry flower to harvest.

Table 12. Common iron fertilisers

Application	Standard sources	% Iron
Foliar	Iron sulphate (ferrous sulphate heptahydrate)	19.7

Iron sprays are not compatible with phosphate fertilisers or with borax or calcium nitrate. Iron is not recommended as a preplant soil additive as it can be "locked up" in soil complexes.

Zinc

Function
Zinc (Zn) is an essential micronutrient. It acts as a catalyst in many plant functions, and is particularly important in hormone transport.

Symptoms
Zinc deficiency causes the typical crook-neck symptoms of younger pineapple plants, common in August when warmer air temperatures accelerate leaf and stem growth but root function is still slow due to low soil temperature. Heart leaves feel hard and brittle, gather together, and tilt away from the vertical. Not all plants will show symptoms to start with. In severe cases, the bunched leaves bend almost horizontal to the ground.

In older plants, pinhead-sized yellow dashes occur on the margins of older leaves. As the deficiency worsens, more dashes appear and later, large brownish blisters form on the upper leaf surface as the dashes coalesce. The leaves feel bumpy, as though there are small drops of wax on the leaf surface.

See Figure 11, page 20.

Optimum levels

Soil

Soil analysis for zinc is not normally used in Queensland. It is accepted that soils with more than 3 ppm are adequate.

Leaf

Leaf analysis for zinc is not considered diagnostic in pineapples. Analysis of the apex tissue of plant stems indicates that zinc levels in excess of 4 ppm are desirable. This analytical technique destroys plants and is not used in field evaluations.

Management of disorder

- Zinc deficiency is widespread in Queensland soils and almost universally present in previously uncultivated soils. To avoid zinc deficiencies in new soils, apply the equivalent of 7 kg/ha zinc pre-plant, e.g. 30 kg zinc sulphate heptahydrate/ha. In replant soils, applications of zinc at this level should not be required, although such applications may need to be repeated on very light sandy soils. Several fertiliser blends contain zinc (usually as the oxide) and are an effective source of this nutrient.

- Note that zinc sulphate heptahydrate is very hygroscopic (attracts water) so should not be mixed with other fertilisers in broadcast or side-dressing applications. Also it is not compatible with phosphorus sprays or with borax or calcium nitrate.

- Zinc deficiencies can occur in plants even where soils have received this nutrient. In some soils, zinc becomes less available to plants with time. Crook-neck symptoms can also develop in young plants in spring, when growth exceeds the rate at which the plant can take zinc from cold soil.

- Zinc sulphate sprays can correct crook-neck symptoms quickly and effectively. Two sprays, a month apart, at a rate of 2 kg/ha zinc sulphate in 2000 L spray volume are normally adequate. In areas where crook-neck persists, monthly sprays of 1 kg zinc sulphate/ha may be required after the initial two heavier applications.

Table 13. Common zinc fertilisers

Application	Standard sources	% Zinc
Soil	Zinc sulphate heptahydrate	23
	Zinc blended fertiliser	see label
Foliar	Zinc sulphate heptahydrate	23

Copper

Function
Copper (Cu) plays an important role in several metabolic processes.

Symptoms
Copper deficiency used to be rare, but since copper has been removed from many fertilisers used for basal dressings, deficiency has become more common.

Deficiency severely stunts plant growth. Leaves become very narrow and light green. In cross section, the leaf shows a distinct U-shape and the tips curve downward. Younger leaves can show dieback just behind the tip. Trichomes on the back of affected leaves are often missing, giving the plant an oily appearance.

See Figure 12, page 20

Optimum levels
Soil
The optimum level of copper in soil at planting is 2+ ppm.

Leaf
In leaves the optimum level is 10 to 50ppm (fresh weight) in white tissue at the base of the D-leaf.

Management of disorder
- Copper deficiency is extremely common in the heavily leached, coastal, sandy soils of southern Queensland and seems to be particularly severe where felled trees have been burned in heaps on previously uncultivated soils. In this situation, a pre-plant or immediate post-plant treatment with a fertiliser containing copper is essential.

