

6 Fertilizer management



General concept of fertilizer efficiency

“The Law of the Minimum Nutrient” means that in citrus trees, as in other crops, the growth of the plant is limited by the nutrient element present in the smallest quantity, even if all other nutrients are present in adequate amounts (Fig. 6-1). It is of the utmost importance in citrus production to know which, if any, nutrient element is the limiting factor. If there is a deficiency of any nutrient, then the fertilizer program must remedy this.

Any increase in fertilizer applications will give a yield increase (Fig. 6-2). However, the yield increase is highest from the initial unit of fertilizer applied. As more fertilizer is added, the yield increase becomes smaller and smaller. This is known as “The Law of Diminishing Returns”.

Hence, the amount of fertilizer which growers need to apply to get the maximum yield is not necessarily the same as the amount needed to get the maximum economic yield (Fig. 6-3). It is the second, the maximum economic yield, which gives the best return for applied fertilizer. It is this yield level which growers should try to achieve.

Too much fertilizer may harm the trees

Excessive fertilizer applications may reduce the yield, and damage fruit quality. For example, fruits from trees given too much fertilizer

may be smaller than usual. They may have thicker peel, a lower sugar content and may be late in turning color. Overuse of fertilizer will also pollute the soil and irrigation water.

If they are available, soil testing and leaf analysis are a good way to monitor the nutrient status of citrus orchards and modify the fertilizer management. Once growers know the nutrient status of the soil and the trees in their orchard, they can develop a management program which will optimize fertilizer applications, thus increasing production and reducing costs.

Fertilizer recommendations

In theory, the amount of fertilizer which should be applied can be derived by dividing the difference between what the crop needs (uptake) and what the soil provides (after losses from soil erosion, evaporation and leaching). However, such information is rather difficult to come by. In practice, the application rate of fertilizers for citrus trees varies according to the age of the tree, the fruit load, the soil fertility and the nutrient status of the tree.

With this in mind, the standard recommended fertilizer rates are shown in Table 6-1. The timing of the applications, including split applications, is shown in Table 6-2. A fertilizer program based on these recommendations may be modified as the result of leaf analysis and soil testing.

Fertilizer demand in different seasons

After harvest and before the spring flush

A basal application of fertilizer is given after harvest, during the winter pruning season. The main purpose of this fertilizer is to restore tree vigor after fruit production. At the same time,

growers may improve the condition of the soil by applying organic manure and/or liming materials. About 40% of the orchard's total annual chemical fertilizer is applied at this time (Table 6-1 and Table 6-2).

If we take as an example a citrus orchard where each tree is producing 60 kg of fruit, the application rate of chemical mixed

fertilizer e.g. Compound Fertilizer No. 5 (N-P₂O₅-K₂O, 16-8-12) per tree will be about 3.75 kg x 40% = 1.5 kg. To prevent unnecessary losses of nitrogen on acid soils, liming for soil reclamation should be carried out one month after the chemical fertilizer has been applied. Whether liming is necessary is decided by soil testing (analysis of the soil pH).

Table 6-1. Recommended fertilizer rates of N, P and K for citrus tree (g/tree/year)

Tree age (years) or fruit yield kg	N	P ₂ O ₅	K ₂ O	Converted to rate of Compound Fertilizer No. 5 for mature trees, and No. 43 for young trees
Young tree (1-3)	75	75	75	500
Young tree (5)	150	150	150	1,000
Mature tree (40 kg)	500	250	375	3,125
Mature tree (60 kg)	600	300	450	3,750
Mature tree (90 kg)	800	400	600	5,000
Mature tree (120 kg)	1000	500	750	6,250
Mature tree (150 kg)	1200	600	900	7,500

Table 6-2. Timing and percentage (%) of split fertilizer applications for citrus

Chemical fertilizer	From after harvest to emergence of spring flush	Blooming and fruit set	Fruit development
N	40	40	20
P ₂ O ₅	40 or 100	40 or nil	20 or nil
K ₂ O	30	30	40

Variety	From after harvest to emergence of spring flush	Blooming and fruit set	Fruit development
Ponkan mandarin	November - December	February - March	June - July
Liucheng orange	December - January	March - April	July - August
Wentan pomelo	November - December	February - March	June - July
Grapefruit	November - December	March - April	July - August

