Parameter	Range	Water Quality Class	No. of samples	Range	%
EC or Salinity (μS/cm) hazard classification	100–250	Excellent	-	-	-
	250–750	Good	10	269–717	29.41
	750–2,250	Doubtful	23	780–2055	67.65
	> 2,250	Unsuitable	1	2962	2.94
Total dissolved solids (TDS) (Davis & DeWiest, 1966)	< 500	Desirable for drinking	11	167.9–486.7	32.35
	500–1,000	Permissible for drinking	21	514.8–997.8	61.76
	1,000–3,000	Useful for irrigation	2	1282.3–1848.3	5.88
	> 3,000	Unfit for drinking and irrigation	-	-	-
% Na based classification (Wilcox, 1955)	< 20	Excellent	2	19.95–19.65	5.89
	20–40	Good	29	20.55–38.66	85.29
	40–60	Permissible	3	43.09–51.91	8.82
	60–80	Doubtful	-	-	-
	> 80	Unsuitable	-	-	-
SAR based Classification (Richards, 1954)	< 10	Excellent	34	0.75–2.29	100
	10–18	Good	-	-	-
	19–26	Doubtful / fair poor	-	-	-
	> 26	Unsuitable	-	-	-
Water Quality Index	0–25	Excellent	24	7.89–24.7	70.59
	26–50	Good	10	26.22–38.93	29.41
	51–75	Poor (Moderately polluted)	-	-	-
	76–100	Very poor (Severely polluted)	-	-	-
	> 100	Unsuitable (Unfit for consumption)	-	-	-

. Poor Quality of Irrigation Water and Management Practices

13.1 INTRODUCTION

Poor quality of water is one of the main factors turning good soil into saline or sodic. Several salts dissolved in it, as universal solvent. Irrigation with saline water adversely affects crop growth and productivity. High subsoil water table, aridity, seepage from canals, poor drainage, back water flow, intrusion of sea water also leads to salinity and sodicity. Around 1.5 mha areas are affected by poor quality water in India. The most affected state is Rajasthan. In world, over 50 million ha are affected by salinity spread over 24 countries.

13.2 PROBLEMS WITH POOR QUALITY WATER

Several soil and plant related problems arise due to use of poor quality water for irrigation.

13.2.1 Extraction of Water:

- If excess soluble salts of irrigation water accumulated in crop root zone, crop has difficulty in extracting enough water

- Root growth is also suppressed; increasing the difficulty of water uptake.
- Salinity stress in plants is often called physiological drought.
- Due to reduced uptake of water and other effects, yields are reduced.
- The reduction in yield due to salinity is more in warm climate than cool climate.

13.2.2 Soil permeability:

- Soil permeability is reduced due to the deflocculation effect of sodium.
- If permeability is reduced, infiltration of water into and through the soil is reduced.
- Adequate root penetration is inhibited due to the presence of impermeable soil layer caused by $CaCO_3$ and high exch.Na %
- Crusting of seed bed, Water logging, reduced oxygen and nutrient supply to the crops are the problems due to high sodium content relative of Ca& Mg.

13.2.3 Toxicity Symptoms:

- More uptake of B, Cl, Na, sulphate and bicarbonate by plant creates toxicity problems.
- Vegetative growth decrease as osmotic pressure of the soil solution increases.
- Reduction in growth takes place even without any external toxic symptoms.
- Increase in salinity, salt injury appears.
- Thick cuticle, waxy bloom and deep blue-green colour of leaves.
- At high salt levels, leaf burn appears in barley, sorghum and field beans.

13.2.4 Anatomical and Physiological Effects:

- Salinity reduces cell division, cell enlargement and protein synthesis.
- It affects the structure and integrity of plant membranes and causes mitochondria and chloroplast to swell.
- Sodium and chloride at toxic levels disrupt the structure of the protein molecules.
- High chloride content hinders the development of xylem tissue.

