# Chapter 6. Boron deficiency

## PEANUT (*Arachis hypogaea* L.)

Plate 109

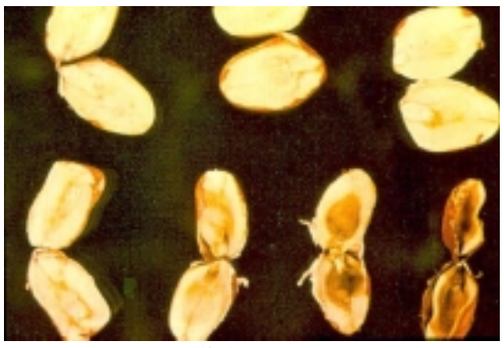

Plate 110

Plate 109. Recently mature leaves show watery lesions
Plate 110. Seed of peanuts with hollow heart

**Thailand: Tropical climate**

***Description of symptoms***

A distinctive symptom of boron deficiency of peanut is "hollow heart" inside the seeds. The damage increases as boron deficiency becomes more severe.

***Soil conditions likely to produce boron deficiency***

The condition is common on highly leached sandy soils with a low pH (4.8-6.0) and a low organic matter content (less than 1.5%). In Thailand, boron deficiency is found in peanut growing in Oxic Paleustults in Khon Kaen Province.

***Diagnosis by soil analysis***

Boron deficiency is likely to be observed if the boron concentration in the soil is less than 0.14 mg/kg$^{-}$ (hot-water-soluble boron), especially if the pH is low (4.8-6.0) (Bell 1990).

***Diagnosis by plant analysis***

The critical level for deficiency is 12 mg/kg boron in the youngest fully expanded leaves. The critical level for deficiency is 10 mg/kg (dry weight) of boron.

***How to correct boron deficiency***

The deficiency can be corrected by the soil application of 0.5-1.0 kg/ha, applied in the form of borax. An alternative is the foliar application of borax at a very low rate of 50 g/ha. This should be done twice during the cropping season, once at the beginning of flower development, and once at the pod set stage.

*Photos and information from Dr. Youngyuth Osotsapar, Kasetsart University, Thailand*

## CAULIFLOWER (*Brassica oleracea* L. var. *botrytis* L.)

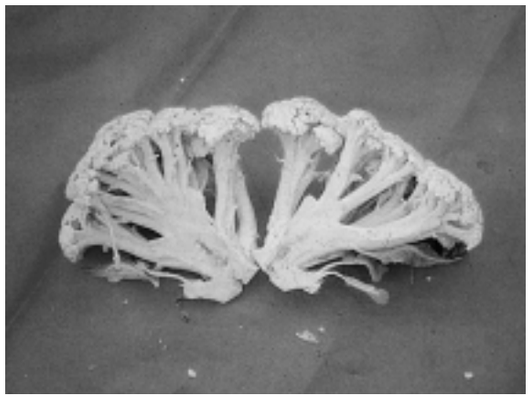

Plate 111. Cauliflower suffering from boron deficiency. The head is small and discolored.

**Taiwan: Subtropical climate**

*Photo by Mr. Ching-Hsee Lin, Taiwan ROC*

***Description of symptoms***

A common result of boron deficiency in cauliflower is an interruption in flowering and an empty space known as "hollow heart". Yields are poor, and the cauliflower heads are deformed or a discolored brown color.

***Climatic conditions likely to result in boron deficiency***

Boron deficiency is common in high-rainfall areas with high temperatures (more than 33°C), on acidic soils with a coarse texture. Soil boron is highly soluble, and easily leaches out from such soils.

***Soil conditions likely to result in boron deficiency***

Boron deficiency is common in calcareous soils (with a pH higher than 7.5), and soils with a very low soil boron content (less than 0.5 mg/kg hot-water-soluble B). The condition is also often found in sandy soils and acidic soils (pH lower than 5), soils with a very low organic matter content (lower than 0.75%), and soils derived from acid igneous rocks (granite). Boron deficiency may also be encountered in soils which have been given excessive applications of nitrogen and potassium fertilizers.

