

MINERAL DEFICIENCY SYMPTOMS OF COFFEE

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INTRODUCTION

High yields of coffee (*Coffea arabica* L.) in the Kona district of Hawaii are attributed to Kona's unique climatic conditions, pruning, dense plantings, and high fertilization rates (1). Fresh cherry yields of 16,800 kg/ha have been recorded (4) and are estimated to remove 43.1, 3.6, and 38.1 kg/ha of nitrogen (N), phosphorus (P), and potassium (K) respectively (7). The importance of nitrogen and potassium for high yields was shown in a study in which coffee fields receiving low nitrogen and potassium fertilization had a nine-fold yield reduction within two years (3). Although a response to phosphorus fertilization was not observed in this study, yields increased 28 percent when nitrogen was supplemented with phosphorus and given in four applications during the crop cycle (2). It was concluded that when nitrogen requirements were satisfied, plants responded to phosphorus.

Three other macronutrients, and seven micronutrients, also are essential to crop production. The macronutrients are calcium (Ca), magnesium (Mg), and sulfur (S); the micronutrients are iron (Fe), zinc (Zn), boron (B), manganese (Mn), copper (Cu), molybdenum (Mo), and chlorine (Cl).

When plants are grown without adequate essential nutrients, characteristic deficiency symptoms result. Recognizing these visual symptoms can aid growers in assessing the nutritional status of their coffee crops and applying corrective measures. This study provides descriptions and photographs of mineral deficiency symptoms of the Guatemalan, Caturra, and Maragogipe (Java) coffee cultivars. Mineral nutrient concentrations in leaves of deficient and normal (control) plants are also given.

MATERIALS AND METHODS

Experiments were conducted in Hilo and Kona, Hawaii, between March 1984 and October 1985.

Seeds of the Guatemalan, Caturra, and Maragogipe cultivars were obtained from the University of Hawaii Experimental Station in Kona, germinated in vermiculite, and planted into 15.5x11.5-cm pots containing vermiculite. Plants were kept in a fiberglass greenhouse and irrigated twice a week with 200 ml of a complete nutrient solution (5). The medium was leached with 200 ml distilled water every two weeks. After reaching heights of 15 cm (Guatemalan and Caturra cultivars) and 25 cm (Maragogipe cultivar), plants were transplanted to 15.5x11.5-cm pots containing perlite. Control plants were then watered three times a week with 200 ml of a complete nutrient solution; test plants were similarly watered with a solution lacking in nitrogen, phosphorus, potassium, calcium, magnesium, sulfur, or iron (5). The pH of the solutions was adjusted to 6.5–6.8 with 1.0 N HCl or NaOH. Pots were leached with 200 ml distilled water every two weeks. The study was set up in a statistically random design with two to four plants per treatment.

When visual symptoms became severe, all fully expanded leaves were harvested from deficient and control plants and analyzed for nutrient content with an X-ray fluorescent quantometer. The experiments were performed three times for the Guatemalan and twice for the Caturra and Maragogipe cultivars.

Only the Guatemalan cultivar was used to observe boron and zinc deficiencies. Plants 15 cm high were transferred to foil-covered wide-mouth glass jars containing 850 ml of a complete solution (control) or solutions lacking zinc or boron (5). Solutions were adjusted to pH 6.5, constantly aerated, and replaced at two-week intervals. Plants were kept in a fiberglass greenhouse. Each treatment consisted of two replicate plants. After six months the plants were analyzed for nutrient content as previously described.

Table 1. Abbreviated key to nutrient deficiency symptoms of coffee.

