DIAGNOSIS OF NUTRITIONAL DISORDERS

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Nutritional disorders are basically physiological disorders in the plants that affect productivity as well as the quality of fruits. Disturbance in the plant metabolic activities resulting from an excess or deficit of environmental variables like temperature, light, aeration and nutritional imbalances result in disorders. In fruit crops, the deficiency of micronutrients causes many more disorders than that of macronutrients. Nutritional disorders have become widespread with diminishing use of organic manures, adoption of high density planting, use of root stocks for dwarfing, disease and salt tolerance, unbalanced NPK fertiliser application and extension of horticulture to marginal lands. To get high quality fruit and yields, micronutrient deficiencies have to be detected before visual symptoms are expressed.

The deficiencies of Zn, Mn and B are common in sweet orange, acid lime, banana, guava and papaya in India. To correct both visual and hidden micronutrient deficiencies, appropriate foliar and soil applications are necessary. The description of physiological and nutritional disorders in crops includes a number of technical terms and it is essential to understand the terms for better identification of symptoms. Some common terms are, *bronzing* (development of bronze or copper colour on the tissue), *chlorosis* (loss of chlorophyll resulting in loss of green colour leading to pale yellow tissues), *decline* (onset of general weakness as indicated by loss of vigour, poor growth and low productivity), *die-back* (collapse of the growing tip affecting the younger leaves), *firing* (burning of tissue accompanied with dark brown or reddish brown colour), *lesion* (a localised wound of the leaf/stem tissue accompanied with loss of normal colour), necrosis (death of tissue), scorching (burning of the tissue accompanied with light brown colour resulting from faulty spray, salt injury etc.)

Some crops are more sensitive than others to the deficiency of a micronutrient and it can be inferred that the critical concentration of a nutrient is not same for all the crops. The susceptibility or tolerance rating of crops to nutrient deficiencies shows considerable variation due to wider hereditary variability within a crop species. Further, terms such as low, moderate or high are very relative and should be used with caution.

Diagnostic plant symptoms of nutrient element insufficiencies

When a nutrient element insufficiency (deficiency and/or toxicity) occurs, visual symptoms may or may not appear, although normal plant development will be slowed. When visual symptoms do occur, such symptoms can frequently be used to identify the source of the insufficiency.

Deficiency symptoms

Visual symptoms of deficiency may take various forms, such as

- stunted or reduced growth of the entire plant with the plant itself either remaining green or lacking an over-all green colour with either the older or younger leaves being light green to yellow in colour.
- chlorosis of leaves, either interveinal or of the whole leaf itself, with symptoms either on the younger and/or older leaves, or both (chlorosis is due to the loss or lack of chlorophyll production).
- necrosis or death of a portion (margins or interveinal areas) of a leaf, or the whole leaf, usually occurring on the older leaves.
- slow or stunted growth of terminals (rosetting), the lack of terminal growth, or death of the terminal portions of the plant.
- reddish purpling of leaves, frequently more intense on the underside of older leaves due to the accumulation of anthocyanin.

Toxicity symptoms

Visual symptoms of toxicity may not always be the direct effect of the element in excess on the plant, but the effect of the excess element on one or more other elements. For example, an excessive level of potassium (K) in the plant can result in either a magnesium (Mg) and/or calcium (Ca) deficiency, excess phosphorus (P) can result in a zinc (Zn) deficiency, and excess Zn in an iron (Fe) deficiency.

These effects would compare to elements, such as boron (B), chlorine (Cl), copper (Cu), and manganese (Mn), which create visual symptoms that are the direct effect of an excess of that element present in the plant. Some elements, such as aluminum (Al) and copper (Cu) can affect plant growth and development due to their toxic effect on root development and function.

Hidden hunger

In some instances, a nutrient element insufficiency may be such that no symptoms of stress will visually appear with the plant seeming to be developing normally. This condition has been named *hidden hunger*, a condition that can be identified by means of either a plant analysis and/or tissue test.

