Chapter 8. Micronutrient toxicities

ZINC TOXICITY OF RICE (*Oryza sativa* L.)

Plate 141

Plate 142

Plate 141. Field rice (*var. Chuchungbyeo*) at the heading stage, with slight symptoms of zinc toxicity in the older leaves
Plate 142. Leaves of rice plant with severe symptoms of zinc toxicity

Korea: Temperate climate

Description of symptoms

The symptoms of zinc toxicity in rice plant occur in the lower leaves. Severely affected leaves show reddish-brown necrotic spots or white blotches.

How to correct zinc deficiency

Growers should apply lime, to increase the soil pH. If possible, they should bring healthy soil to the field and mix it with the deeper soil

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

BORON TOXICITY OF RICE (*Oryza sativa* L.)

Plate 143

Plate 144

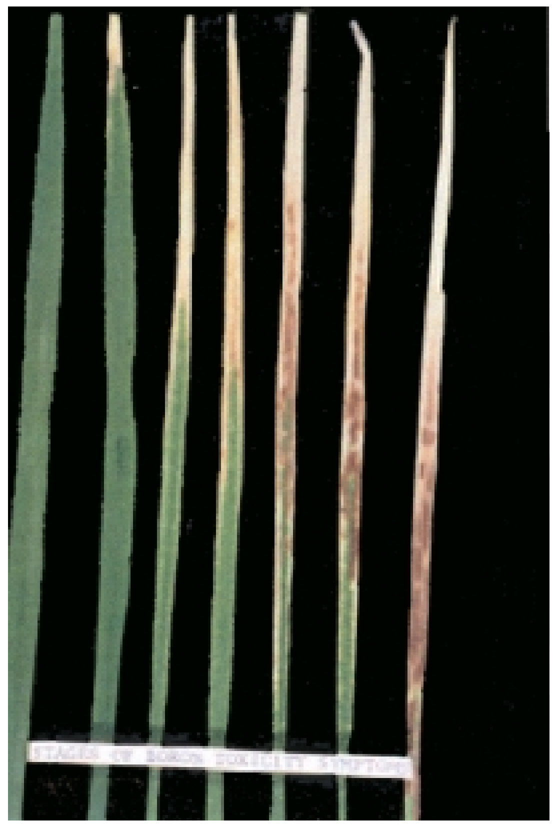

Plate 145

Plate 143. Rice leaf showing typical symptoms of boron toxicity
Plate 144. Progression of boron toxicity symptoms on rice leaves
Plate 145. Damage from boron toxicity in a paddy field near a volcanic area and irrigated with water high in boron

Photos by the International Rice Research Institute, Philippines

Description of symptoms

The first symptom is the appearance of a light brown or yellowish white discoloration on the tips and margins of the older leaves about six weeks after transplanting. As the disorder progresses, the tips and leaf margins turn yellow. Two to four weeks later, elliptical dark brown blotches appear in the discolored areas in most rice varieties, although not all. Finally the entire leaf blade turns light brown and withers.

Vegetative growth is not markedly depressed unless the problem is severe. The necrosis may be mistaken for brown-spot disease. However, in brown-spot diseases, the oval necrotic spots appear over the entire leaf area. In cases of boron toxicity, the elliptical brown blotches are on the discolored area along the leaf margin.

Soil conditions likely to produce boron toxicity

Rice crops are at risk of boron toxicity in arid irrigated areas, in saline, sodic and coastal soils, and in volcanic areas irrigated with well water.

Diagnosis by soil analysis

The following boron concentrations in the soil are considered critical levels for toxicity: 5 mg/L extracted by hot water, 4 mg/kg extracted with 0.05M HCl, and 2.5 mg/L in the soil solution.

Diagnosis by plant analysis

The critical toxicity level of boron in rice plants is 35 mg/kg in the shoot at tillering, and 100 mg/kg in rice straw at maturity.

How to correct boron toxicity

Growers should use irrigation water with a low boron content. The boron should be leached from the soil by low-boron water.