Symptoms	Deficient Nutrient
I. Originating in older leaves or generally on the entire plant.	
A. Uniform chlorosis or light interveinal chlorosis.	
1. Lower leaves exhibiting slight chlorosis, young leaves remaining darker green; faint interveinal chlorosis of older leaves at advanced stages; small necrotic spots may be present	Phosphorus
B. Localized necrosis or interveinal chlorosis evident on older leaves.	
1. Marginal chlorosis followed by development of dark brown necrotic spots on the margins; necrotic areas coalescing until entire margins are dark brown while the areas along the midrib remain green	Potassium
2. Faint marginal chlorosis with sunken, yellow-brown to light brown necrotic spots developing in a wide band along margins; interveinal chlorosis evident in affected leaves, particularly along the midrib	Magnesium
II. Originating in younger leaves near shoot tips.	
A. Uniform chlorosis to faint interveinal chlorosis; plants with sparse vegetative growth.	
1. Leaves rapidly becoming pale green; emerging leaves uniformly pale green with a dull green sheen. Entire plant becoming pale green, with sparse vegetative growth; leaves becoming yellow-green at advanced stages; whitish veins may be present in lower leaves	Nitrogen
2. Leaves light green to yellow-green, with faint interveinal chlorosis; deficient leaves retaining shiny luster	Sulfur
B. Sharp interveinal chlorosis of youngest leaves; older leaves unaffected.	
1. Leaves expanding normally, with vein network remaining green and clearly visible against the light green to yellow-green background; background becoming nearly creamy white at acute stages	Iron
2. Leaves not expanding normally; narrow, often strap-shaped; veins visible against a yellow-green background; failure of internode to elongate properly, giving plants a rosette appearance	Zinc
C. Bronzing, mottling, or necrosis of youngest leaves; dieback of terminal buds.	
1. Leaves bronzed along margins, cupped downward; emerging leaves necrotic; eventual dieback of terminal buds	Calcium
2. Youngest leaves light green, mottled, with uneven margins and asymmetric shape; emerging leaves with necrotic spots or tips	Boron

RESULTS AND DISCUSSION

Deficiency symptoms for nitrogen, phosphorus, potassium, calcium, magnesium, sulfur, and iron were consistent among all cultivars studied. A key to these symptoms is given in Table 1.

Nitrogen

Nitrogen deficiency, observed four to six weeks after treatments began, was characterized at first by general chlorosis of the youngest leaves (Fig. 1). Later, older leaves also became chlorotic (Figs. 2, 3), resulting in the entire plant having a pale green to yellow-green appearance. These observations agree with those of Muller (6), who noted that nitrogen deficiency of coffee grown in full sun develops rapidly in younger leaves. At the advanced stages, all leaves were dull, lacking their normal shiny appearance, with whitish veins occasionally present in older leaves (Fig. 3).

Shoot growth was severely inhibited in nitrogen-deficient plants; growth was reduced 50–75 percent compared with control plants (Fig. 2). Leaf nitrogen content on a dry weight basis was 1.46–1.92 percent in deficient plants and 3.0–3.72 percent in the controls.

Phosphorus

Phosphorus deficiency was the slowest of the macronutrient deficiencies to develop. Symptoms began as a slight mottled chlorosis of the older leaves (Fig. 4). Later, older leaves became more chlorotic, with faint interveinal yellowing (Fig. 5). At advanced stages, necrotic spots developed on the leaves. Root growth also was inhibited (Fig. 6). Leaf phosphorus concentrations were 0.05–0.08 percent in deficient plants and 0.14–0.18 percent in control plants.

Potassium

Potassium deficiency symptoms were localized in older leaves and first appeared as a chlorotic band along leaf margins. Later, dark brown necrotic spots developed along the leaf margins (Fig. 7). Spots continued to enlarge until entire margins were necrotic, with the central portion of the blade remaining green (Figs. 7, 8). Young leaves were unaffected. Leaves of deficient plants contained 0.36–1.07 percent leaf potassium, compared with 2.62–3.86 percent for control plants.

Calcium

Poor mobility of calcium within plants was evidenced by development of deficiency symptoms in the youngest leaves (Fig. 9). Young leaves turned bronze in color, particularly along the margins, while the area along the midrib stayed green; leaves did not expand normally and were cupped downward. In advanced stages, emerging leaves were necrotic, and eventually the entire apical bud died back (Fig. 10). Older leaves had some chlorosis, generally along the margins, or large necrotic patches on the blade. Poor root development was also observed in deficient plants (Fig. 11). Leaf calcium was 0.36–0.55 percent in deficient plants and 0.94–1.16 percent in control plants.

