Impact of Mineral Deficiency Stress

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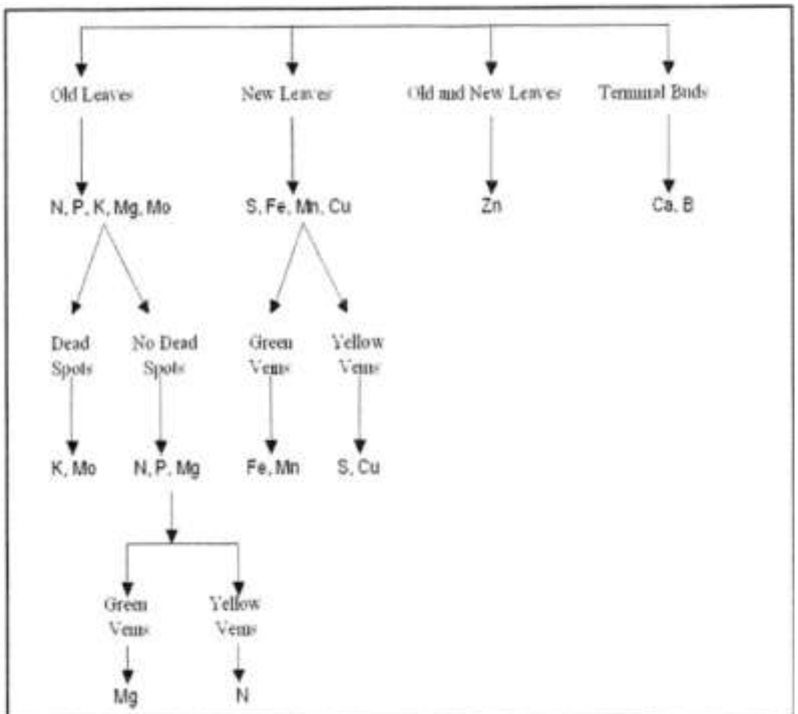

Fig. 1. Flowchart for the identification of deficiency symptoms according to Reddy and Reddi (1997).

A mineral element is considered as essential, when plants cannot complete reproductive stage of life cycle due to its deficiency. Deficiency must be corrected only by supplying the element in question and when the element is directly involved in the metabolism of the plant (Arnon, 1954). Based on these criteria, sixteen elements so far were identified as essential. These are: carbon, hydrogen, oxygen, nitrogen, phosphorus, potassium, calcium, magnesium, sulfur, iron, manganese, zinc, copper, boron, molybdenum and chlorine. Most of the carbon as carbon dioxide enters the plant from the air; hydrogen and oxygen are taken up as water. The rest of the elements are taken up from the soil solution as mineral nutrients. Among these nutrients N, P, K, Ca, Mg, and S are considered major or macro-nutrients, because they are required in large quantities that range between 1 to 150 g per kg of plant dry matter. Fe, Zn, Mn, Cu, B, Mo and Cl are minor or micro-nutrients that are required at rates of 0.1 to 100 mg per kg of plant dry matter (Marschner, 1997a). Chloride is essential in micro quantities but can accumulate in the plant in large quantities when present in high concentrations in the soil solution, (Xu *et al*., 2000).

Table 1. *Soil conditions inducing nutrient deficiencies in crop plants (from Fageria et al. (1997a).*

Nutrient	Conditions inducing deficiency
N	Excess leaching with heavy rainfall, low organic matter content of soils, burning of crop residue, denitrification (losses of N_2 and N_2O to the atmosphere)
P	Acidic (high Al content), organic, leached and calcareous soils, high rate of liming
K	Sandy, organic, leached and eroded soils; intensive cropping system without fertilizer addition
Ca	Acidic, alkali, or sodic soils
Mg	Low clay content, sodic low Mg soils
S	Low organic matter content of soils; continued use of N and P fertilizers containing no sulfur; burning of crop residue
Fe	Calcareous soils, soils high in P, Mn, Cu or Zn; high rate of liming
Zn	Highly leached acidic soils, calcareous soils, high levels of Ca, Mg and P in the soils
Mn	Calcareous silt and clays, high organic matter, calcareous soils
B	Sandy soils, naturally acidic leached soils, alkaline soils with free lime
Mo	Highly podzolized soils; well drained calcareous soils