A hidden hunger occurrence frequently affects the final yield and the quality of the product produced. For fruit crops, abnormalities, such as blossomed rot and internal abnormalities may occur, and the post harvest characteristics of fruits and flowers will result in poor quality and reduced longevity. A generalized visual leaf and plant nutrient deficiency and excess symptoms in horticultural crops are given in Table.

Climatic and other causes

The occurrence of the symptoms may not necessarily be the direct effect of a nutrient element insufficiency. For example, stunted and slowed plant growth and the purpling of leaves can be the result of climatic stress, cool air and / or root temperatures, lack of adequate moisture, etc. Damage due to wind, insects, disease and applied foliar chemicals can produce visual symptoms typical of a nutrient element insufficiency. Some nutrient element deficiencies have been classed as physiological disorders as given in the Table 2. In all these cases, carefully followed diagnostic techniques must be employed –

particularly the use of plant analyses and / or tissue tests if the cause for visual disorders is to be correctly identified.

Other effects

A nutrient element insufficiency (deficiency or excess) can make the plant sensitive to climatic stress, and/or be easily subjected to insect and disease infestations. A high nitrogen (N) level in the plant can make the plant sensitive to moisture stress and easily susceptible to insect and disease infestations. If ammonium-nitrogen (NH_4-N) is the primary source of nitrogen (N), symptoms of NH_4 toxicity, fruit disorders, and the decay of conductive tissues may occur. Some fungus diseases are more likely to occur on plants that are marginally deficient in a particular element, an example being the occurrence of powdery mildew on leaves of greenhouse-grown cucumber when magnesium (Mg) is not fully sufficient.

Generalized symptoms of nutrient deficiency and excess in crops

Element/status	Visual symptoms
Nitrogen (N) Deficiency	Light green leaf and plant colour with the older leaves turning yellow, leaves that will eventually turn brown and die. Plant growth is slow, plants will be stunted, and will mature early.
Excess	Plants will be dark green in colour and new growth will be succulent; susceptible, if subjected to disease and insect infestation; and subjected to drought stress, plants will easily lodge. Blossom abortion and lack of fruit set will occur.
Ammonium toxicity	Plants fertilized with ammonium-nitrogen (NH_4-N) may exhibit ammonium toxicity symptoms, with carbohydrate depletion and reduced plant growth. Lesions may occur on plant stems, there may be a downward cupping of the leaves, and a decay of the plants under moisture stress. Blossom-end rot of fruit and Mg deficiency symptoms may also occur.
Phosphorus (P) Deficiency	Plant growth will be slow and stunted, and the older leaves will have a purple coloration, particularly on the underside.
Excess	Phosphorus excess will not have a direct effect on the plant, but may show visual deficiencies of Zn, Fe and Mn. High P may also interfere with the normal Ca nutrition, with typical Ca deficiency symptoms occurring.
Potassium (K) Deficiency	On the older leaves, the edges will look burned, a symptom known as scorch. Plants will easily lodge and be sensitive to disease infestation. Fruit and seed production will be impaired and of poor quality.
Excess	Plants will exhibit typical Mg, and possibly Ca deficiency symptoms due to a cation imbalance.
Calcium (Ca) Deficiency	The growing tips of roots and leaves will turn brown and die. The edges of the leaves will look ragged as the edges of emerging leaves stick together. Fruit quality will be affected with the occurrence of blossom-end rot on fruits.