13.2.5 Nutritional Effects:

- Higher level of certain ions affect the absorption of other nutrient elements
- High concentration of sulphate reduces the uptake of calcium enhances the uptake of sodium.
- This process causes high level of sodium in plants, thus causing sodium toxicity.
- High concentration of Ca reduces the uptake of K.
- High concentration of Mg induces Ca deficiency.

13.2.6 Soil Microorganisms:

- NO_2 & NO_3 producing bacteria sensitive to high salt concentration than NH_4 producing bacteria.
- *Azotobacter* is resistance to salt concentration.

13.2.7 Other effects:

- Excessive vegetative growth, lodging, delayed crop maturity result due to excessive nitrogen in water.
- White and black deposit on soil due to high salt content and sodium and leaf burn due to using poor quality irrigation water in sprinkler irrigation are some of the problems.
- Tilth of the soil will be poor due to high exchangeable sodium percentage.

- Exchgeable Na tends to make moist soil impermeable to air and water & on drying soil becomes hard and difficult to work.
- The dense crusts formed interfere with germination and emergence of seedlings.
- Soluble carbonates are in water applied to soil in absence of Ca and Mg in soil, soil becomes alkaline &unfavorable.
- Na_2CO_3 in irrigation water is toxic to plants.

13.3 Management level of the irrigation

13.3.1 Use of saline water

Even the waters containing high amount of dissolved salts has been used successfully in highly permeable sandy soils. Similarly, the waters showing considerable alkali hazards have also been used successfully on permeable soils or by addition of gypsum and FYM on semi-permeable soils. The high RSC content can be corrected by addition of gypsum and the water can be used for the purpose of irrigation. Attempts have also been made for using saline waters by diluting it with good quality water or by giving alternate irrigation with good and bad quality water.

The CSSRI, Karnal has recommended following limits of EC for use of saline waters:

Tentative water quality ratings for Indian conditions

Soil groups	Soil texture	Clay content (%)	Crop tolerance to salinity	Upper permissible limits for water (EC in dS/m)	
				No drainage	Ground water level

				limitation	less than 1.51 m
Deep black and alluvial	Clayey	30	Fairly High	1.5 2.0	0.75 1.0
Alluvial	Clay loam	20-30	Fairly High	2.0 4.0	1.0 2.0
	Loam	10-20	Fairly High	4.0 6.0	2.0 3.0
	Sandy loam to sandy	10	Fairly High	6.0 8.0	3.0 4.0

The waters having high salinity can be used successfully in lighter textured soils by growing salt tolerant crops.

13.3.2 Leaching requirement (LR)

The leaching requirement may be defined as the fraction of the irrigation water that must be leached through the root zone to control soil salinity at any specific level.

The leaching requirement (LR) is simply the ration of the equivalent depth of the drainage water to the depth of irrigation water and may be expressed as a fraction or as per cent. Under the assumed conditions (uniform aerial application of irrigation water, no rainfall, no removal of salt in the harvested crop and no precipitation of soluble constituents in the soil), this ration is equal to the inverse ratio of the corresponding electrical conductivities as follows :

$$LR \ : \ \frac{D_{dw}}{D_{iw}} \ x \ 100 \ = \ \frac{EC_{iw}}{EC_{dw}} \ x \ 100$$

where;

LR	:	Leaching requirement expressed in percentage
D_{dw}	:	Depth of drainage water in cm
D_{iw}	:	Depth of irrigation water in cm
EC_{iw}	:	Electrical conductivity of the irrigation water in dS/m
EC_{dw}	:	Electrical conductivity of the drainage water in dS/m