All the essential nutrients are required by plants in balanced proportions. Deviation from this may result in nutritional disorders. Early detecting of nutritional deficiency stress is important. Stress might extend to the entire plant with loss of yield if relief of stress is not employed. Continuous shortage of a nutrient or nutrients might cause plant death. When two or more elements are deficient simultaneously, the composite picture of symptoms may resemble no single known deficiency. Mineral deficiency symptoms are sometimes confused with other complex field events such as damage caused by insect-pest, disease, salt stress, water stress, pollution, light and temperature injury (Bennett,1993) and herbicide damage. Toxicity of Mo or Se is similar to P deficiency (Bennett, 1993), Fe deficiency in Mango is similar to Chloride toxicity (Xu *et al*., 2000). Therefore, it is necessary to critically observe and define these deficiency symptoms. The deficiency symptoms might be distinguished based on the plant part that shows deficiency symptoms, presence or absence of dead spots and entire leaf or interveinal chlorosis. A description of initial appearance of deficiency symptoms on leaves is given in Fig.1 and the associated text below.

Generally, nutrient deficiency in the plant occurs when a nutrient is insufficient in the growth medium and/ or cannot be absorbed and assimilated by the plants due to unfavorable environmental conditions. Nutrient disorders limit crop production in all types of soil around the world. Table 1 shows soil conditions associated with nutrient deficiencies of various nutrient elements.

Visible Symptoms of Stress

More on nutrient deficiency symptoms

Nutrient deficiency symptoms
114 photos of nutrient deficiency symptoms (1943)
Visual symptoms of nutrient deiciency
Diagnosis of mineral deficiency by visual symptoms

1. Nitrogen (N)

The characteristic deficiency symptom of nitrogen is the appearance of uniform yellowing of leaves including the veins, this being more pronounced on older leaves as expressed in rabbit-eye and blueberries (Tamada, 1989); Fescue (Razmjoo, 1997); *Ailanthus triphysa* (Anoop *et al.*, 1998); chili (Balakrishnan 1999) and sugarcane (Nautiyal *et al.*, 2000). The leaves become stiff and erect. In dicotyledonous crops the leaves detach easily under extreme deficiency condition. Cereal crops show characteristics 'V' shaped yellowing at the tip of lower leaves. O'Sullivan *et al*.,(1993) observed relatively small and pale green leaves with dull appearance in sweet potato. If such condition of nitrogen stress do persist, the result is a decreased foliage growth and shoot growth. See for example: black pepper (Nybe and Nair, 1986); douglas-fir (Friend *et al.,*1990) and sapota (Nachegowda *et al*.,1992).

2. Phosphorus (P)

In phosphorus deficiency, leaves remain small, erect, unusually dark green with greenish red in sweet potato (O'Sullivan *et al*., 1993), bluish green in chili (Balakrishnan 1999), brown in birdsfoot trefoil (Russelle and McGraw, 1986) or purplish tinge in sugar maple (Bernier and Brazeau, 1988); blueberry (Tamada,1989) and sugarcane (Nautiyal *et al*., 2000). The under side develops bronzy appearance. The root growth is also restricted under phosphorus stress in black pepper (Nybe and Nair, 1986). Anthocyanin pigment increases in leaves of barley (Hamy,1983) and *Arabidopsis thaliana* (Trull *et al*., 1997) under phosphorus stress,

3. Potassium (K)

Under potassium stress condition, yellowing of leaves starts from the tips or margins of leaves extending towards the center of leaf base. The yellowing is interveinal and irregular in the leaves of tomato (Besford, 1978) and blueberry (Tamada, 1989). These yellow parts become necrotic (dead spots) with leaf curling in tobacco (Arnold *et al*., 1986); sugar maple (Bernier and Brazeau, 1988); sapota (Nachegowda *et al*.,1992) and sugarcane (Nautiyal *et al*., 2000). There is a sharp difference between green, yellow and necrotic parts.