Excess	Plants may exhibit typical Mg deficiency symptoms, and when in high excess, K deficiency may also occur.
Magnesium (Mg) Deficiency	Older leaves will be yellow in colour with interveinal chlorosis (yellowing between the veins) symptoms. Plant growth will be slow and some plants may be easily infested by disease.
Excess	Results in a cation imbalance showing signs of either a Ca or K deficiency.
Sulfur (S) Deficiency	A general overall light green colour of the entire plant with the older leaves being light green to yellow in colour as the deficiency intensifies.
Excess	A premature senescence of leaves may occur.
Boron (B) Deficiency	Abnormal development of the growing points (meristematic tissue) with the apical growing points eventually becoming stunted and dying. Flowers and fruits will abort. For some grain and fruit crops, yield and quality is significantly reduced.
Excess	Leaf tips and margins will turn brown and die.
Chlorine (Cl) Deficiency	Younger leaves will be chlorotic and plants will easily wilt. For wheat, a plant disease will infest the plant when Cl is deficient.
Excess	Premature yellowing of the lower leaves with burning of the leaf margins and tips. Leaf abscission will occur and plants will easily wilt.
Copper (Cu) Deficiency	Plant growth will be slow and plants stunted with distortion of the young leaves and death of the growing point.
Excess	A Fe deficiency may be induced with very slow growth. Roots may be stunted.
Iron (Fe) Deficiency	Interveinal chlorosis will occur on the emerging and young leaves with eventual bleaching of the new growth. When severe, the entire plant may be light green in colour.
Excess	Bronzing and tiny brown spots on the leaves.
Manganese (Mn) Deficiency	Interveinal chlorosis of young leaves while the leaves and plants remain generally green in colour. When severe, the plants will be stunted.
Excess	Older leaves will show brown spots surrounded by a chlorotic zone and circle.
Molybdenum (Mo) Deficiency	Symptoms will frequently appear similar to N deficiency. Older and middle leaves become chlorotic first, and in some instances, leaf margins are rolled and growth and flower formation are restricted.
Excess	Not of common occurrence.
Zinc (Zn) Deficiency	Upper leaves will show interveinal chlorosis with an eventual whiting of the affected leaves. Leaves may be small and distorted with a rosette form.
Excess	Fe deficiency will develop.

Common nutritional disorders in horticultural crops

Deficient element	Disorder	Crop	Symptoms
Boron (B)	Brown heart	Turnip	Rotting of centre of root
	Heart rot	Beets	Death of centre of crown, rotting of centre of root
	Hollow stem	Cauliflower	Rotting of centre of stem
	Bitter pit	Apple	Decay or corking of the flesh under the skin
Calcium (Ca)	Blossom-end rot	Tomato, Pepper	Decay of the blossom-end of the fruit
Manganese (Mn)	Speckled yellows	Sugar beet	Chlorosis between leaf veins, inward curling of leaves
	Marsh spot	Pea	Brown area in centre of seed
	Little leaf	Apple	Small, malformed leaves shortened internodes
Molybdenum (Mo)	Whiptail	Cauliflower	Reduction or suppression of leaf blades

Leaf sampling technique and nutrient norms for fruit crops

Crop	Plant part, age, stage and position	Optimum leaf nutrient norms		
		N (%)	P (%)	K (%)
Mango	Collect 4-5 month-old leaf from current season's growth from middle part of the shoot	0.84-1.53	0.06-0.15	0.52-1.10
Banana	20 cm^2 of leaf lamina on either side of third leaf from apex	2.50-3.00	0.18-0.40	2.30-4.00
Mandarin	Basal leaf at 6-month-old leaf from current growth in March	3.00-3.50	0.15-0.25	0.90-1.10
Acid Lime	Basal leaf at 5-month-age from current season's growth	1.96-2.30	0.12-0.29	1.60-1.90
Sweet Orange	Basal leaf 6-month-old leaf from current season's growth emerged in March or September	2.00-2.20	0.10-0.11	0.40-1.20
Lemon	Basal 6-month-old leaf from current season's growth	2.20-2.70	0.15-0.30	1.00-2.00
Guava	Third pair of leaf from age in August-December	1.60-2.40	0.15-0.30	1.30-1.70