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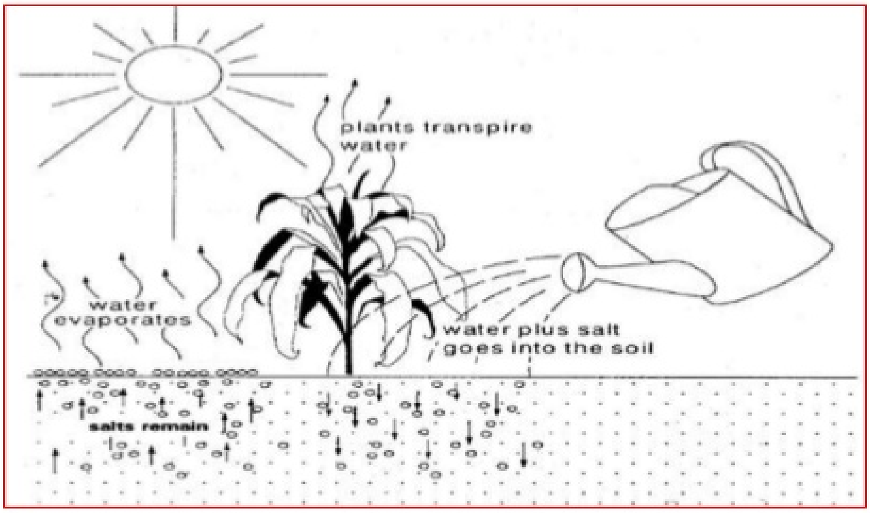
QUALITY OF IRRIGATION WATER AND MANAGEMENT OF SALINE WATER FOR IRRIGATION

INTRODUCTION

The suitability of irrigation water is mainly depends on the amounts and type of salts present in water. The main soluble constituents are calcium, magnesium, sodium as cations and chloride, sulphate, biocarbonate as anions. The other ions are present in minute quantities are boron, selenium, molybdenum and fluorine which are harmful to animals fed on plants grown with excess concentration of these ions

All irrigation waters are not pure and may contain some soluble salts. In arid and semi-arid regions successful crop production without supplemental irrigation is not possible. Irrigation water is usually drawn from surface or ground water sources, which typically contain salts in the range of 200 to 2000 ppm (= 200 to 2000 g/m^3). Irrigation water contains 10 – 100 times more salt than rain water. Thus, each irrigation event adds salts to the soil. Crop removes water from the soil to meet its water needs (ETc) leaving behind most of the salts to concentrate in the shrinking volume of soil water (Fig. 26.1). This is a continuous process. Application of saline water may hinder the crop growth directly and may also cause soil degradation. Beyond its effect on crop and soil, irrigation water of low quality can also affect environment by introducing potentially harmful substances in to surface and ground water sources. Therefore, a salt balance in the soil has to be maintained through proper water management practices for continuous and successful cultivation of crops.



CRITERIA TO DETERMINE THE QUALITY OF IRRIGATION WATER

The criteria for judging the quality of irrigation water are: Total salt concentration as measured by electrical conductivity, relative proportion of sodium to other cations as expressed by sodium adsorption ratio, bicarbonate content, boron concentration and soluble sodium percentage.

Total soluble salts

Salinity of water refers to concentration of total soluble salts in it. It is the most important single criterion of irrigation water quality. The harmful effects increase with increase in total salt concentration. The concentration of soluble salts in water is indirectly measured by its electrical conductivity (ECw). The quality of saline waters has been divided into five classes as per USDA classification given in Table.

Salinity classes of irrigation water

Salinity class		
	Micro mhos/cm	Milli mhos/cm
C_1 – Low	< 250	< 0.25
C_2 – Medium	25 – 750	0.25 – 0.75
C_3 – Medium to high	750 – 2250	0.75 – 2.25
C_4 – High	2250 – 5000	2.25 – 5.00
C_5 – Very high	> 5000	> 5.00

Adverse effects of saline water include salt accumulation, increase in osmotic potential, decreased water availability to plants, poor germination, patchy crop stand, stunted growth with smaller, thicker and dark green leaves, leaf necrosis & leaf drop, root death, wilting of plants, nutrient deficiency symptoms and poor crop yields.