Notes to Table 1 and Table 2

- Recommended application rates for fertilizer should be modified according to soil texture. An extra 30 - 40% above the recommended level should be applied to gravel soils or coarse-textured soils, since they have very poor ability to hold nutrients. On fine-textured clay loam soils, on the other hand, fertilizer applications may be reduced by 20 - 30%. If the citrus orchard is covered with grass, an extra 20 - 30% of nitrogen should be applied in spring and summer, so that the grass and the citrus trees do not compete for nutrients.
- Fruit quality and color, and flower bud formation, are often damaged by the application of too much nitrogen fertilizer. After harvest, growers might apply a compound fertilizer which contains less nitrogen (e.g. Taiwan's Compound Fertilizer No. 2), especially if the orchard has very fertile soil.

If organic fertilizer is used for the basal application, growers should use soybean meal or some other organic fertilizer with a nitrogen content of more than 5%. The approximate application rate should be 10-15 kg per tree. If this is done, the amount of applied chemical fertilizer can be reduced by 350 to 500 g per tree.

When organic fertilizers with a lower nitrogen content are used, such as composted rice straw or livestock manure, the application rate should be at least 30 - 60 kg per tree. Growers are recommended to apply manure or compost at the same time as any liming materials, and mixed together with them. This speeds up the decomposition of organic matter, and reduces the labor cost of application.

When organic fertilizers are combined with liming materials, they should be mixed into the soil

at a depth of 30 cm below the soil surface. Generally, limestone or dolomite is spread at the bottom of a furrow or hole. Over this is spread a layer of organic fertilizer, and they are both then covered with topsoil. Several methods of deep placement may be used in a citrus orchard. Different methods may be used in different years. Some examples are listed below.

Circle banding

A furrow is cut, 20 cm wide and 30 cm deep, around the tree in a circle beneath the outer canopy.

Strip band application

This method is suitable for old orchards, where the trees are more than 10 years old. Parallel furrows are cut, 20 cm wide and 30 cm deep, between the rows of the trees.

Hole placement

Four or five holes are dug beneath the outer canopy of each tree. The holes should be 15-20 cm in diameter, and at least 30 cm deep.

Spring flush growth, blooming and early fruit development

About 30% of the year's total fertilizer is broadcast. This application may be divided into two split applications for better uptake efficiency by the trees. All applications of fertilizer should be followed a few days later by irrigation, unless rain falls within this period. The extra water is needed to dissolve the fertilizer and move it into the soil moisture system so it can be taken up by the trees. If a citrus orchard which produces 60 kg fruit per tree is taken as an example, the application rate of (Taiwan's)