4. Calcium (Ca)

Calcium stress in plants results in chlorosis of young leaves along the veins of birdsfoot trefoil (Russelle and McGraw, 1986) and blueberry (Tamada, 1989), if deficiency persist longer, bleaching of upper half leaf followed by leaf tip curling do occur in black pepper (Nybe and Nair, 1987) and sugarcane (Nautiyal *et al*., 2000). The growing bud leaf becomes chlorotic white with base remaining green, the distortion of the tips of shoots i.e. dieback was observed by Edwards and Hortan, (1997) in peach seedlings. Similarly, Spehar and Galway, (1997) found brown spots on leaves, reduced expansion and premature leaf senescence under Ca stress in soybean crop. Stress during fruiting in tomato increases susceptibility to blossom end rot (Adams and El-Gizawy, 1988; Sonneveld and Voogt, 1991 and Ho *et al*., 1999). Calcium stress is also responsible for other disorders such as bitter pit in apple (Ford, 1979; Monge *et al*., 1995 and Silva and Rodriguez, 1996); leaf tip burn in cabbage (Miao *et al*., 1997) and lettuce; black heart of celery; cavity spot of carrots (Scaife and Clarkson 1978); vitrescence in melons (Jean-Baptist *et al*., 1999).

5. Magnesium (Mg)

Magnesium deficiency causes yellowing, but differs from that of nitrogen. The yellowing takes place in between veins of older leaves (Makkanen, 1995) of *Picea abies* and veins remain green, this is followed by necrosis of tissues in birdsfoot trefoil (Russelle and McGraw, 1986), melons (Simon *et al*., 1986). black pepper (Nybe and Nair, 1987) and blueberry (Tamada, 1989). Mg deficiency my be induced in tomatoes by high levels of ammonium in the nutrient solution (Kafkafi *et al*., 1971).

6. Sulfur (S)

Sulfur deficiency cause leaves to become yellowish in black pepper (Nybe and Nair, 1987); potato (Gupta and Sanderson, 1993) and *Brassica oleracea* (Stuiver *et al*., 1997) and it appears similar to nitrogen deficiency, but the symptoms are first visible on younger leaves (Russelle and McGraw, 1986). The affected leaves are narrow and the veins are paler and chlorotic than interveinal portion, especially towards the base with marginal necrosis in sugarcane (Nautiyal *et al*., 2000).

7. Iron (Fe)

The principal veins remain conspicuously green and surrounding portion of the younger leaves turn yellow tending towards whiteness in chickpea (Mehrotra and Gupta, 1990 and Saxena *et al*., 1990); groundnut (Reddy *et al*., 1993); radish, cauliflower, cabbage and sorghum (Preeti *et al*., 1994); lentil (Zaiter and Ghalayini, 1994) and soybean (Fonts and Cox, 1998). Under sever deficiency, most part of the leaf becomes white (Russelle and McGraw, 1986).

8. Zinc (Zn)

The leaves become narrow and small in chili (Balakrishnan, 1999), the lamina becomes chlorotic in sweet potato (O'Sullivan *et al*., 1993), sour orange seedlings (Swietlik, 1995) and chickpea (Khan *et al*., 1998)**,** while veins remain green. Subsequently, dead spots develop all over the leaf including veins, tips and margins under sever deficiency, shoot growth is reduced (O'Sullivan *et al*., 1993; Swietlik, 1995 and Yu and Rengel, 1999). Khaira disease in rice results due to zinc deficiency (Gautam and Sharma, 1982; Sharma *et al*., 1988 and Sahi *et al*., 1992). Shoot elongation is reduced and a tuft or rosette of distinctly narrow leaves is produced at the shoot terminal in apple and pear. The symptoms are termed 'little leaf' or 'rosette' (Hanson, 1993).