Sodium Adsorption Ratio (SAR)

SAR of water indicates the relative proportion of sodium to other cations. It indicates sodium or alkali hazard.

$$SAR = \frac{Na^{+}}{\sqrt{\frac{Ca^{++} + Mg^{++}}{2}}}$$

The ion concentration is expressed as meq per litre. Increase in SAR of water increases the exchangeable sodium percentage (ESP) of soil. There is a linear relationship between SAR and ESP of the soil:

$$ESP = \frac{100\,(0.23 + 0.0042SAR)}{1 + (0.23 + 0.0042SAR)}$$

Sodicity classes of water

Sodium class	SAR value
S_1 – Low	< 10
S_2 – Moderate	10 – 18
S_3 – High	18 – 26
S_4 – Very high	> 26

Harmful effects of sodic water include destruction of soil structure, crust formation, poor seedling emergence, reduction in availability of N, Zn and Fe due to increased soil pH, Na toxicity and toxicity of B & Mo due to their excessive solubility.

Residual sodium carbonate

Bicarbonate is important primarily in its relation to Ca and Mg. There is a tendency for Ca to react with bicarbonates and precipitate as calcium carbonate. As Ca and Mg are lost from water, the proportion of sodium is increased leading to sodium hazard. This hazard is evaluated in terms of Residual Sodium Carbonate (RSC) as given below

$$RSC\,(meq/litre) = (CO_3^{--} + HCO_3^{-}) - (Ca^{++} + Mg^{++})$$

:

RSC is expressed in meq per litre. Water with RSC more than 2.5 meq/L is not suitable for irrigation. Water with 1.25 to 2.5 meq/L is marginally suitable and water with less than 1.25 meq/L is safe for use.

Boron content

Though boron is an essential micronutrient for plant growth, its presence in excess in irrigation water affects metabolic activities of the plant. For normal crop growth the safe limits of boron content are given in Table

Table . Permissible limts of boron content in irrigation for crops

Boron (ppm)	Quality rating
< 3	Normal
3 – 4	Low
4 – 5	Medium
5 – 10	High
More than 10	Very high

Leaching requirement

Leaching requirement (LR) is that fraction of total crop water requirement which must be leached down below the crop root zone depth to control salts within the tolerance level (ECe) of the crop.

$$Leaching\ Requirement\ (LR) = \frac{ECw}{5\ (ECe) - ECw}$$

Where:

ECw = Salinity of applied water in dS/m

ECe = Threshold level soil salinity of the crop in dS/m

MANAGEMENT PRACTICES FOR USING POOR QUALITY WATER

Whenever, it is inevitable to use water of poor quality water for crop production appropriate management practices helps to obtain reasonable yield of crops. Some of the important management practices are as follows:

a) Application of gypsum: Chemical amendments such as gypsum, when added to water will increase the calcium concentration in the water, thus reducing the sodium to calcium ratio and the SAR, thus improving the infiltration rate. Gypsum requirement is calculated based on relative concentration of Na, Mg & Ca ions in irrigation water and the solubility of gypsum. To add 1 meq/L of calcium, 860 kg of gypsum of 100% purity per ha m of water is necessary.

b) Alternate irrigation strategy:

Some crops are susceptible to salinity at germination & establishment stage, but tolerant at later stage. If susceptible stages are ensured with good quality water, subsequent tolerant stages can be irrigated with poor quality saline water.

c) Fertilizer application:

Fertilizers, manures, and soil amendments include many soluble salts in high concentrations. If placed too close to the germinating seedling or to the growing plant, the fertilizer may cause or aggravate a salinity or toxicity problem. Care, therefore, should be taken in placement as well as timing of fertilization. Application of fertilizers in small doses and frequently improve uptake and reduce damage to the crop plants. In addition, the lower the salt index of fertilizer, the less danger there is of salt burn and damage to seedlings or young plants.

d) Methods of irrigation:

The method of irrigation directly affects both the efficiency of water use and the way salts accumulate. Poor quality irrigation water is not suitable for use in sprinkler method of irrigation. Crops sprinkled with waters having *excess* quantities of specific ions such as Na and Cl cause leaf burn. High frequency irrigation in small amounts as in drip irrigation improves water availability and uptake due to microleaching effect in the wetted zone.