Nutrition deficiency for crop production

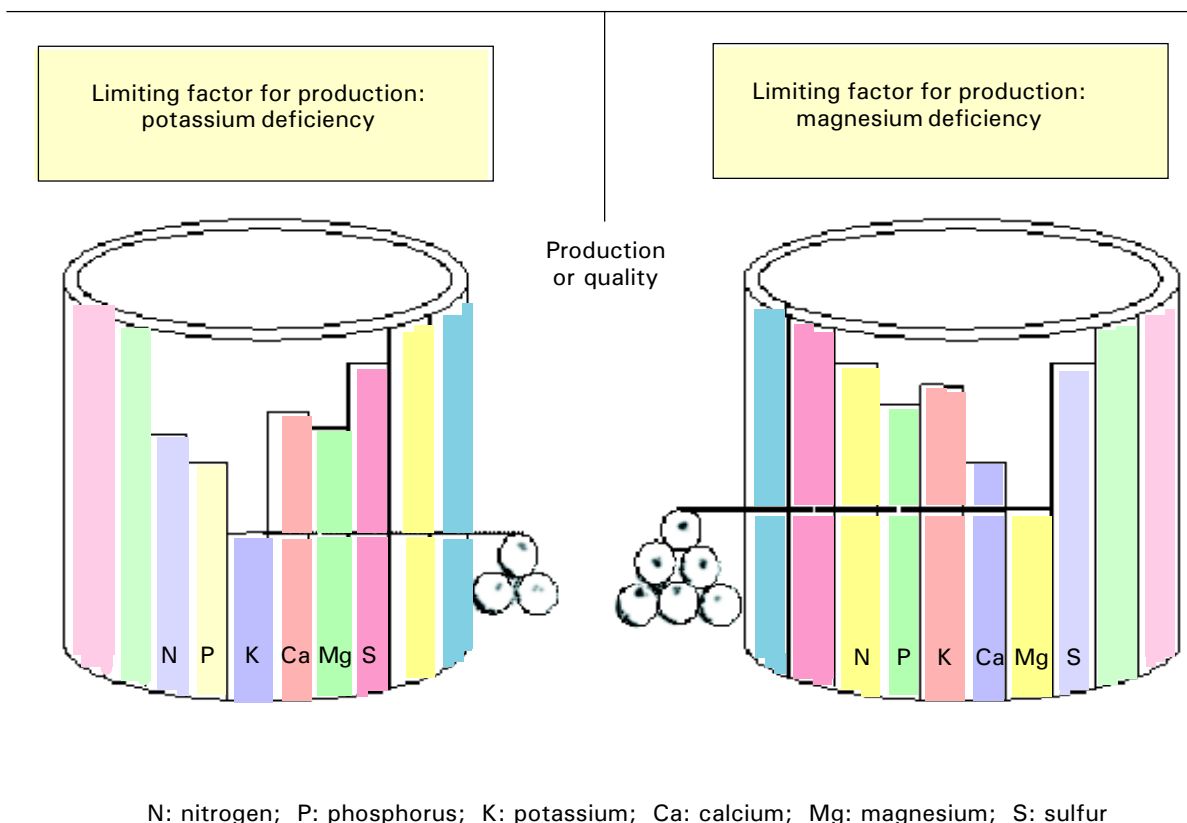


Fig. 6-1. Example of the "Law of the Minimum Nutrient".

Compound Fertilizer No. 5 (N-P₂O₅-K₂O, 16-8-12) would be about 3.75 kg x 30% = 1.13 kg per tree (Table 6-1 and Table 6-2).

During fruit development

Trees need the same amount of fertilizer at this time as during the spring flush. They also need the same level of soil moisture. While the fruit is developing, however, the emphasis should be on an additional dose of potassium fertilizer, perhaps 0.5

kilogram per tree.

This helps to improve both the quality and size of the fruit. Growers should be careful about applying nitrogen fertilizer at this time, and should observe their trees closely before using it. Nitrogen fertilizer should be reduced or not used at all if there is excessive growth of the summer and fall flushes, especially in a fertile orchard with abundant rainfall. However, orchards on infertile gravel or sandy soils may still require a

dressing of Compound Fertilizer No. 5 or No. 2, at a rate of 0.5 - 1.0 kg per tree.

Soil testing and plant analysis

If growers have access to a testing service, they should take samples for leaf analysis and soil testing as a reference and guide for improved fertilizer management after harvest (in Taiwan, this is in late summer, in August or September).

Micronutrients

It is difficult to tell by the visible symptoms alone whether a plant is suffering from a micronutrient deficiency. Many of the symptoms may look exactly the same as those produced by virus and other plant diseases. Sometimes the only symptom is a fall in yield.

The best way of judging whether citrus trees need supplements of secondary nutrients and micronutrients is to carry out soil testing. If this can be combined with leaf analysis, the results are even more accurate. If no nutrition disorders are diagnosed or confirmed by analysis, growers do not need to apply any micronutrient fertilizers.

In general, growers can expect micronutrient deficiencies in the following circumstances.

Magnesium

Magnesium deficiency tends to occur on acid sandy soils. If the level of magnesium in the leaf is less than 0.25%, it is considered low, and the tree is in need of liming with dolomite. Although the use of dolomite is the best long-term approach, severe deficiencies may be corrected by the application of Epsom Salts (MgSO₄·7H₂O), at a rate of 1 kg per tree. Another effective treatment is an application of magnesium oxide, at the rate of 150 - 200 g per tree.

Foliar sprays may also be used. Five foliar sprays per year of 2-3% (i.e., diluted x 30 - 50) magnesium sulfate or magnesium nitrate are recommended.

Sometimes magnesium deficiency is seen in trees growing in neutral or alkaline soil. In this case, growers should apply a foliar spray of

magnesium sulfate rather than apply dolomite to the soil.

Boron

For citrus orchards on clay loam, and for trees more than 10 years old, the recommended rate of applied boron is 50 g per tree of boric acid. This should be applied by broadcasting.