***Diagnosis by soil analysis***

Levels of hot-water-soluble boron (HWS-B) in low or deficient soils are less than 0.5 mg/kg. In soils with medium and adequate levels, the boron content is 0.5 - 2 mg/kg. Soils with high or excessive levels contain more than 2 mg/kg. Thus, soils with a level of boron (HWS-B) of 0.5 or less can probably not supply enough boron to support normal plant growth and yields.

***Diagnosis by plant analysis***

In most crops, a level of boron in plant tissue of 15-100 mg/kg is considered adequate for normal growth. More than 200 mg/kg is probably excessive, and may induce toxicity which reduces crop growth and yields.

***How to correct boron deficiency***

The problem of boron deficiency can be easily solved by applying boron, usually in the form of borax, a white crystalline salt. The quantities needed for the crop are very small. As little as 5-10 kg/ha can correct boron deficiency of cauliflower in Taiwan.

Alternatively, a foliar spray of 0.4% of borax solution can applied repeatedly every 10 days until the deficiency is corrected. For calcareous soils, sulfur should be applied at a rate of 2 mt/ha, to reduce the soil pH to 6.0 - 7.0.

*Information from Dr. Zueng-Sang Chen, National Taiwan University*

## PEPPER (*Capsicum annuum* L.)

Plate 112

Plate 113

Plate 112. Pepper plants with manganese deficiency. They were in a hydroponic culture in a plastic greenhouse without boron nutrition. The plants are stunted, and the leaves are smaller than normal.
Plate 113. The growing points die and decay, and the leaves are misshapen.

**Korea: Temperate climate**

***Description of symptoms***

Pepper plants with boron deficiency are stunted or dwarfed. The leaves are small, and often become twisted and discolored.

***Description of soil and climatic conditions likely to result in boron deficiency***

The severity of boron deficiency symptoms depends on other factors beside the boron content of the soil. High soil moisture and the application of too much lime may contribute to boron deficiency in crops.

***How to correct boron deficiency***

The condition can be corrected by a soil application of 10 kg/ha of borax. The pH of the soil, and of any nutrient solution used, should be adjusted to 5.5-6.5.

*Photos and information from Dr. Byoung-Choon Jang, National Institute of Agricultural Science and Technology, Korea*

## CUCUMBER (*Cucumis sativus* L.)

Plate 114

Plate 115

Plate 116

Plate 114. Cucumber plant with boron deficiency showing abnormal shoots. The apical growing points are stunted and eventually die. The plants were grown by hydroponic culture in a plastic greenhouse, without boron nutrition.

Plate 115. Cucumber plant with deformed, chlorotic and necrotic leaves and dying growing points, the result of very severe boron deficiency.

Plate 116. Cucumber plant with cracks in the stem and deformed fruits as a result of boron deficiency.

**Korea: Temperate climate**

***How to correct boron deficiency***

The condition can be corrected by the soil application of 10 kg/ha of borax. The pH of the soil and nutrient solution should be adjusted to 5.5-6.5.

*Photos and information from Dr. Byoung-Choon Jang, National Institute of Agricultural Science and Technology, Korea*

## TOMATO (*Lycopersicon esculentum* Mill.)


Plate 117

Plate 118

Plate 117. Tomato plant with boron deficiency are stunted. The leaves are smaller than normal, and gradually assume a variegated appearance. The plants were grown in a plastic greenhouse by hydroponic culture, without boron nutrition.
Plate 118. The growing points die and decay. Leaves with boron deficiency are misshapen and discolored.

**Korea: Temperate climate**

***Description of symptoms***

Tomato plants with boron deficiency have stunted growth and are dwarfed. The leaves are twisted and small in size, and may have a variegated appearance. The young shoots may wither and die.

***Conditions likely to result in boron deficiency***

As well as the level of boron in the soil, the severity of boron deficiency symptoms depends also on other factors such as high soil moisture and over-liming of the soil.

***How to correct borax deficiency***

The condition can be corrected by 10 kg/ha of borax, applied to the soil. The pH of the soil and nutrition solution should be adjusted to 5.5-6.5.