e) Crop tolerance:

The crops differ in their tolerance to poor quality waters. Growing tolerant crops when poor quality water is used for irrigation helps to obtain reasonable crops yields. Relative salt tolerance of crops is given in Table

Method of sowing:

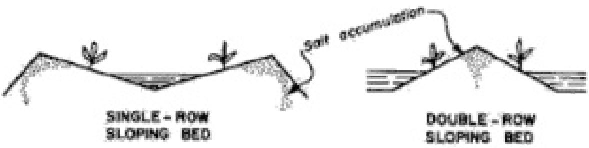
Salinity reduces or slows germination and it is often difficult to obtain a satisfactory stand. Suitable planting practices, bed shapes, and irrigation management can greatly enhance salt control during the critical germination period. Seeds have to be placed in the area where salt concentration is less. Salt accumulation is less on the slope of the ridge and bottom of the ridge. Therefore, placing the seed on the slope of the ridge, several cm below the crown, is recommended for successful crop establishment

g) Drainage:

Provide adequate internal drainage. Meet the nece ssary leaching requirement depending on crop and EC of water. This is necessary to av oid build of salt in the soil solution to leve ls that will limit crop yields. Leaching requ irement can be calculated from water test results and tolerance levels of specific crops.

. Relative salt tolerance of crops

Tolerant	Field crops: Cotton, Safflower, Sugarbeet & Barley Fruit crops: Date palm & Guava Vegeta bles: Turnip & Spinach Forage crops: Berseem & Rhodes grass
Semi tolerant	Field crops: Sorghum, Maize, Sunflower, Bajra, M ustard, Rice & Wheat Fruit crops: Fig, Grape & Mango Vegeta bles: Tomato, Cabbage, Cauliflower, Cucu mber, Carrot & Potato Forage crops: Senji & Oats
Sensitive	Field crops: Chick pea, Linseed, Beans, Greengram & Blackgram Fruit c rops: Apple, Orange, Almond, Peach, Strawberry, Lemon & Plum Vegeta bles: Radish, Peas & Lady's finger



Salinity control with sloping beds

h) Other management practices

- Over aged seedlings in rice:
  Transplanting of rice with over age d seedlings at a closer spacing results in better establishment in salt effected soils than normal aged seedlings. In case of other crops like finger millet, pearl millet etc., transplanting is better method than direct sowing of these crops for proper establishment.

- Mulching: Mulching wit h locally available plant material help i n reducing salt problems by reducing evaporation and by increasing infiltration.

- Soil management: All so il management practices that improve infiltration rate and maintain favourable soil structure reduces salinity hazard.

Crop rotation: Inclusion of crops such as rice in the rotation reduces salinity

References :

Books;-

Panda SC. 2003. Principles and Practices of Water Management. Agrobios.

Michael AM. 1978. Irrigation Theory and Practice. Vikas Publ.

Paliwal KV. 1972. Irrigation with Saline Water. IARI Monograph, New Delhi.

Lenka D. 1999. Irrigation and Drainage. Kalyani

Web pages:-

http://site.iugaza.edu.ps/halnajar/files/2010/03/L8-Irrigation-Water-Quality.pdf
http://www.agriinfo.in/?page=topic&superid=1&topicid=30
http://www.fao.org/docrep/x5871e/x5871e07.htm
http://agritech.tnau.ac.in/agriculture/agri_irrigationmgt_suitabilityofwater.html

Articles /research papers;-

http://www.ajer.org/papers/v2(3)/I0235968.pdf
https://www.researchgate.net/publication/266506192_Irrigation_water_quality_and_its_effects_upon_soil