Additional boron is needed if the level of boron in the leaf (sampled in late summer from the spring flush) is less than 20 mg/kg. Two foliar sprays each year of 0.3% (i.e., diluted x 300) boric acid or borax is another alternative.

Boron toxicity

Growers must avoid inducing boron toxicity from applying too much boron. If the deficiency symptoms disappear, growers should not apply any more boron in later years, whether broadcast on the soil surface or as a foliar spray.

Zinc and manganese

Trees have a deficiency of zinc and manganese, if leaves from the spring flush, sampled in August (late summer) contain less than 25 mg/kg. These deficiencies are usually corrected by three or four foliar sprays of zinc sulfate or manganese sulfate, at a rate of 0.3 - 0.5% (i.e., diluted x 300 - 200). The same amount of solid calcium oxide (CaO) should be added to the spray as an emulsifying agent. These foliar sprays should be applied at intervals of 7 - 10 days.

Some fungicides or bactericides contain zinc and manganese. They also are effective in alleviating and preventing deficiencies of zinc and manganese in citrus trees.

Leaf analysis and soil testing

Citrus is a perennial, deep-rooted crop. The availability of nutrients in the soil which can be taken up by the trees is strongly influenced by the soil pH. Tree growth and fruit yield are also influenced by the soil organic matter content, and the levels of various nutrients such as phosphorus, potassium, calcium and magnesium.

The benefits of analysis

Leaf analysis is recognized all over the world as the best indicator of the actual nutrient status of plants. This is because the leaves of plants are the organs in which occur both photosynthesis and the assimilation of mineral nutrients taken up from the roots. The

results of leaf analysis in citrus orchards always have a good correlation with citrus yield, and the nutrient content of the fruit.

The main advantage of leaf analysis and soil testing is that they can detect and monitor the nutrient status of the citrus trees, and the fertility of the soil in the orchard.

As a result, growers can revise their soil management and fertilizer program, and gain both economic benefits and improved yields, while avoiding damage to the environment.

Taking the samples

The crucial step for growers is to collect representative and meaningful samples of plants and soil. This is vital for correct diagnosis and sound

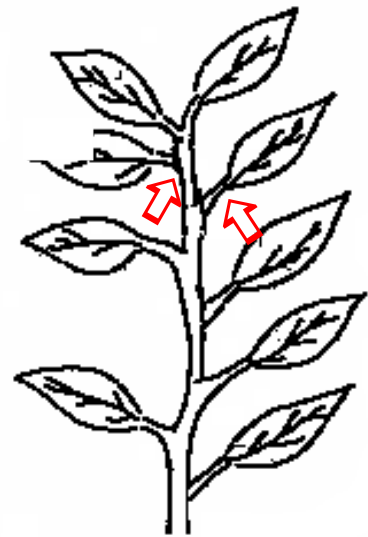


Fig. 6-2. Example from Taiwan of where to take a citrus leaf sample for analysis (3rd or 4th leaf of a current-year spring flush, on a non-fruiting twig)