9. Boron (B)

Boron deficiency causes yellowing or chlorosis of youngest leaves and stems (Yu *et al*., 1998) which starts from the base to the tip. Rosetting of terminal shoots of potato (Roberts and Rhee, 1990). Leaf tip burn, elongate and become whitish brown in rice (Yu *et al*., 1998). Death of terminal bud occurs in extreme cases. Boron deficiency causes brown heart in radish (Shelp *et al*., 1987) and crown choking in coconut (Baranwal *et al*., 1989).

10. Manganese (Mn)

The principal veins as well as smaller veins are green, the interveinal portion become chlorotic in *Ailanthus triphysa* (Anoop *et al*., 1998) followed by necrosis and browning of interveinal tissue in melons (Simon *et al*., 1986).

The affected young leaves remain small and abscise before older leaves in birdsfoot trefoil (Russelle and McGraw, 1986).

11. Molybdenum (Mo)

The common symptoms of Mo deficiency in plants include a general yellowing, marginal and interveinal chlorosis, marginal necrosis, rolling, scorching and downward curling of margins in poinsettia cultivars (Cox and Bartley, 1987; Cox, 1992) and in various field, horticulture and forage crops (Gupta and Gupta, 1997). The deficiency of molybdenum in cauliflower causes the disorder described as 'Whiptail' (Duval *et al.*, 1991).

12. Copper (Cu)

In copper deficiency, visible foliar symptoms appear on young leaves as chlorosis changing to necrosis (Conover *et al*., 1991; Del, 1994); rolling, wilting and twisting of leaves in wheat (Owuoche, 1995). The later affected leaves appear papery and twisted in rice (Nautiyal *et al*., 1999).

13. Chlorine (Cl)

The symptoms of chlorine deficiency develop first on the older leaves. Discrete patches of pale green chlorotic tissue appear between the main vein near the tip of the leaf, downward cupping of some of the older leaves of Kiwifruit was observed by Smith *et al*., (1987). The leaflets of youngest leaves shrivel completely, older leaflets develop a brown necrosis which start near the tip and extend backwards particularly at the margins of red clover (Whitehead, 1985).

14. Nickel (Ni)

Plant growth is reduced and older leaves turn chlorotic giving plants a nitrogen deficient phenotype, when grown on urea-based nutrient solutions not supplemented with Ni in tomato and soybean (Shimada and Ando, 1980; Krogmeier *et al*., 1991). Similar results were obtained in oilseed-rape, zucchini and soybean by Gerendás and Sattelmacher (1997).

Related Publications

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- *Diagnosis of Mineral Disorders in Plants. Vol. 1, Principles*, by C. Bould, E. H. Hewitt, and P. Needham. (Chemical Publishing, New York, 1984).
- *Diagnosis of Mineral Disorders in Plants. Vol. 2, Vegetables*, by A. Scarfe and Mary Turner. (Chemical Publishing, New York, 1984).
- *Plant Analysis Handbook*, by J. Benton Jones Jr., B. Wolf, and H. A. Mills. (Micro-Macro Publishing, Athens, GA, 1991).
- *Nutritional Disorders of Plants*, Ed. by, Werner Bergmann. (Gustav Fischer Verlag, Gena, Germany, 1992).
- *Nutrient Deficiencies and Toxicities in Crop Plants*, Ed. by, William F. Bennett. (The American Phytopathological Society, St. Paul Minnesota, 1993).
- *Mineral Nutrition of Higher Plants* 2^{nd} Ed. by, H. Marschner (Academic Press, London, 1997).
- *Growth and nutrition of field crops* 2^{nd} Ed. by, N. K. Fageria; V. C. Baligar, and C. A. Jones. (Marcel Dekker, Inc. New York, 1997).

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