Article
Irrigation Water Quality for Leafy Crops: A Perspective of Risks and Potential Solutions
Ana Allende and James Monaghan

ossible effects of pH and soil type on nutrient availability

Soil type	Low pH <6.0	Normal pH 6.0 –	High pH >7.0

		7.0	
Clay	Phosphorus Molybdenum		Boron Manganese Zinc
Clay Loam	Phosphorus Potassium Molybdenum	Manganese	Boron Manganese Zinc
Loam	Phosphorus Potassium Molybdenum	Boron Manganese	Boron Copper Iron Manganese Zinc
Sandy Loam	Nitrogen Phosphorus Potassium Magnesium Copper Molybdenum	Nitrogen Magnesium Sulfur Boron Copper Manganese Zinc	Nitrogen Phosphorus Magnesium Sulfur Boron Copper Iron Manganese Zinc
Sandy soils	Nitrogen Phosphorus Potassium Magnesium Sulfur Boron Copper Molybdenum Zinc	Nitrogen Potassium Magnesium Sulfur Boron Copper Manganese Zinc	Nitrogen Phosphorus Potassium Magnesium Sulfur Boron Copper Iron Manganese Zinc
Organic soils – Peat	Phosphorus Copper Zinc	Copper Manganese Zinc	Boron Copper Manganese Zinc
Thin soil over Limestone	Magnesium	Magnesium Copper Manganese Zinc	Magnesium Copper Manganese Zinc

Essentiality of Elements in Plant Nutrition

A mineral element is considered essential to plant growth and development if the element is involved in plant metabolic functions and the plant cannot complete its life cycle without the element. Usually the plant exhibits a visual symptom indicating a deficiency in a specific nutrient, which normally can be corrected or prevented by supplying the nutrient. Terms commonly used to describe levels of nutrients in plants:

***Deficient*:** When the concentration of an essential element is low enough to limit yield severely and distinct deficiency symptoms are visible. Extreme deficiencies can result in plant death. With moderate or slight deficiencies, symptoms may not be visible, but yields will still be reduced.

***Critical range*:** The nutrient concentration in the plant below which a yield response to added nutrient occurs. Critical levels or ranges vary among plants and nutrients, but occur somewhere in the transition between nutrient deficiency and sufficiency.

***Sufficient*:** The nutrient concentration range in which added nutrient will not increase yield but can increase nutrient concentration. The term *luxury consumption* is often used to describe nutrient absorption by the plant that does not influence yield.

***Excessive or toxic*:** When the concentration of essential or other elements is high enough to reduce plant growth and yield. Excessive nutrient concentration can cause an imbalance in other essential nutrients, which also can reduce yield.

Essential Elements

Sixteen elements are considered essential to plant growth. Carbon (C), hydrogen (H) and oxygen (O) are the most abundant elements in plants. The photosynthetic process in green leaves converts CO_2 and H_2O into simple carbohydrates from which amino acids, sugars, proteins, nucleic acid and other organic compounds are synthesized. Carbon, H and O are not considered mineral nutrients. The supply of CO_2 is relatively constant. The supply of H_2O rarely limits photosynthesis directly but does indirectly though the various effects resulting from moisture stress.

The remaining 13 essential elements are classified as macronutrients and micronutrients and the classification is based on their relative abundance in plants. The macronutrients are nitrogen (N), phosphorus (P), potassium (K), sulfur (S), calcium (Ca) and magnesium (Mg). Compared to the macronutrients, the concentrations of the seven micronutrients – iron (Fe), zinc (Zn), manganese (Mn), copper (Cu), born (B), chlorine (Cl) and molybdenum (Mo) – are very small. Five additional elements – sodium (Na), cobalt (Co), vanadium (Va), nickel (Ni) and silicon (Si) have been established as essential micronutrients in some plants. Micronutrients are often referred to as minor elements, but this does not mean that they are less important than macronutrients. Micronutrient deficiency or toxicity can reduce plant yield similar to macronutrient deficiency or toxicity.

In fact, plants absorb many nonessential elements, and over 60 elements have been identified in plant materials. When plant material is burned, the remaining plant ash contains all the essential and nonessential mineral elements except, C, H, O, N and S which are burnt off as gases.