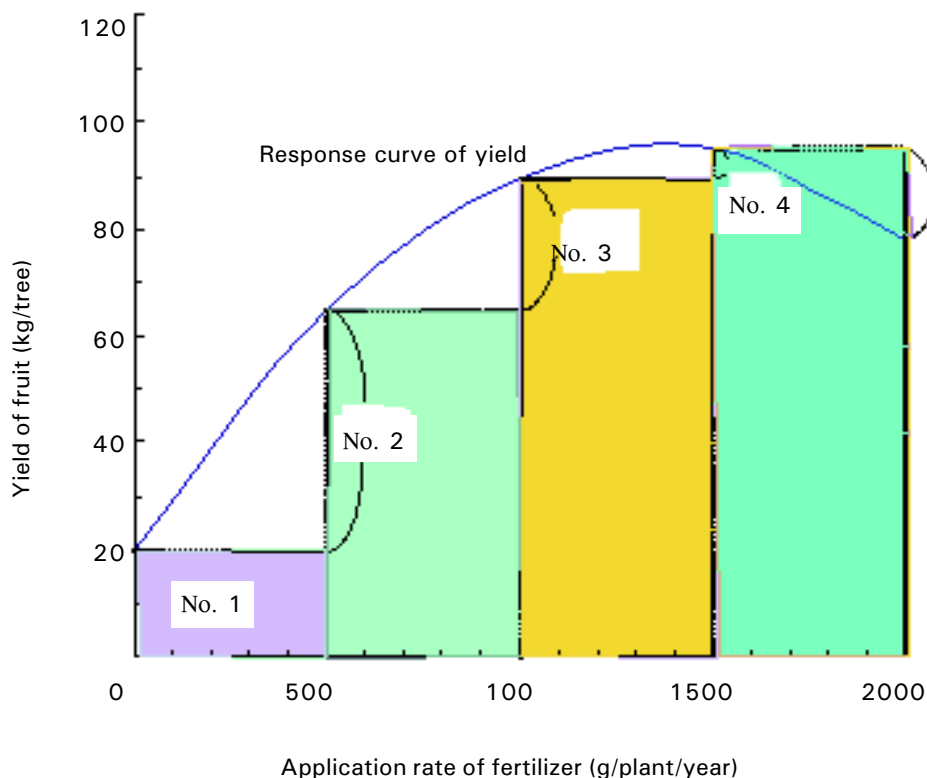


Fig. 6-3. Response curve shows the increases in yield with increased fertilizer inputs

- No. 1: Increase in yield by increasing fertilizer input from 0 to 500 (g/plant/year)
- No. 2: Increase in yield by increasing fertilizer input from 500 to 1000 (g/plant/year)
- No. 3: Increase in yield by increasing fertilizer input from 1000 to 1500 (g/plant/year)
- No. 4: Increase in yield by increasing fertilizer input from 1500 to 2000 (g/plant/year)

interpretation. Incorrect sampling will lead to an unsuitable fertilizer program, and also waste the grower's labor, resources and time.

Therefore, the guidelines for leaf and soil sampling in citrus orchards must be strictly followed. Different countries have slightly different sampling procedures.

In Taiwan, growers pick the third or fourth leaf of the current year's spring flush for a leaf sample. They choose a non-fruiting twig, as shown in Fig.6-2. (In fact, the terminal twigs of spring flushes do not normally bear fruit). Other countries take their leaf samples from other parts of the tree. However, within each country, all growers must follow the same procedure.

Soil samples are usually taken from directly beneath the outer canopy, just below the drip line of the tree, as shown in Fig. 6-4. The usual procedure is to take two sets of 8-12 samples from different parts of the orchard, one set from the topsoil and one from the subsoil. All the topsoil samples are then mixed together, and the subsoil samples are mixed together, each in a separate container. Then about 600 g of mixed topsoil is put in a bag or box, and 600 g of subsoil in a separate bag. The two samples are sent to the laboratory for analysis.

As with leaf analysis, each country has its own procedures, and these differ slightly from one country to another. Growers who are using soil testing for the first time should check with the laboratory or extension staff about the exact details of where and how to take the soil samples.

Labelling the samples

Before growers send samples to the laboratory, they must be sure to label them properly. Labels should include the name and address of the grower, his telephone number, the orchard

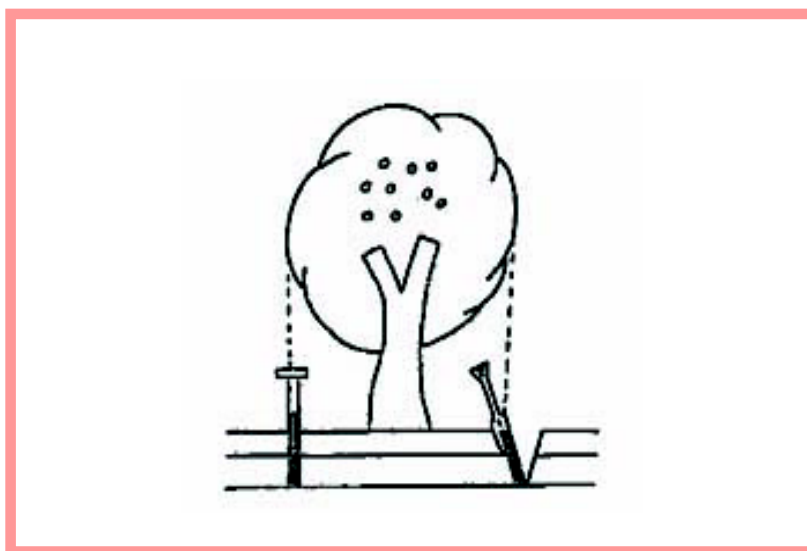


Fig. 6-4. Position of soil sample. It should be taken from directly beneath the outer canopy of the tree. Two separate soil samples should be taken, one from the topsoil and one from the subsoil.

number and the citrus varieties.