Pineapple	Leaf basal from fourth leaf from apex	1.50-1.00	0.10-0.15	2.20-3.00
Litchi	Second pair of leaflets from tip from autumn flush 6-month-old	1.50-1.75	0.10-0.20	0.40-0.70
Papaya	Petiole from sixth leaf from top, 6 months after planting	1.01-2.50	0.22-0.40	3.30-5.50
Grape	For potential yield: Petiole from 5-leaf from base at bud-initiation and differentiation stages. The petiole is taken from growth after pruning March/April in tropical viticulture or one year prior in temperature viticulture at bloom time. For quality: petiole from 5-leaf from base at bloom stage for the current crop in tropical as well as temperature viticulture.	0.87-1.60 0.80-1.25	0.30-0.65 0.46-0.68	2.00-3.00 1.16-2.40
Pomegranate	8-leaf pair from tip in April flush for February crop and from August flush for June crop	1.20-1.40	0.10-0.20	1.00-1.40
Passion fruit	Leaf opposite to last open flower at bloom stage	3.00-4.30	0.10-0.20	2.50-2.80
Ber	5-leaf from tip of secondary and tertiary shoot in June	1.50-2.20	0.14-0.45	1.60-2.00
Phalsa	4-leaf from growing tip one month after pruning.	1.50-1.60	0.15-0.20	1.60-2.00
Custard-apple	5-leaf from growing point in May/June.	1.40-1.80	0.07-0.10	0.80-1.20
Sapota	10-leaf from growing tip in September	1.60-1.70	0.07-0.09	0.70-0.90
Fig	Basal leaf from mid-summer growth	2.00-2.50	0.09-0.10	0.70-0.90
Cherry	Fully expanded leaf from mid-shoot of current growth	2.60-3.00	0.16-0.22	1.60-2.10
Avocado	3-leaf from tip	1.60-2.00	0.08-0.25	0.75-2.00
Strawberries / Cherry	Fully expanded youngest leaf at bloom tissue	2.50-4.00	0.15-0.20	1.30-3.00
Apple	5-leaf from tip on new growth	2.00-2.40	0.20-0.30	1.50-2.00
Pear	Leaves from mid-shoot in current growth	2.20-2.80	0.11-0.25	1.00-2.00
Plum	Leaves from mid-shoot of current growth	1.74-3.10	0.22-0.40	1.80-3.60
Peach	Leaves from mid-shoot of current growth	3.00-3.50	0.14-0.25	2.00-3.00
Apricot	Fully expanded leaf from mid-shoot	2.00-2.50	0.13-0.25	2.50-3.00
Almond	3-leaf from tip	2.20-2.50	0.10-0.30	1.40-2.00
Walnut	Fully expanded leaf from mid-shoot	2.50-3.25	0.12-0.30	1.20-3.00

Index tissue sampling technique and optimum range of nutrient requirement in vegetable crops

Crop	Sampling time / part	Optimum leaf nutrient norms		
		N (%)	P (mg) (%)	K (%)
Tomato	Petioles opposite or below top flower cluster at pre-bloom	3.50-5.00	0.71-1.30	4.00-8.00
Turnip	Most recently fully developed leaf	3.50-5.00	0.33-0.60	3.50-5.00
Cabbage	Top plant 2-6-week-old	3.00-5.00	0.33-0.75	3.00-5.50
Carrot	Most recently fully matured leaf at mid growth	3.00-5.00	0.20-0.40	2.80-4.00
Onion	Top, no white portion one-third to half grown	5.00-6.00	0.30-1.20	3.50-5.00
Brinjal	Leaf blades with midribs minus petiole most recently developed leaves	3.00-5.00	0.33-0.75	3.00-5.50
Cucumber	Leaf blades with midrib, fifth leaf from tip omit unfurled leaves. Flower bud start to small fruit	4.30-6.00	0.25-1.00	3.50-4.50
Pepper	Most recent fully developed leaf. Flower bud start to small fruit	4.00-6.00	0.35-1.00	4.00-6.00
Radish	Most recent fully developed leaf	3.00-6.00	0.30-0.70	4.00-6.00
Watermelon	Fifth leaf from tip, omit unfurled. Flower start to small fruit	4.00-5.50	0.30-0.80	4.00-5.00
Pea	Recently fully developed leaflets. First bloom	4.00-6.00	0.30-0.80	2.00-3.50

Deficiency Symptoms

When nutrient is not present in sufficient quantity, plant growth is affected. Plants may not show visual symptoms up to a certain level of nutrient content, but growth is affected and this situation is known as hidden hunger. When a nutrient level still falls, plants show characteristic symptoms of deficiency. These symptoms, through vary with crop, have a general pattern. These are generally masked by diseases and other stresses and so need careful and patient observation on more number of plants for typical symptoms. The deficiency symptoms appear clearly in crops with larger leaves.