Rates of fertilizer application will vary, depending on the type of soil where the toxicity occurs.

Information from Dr. Corinta Quijano-Guerta, International Rice Research Institute, Philippines

IRON TOXICITY OF RICE (*Oryza sativa* L.)

Plate 146

Plate 147

Plate 148

Plate 149

Plate 146. Rice leaf showing typical symptoms of bronzing from iron toxicity
Plate 147. Rice plant at the flowering stage exhibiting leaf bronzing, stunted growth, depressed tillering and reduced grain yield
Plate 148. Plants affected by iron toxicity. Iron has precipitated onto the soil surface under acid field conditions.
Plate 149. Varietal differences in tolerance to iron toxicity

Photos by the International Rice Research Institute, Philippines

Description of symptoms

Symptoms of iron toxicity in rice are variable. Small brown spots appear on the lower leaves, starting at the tips. This is termed "bronzing". Later, the entire leaf turns brown, purple, yellow or orange, depending on the variety. The leaves of some varieties may roll. In severe cases of iron toxicity, the lower leaves turn brown and die. Growth and tillering are depressed, and the root system is coarse, scanty and dark brown. If iron toxicity occurs at a late stage of crop growth, vegetative growth is not severely affected but the grain yield is reduced because of sterility.

Soil conditions likely to produce iron toxicity

Iron toxicity severely limits production of wetland rice on strongly acid soils (with a pH of more than 5), which contain moderate to high amounts of organic matter and reactive iron.

Iron toxicity occurs in young acid sulfate soils; poorly drained colluvial and alluvial sandy soils; in valleys receiving interflow water from adjacent acid highlands; and in alluvial or colluvial clayey acid soils, and acid peat soils.

Soil features that are also associated with iron toxicity, aside from low pH, are low cation exchange capacity, low base status, low levels of potassium, phosphate and zinc, and a low supply of easily reducible manganese.

Diagnosis by soil analysis

The reported values of iron toxicity levels in the soil solution range from 10-1000 mg/L. This wide range indicates the lack of specific criteria for iron toxicity. The form of the iron, the growth stage and variety of the rice, the presence of respiration inhibitors, the nutrient status, and environmental factors all affect the toxicity level.

In acid sulfate soils, iron toxicity generally occurs because the solubility of iron is very high, even if the supply of nutrients is adequate. In soils with a low nutrient status, iron toxicity may be observed at relatively low levels of water-soluble iron.

In sandy soils receiving a continuous supply of iron from interflow, symptoms of iron toxicity may occurr at levels of only 40-100 mg/L.

Diagnosis by plant analysis

Shoots of plants affected by iron toxicity usually, but not always, have 300-500 mg/kg of iron. It is possible that the iron content of leaves showing symptoms may be the same as, or even lower than, that of healthy plants, if the toxicity is induced by the low nutrient status of the soil and mineral imbalances in the plant.

The roots of rice plants with iron toxicity are poorly developed, black, decaying and coated in iron.

Interaction with other elements

Iron toxicity is often associated with a deficiency of phosphate, potassium, zinc, calcium and manganese. It is also often associated with a marked imbalance of nutrients, or the presence of hydrogen sulfide (H_2S).

How to correct iron toxicity

Reclamation can be carried out by means of liming. The application of manganese oxide (MnO_2) at a rate of 50-100 kg/ha may help correct iron toxicity by maintaining the correct iron/manganese ratio in the plant.

The application of NPK fertilizer and zinc is recommended. Acidifying nitrogen sources should not be used.

Other cultivation practices

Prolonged soil submergence and delayed planting may help reduce iron toxicity. So may the incorporation of organic matter into the soil. Growers should choose varieties tolerant of excess iron, to reduce the need for applications of lime and manganese dioxide.

Information from Dr. Corinta Quijano-Guerta, International Rice Research Institute, Philippines

MANGANESE TOXICITY OF RICE (*Oryza sativa* L.)