Soil samples should include the sampling depth. Leaf samples should include the sampling date. If possible, leaf samples should be delivered to the laboratory for analysis within 24 hours after being collected. The leaf samples should be kept at a temperature of less than 5°C (in a refrigerator, but not frozen).

Information sheet about fertilizer applications

An efficient fertilizer management program always needs careful

modification, according to the nutrient diagnosis, fruit yield and management records.

Therefore, it is essential for farmers to record on an information sheet all the details of fertilizer applications, including organic materials. The same sheet should record levels of fruit production.

The sheet should accompany the samples to the laboratory. Ideally, for each orchard, growers should have analyzed one leaf sample and two soil samples (taken at different depths), for each variety of citrus in the orchard.

Results of the tests

Major items analyzed in soil samples are the soil pH, the organic matter content and the texture. Most analyses will also give the levels of available phosphate, exchangeable calcium, magnesium etc.

Items for leaf analysis include the levels of major nutrients such as nitrogen, phosphorus, calcium and magnesium, and also of minor nutrients such as iron, manganese, copper, zinc and boron.

The laboratory will compare these levels with the optimum levels already established, and recommend that the application of various fertilizers be increased or reduced as needed. If there is a deficiency of magnesium and calcium in an orchard growing in acidic soil, liming is recommended.

Common nutrient disorders of citrus orchards

Many citrus orchards in Asia are located in slopeland areas where the soils are infertile, strongly acidic and have a low soil organic matter content. They also contain low levels of calcium and magnesium. In the past, many Asian farmers tended to overlook the importance of liming and organic manure, and used too much chemical fertilizer to maximize yields.

As a result, orchards may suffer from an imbalance of nutrients, and an overdose of N, P and K (nitrogen, phosphorus and potassium). When this happens, there is a decline in both the quantity and quality of the yield, and many trees suffer from nutrient disorders. Some of the common nutrient disorders are listed below.

Excess or deficiency of nitrogen (N)

Many citrus orchards have a high nitrogen content in their leaves, because of heavy applications of nitrogen fertilizer. The main symptom is excessive growth of the summer/autumn flushes, which have dark green leaves (Fig. 6-5).

Excess nitrogen also results in poor-quality fruit, with thick peel, a low level of total soluble solids (which contribute to the sweet flavor), delayed color break and a short storage life (Fig. 6-6).

Severe nitrogen deficiency is rare. The main symptoms are a reduction in yield, and yellow or pale green leaves. Leaves drop off earlier than usual (Fig. 6-7).

The same symptoms are also observed in orchards affected by nematodes. Rather than increasing the amount of nitrogen fertilizer they apply, growers may need to focus on nematode control.

Excess or deficiency of potassium (K)

Potassium deficiency is widespread in Asia. For example, one survey found that 90% of the orchards in Taiwan had a potassium level lower than the critical concentration (1.4%), below which the tree may show deficiency symptoms. The main symptom of potassium deficiency is small fruit which have low levels of sugar and acidity. Growers should apply fertilizer containing potassium in order to increase the fruit size.



Fig. 6-5. Excessive growth of summer/autumn flushes in Ponkan mandarin, with dark green leaves. This indicates the overuse of nitrogen fertilizer.



Fig. 6-6. Fruit of Liucheng orange which has been given too much nitrogen fertilizer. The fruit have thick peel, a low sugar content and delayed color break.



Fig. 6-7. Symptoms of severe nitrogen deficiency. The tree lacks vigor, the yield is low, and leaves are yellow or pale green. Leaves fall early, as they do also in orchards which are infected with nematodes.

However, excessive potassium applications may create magnesium deficiency. This is because the two nutrients are antagonists, and a high level of potassium may reduce the normal uptake of magnesium. High potassium status will also have some negative effects on the fruit, which may have a rough peel and high acidity (Fig. 6-8).

Calcium (Ca) deficiency

The symptoms of calcium deficiency of citrus may be seen when the concentration of calcium in the leaves is lower than the critical value of 2.5%. Calcium deficiency is usually associated with strongly acidic soils, and a climate with many cloudy or rainy days.