*Photos and information from Dr. Byoung-Choon Jang, National Institute of Agricultural Science and Technology, Korea*

## MELON (*Cucumis melo* L.)

Plate 119

Plate 120

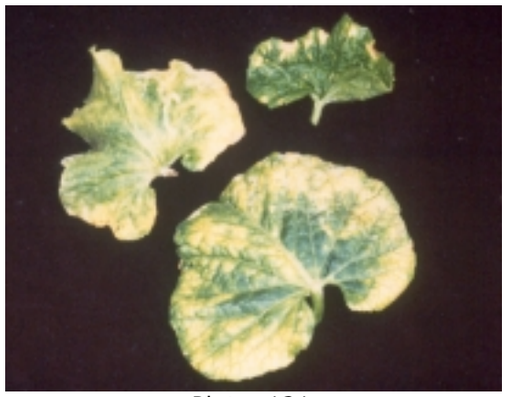

Plate 121

Plate 119. Melon plant with boron deficiency. The plant was cultivated without boron nutrition in hydroponic culture in a plastic greenhouse.

Plate 120 and Plate 121. Leaves of boron-deficient melon are curled and discolored.

**Korea: Temperate climate**

***Description of symptoms***

Melon plants suffering from boron deficiency become stunted or dwarfed. The young leaves of new shoots are smaller than normal, and curled back. They are often discolored with yellow mottles.

***Conditions likely to result in boron deficiency***

As well as the level of boron in the soil or nutrient solution, the severity of symptoms in boron-deficient plants also depends on other factors. The most important are a high soil moisture content and over-liming of the soil.

***How to correct borax deficiency***

The condition can be corrected by the application of 10 kg/ha of borax applied to the soil. The pH of the soil and nutrient solution should be adjusted to 5.5-6.5.

*Photos and information from Dr. Byoung-Choon Jang, National Institute of Agricultural Science and Technology, Korea*

## PINEAPPLE (*Ananas comosus* Merr.)

Plate 122. Pineapple plant suffering from boron deficiency

**Taiwan: Subtropical climate**

*Photo by Mr. Ching-Hsee Lin, Taitung District Agricultural Improvement Station, Taiwan ROC*

***Description of symptoms***

Boron deficiency of pineapple often produces an empty space in the fruit, known as "hollow heart" or "woody tissue". The leaves of pineapple plants which are deficient in boron are often thicker and harder than normal leaves. New leaves are curved together. Yields are poor, and the roots are abnormal. The fruit are often deformed, and are easily damaged.

***Climatic conditions likely to result in boron deficiency***

Boron deficiency is common in high-rainfall areas with high temperatures (more than 33°C), on acidic soils with a coarse texture. Soil boron is highly soluble, and easily leaches out from such soils.

***Soil conditions likely to result in boron deficiency***

Boron deficiency is common in calcareous soils with a pH higher than 7.5, and in soils with a very low soil boron content of less than 0.5 mg/kg boron (hot-water soluble). The condition is also found in sandy soils, in acidic soils with a pH lower than 5, in soils with a very low organic matter (content lower than 0.75%), and in soils derived from acid igneous rocks (granite). Boron deficiency may also be encountered in soils which have been given excessive applications of nitrogen and potassium fertilizers.

***Diagnosis by soil analysis***

Levels of water-soluble boron in low or deficient soils are less than 1.5 mg/kg. In soils with medium and adequate levels, the boron content is 1.5 - 3 mg/kg. Soils with high or excessive levels contain more than 3 mg/kg. Thus, soils with a level of hot-water-soluble boron of 1.5 or less can probably not supply enough boron to support normal pineapple plant growth and yields.

***Diagnosis by plant analysis***

A level of boron in plant tissue of 15-100 mg/kg is considered adequate for normal growth. More than 200 mg/kg is probably excessive, and may be toxic and reduce crop growth and yields.

***How to correct boron deficiency***

The problem of boron deficiency can be easily solved by applying boron, usually in the form of borax, a white crystalline salt. The quantities needed for the crop are very small. The application of 5 - 10 kg/ha can correct boron deficiency of pineapple in Taiwan.