Soil, climate, crop variety and management factors exert considerable influence on plant composition. Because many biological and chemical reactions occur with fertilizers in soils, the quantity of nutrients absorbed by plants does not equal the quantity applied as a fertilizer. Proper fertilizer management can maximize the proportion of fertilizer nutrient absorbed by the plant. As plants absorb nutrients from the soil, complete their life cycle and die, the nutrients in the plant residue are returned to the soil. These plant nutrients are subject to the same biological and chemical reactions as fertilizer nutrients. Although this cycle varies somewhat among nutrients, understanding nutrient dynamics in the soil plant atmosphere system is essential to successful fertilizer management.

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Plant Nutrition :: Mineral Nutrition

Essentiality of Elements in Plant Nutrition

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***Critical range*:** The nutrient concentration in the plant below which a yield response to added nutrient occurs. Critical levels or ranges vary a the transition between nutrient deficiency and sufficiency.

***Sufficient*:** The nutrient concentration range in which added nutrient will not increase yield but can increase nutrient concentration. The term nutrient absorption by the plant that does not influence yield.

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Table 1. Essential Nutrients for plant growth and their principal forms for uptake

Nutrient	Chemical Symbol	Principal forms for uptake
Carbon	C	CO2
Hydrogen	H	H2O
Oxygen	O	H2O, O2
Nitrogen	N	NH+4, NO-3
Phosphorus	P	H2PO-4, HPO2-4
Potassium	K	K+
Calcium	Ca	Ca2+
Magnesium	Mg	Mg2+
Sulfur	S	SO2-4, SO2
Iron	Fe	Fe2+, Fe3+
Manganese	Mn	Mn2+
Boron	B	H3BO3
Zinc	Zn	Zn2+
Copper	Cu	Cu2+
Molybdenum	Mo	MoO2-4
Chlorine	Cl	Cl-

Table 2 . Relative and Average Plant Nutrient Concentrations

Plant Nutrient	Average Concentration*
H	6.0%
O	45.0%
C	45.0%
N	1.5%
K	1.0%
Ca	0.5%
Mg	0.2%
P	0.1%
S	0.1%
Cl	100 ppm (0.01%)
Fe	100 ppm
B	20 ppm
Mn	50 ppm
Zn	20 ppm
Cu	6 ppm
Mo	0.1 ppm

* Concentration expressed by weight on a dry matter basis.

Table 3 . Functions of Essential Nutrients in Plants

Nutrient	Function
Carbon	Basic molecular component of carbohydrates, proteins, lipids, and nucleic acids.
Oxygen	Oxygen is somewhat like carbon in that it occurs in virtually all organic compounds of living organisms.
Hydrogen	Hydrogen plays a central role in plant metabolism. Important in ionic balance and as main reducing agent and plays a key role in energy relations of cells.
Nitrogen	Nitrogen is a component of many important organic compounds ranging from proteins to nucleic acids.
Phosphorus	Central role in plants is in energy transfer and protein metabolism.
Potassium	Helps in osmotic and ionic regulation. Potassium functions as a cofactor or activator for many enzymes of carbohydrate and protein metabolism.
Calcium	Calcium is involved in cell division and plays a major role in the maintenance of membrane integrity.
Magnesium	Component of chlorophyll and a cofactor for many enzymatic reactions.
Sulfur	Sulfur is somewhat like phosphorus in that it is involved in plant cell energetic.
Iron	An essential component of many heme and nonheme Fe enzymes and carries, including the cytochromes (respiratory electron carriers) and the ferredoxins. The latter are involved in key metabolic function such as N fixation, photosynthesis, and electron transfer.
Zinc	Essential component of servral dehydrogenases, and peptidases, including carbonic anhydrase, alcohol dehydrogenase, glutamic dehydrogenase, and malic dehdrogenase, among others.
Manganese	Involved in the O2 – evolving system of photosynthesis and is a component of the enzymes arginase and phosphotransferases.
Copper	Constituent of a number of important enzymes, including cytochrome oxidize, ascorbic acid oxidase, and laccase.
Boron	Involved in carbohydrate metabolism and synthesis of cell wall components.
Molybdenum	Required for the normal assimilation of N in plants. An essential component of nitrate reductase as well as nitrogenase (N2 fixation enzyme)
Chlorine	Essential for photosynthesis and as an activator of enzymes involved in splitting water. It also functions in osmoregulation of plants growing on saline soils.

