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A review: Nutrient deficiencies and physiological disorders of citrus

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Abstract
Nutrient refers to all those compounds required by an organism as a source of body building material and energy, without which, it will not be able to complete its life cycle. The nutrient elements required by the plants are classified into macro and micronutrients, the former being required in larger quantities and the latter in smaller doses. Lack of any one of these elements is reflected in defective growth or yellowing of leaves. Micro-nutrient deficiencies in Indian orchard soils have been increased in recent years and quite extensive, especially of Zn, Fe, B. Citrus is a nutrient sensitive and responsive fruit crop and requires adequate nutrition for proper growth and development. There are a number of disorders caused by some micronutrients in fruits like 'fruit cracking' in citrus due to 'B' deficiency, 'die-back of citrus due to 'Cu' deficiency, 'interveinal chlorosis' in citrus due to 'Fe' deficiency, Frenching or foliocellosis or mottle leaf in citrus due to 'Zn' deficiency, 'yellow spot' disease in citrus due to 'Mo' deficiency. The deficiencies may be caused either by the lack of a particular element in the soil or by its fixation in the soil, thus becoming not available to the plant. Important nutrient deficiencies and physiological disorders of citrus and its management are summarized below.

Keywords: Citrus, nutrient deficiency, physiological disorders, corrective measures

Introduction
Citrus, one of the most important fruits of the world, is cultivated widely in the tropical and sub-tropical regions. It ranks third among the sub-tropical fruits of the world with different varieties. There are four commercially important species of lime namely, *Citrus aurantifolia* (Acid lime), *C. latifolia* (Tahiti lime), *C. limonia* (Rangpur lime) and *C. limettoides* (Sweet lime). Acid lime (*Citrus aurantifolia*) is the member of family *Rutaceae*. It is believed to be a native of Malaya, Assam and China. The major lime producing Indian states are Andhra Pradesh, Maharashtra, Gujarat, Karnataka, Tamil Nadu, Assam and Chhattisgarh.
Citrus occupies an important place in the fruit industry, but yield levels of citrus orhcards are still very low. A pH range of 5.5 to 7.5 and EC upto 1.8 ds. m^{-1}, ESP upto 5- 10% and CaCO3 around 10 to 12% are suitable soil criteria for most of the citrus cultivation (Srivastava and Kohli, 1997) [12]. Out of many factors, poor nutrient status of soil as well as malnutrition is considered to be major factors responsible for citrus decline and low yield (Lal and Dayal, 2014) [6]. Nutritional disorders especially micronutrient deficiencies are frequently encountered in citrus orchards.
Citrus cultivation today is threatened due to various nutrient deficiency symptoms, physiological disorders, fungal, viral and bacterial diseases, pests and nematodes etc. The intensity of these problems varies from region to region impacting seriously the production and quality. While some of the problems are specific to a particular kind (Eg: Granulation in Sweet Orange), others are common to many citrus kinds. Among the various production problems, apart from pests and diseases, the following can be considered as important for researchers to tackle (Soorianathasundaram, 2005) [11].

1. Non availability of reliable & virus free planting material
2. Unsuitable rootstocks for specific situations
3. Unfavourable soil conditions and poor water quality leading to physiological disorders
4. Poor nutritional management
5. Physiological problems due to environmental conditions

Nutrient Deficiency symptoms in Citrus and their corrective measures
Nitrogen
Dull green, yellowish, smaller leaves, die back of twigs, thin and bushy appearance of tops with sparse bloom are the particular symptoms of nitrogen deficiency in citrus. Deficiency is expressed by light green to yellow foliage over the entire tree.

With mild deficiency, foliage will be light green progressing to yellow as conditions intensify. New growth usually emerges pale green in colour, but darkens as foliage expands and hardens. With yellow vein chlorosis, the midribs and lateral veins turn yellow while the rest of the leaf remains a normal green colour (Bangarusamy and Vijayalakshmi, 2005) [2].

Correction measures: Foliar spraying of urea @ 2% at 15 days interval is recommended to correct N deficiency.

Potassium

The deficiency results in twisting, curling and puckering of leaves. Leaves may show uniform yellowing and bronzing. Small brown resinous spots on the leaf. New shoots poorly attached to twig and twig growth is weak. Trees are stunted. Fruit size gets reduced and peel thinned.

Correction measures: Foliar application of 5% KNO3 or 2% KCl could effectively alleviates the K deficiency and notably increases K content of leaves.