Alternatively, a foliar spray of 0.3% borax solution should be applied three times from late summer to early winter (August to November), until the deficiency status is corrected. For calcareous soils, sulfur should be applied at a rate of 2 mt/ha to reduce the soil pH to 6.0 - 7.0

*Information from Dr. Zueng-Sang Chen, National Taiwan University*

## COCONUT (*Cocos nucifera* L.)

Plate 123

Plate 124

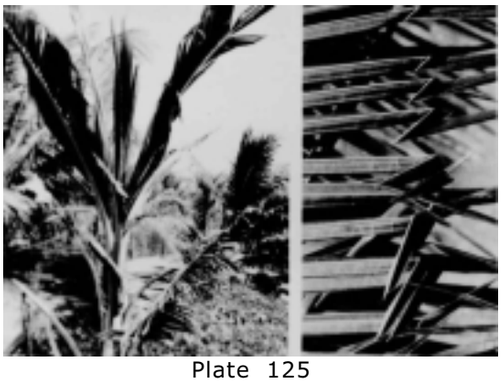

Plate 125

Plate 126

Plate 123. Boron deficiency in young coconut seedlings. The soil is a clay (Tropuldalf, Tugbok Series; Tropaquent).
Plate 124. Young coconut palms with boron deficiency
Plate 125 and Plate 126. Coconut palms with boron deficiency. The leaflets have not split as normal, giving the fronds a serrated appearance.

**Philippines: Tropical climate**

***Description of symptoms***

Boron deficiency of coconut is clearly shown in the apical shoot, the most actively growing tissues of the plant. It is also seen in very young leaves of seedlings and young palms. At an early stage of deficiency, “little leaf” or deformed fronds are seen. These are followed by abnormal leaflets which do not split as usual, so that the leaves have a serrated, zigzag appearance. At an advanced stage, the apical shoot eventually exhibits “blackening”, growth failure, and finally the death of tissues and the plant.

In the field, low yield of bearing palms is associated with boron deficiency as the result of sterility and malformation of reproductive organs (as coconut pollen). This causes very low fruit set and abnormal development of the nuts.

Symptoms of calcium deficiency - the abnormal growth of very young leaves and/or growing points of the plant - closely resemble those of boron deficiency. Both calcium and boron play a vital role in cell division and differentiation, and cell wall integrity. Both are highly immobile in the plant, so that if either or both are deficient, the growth of the plant is impaired. Marked

deficiency usually leads to the death of the bud. Leaf analysis, supplemented by soil analysis, can differentiate the two conditions.

***Climatic conditions likely to result in boron deficiency***

Boron deficiency of coconut is common in high-rainfall areas (over 2500 mm/year) with high temperatures (over 33°C). It is also found in areas with high light intensity during the dry season, especially in fairly dry areas.

***Soil conditions likely to produce boron deficiency***

The condition is common in alkaline, calcareous soils (with a pH higher than 8), and in highly acidic soils (with a pH lower than 4.5). As might be expected, it is also found in soils with a very low soil boron content (less than 0.5 mg/kg hot-water soluble boron). It is found in sandy soils (more than 65% sand content), in soils with a very low organic matter (lower than 0.75%), and in soils derived from acid igneous rocks (granite).

***Diagnosis by soil analysis***

Boron which is readily available as a nutrient for plants exists in the soil as the water-soluble form. The normal level ranges from 0.05 – 3 mg/kg, with arid soils having an exceptionally high boron content. For soil diagnosis, a level of less than 0.5 mg/kg of water-soluble boron is low or deficient. A medium or adequate level is 0.5 – 2 mg/kg, while soils with more than 2 mg/kg are considered to have a high or excessive boron content. Thus, soils with 0.5 mg/kg hot water soluble boron or less are probably incapable of supplying enough boron to support normal coconut growth and yield.

***Diagnosis by plant analysis***

In most crops, plant tissue boron of 15-100 mg/kg is considered adequate for normal growth, while more than 200 mg/kg might be expected to be excessive, and have a toxic or depressive effect.