Plate 150

Plate 151

Plate 152

Plate 150. Rice leaf showing typical symptoms of manganese toxicity
Plate 151. Rice plant at the vegetative stage with injury from manganese toxicity
Plate 152. Damage from combination of manganese and aluminum toxicity under severely acid field conditions

Photos by the International Rice Research Institute, Philippines

Description of symptoms

Visual symptoms of manganese toxicity in rice appear as brown spots on older leaves. The tips of the leaves dry out about eight weeks after planting. Vegetative growth is not appreciably affected, but grain yield is markedly depressed because of high sterility.

Soil conditions when manganese toxicity is likely

Manganese toxicity is sometimes observed in dryland rice where the soil has a pH of less than 5.5

It rarely occurs in lowland paddy soils, but may occur if the soil contains very large amounts of easily reducible manganese, or in areas contaminated by manganese mining.

Diagnosis by soil analysis

The toxicity is probably related to the concentration of easily reducible manganese in the soil, but no critical level is known. An aqueous soil solution with a manganese level of more than 2mg/L is considered toxic.

Diagnosis by plant analysis

A manganese content greater than 7000 mg/kg in the shoot at tillering, or more than 3000 mg/kg manganese in leaves at flowering, are considered the critical limits.

Interaction with other elements

The solubility of manganese increases sharply in aerobic soils as the pH drops below 4.5, while that of iron hardly changes until the pH is down to 2.7-3.0. This fall in pH increases the ratio of manganese to iron, leading to manganese toxicity. However, it does not follow that manganese toxicity induces iron deficiency, or vice versa.

Silica has been reported to alleviate manganese toxicity by decreasing the uptake of manganese, and by increasing the internal tolerance to manganese in the plant tissue. Manganese toxicity is usually accompanied by aluminum toxicity and phosphorus deficiency.

How to correct manganese toxicity

Liming is a remedy for manganese toxicity. The application of ferrous sulfate ($FeSO_4$), gypsum and farmyard manure can also be helpful, as can be application of silica slag at a rate of 1.5 to 3 mt/ha. NPK fertilizer is often needed, but acidifying nitrogen sources should not be used.

Other cultivation practices

Incorporating rice straw into the soil may help replenish levels of silica and potassium.

Information from Dr. Corinta Quijano-Guerta, International Rice Research Institute, Philippines

ALUMINUM TOXICITY OF RICE (*Oryza sativa* L.)

Plate 153

Plate 154

Plate 155

Plate 153. Rice plant at the vegetative stage showing injury from aluminum toxicity
Plate 154. Leaf showing typical symptoms of aluminum toxicity
Plate 155. Damage to upland rice from aluminum toxicity under acid field conditions

Photos by the International Rice Research Institute, Philippines

Description of symptoms

Rice suffering from aluminum toxicity shows interveinal white to yellow discoloration of the tips of older leaves, which may later turn necrotic. The roots of affected plants are stunted and deformed.

Soil conditions likely to produce aluminum toxicity

Aluminum toxicity commonly occurs in Oxisols and Ultisols as well as in other heavily leached soils such as lateritic soils of the humid tropics. It is an important growth limiting factor on upland soils with a pH of less than 5.

Aluminum toxicity in wetland rice is observed in most acid sulfate soils during the initial phase of soil flooding. The rise in pH of acid sulfate soils after submergence is very slow, so that toxicity may persist for many weeks.

Diagnosis by soil analysis

A soil pH of less than 4, and an aluminum concentration in the soil solution of more than 1 mg/L, indicate toxic levels of aluminum.

Diagnosis by plant analysis

An aluminum concentration of more than 300 mg/kg in the shoot at the tillering stage is generally considered toxic.

Interaction with other elements

Aluminum toxicity in upland rice is always associated with manganese toxicity and phosphorus deficiency. Aluminum toxicity hinders the uptake by rice of phosphorus, calcium and potassium.

How to correct aluminum toxicity

Liming will increase the soil pH. Growers should use dolomitic lime, if possible. It is necessary to apply phosphorus and potassium fertilizers. Acidifying nitrogen sources should not be used.