Identification of Deficiency Symptoms

The deficiency symptoms can be distinguished based on the (1) region of occurrence, (2) presence or absence of dead spots, and (3) chlorosis of entire leaf or intervenial chlorosis.

The region of appearance of deficiency symptoms depends on mobility of nutrient in plants. The nutrient deficiency symptoms of N, P, K, Mg and Mo appear in lower leaves because of their mobility inside the plants. These nutrients move from lower leaves to growing leaves thus causing deficiency symptoms in lower leaves.

Zinc is moderately mobile in plants and deficiency symptoms, therefore, appear in middle leaves. The deficiency symptoms of less mobile elements (S, Fe, Mn and Cu) appear on new leaves. Since Ca and B are immobile in plants, deficiency symptoms appear on terminal buds. Chlorine deficiency is less common in crops.

Deficiency symptoms on old leaves

The symptoms that appear on old leaves can be further distinguished based on the presence or absence of dead spots.

Without Dead Spots. The characteristic deficiency symptoms of nitrogen is uniform yellowing of the leaves including the veins. The leaves become stiff and erect especially in cereals. The leaf may detach after a little forceful pull in extreme deficiency in dicotyledonous crops. Cereal crops show characteristic 'V' shaped yellowing at the tip of lower leaves. In phosphorus deficiency, leaves are small, erect, unusually dark green with a greenish red, greenish brown or purplish tinge. The rear side develops bronzy appearance. Magnesium deficiency also causes yellowing, but differs from that of nitrogen. The yellowing takes place in between the veins and the veins remain green. The leaf is not erect. The leaf detaches very easily and may be shed by blowing wind. Necrosis (death of tissues) occurs in extreme cases only in the margins.

With Dead Spots. In potassium deficiency, yellowing starts from tips or margins of leaves extending to the center of leaf base. These yellow parts become necrotic (dead spots) very soon. There is sharp difference between green and yellow and yellow and necrotic portions. The dead spots appear particularly on margins and tips.

Molybdenum deficiency causes translucent spots of irregular shape in between the veins of leaves. These spots are light green, yellow or brown in colour. The affected spots are impregnated with resinous gum which exudes from rear side of the leaf from the reddish brown spots.

Deficiency Symptoms on New Leaves

These symptoms may be spread over entire leaf or the veins may remain green.

Veins Remaining Green. Veins remain green in iron and manganese deficiency. In iron deficiency, the principal veins remain conspicuously green and other portions of the leaf turn, yellow tending towards whiteness. Under severe deficiency, most part of the leaf becomes white. In manganese deficiency, the principal veins as well as the smaller veins are green. The interveinal portion is yellowish, not tending towards whiteness. Dead spots also appear at a later stage. There is a chequered appearance to the leaf.