Magnesium

Plants deficient in magnesium first showed light chlorosis along margins of older leaves, then developed sunken, light brown necrotic spots in a wide band along the margins (Fig. 12). Interveinal chlorosis of the older leaves, particularly near the midvein, was also evident (Fig. 13). Older leaves eventually abscised after prolonged magnesium deficiency. Young leaves were unaffected. Deficient plants had leaf magnesium levels of 0.04–0.11 percent, whereas control plant levels were 0.30–0.35 percent.

Sulfur

Sulfur deficiency was characterized by general chlorosis of the youngest leaves. Faint, diffuse, interveinal yellowing was also evident, particularly along the midrib (Fig. 14), a symptom that helps to distinguish sulfur deficiency from nitrogen deficiency. Also unlike plants with nitrogen deficiency, sulfur-deficient plants did not lose their luster. Shoot growth was inhibited. At very advanced stages, older leaves also exhibited some chlorosis (Fig. 15). Leaf sulfur concentrations in deficient plants were 0.04–0.05 percent; control plants had concentrations of 0.12–0.17 percent.

Iron

Iron deficiency produced distinct interveinal chlorosis of younger leaves (Fig. 16). During early stages, leaf tissues between veins were light green (Fig. 17); later, interveinal areas became yellow or creamy white (Fig. 18). At advanced stages, veins remained green and clearly visible against



Figure 1. Nitrogen deficiency, early symptom. General chlorosis of young leaves. Control plant (left); three deficient plants (right).



Figure 2. Nitrogen deficiency, effect on shoot growth. General chlorosis of entire plant and reduction of vegetative growth after continued N deficiency (right).



Figure 3. Nitrogen deficiency, advanced symptoms. Entire plant pale green, with whitish veins evident after prolonged deficiency.



Figure 4. Phosphorus deficiency, early symptom. Mottled chlorosis of the oldest leaves.



Figure 5. Phosphorus deficiency, advanced symptoms. Faint interveinal yellowing of older leaves (left). Necrotic spots may develop in older leaves during acute deficiency (right).



Figure 7. Potassium deficiency, early and advanced symptoms. Older leaf with initial symptoms of chlorosis and necrotic spots along margins (left); in advanced deficiency, leaf margin is necrotic with a chlorotic halo (right).



Figure 6. Phosphorus deficiency, effect on root development. Deficient plant (left); control plant (right).



Figure 8. Potassium deficiency, advanced symptoms. Marginal necrosis of older leaves while young leaves remain unaffected.



Figure 9. Calcium deficiency, early symptom. Bronze coloration of young leaves.



Figure 11. Calcium deficiency, effect on root development. Deficient plant (left); control plant (right).



Figure 10. Calcium deficiency, advanced symptoms. Young leaves are necrotic, and the shoot apex dies back.



Figure 12. Magnesium deficiency, early symptoms. Chlorosis along margins of older leaves and development of a wide band of necrotic spots along leaf margins (left). Necrotic spots along margins are more numerous with continued deficiency (right).



Figure 13. Magnesium deficiency, advanced symptom. Interveinal chlorosis of older leaves.



Figure 14. Sulfur deficiency, early symptom. Chlorosis of young leaves, particularly along the midvein.