Other cultivation practices

Early plowing is recommended, right after the recession of floods at the end of the rainy season. Acid sulfate soils should have a shallow drainage system.

The rice should be planted after prolonged soil submergence, and growers should select rice varieties with tolerance to aluminum toxicity.

Information from Dr. Corinta Quijano-Guerta, International Rice Research Institute, Philippines

BORON TOXICITY OF SWEET POTATO (*Ipomoea batatas* Poir)

Plate 156

Plate 157

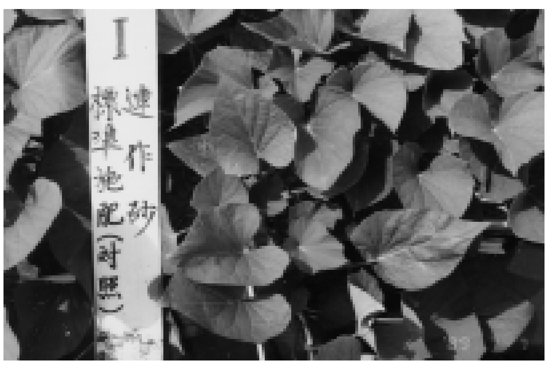

Plate 158

Plate 159

Plate 156. Sweetpotato grown with mulching film on Sand-dune Regosol, Tokushima Prefecture, Japan
Plate 157. Sweetpotato with boron toxicity. There are interveinal symptoms, and marginal chlorosis in leaves. In severe cases, the chlorotic areas turn brown and become necrotic (die).
Plate 158. Normal plant
Plate 159. Severe symptoms of boron toxicity in plot with successive crops given boron fertilizer (2 mg/kg) of hot-water-soluble boron

Japan: Temperate climate

Description of symptoms

When sweetpotato take up too much boron, the margins of the leaves develop chlorosis and eventually burn. If the absorption of boron continues, the plant may die.

Soil conditions

In Tokushima Prefecture, Japan, boron toxicity is often found on sandy soils where new sand has been applied as a dressing to paddy fields (Kuroda *et al.* 1993). The sand contains 1-2 mg/kg boron that is derived from seawater. It accumulates on the beaches of northeastern Tokushima Prefecture.

Diagnosis by soil analysis

A level of hot-water-soluble boron greater than 1 mg/kg in the soil is likely to result in toxicity symptoms.

Diagnosis by plant analysis

Chlorosis on the margin leaves is likely to occur when the boron concentration in the leaves is higher than 200 mg/kg.

How to correct boron toxicity

In years when sea sand is applied to farmland as a dressing, no boron fertilizer should be applied. In the following years, the application of 1-1.5 kg/ha boron is recommended.

As time elapses and the crop grows, symptom are often no longer observed on newly developed leaf-blades. In such cases, boron toxicity tends to result in low productivity, or small and short roots.

Photos and information from Dr. Yasufumi Kuroda, Tokushima Agricultural College, Japan

BORON TOXICITY OF MELON (*Cucumis melo* L.)

Plate 160

Plate 161

Plate 162

Plate 160. Slight symptoms of boron toxicity in a melon plant in a pot trial. Early symptoms occur on older leaves

Plate 161. Characteristic symptoms of boron toxicity, with chlorosis on the margins of the lower leaves of the melon plant

Plate 162. Leaves of a melon plant with severe boron toxicity. The whole leaf is chlorotic, with necrosis along the edges of the leaf

Korea: Temperate climate

Soil conditions likely to produce boron toxicity

In Korea, the symptoms of boron toxicity often appear in fields to which have been applied organic fertilizers made from agroindustrial wastes.

How to correct boron toxicity

The soil pH should be adjusted to 5.5-6.0. Before planting, fields should be irrigated with sufficient water to leach out the excess boron.