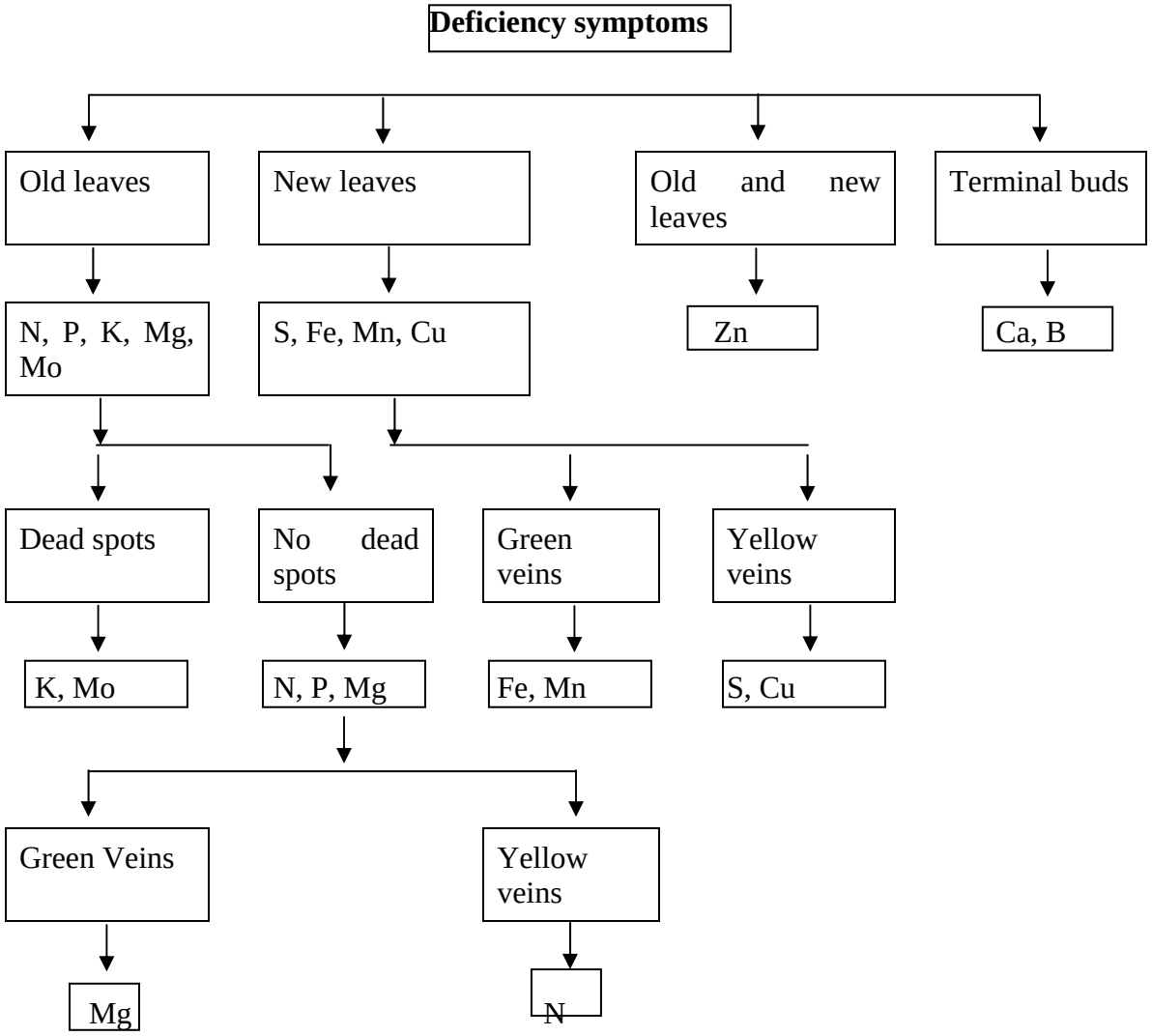

Fig. . Identification of deficiency symptoms

Veins not Remaining Green. The leaf becomes yellowish due to sulphur deficiency, but looks like nitrogen deficient leaf. The leaf is small and the veins are paler than intervenial portion. No dead spots appear. Plant does not lose the lower leaves as in the case of N deficiency. In copper deficiency, leaf is yellowish tending towards whiteness. In extreme deficiency, chlorosis of veins occurs and leaf loses luster. Leaf is unable to retain its turgidity and hence, wilting occurs. Leaf detaches due to water soaked conditions of the base of petiole.

Terminal Buds

The deficiency symptoms of Ca and B are many times seen on new leaves. However, it is easy to recognize their deficiency symptoms on the terminal buds or growing points than on new leaves.