However, in monocotyledons such as coconut, the range observed is 7-60 mg/kg. The critical boron concentration, below which deficiency is likely, in reference leaves is as follows:

| Leaf Rank | Stage | Critical level (mg/kg) |
|---|---|---|
| Leaf No. 1 | Nursery | At least 14 |
| Leaf No. 4 | Young Palm | 13 |
| Leaf No. 9 | Pre-Bearing | 12 |
| Leaf No. 14 | Bearing | At least 11 |

A leaf concentration (mg/kg) at or below the critical level indicates that growth or yield is not being optimized. Correcting the boron deficiency will probably improve both the growth and the yields, and more than justify the cost of the applied boron.

***Interaction with other elements***

In most plants, a high potassium concentration due to excessive applications of potassium fertilizers usually induces boron deficiency. A high level of soil calcium depresses the availability of boron in limestone soils. Therefore, in soils with excessive levels of boron, boron toxicity of plants may be avoided by the application of calcium. This will reduce the availability of the boron.

***How to correct boron deficiency***

Boron deficiency of coconut can be corrected either by spraying (0.2% borax or some other form of boron) or direct soil application at the appropriate rates of fertilization. Spraying is commonly practiced when coconut palms are at the nursery stage (1-1.50 g/seedling of boron).

There are several common sources of boron: borax (11% B); Sodium tetraborate (14% B); Disodium Octaborate Tetrahydrate (20% B), and Boric Acid (17% B).

Organic fertilizers such as chicken manure contain 15-100 mg/kg boron (an average of 45 mg/kg) and also improve the physical condition of the soil. They can supply many other micronutrients (zinc, copper, manganese, calcium, iron) as well as the major nutrients N, P and K.

Application of boron to coconut:

| Stage | Source (one only) | Rate | Time and Method |
|---|---|---|---|
| Nursery | Borax/Sodium Tetraborate | 0.2% (2 g/L $H_2O$) 75-100 mL/seedling | 1-2 times by spraying or drenching |
| 1 year old | Borax/Sodium Tetraborate/Octaborate | 5-10 g/plant application | Once each year to soil |
| 2-3 years old | Borax/Sodium Tetraborate/Octaborate | 15-20 g/plant application | Once each year to soil |
| 4 years old and more | Borax/Sodium Tetraborate/Octaborate | 30-50 g/plant application | Once every 2 years by soil |

Solid or granular forms of boron fertilizer may be mixed together with other mineral (inorganic) fertilizers. In some cases, growers may apply too much, and see 'tip-burning' of the leaf margins. This is due to the concentration of boron in the leaf margins (the natural behavioral movement of boron in leaves) and should not be a cause for alarm. It is better to correct the deficiency and have some level of toxicity, than ignore the deficiency which eventually makes the crop unproductive and farming marginal.

*Photos and information from Dr. Severino S. Magat, Philippine Coconut Authority*

## PAPAYA (*Carica papaya* Linn.)

Plate 127

Plate 128

Plate 127, Plate 128. Lumpy papaya fruit caused by boron deficiency

*Plate 127 by Dr. Su-San Chang, Plate 28 by Mr. Ching-Hsee Lin, Taiwan ROC*

**Taiwan: Subtropical climate**

***Description of symptoms***

In papaya, boron deficiency often results in an interruption in flowering and fruiting. The fruits are deformed with a bumpy appearance, and yields are poor.

***Climatic conditions likely to result in boron deficiency***

The deficiency is common in high-rainfall areas with high temperatures (more than 33°C), on acidic soils with a coarse texture. Soil boron is highly soluble, and easily leaches out from such soils.

***Soil conditions likely to result in boron deficiency***

Boron deficiency is common in calcareous soils (with a pH higher than 7.5), and soils with a very low soil boron content (less than 0.5 mg/kg hot-water soluble boron: HWS-B). The condition is also often found in sandy soils and acidic soils (pH lower than 5), soils with a very low organic matter (content lower than 0.75%), and soils derived from acid igneous rocks (granite). Boron deficiency may also be encountered in soils which have been given excessive applications of nitrogen and potassium fertilizers.