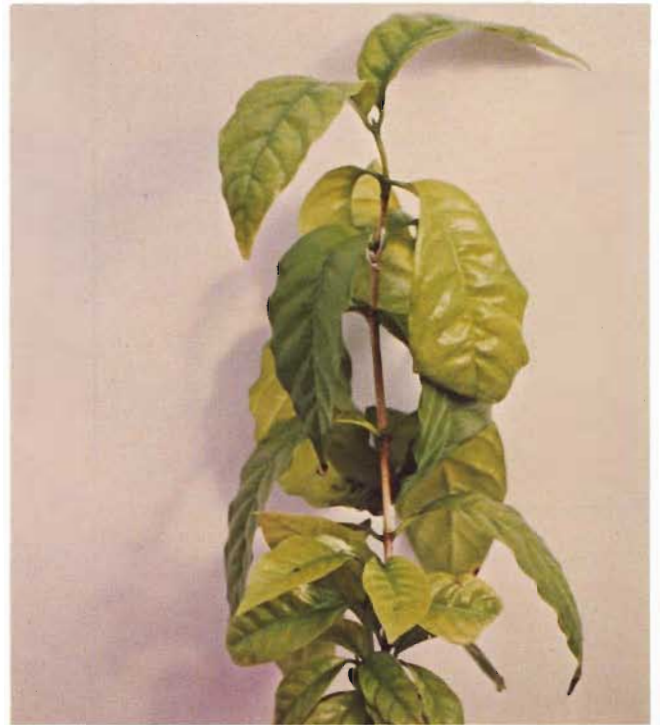


Figure 15. Sulfur deficiency, advanced symptoms. Reduction of vegetative growth and general or faint interveinal chlorosis of all leaves.



Figure 16. Iron deficiency, early symptom. Interveinal chlorosis of younger leaves.



Figure 17. Iron deficiency, advanced symptom. Distinct interveinal chlorosis in young leaf.



Figure 19. Boron deficiency, effect on shoot growth. Abnormal growth of shoot apex and young leaves.



Figure 18. Iron deficiency, severe. Young leaves are yellow-green to creamy white.



Figure 20. Boron deficiency, effect on leaf development. Young leaves mottled with necrotic spots.



Figure 21. Boron deficiency, advanced symptoms. Irregular margins of young leaves and abnormal growth of apical buds.



Figure 22. Zinc deficiency, early symptom. Inter-veinal chlorosis of young leaves.



Figure 23. Zinc deficiency, advanced symptoms. Young leaves interveinally chlorotic and straplike.



Figure 24. Zinc deficiency, severe. Plants rosette in appearance. Older leaves appear normal.

the light-colored mesophyll tissue. Although young leaves exhibited severe symptoms, older leaves remained green. Iron concentrations ranged from 1 to 25 ppm in deficient leaves and from 43 to 61 ppm in control leaves.

Boron

Boron deficiency resulted in abnormal growth of young leaves and the apical bud (Fig. 19). The youngest leaves were light green, smaller, curved, and mottled with small necrotic spots; leaf tips also were necrotic (Fig. 20). Failure of leaves to expand normally resulted in irregular margins (Fig. 21). Symptoms were also present on youngest leaves of lateral branches. Older leaves were unaffected. Boron concentrations were 9 ppm in leaves of deficient plants and 31–52 ppm in the control plants.

Zinc

Zinc deficiency showed in the youngest leaves and was characterized by interveinal chlorosis of the leaf blade. During early stages, symptoms resembled those of iron deficiencies (Fig. 22). In advanced stages, young emerging leaves remained small and narrow and were often straplike. Veins were dark green, particularly along the midrib; interveinal areas were yellowish-green (Fig. 23). Shortening of internodes also occurred, giving the plant a rosette appearance. Older leaves were unaffected (Fig. 24). Zinc levels in control plants ranged from 18 to 25 ppm (Table 1). Concentrations from the leaves of deficient plants were not available; however, zinc levels less than 10 ppm (8) and 15 ppm (6) have been reported for deficient plants.

GLOSSARY

Abscise: To shed plant parts, e.g., leaves, flowers, fruit.

Acute: Condition when severe symptoms are visible.

Apical Bud: Growing region at the tip of a shoot.

Blade: Broad, expanded part of the leaf.

Chlorosis: Yellowing of plant tissues due to loss of green pigmentation.

Internode: Region on a stem between two successive leaves or nodes.

Interveinal: Area on the leaf between the veins.

Macronutrient: An essential chemical element required in large amounts for growth of plants, e.g., nitrogen, phosphorus, potassium.

Mesophyll: Major tissue between veins in leaves.

Micronutrient: An essential chemical element required in small amounts for growth of plants, e.g. iron, boron, zinc.

Midrib (midvein): Main or largest vein on a leaf.

Necrosis: Death associated with discoloration and dehydration of plant tissues or organs.

ppm: Concentration unit: parts per million.

Replicate: Repeated under controlled conditions so that a specific result may be observed.

Rosette: Plant parts closely clustered in circular form around a stem.

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