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

BORON TOXICITY OF CUCUMBER (*Cucumis sativus*)

Plate 163

Plate 164

Plate 165

Plate 163. Greenhouse crop of cucumber with boron toxicity, Miyazaki Prefecture

Plate 164. Cucumber plants in the field with boron toxicity. The soil is a wet Andosol.

Plate 165. Close-up of boron-deficient cucumber plant

Japan: Temperate climate

Description of symptoms

Boron toxicity in cucumber is shown by necrosis along the margins of old leaves. There is cupping of the middle leaves, which take a concave shape, and chlorosis of the uppermost leaves.

Diagnosis by soil analysis

A level of hot-water-soluble boron of more than 18 mg/kg is likely to result in boron toxicity.

Photos and information from Dr. Akitoshi Yokoyama, Miyazaki Agricultural Experiment Station, Japan

BORON TOXICITY OF PERILLA (*Perilla frutescens Britto* var. *crispa*)

Plate 166

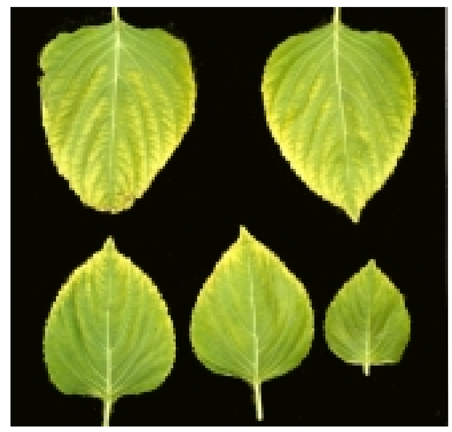

Plate 167

Plate 168

Plate 169

Plate 171

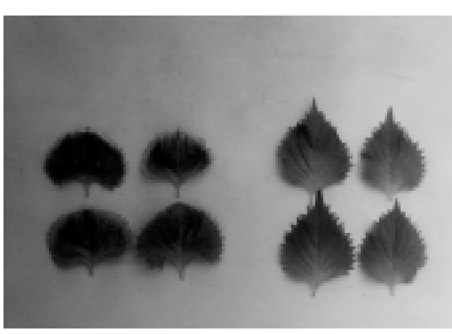

Plate 170

Plate 166. Severe symptoms of boron toxicity in perilla crop (var. *typica* Makino) grown in a plastic greenhouse in Korea. The foliage was sprayed with a nutrient solution containing a high concentration of boron. The soil was a clay loam, a former paddy soil.

Plate 167. Perilla leaves with progressively more serious symptoms of boron toxicity from lower right to top left

Plate 168: Perilla crop in greenhouse with severe boron toxicity
Plate 169: Field crop of perilla (Va. *Vojiso*) with boron toxicity. The crop was grown on a sand-dune Regosol in Saga Prefecture, Japan. The leaf margins trun brown on one-day-old leaves, and yellow on new leaves.
Plate 170: Damaged leaves (left) and normal ones
Plate 171: Close-up of damaged leaves in Plate 170
(Plates 166 - 168, Korea. Plates 169 - 171, Japan)

Korea and Japan: Temperate climate

Description of symptoms

The leaves show chlorosis along the margins, and are holded back. the first symptoms appear in the left tips. The ssymptoms of boron toxicity in plants are generally found on the lower leaves, but may appear on upper leaves, if these have been sprayed.

Diagnosis by soil analysis

The level of hot-water-soluble boron (mg/kg) in normal plants (0-20 cm) was 0.58. The level of hot-water-soluble boron in plants of the same size damaged by boron toxicity was 3.08 mg/kg.

Diagnosis by plant analysis

The boron content in normal (young) leaves was 35 mg/kg. In old leaves damaged by boron toxicity it was 158 mg/kg.

How to correct boron toxicity

Boron which has accumulated on the leaves should be washed off with water, or can be leached from the soil by irrigation.

Photos and information from Dr. Byoung-Choon Jang, National Institute of Agricultural Science and Technology, Korea. Dr. Susumu Eguchi, Ferro Enamels (Japan) Ltd.