Magnesium

The deficiency is chiefly the result of accumulation of imbalanced availability of calcium and potassium in the soils grown with continuous imbalance manuring with potassium or calcium containing fertilizers. Symptoms are prominent on the older leaves. The yellowing is prominent on both the sides of the midrib and extends from the base to apex of the leaf. The green portion tapers towards the tip of the leaf so that an inverted "V" shape results in leaf.

Correction measures: Apply MgSO4 @ 500g / tree as basal dose + foliar sprays of MgSO4 @1kg / 100 lit. of water.

Iron

Iron deficiency is a common problem in alkaline soils. Deficiency results in a network of green veins against light green or yellowing background. In extreme cases, the entire leaf becomes chlorotic with the veins remaining green. In advanced stages, the veins loose the green colour. Growth is retarded and yield becomes reduced and fruits are hardy.

Correction measures: Apply Ferrous sulphate @ 500 g / 100 litres of water as foliar sprays twice at 15 days interval after the appearance of the symptoms.

Zinc

The most striking effect of zinc deficiency in citrus is characteristic irregular and chlorotic leaf spots, small leaves on terminal growth and severe dieback of twigs. The first leaf effects are fading of chlorophyll in mesophyll areas between the veins, within the main veins midribs and bands of fringes adjacent to these remaining green. As a result, a series of irregular, chlorotic blotches and patterns appear on the leaves. Chlorosis is more prominent and abundant on the sunny side to the tree. Leaves are drastically reduced and become narrow, pointed and chlorotic. Stem elongation is reduced and internodes shortened which results in small leaf clusters producing a rosette appearance of twigs. Weakened terminal growth results in marked twig die-back. Twig severely deficient in zinc become open and bushy in appearance. The small, narrow and pointed leaves often stand more erect. A fruit size is also decreased and often lighter in colour. Fruits may be misshapen. Fruit is woody, dry, insipid and low in acid and vitamin C content.

Causes: Zinc deficiency is especially prevalent in acid – leached sandy soils, where the cause is commonly low-zinc content. It also occurs widely in alkaline soils, where low zinc solubility is the chief cause. High phosphorus and nitrogen fertilizers (especially alkaline forming type) may increase severity of zinc deficiency. Shortage of organic manures, use of chemically pure fertilizers, imbalances from other elements and lack of zinc application in fertilization programme also cause zinc deficiency

Correction measures: Zinc deficiency in citrus can be corrected by spraying with 2 per cent zinc suphate with 1 percent lime on young flushes.

Boron

Boron deficiency in citrus (lime) is commonly known as hard fruit or stony fruit. Trees deficient in boron produces distorted leaves. Mature leaves show thick and corky veins and midribs. Leaves are twisted. Fruits of all ages show deficiency symptoms. Many fruits set but fall of in first 3 or 4 months. The few fruits that persist are insipid and low in juice content. Young fruits tend to lose green colour in large area and shed excessively. Fruits tend to be hard and misshapen. The white portion of the rind (albedo) shows brownish discolouration (due to presence of brown gum pockets) and is thickened. Seeds are few and the centre of the fruit has gummy excretions. The deficiency symptoms are prominent on older leaves. Margins of the leaf turns brown, the veins turn yellow. Fruits become thickened and corky and split along the length (fruit cracking). Fruits have thickened rind. Brown gum pockets are seen in the albedo and around the seeds, which may be aborted. Seeds may be dark coloured.

Correction measures: Spraying borax 0.25 per cent three or four times at 10 days interval corrects the deficiency. Soil application of borax at 25 to 50g per tree along with NPK fertilizers also corrects the boron deficiency.

Copper

Copper deficiency in citrus is variously called as exanthema, red rust, die-back, multiple bud or peach leaf conditions. The physiological disease caused by Cu shortage is also commonly known as foliocellosis. Deficiency results in dark green leaves borne on 'S' shaped twigs. Shoots that develop laterally may show aphotrophic response by turning upward at their outer ends, giving rise to 'S' shaped conditions. Later, yellowish blotches appear on the shoots just below the leaf nodes. These areas indicate the stoppage in the phloem so that the carbohydrates cannot move from the leaves into the stem and fruits. Small swellings or bumps develop along the stem simultaneously with yellowish blotches. When these swellings are punctured, brownish gum in the bark region oozes out. This condition is called exanthema. Copper deficiency is seen in situations, where zinc, iron and manganese deficiency is seen and copper-based fungicides are not used. Lack of copper produces stained terminal branches, stained fruits, and small gum pockets in the twigs bark excretion. The deficiency is frequently noticed in fruits than in foliage. The fruits will show brown gum soaked eruptions with irregular blotches around central pith. This can be seen on young and mature fruits. Often there are brown or reddish brown gum excretions on rind, sometimes with a small to

large splits in the rind. On leaf, the deficiency symptoms resemble like excess of N with long, vigorous plants often borne on 'S' shaped twigs. Die-back of twigs noted. Slits occur on the bark of stems and gum exudes. The condition is called 'exanthema'.