Fruit from citrus orchards which have a low calcium and nitrogen content in the leaf will tend to have a higher percentage of fruit rot after three months of storage. Lime should be applied to the trees. This will improve the storage life of the fruit.

Magnesium (Mg) deficiency

The characteristic symptom of magnesium deficiency is chlorosis of the leaves. (Chlorosis is a condition where the leaves turn pale. The color may be pale green, yellowish or almost white).

The chlorosis is seen mainly on the margins and tips of the leaves, and in the part of the leaf between the veins (the interveinal area). It is seen mainly in old leaves, or in the bottom leaves of a fruiting twig, while young leaves remain green (Fig. 6-9). It may appear when the concentration of magnesium in the leaves is less than 0.25%.

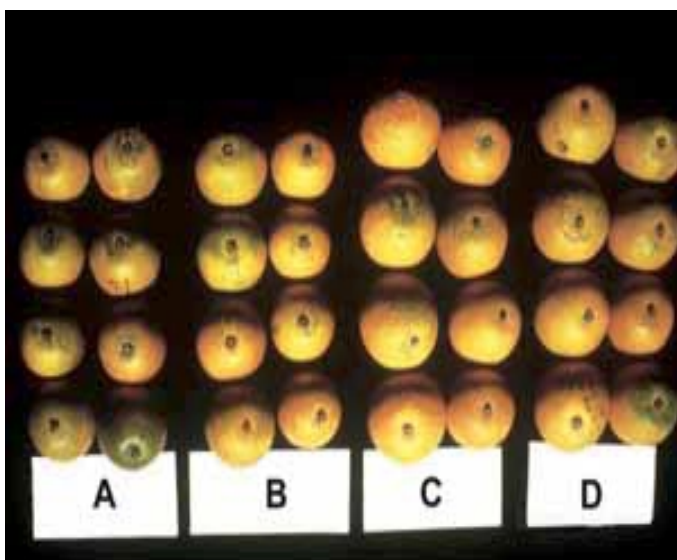
In severe cases, the leaves may fall early. The whole leaf blade may die, except the veins (middle ribs) and the bottom of the blade, which remains green. The green part of the leaf thus looks like an inverted V (Fig. 6-10). Fruit from trees with magnesium deficiency are generally small in size, and contain a low level of sugar and acidity.

Boron (B) deficiency and toxicity

If the boron content of the leaf is less than 25 mg/kg, deficiency symptoms may appear, particularly during a drought. Boron deficiency is more likely to occur in dry years, especially in calcareous soils.

Symptoms of boron deficiency include poor development of the flower's pollen tube, and subsequent pollination failure and poor fruit set. Boron deficiency often causes fruit to be abnormal in shape and "as hard as stones", "stone fruit". Such fruit are also lacking in juice (Fig. 6-11).

Growers should avoid excessive applications of boron. Toxicity symptoms usually occur in old leaves, which show a scorching or yellowing of the margins and tips (Fig. 6-12). Small brown spots may appear on the leaf blades. Leaves on trees with severe boron toxicity may drop off, or wilt until they are dead.



(Above) Fig. 6-8. The Liucheng orange trees on the right (rows C and D) have high potassium status. The fruits are larger than the normal ones (rows A and B) but the surface of the peel is rough, and they have higher acidity.



Fig. 6-9. Tankan hybrid showing symptoms of magnesium deficiency. These begin on the edges, tips and interveins of old leaves, or the bottom leaves of a fruiting twig. The young leaves remain green. In severe cases, the entire leaf becomes brown, except for an inverted V of green near the stalk.



Fig. 6-10. Typical symptom of magnesium deficiency in leaves of Ponkan mandarin: An inverted V of green in a chlorotic leaf.

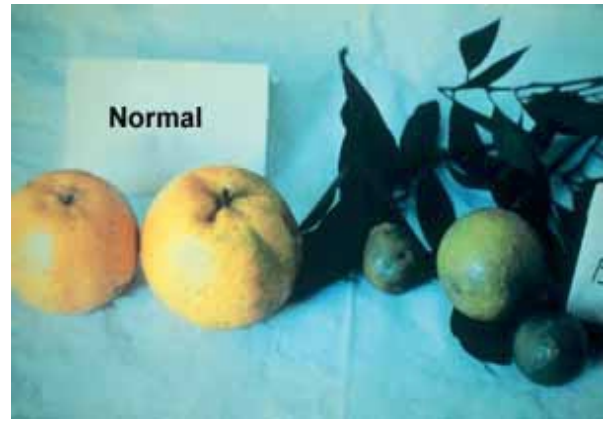


Fig. 6-11. Symptoms of boron deficiency (right): Abnormally shaped fruit, and fruit which are "as hard as stones" and lacking in juice.