***Diagnosis by soil analysis***

Levels of boron (HWS-B) in low or deficient soils are less than 0.5 mg/kg. In soils with medium and adequate levels, the boron content is 0.5 - 2 mg/kg. Soils with high and excessive levels contain more than 2 mg/kg. Thus, soils with a level of boron (HWS-B) of 0.5 or less can probably not supply enough boron to support normal plant growth and yields.

***Diagnosis by plant analysis***

In most crops, a level of boron in plant tissue of 15-100 mg/kg is considered adequate for normal growth. More than 200 mg/kg is probably excessive, and have a toxic effect on crop growth and yields.

***How to correct boron deficiency***

The problem of boron deficiency can easily be solved by applying boron, usually in the form of borax, a white crystalline salt. The quantities needed for the crop are very small. As little as 0.5 to 5 g/plant or 5-10 kg/ha can correct boron deficiency of papaya in Taiwan.

Alternatively, a foliar spray of 0.4 % of borax solution can applied repeatedly every 10 days until the deficiency is corrected. For calcareous soils, sulfur should be applied at a rate of 2 mt/ha, to reduce the soil pH to 6.0 - 7.0.

*Information from Dr. Zueng-Sang Chen, National Taiwan University*

## CITRUS *(Citrus reticulata, Citrus grandis)*


Plate 129. Mandarin *(Citrus reticulata* Blanco, cv. Pongkan). Normal fruit (left) and citrus from tree with boron deficiency (right). The skin of boron deficient fruit is rough, and the fruit is hard with little juice.

*Photo by Dr. William T. F. Chiu, FFTC*

Plate 130. Pummelo *(Citrus grandis* Osbeck var. Mato-Wentan). The growing points of bunches with deficiency die (right). The leaves are smaller than normal (left) and gradually assume a variegated appearance.

*Photo by Mr. Ching-Hsee Lin, Taiwan ROC*

**Taiwan: Subtropical climate**

***Description of symptoms***

In mandarins, tangerines and pummelo, the skin of fruits becomes rough. The fruits are hard and lacking in juice. They are sometimes called “stone fruit”.

The growing points of the branches die and decay, and leaves with boron deficiency become twisted and discolored. The leaves are smaller than normal, and gradually assume a variegated appearance. Yields are poor.

***Climatic conditions likely to result in boron deficiency***

Boron deficiency is common in high-rainfall areas with high temperatures (more than 33°C), on acidic soils with a coarse texture. Soil boron is highly soluble, and easily leaches out from such soils.

***Soil conditions likely to result in boron deficiency***

Boron deficiency is common in calcareous soils (with a pH higher than 7.5), and soils with a very low soil boron content (less than 0.5 mg/kg hot-water soluble boron (HWS-B)). The condition is also often found in sandy soils and acidic soils (pH lower than 5), soils with a very low organic matter content (lower than 0.75%), and soils derived from acid igneous rocks (granite). Boron deficiency may also be encountered in soils which have been given excessive applications of nitrogen and potassium fertilizers.

***Diagnosis by soil analysis***

Levels of boron (HWS-B) in low or deficient soils are less than 0.5 mg/kg. In soils with medium and adequate levels, the boron content is 0.5 - 2 mg/kg. Soils with high or excessive levels contain more than 2 mg/kg. Thus, soils with a level of hot-water-soluble boron of 0.5 or less probably do not supply enough boron to support normal citrus growth and yields.

***Diagnosis by plant analysis***

In Ponkan mandarins, a level of boron in plant tissue of 20 mg/kg is considered adequate for normal growth. More than 200 mg/kg is probably excessive, and may be toxic and depress crop growth and yields.

***How to correct boron deficiency***

The problem of boron deficiency can be easily solved by applying boron, usually in the form of borax, a white crystalline salt. The quantities needed for the crop are very small. As little as 5-10 kg/ha can correct boron deficiency of citrus in Taiwan.

Alternatively, a foliar spray of 0.25% of borax solution can applied repeatedly every 10 days until the deficiency is corrected. For calcareous soils, sulfur should be applied at a rate of 2 mt/ha. This reduces the soil pH to 6.0, and increases the solubility of boron in the soil solution.