Fruits show gum pockets around central pith. Gum exudation can be seen on the rind also. In acute cases, the plants become stunted. Leaves become twisted or malformed. The Cu deficient twigs usually show multiple bud development. They produce a dense, somewhat bushy growth. Quite frequently, copper deficiency results in the appearance of Witchs' broom habit.

Correction measures: Apply copper sulphate @ 500 g/tree as basal + 2 foliar sprays of copper sulphate at 500 g/100 lit of water twice at 30 days interval before flowering.

Physiological disorders in Citrus

Citrus suffer several physiological disorders, which are due to a combination of several factors but mostly due to nutrient related deficiencies and adverse environmental conditions. Important physiological disorders which affect growth, yield and quality of citrus are summarized below.

Fruit cracking

It is mainly due to high atmospheric humidity following heavy rains or heavy irrigation during hot weather. Two types of splitting, namely radial (longitudinal) and transverse have been noticed. In both form, fruits crack severely down to the core and in extreme cases, there is complete splitting of fruits. Radial cracking is more common than transverse one. Partial splitting is more prevalent while splitting down to inner core is rather rare. Often the cracked surface of the fruit gets infected by disease causing organisms such as *Aspergillus*, *Aalternaria*, *Fusarium*, and *Penicillum* which lead to partial rotting and early fruit dropping from trees. 90% cracked fruits show radial cracks and only 10% exhibit transverse injury.

Cracking occurred due to increase in moisture content within the tissue due to heavy rain followed by a period of drought. Cracking was more evident when the fruits were at maturity stage. Soil moisture fluctuations, infestation by diseases and pests and mechanical injuries can also contribute to its occurrence.

Management: Proper application of potassic fertilizers, keeping of regular moisture during summer around bearing trees and application of 2-3 sprays of gibberellic acid (10 mg /litre water) during fruit development are some preventive measures for this physiological disorder. In lime, the spray of 40 ppm NAA after fruit set of monsoon crop (3rd week of May) reduces fruit cracking and improves weight and size of fruit. GA3 10-20 ppm can also reduce fruit cracking to some extent and improve fruit quality.

Granulation

A. Symptoms

First reported from California, later reported from many citrus growing countries such as Brazil, South Africa, Egypt, Australia, Vietnam, Japan, Israel, West Indies, India and Thailand (Bartholomew *et al*., 1934) [3]. Almost all citrus fruits suffer from granulation, but sweet oranges and mandarins are more severely affected than other types of citrus (Singh, 2001, Sharma and Saxena, 2004) [10, 9]. Large sized fruits are more affected since there is no evident until fruit is nearly or fully mature. Juice sacs comparatively enlarged, giving a flat and insipid taste. Fruits develop abnormal shape due to lopsided growth of juice vesicles and resultant bulging of the affected portion. Affected portion of the pulp assumes a granular texture with low TSS value. With increase in granulation, alcohol insoluble solids like cellulose, pectic substances, hemicelluloses, starch and lignin also increased. Less extractable juice because most of it turns into gelatinous mass and results in more quantity of rag and thus low pulp / rag ratio (Zong *et al*., 1979) [14].

B. Factors

Although specific causes of granulation are still not confirmed many causes have been attributed. Some of the important ones are as follows.

1. Humidity: Humid climate particularly in coastal district favours granulation.
2. Temperature: Low temperature increases the extent of granulation
3. Tree age: Higher in younger trees than in old trees.
4. Tree health: Granulation in case of young trees found to be higher in declining trees than in healthy trees.
5. Tree vigour: Granulation is abundant in fruits produced on old trees which are heavily pruned and produce luxuriant growth.
6. Crop load: Higher incidence of granulation in trees carrying a heavy crop.
7. Fruit size: Incidence of granulation is higher in large sized fruits.