Fig. 6-12. Symptoms of boron toxicity in Ponkan mandarin. These are seen on old leaves, which show scorching or yellowing on the margins and tips, sometimes with little brown spots.



Fig. 6-13. Symptoms of mild zinc deficiency in Ponkan mandarin. There is interveinal chlorosis of young leaves at the shoot tips, while the old leaves remain normal.



Fig. 6-14. Symptoms of severe zinc deficiency in Liucheng orange. The leaves show interveinal chlorosis, and are smaller and narrower than normal with shortened internodes, resulting in poor yields.



Fig. 6-15. Twig of Liucheng orange with typical symptoms of zinc deficiency

Zinc (Zn) deficiency

The critical concentration of zinc in citrus leaves is 25 mg/kg. If there is less than this, symptoms of zinc deficiency may occur. Mild zinc deficiency symptoms are interveinal chlorosis of young leaves at the shoot tips (Fig. 6-13), while old leaves remain normal. With severe zinc deficiency, young leaves become small and narrow, with shortened internodes (Fig. 6-14 and Fig. 6-15). Yields are low.

There are several possible reasons for zinc deficiency. It may be caused by an insufficient supply of native zinc in the soil, or a high soil pH may reduce the availability of zinc to plants. Some cases of zinc deficiency are caused by citrus tristeza virus (Fig. 6-16), or by fungus diseases such as root rot and foot rot. Growers must treat zinc deficiency by disease control or by nutrient management, depending on the cause.

Manganese (Mn) deficiency

The symptoms of manganese deficiency are very similar to those of zinc deficiency. They appear in some citrus orchards when the concentration of manganese in the leaf is less than 25 mg/kg.

The difference between the two is that the color of the interveinal tissue of leaves with manganese deficiency is pale green in color. The leaf size and shape remains normal, and the internodes are not shortened (Fig. 6-17, Fig. 6-18 and Fig. 6-19).

The symptoms of manganese deficiency occur only in young leaves, not in old ones. They are more likely to occur if the soil pH is higher than 7.5. Grapefruit trees seem to be especially susceptible to manganese deficiency.



Fig. 6-16. Symptoms of zinc deficiency induced by citrus tristeza virus disease.



Fig. 6-17. Symptoms of manganese deficiency in orange induced by the application of too much lime. There is interveinal chlorosis only in the young leaves. The interveinal tissue is pale green in color, but the leaf size and shape is normal



Fig. 6-18. Symptoms of manganese deficiency. The younger leaves show interveinal chlorosis

Multiple deficiency symptoms in the same tree

In orchards growing on a calcareous (limestone) soil, symptoms of several nutrient deficiencies such as iron, manganese and zinc, may sometimes appear in the same tree at the same time. An example is shown in Fig. 6-20, where a pummelo tree shows different degrees of deficiency of iron, manganese and zinc. Some young leaves are yellowish white in color, showing only iron deficiency, while others show typical symptoms of zinc and manganese deficiency.

Another example is shown in Fig. 6-21, with deficiency symptoms of zinc and manganese simultaneously on the same grapefruit tree.

Trees with multiple deficiencies are difficult to diagnose from the visible symptoms alone. Leaf analysis is especially valuable in such cases, to indicate what fertilizers are needed to solve the problem.



Fig. 6-19. Typical symptoms of manganese deficiency in a twig from a grapefruit tree.



Fig. 6-20. Several deficiency symptoms (iron, manganese and zinc) occurring together in a Wentan pummelo tree grown in a calcareous soil. Some young leaves are a conspicuous whitish-yellow color, showing iron deficiency, while others show typical symptoms of zinc or manganese deficiency.



Fig. 6-21. *Upper row.* Left, normal grapefruit tree leaf. The two leaves on the upper right show symptoms of manganese deficiency.

Lower row: The two grapefruit leaves on the left show combined zinc and manganese deficiency. The three leaves on the lower right have a combined deficiency of manganese, copper and zinc.