*Information from Dr. Zueng-Sang Chen, National Taiwan University*

## MANGO (*Mangifera indica* L.)

Plate 131

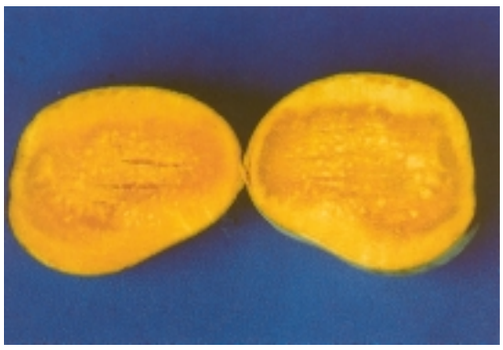

Plate 132

Plate 133

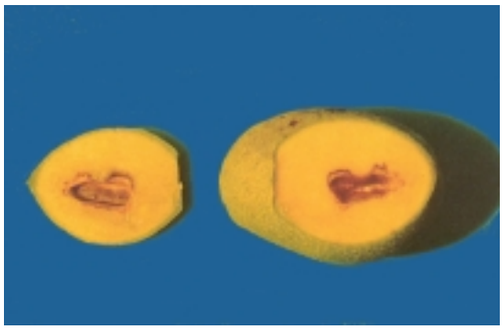

Plate 134

Plate 131. The fruit of mango (var. Irwin) with boron deficiency. The fruits are brown in color and hard with little juice (so-called "stone fruit"). The seeds are brown and crack easily.

Plate 132. The flesh of mango fruit (var. Keitt) with boron deficiency is watery, with long cracks down the center.

Plate 133. The fruit of mango (var. Sensation) with boron deficiency. This is dark in color and too soft.

Plate 134. The center of mango fruit (local variety) with boron deficiency is brown in color. The fruit is hollow, hard and lacking in juice, a so-called "stone fruit".

*Photos by Mr. Ming-Fong Liu, Taiwan ROC*

**Taiwan: Subtropical climate**

***Description of symptoms***

The fruit of mango trees with boron deficiency become brown in color, and hard. The seeds are also brown, and crack easily. The fruit are hard and lacking in juice, sometimes called "stone fruit". The flesh may be soft and watery, with long cracks down the center.

***Climatic conditions likely to result in boron deficiency***

Boron deficiency is common in high-rainfall areas with high temperatures (more than 33°C), on acidic soils with a coarse texture. Soil boron is highly soluble, and easily leaches out from such soils.

***Soil conditions likely to result in boron deficiency***

Boron deficiency is common in calcareous soils (with a pH higher than 7.5), and soils with a very low soil boron content (less than 0.5 mg/kg of hot-water soluble boron (HWS-B)). The condition is also often found in sandy soils and acidic soils (pH lower than 5), soils with a very low organic matter (content lower than 0.75%), and soils derived from acid igneous rocks (granite). Boron deficiency may also be encountered in soils which have been given excessive applications of nitrogen and potassium fertilizers.

***Diagnosis by soil analysis***

Levels of boron (HWS-B) in low or deficient soils are less than 0.5 mg/kg. In soils with medium and adequate levels, the boron content is 0.5 - 2 mg/kg. Soils with high or excessive levels contain more than 2 mg/kg. Thus, soils with a level of hot-water-soluble boron of 0.5 or less can probably not supply enough boron to support normal plant growth and yields.

***Diagnosis by plant analysis***

In mango, a level of boron in plant tissue of 20 mg/kg is considered adequate for normal growth. More than 200 mg/kg is probably excessive, and may be toxic and depress crop growth and yields.

***How to correct boron deficiency***

The problem of boron deficiency can be easily solved by applying boron, usually in the form of borax, a white crystalline salt. The quantities needed for the crop are very small. As little as 5-10 kg/ha can correct boron deficiency of mango in Taiwan. Ammonium sulfate can applied to reduce the soil pH to 6, thus increasing the solubility of boron in the soil solution.

Alternatively, a foliar spray of 0.25% borax solution can be applied every 10 days until the deficiency is corrected.

*Information from Dr. Zueng-Sang Chen, National Taiwan University*