C. Control measures

1. Irrigation the amount and frequency of irrigation reduces granulation without affecting quantity, quality of fruit.
2. Lime spray Lime spray @ 18 – 20 kg in 450 litres of water is effective.
3. Auxin Sprays of 2,4-D at 12 ppm delay the incidence of granulation in Valencia oranges.
4. Nutritional ZnSO4 (0.5%) and CuSO4 (0.5%) in a sprays combination spray is effective in checking both the incidence and extent
5. Selection of cultivars which are less prone to granulation should be used.
6. Proper time of harvesting of fruits is very effective (Singh, 2001) [10]

Fruit drop in citrus

In most commercial varieties heavy fruit drop and low fruit set are serious problems. As the period of development of fruit extends to 8 or 9 months, fruits continue to drop at various stages during this period. Even if 4-6% of the flowers normally set it is enough to produce a normal crop. Natural fruit drop occurs as a result of sink-source adjustment by tree to prevent from exhaustion as a result of excessive bearing. Fruit drop occurs in three stages. Shortly after fruit set, aborted pistils tend to drop. With the onset of summer (May-June) due to desiccating wind, low atmospheric humidity, low soil moisture and high temperature fruit drop can occur (June drop). The third wave of drop occurs just prior to harvest. Sometimes half developed fruits may drop also (premature drop). The intensity of fruit drop may vary with varieties, climate, soil conditions etc. The most pronounced stage of fruit drop occurs when the fruits are at marble stage.

Hormonal status in the developing fruit plays a major role in fruit drop. Stress induced ethylene signaling and reduction in endogenous auxin is associated strongly with fruit drop. Fruits with less seeds tend to drop early.

Management

- Use of synthetic auxins like 2,4-D and NAA @ 10-20 ppm during April -May and August-September has been successfully tested against physiological fruit drop. The spray should not be given at the time when a dicot crop is already standing in the orchard as intercrop (Anonymous, 2004) [1].
- Verma *et al*. (2018) [13] reported that application of growth regulator NAA @ 20 ppm in Nagpur Mandarin at pea and gravel stage increases fruit retention by 45% and also it reduces pre-harvest fruit drop.

Citrus dieback / decline

Citrus decline is another widely reported disorder in many parts of the citrus growing regions like USA, Mexico, Brazil, Argentina, South Africa, Iraq, Iran, Turkey, India, etc. It is attributed to occur due a variety of causes occurring usually in combination It is a symptomatic expression of many disorders in the plant and not a specific disease in India (Dhatt and Dhiman, 2001) [4]. According to Kanwar *et al*. (1965) [5] soil condition leads to citrus decline. Improper and inadequate nutrition in soil lead to decline in India. The declining tree has low level of nutrients and more incidence of pre-harvest fruit drop than the healthy tree (Saini *et al*., 2004) [7].

Symptoms

Generally, the citrus plant after 5-6 year of excellent growth usually starts declining with gradual decrease in vigour and yield. Magnitude of decline increase with the age of plant and after 15 - 20 year affected plant become uneconomical. Declined tree does not die usually but remain unproductive. The symptom comprised of retarded growth of tree, appearance of chlorotic leaves, sparse foliage, die back of twigs and in general appears sickly. Ultimately his lead to death of the tree. The decline may be noted in as high as 40-60% of the trees especially in mandarin.

Casual factors

The factors leading to the decline may be due to one or more of the followings: shallow soil (< 45 cm deep), hard pan in the subsoil surface, moisture stress, poor drainage of soil, higher pH, higher EC value, low organic matter in soil, deficiency of N in soil and plant, deficiency in endogenous hormonal levels, Zn deficiency, Stock - scion incompatibility (Eg 'Fairchild' mandarin on Macrophylla) and Insect pests, diseases and nematodes

Management

- Integrated approach is required based on the factors associated
- Strategies should include use of virus free planting material, selection of proper site and soil, careful selection of rootstocks, judicious irrigation, manuring, timely management of nutritional needs, hormonal applications, use of organics, scientific spray schedule, integrated pest and disease management, nematode control.

Frenching or foliocellosis

Frenching or foliocellosis or mottle leaf is a another disorder of citrus mainly occur due to deficiency of Zn and which is controlled by foliar application of Zinc sulphate @ 0.5% (Sharma, 2005c) [8].

Conclusion

Comprehensive knowledge about the nutrient deficiency symptoms, physiological disorders and its various management approach in citrus fruit production will not only aid the quality production to fruit growers, but also it will be useful for researchers to generate an innovative ideas to control these disorders in a better way.

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