In calcium deficiency, the bud leaf becomes chlorotic white with the base remaining green. About one-third chlorotic portion of the tip hooks downward and becomes brittle. Death of terminal bud occurs in extreme cases.

Boron deficiency causes yellowing or chlorosis which starts from the base to tip. The tip becomes very much elongated into a whip like structure and becomes brownish or blackish brown. Death of the terminal bud occurs in extreme cases.

Deficiency on both old and new leaves

In zinc deficiency, the leaf becomes narrow and small. Lamina becomes chlorotic and veins remain green. Subsequently, dead spots develop all over the leaf including veins, tips and margins. In cereals, zinc deficiency generally appears in 2-4 leaves from the top during vegetative stage. Plants appear bushy due to reduced internodal elongation. Subsequently, panicle fails to emerge completely or emerges partially.

Toxicity Symptoms

When a nutrient is present in the soil in excess of plant's requirement, the nutrient is absorbed in higher amounts which causes imbalance of nutrients or disorder in physiological processes. Unlike deficiency symptoms, toxicity symptoms are less common.

Nitrogen. Excess nitrogen causes delay in maturity and increases succulence. The adverse effects of excess nitrogen are lodging and abortion of flowers. Crop becomes susceptible to pests and diseases.

Phosphorus. Excess phosphorus causes deficiency of iron and zinc. In some crops like maize, leaves develop purple colouration and plant growth is stunted. In cotton, leaves become dark green in colour, maturity of bolls delayed and stems turn red.

Iron. Tiny brown spots appear on the lower leaves of rice starting from tips and spreading towards bases. Leaves usually remain green. In extreme case, the entire leaf turns purplish brown in colour.

Manganese. The plant is stunted and tillering is often limited. Brown spots develop on the veins of the leaf blade and leaf sheath, especially on lower leaves. Manganese toxicity occurs in lowland rice.

Boron. Chlorosis occurs at the tips of the older leaves, especially along the margins. Large, dark brown, elliptical spots appear subsequently. The leaves ultimately turn brown and dry up.

Biochemical parameters as indicators of micronutrient deficiencies

Indicator	**Nutrient**
Nitrate reductase	Molybdenum
Catalase	Iron, Magnesium
Peroxidase	Iron, Manganese

Phenol oxidase	Iron, Magnesium
Polyphenol oxidase	Copper
Ascorbic acid oxidase	Copper
Carbonic anhydrase	Zinc
Aldolase	Zinc
Ribonuclease	Zinc

General recommendation for amelioration of nutritional disorders

Deficiency	**Soil application (kg ha^{-1})**	**Foliar spray (%)**
Nitrogen	i.Application of 50 kg urea (or)	Spraying of 1% urea
	ii.Application of 50 kg DAP	
Phosphorus	Application of 25-50 kg DAP kg ha^{-1}	Spraying of 2% DAP
Potassium	Application of Calcium chloride at 60 to 80 kg ha^{-1} or CAN at 50 kg ha^{-1}	Spraying of KCl 1%
Calcium	Application of Calcium chloride at 60 to 80 kg ha-1 or CAN at 50 kg ha^{-1}	Spraying of 0.5% $CaNO_3$ (or) CaCl2 (or) Calcium ammonium nitrate
Sulphur	Application of Gypsum at 50 kg ha^{-1}	Spraying of 0.5% gypsum
Magnesium	Application of magnesium sulphate 25-50 kg ha^{-1}	Spraying of 0.5% $MgSO_4$ + 1% urea
Iron	Application of ferrous sulphate 50-100 kg ha^{-1}	Spraying of $FeSO_4$ 1 to 2%
Zinc	Application of zinc sulphate 25 kg	Spraying of 0.5% $ZnSO_4$
Manganese	Application of 25 kg manganese sulphate ha^{-1}	Spraying of 0.5% $MnSO_4$
Copper	Application of 5 to 10 kg copper sulphate ha^{-1}	Spraying of 0.1% $CuSO_4$
Boron	Application of sodium tetraborate or borax at 10 kg ha^{-1}	Spraying of borax at 0.05%