- Copper sulphate (bluestone) can be added to pre-plant fertiliser mixes or applied by spray to soils before planting at a rate of 7.5 kg/ha copper (30 kg/ha copper sulphate). In re-plant fields which have had copper treatment in previous plantings, an additional 2.5 kg/ha copper (10 kg/ha of copper sulphate) is adequate soil treatment.

- All copper salts are likely to severely damage plants if applied as foliar sprays so pre-plant dressings are usually the only acceptable method of application. Chelated copper can be sprayed on plants to correct deficiency symptoms but by then plant growth will already have slowed. Pre-plant copper treatment is best.

- Do not over-apply copper compounds. Deficiencies can be corrected, but toxicities are much harder to correct.

Table 14. Common copper fertilisers

Application	Standard sources	% Copper
Soil	Copper sulphate pentahydrate	25
	Copper blended fertiliser	see label
Foliar	Copper chelates	see label

Boron

Function
Growing point and cell wall development, pollination, fruit development and the movement of sugars and plant hormones all require boron (B).

Symptoms
In pineapple no boron deficiency symptoms have been reported on leaves, stems or roots. Fruit on boron-deficient plants develop cracks on and between the individual fruitlets before blossoming, and cork forms over these cracks. In mild deficiencies fruit size is normal, with small, corky flecks on and between the eyes. As the deficiency becomes more severe, the extent of cork formation increases and fruit do not grow as large. With some boron deficiencies (which occur most commonly on ratoon fruit) the fruit have heavy, light-brown corking on and between all the eyes of very small, fist-sized fruit, which are hard and remain green. Occasionally, all that develops is a corky cap on top of the fruit stalk. Deficiency is common on light, sandy soils.

See Figure 13, page 20

Optimum levels
The optimum levels of boron have not been determined for Australian conditions.

Management of disorder
- Boron deficiency appears to be important only during the early stages of fruit development. A foliar spray with a source of boron applied at or before initiation easily overcomes this disorder.

- In flower induction sprays, include 5 kg/ha of borax or 2.5 kg/ha Solubor per 1000L. This is standard practice in Queensland today. Boron also enhances the effect of the chemical inductants by making the pH more alkaline and acting as a pH buffer.

- In fields where natural flower initiation is expected, the boron source can be applied along with the final foliar fertiliser spray. Note that iron and zinc sulphates must not be used in sprays containing borax or Solubor. They are incompatible.

- Excessive amounts of boron can cause leaves to yellow, leaf tips to die back and growth to stop. Do not apply more than 3 kg/ha boron (30 kg/ha borax or 15 kg/ha Solubor) to the crop.

Table 15. Common boron fertilisers

Application	Standard sources	% Boron
Foliar	Borax	10
	Solubor	20

References and further reading

Broadley, R.H., Wassman, R., Sinclair, E. (1993). *Pineapple pests and disorders*. Qld DPI.

Sinclair, Eric (1994). Leaf and soil analysis. *Pineapple industry field day notes*, 45-54.

Appendix I. Levels at which nutrient deficiencies appear vs. optimum levels

Nutrient	Optimum level (ppm)	Level at which visible symptoms appear (ppm)
Phosphorus	25+ in soil	Less than 5 in soil
Potassium	150+ in soil	Less than 60 in soil
Calcium	150 in leaf	Less than 40 in leaf
Magnesium	50+ in soil 250-270 in leaf	Less than 10 in soil Start at 150, obvious at 90

This table illustrates why, for many elements, waiting for the appearance of visible deficiency symptoms is too late to avoid losses. With the exception of using leaf symptoms to diagnose nitrogen, iron and zinc deficiencies in the plant, leaf and soil nutrient analyses are recommended in preference to using symptoms. *Refer to both nutrition chapters for more details.*

Figure 10. Leaves of mildly iron deficient leaves show dark-green mottling on a pale leaf background, severely iron deficient leaves are pale yellow

Figure 11. Early symptoms of zinc deficiency – heart leaves gather together and tilt slightly away from the vertical

Figure 12. Copper deficient leaves get an oily appearance and tips of leaves die

Figure 13. Fruit of boron deficient plants develop corking between the fruitlets