General absorption and mobility rankings for foliar applied nutrients

Absorption	Mobility
Rapid	**Mobile**
Urea Nitrogen, Potassium, Zinc	Urea Nitrogen, Potassium, Phosphorus, Sulf
Moderate	**Partially Mobile**
Calcium, Sulfate, Manganese, Boron	Zinc, Copper, Manganese, Boron, Molybden
Slow	**Immobile**
Magnesium, Copper, Iron, Molybdenum	Iron, Calcium, Magnesium

.

plant nutrient interaction

Nitrogen: When high levels of Nitrogen induce accelerated growth rates, levels of micronutrients that would normally be m
levels of Nitrogen can assist Phosphorus, Calcium, Boron, Iron and Zinc but an excess can dilute these elements. Low soil
Boron, Iron and Zinc uptake. Ammonium Nitrogen can make Molybdenum deficiency appear less obvious.

Phosphorus: High levels of Phosphorus reduce Zinc and, to a lesser degree, Calcium uptake. It is antagonistic to Boron in

Potassium: High levels of Potassium reduce Magnesium and to lesser extent Calcium, Iron, Copper, Manganese and Zinc
toxic. Low levels can accentuate Iron deficiency.

Calcium: High levels of Calcium can accentuate Boron deficiency. Liming can decrease the uptake of Boron, Copper, Iron

Copper: High levels of Copper can accentuate Molybdenum and to a lesser degree Iron, Manganese and Zinc deficiency.

Iron: Iron deficiency can be accentuated by liming, low Potassium levels or high levels of Copper, Manganese or Zinc.

Manganese: High levels of Copper, Iron or Zinc can accentuate Manganese deficiency – especially repeated soil applicati
liming or increased by Sulfur applications (because of the affects on pH)

Molybdenum: Deficiencies can be accentuated by high levels of Copper and to a lesser degree Mnaganese. Uptake can b
can be increased by phosphates and liming. Molybdenum can increase Copper deficiencies in animals.

Zinc: Uptake can be decreased by high Phosphorus levels, liming or high levels of Copper, Iron or Manganese. Zinc defici
Manganese deficiencies, especially in citrus.

Nutrient Deficiency Symptoms of Plants

Growing plants act as integrators of all growth factors and are the products in which the grower is interested. Therefore, careful inspection of
nutrient stress. if a plant is lacking in a particular nutrient, characteristic symptoms may appear. Deficiency of a nutrient does not directly prod
processes are thrown out of balance, with an accumulation of certain intermediate organic compounds and a shortage of others. This leads t
symptoms. Visual evaluation of nutrient stress should be used only as a supplement to other diagnostic techniques (i.e., soil and plant analys
classified as follows:

1. Complete crop failure at the seedling stage.
2. Severe stunting of plants.
3. Specific leaf symptoms appearing at varying times during the season.
4. Internal abnormalities such as clogged conductive tissues.
5. Delayed or abnormal maturity.
6. Obvious yield differences, with or without leaf symptoms.
7. Poor quality of crops, including differences in protein, oil, or starch content, and storage quality.
8. Yield differences detected only by careful experimental work.

Each symptom must be related to some function of the nutrient in the plant. A given nutrient may have several functions, which makes it diffic
particular deficiency symptom. For example, when N is deficient, the leaves of most plants become pale green or light yellow. When the quar
reduced, and the yellow pigments, carotene and xanthophylls are shown through a number of nutrient deficiencies produced such as pale gre
further related to a particular leaf pattern or location on the plant.

Apparent visual deficiency symptoms can be caused by many factors other than a specific nutrient stress. Precautions in interpreting nutrient

1. The visual symptom may be caused by more than one nutrient. For example, N-deficiency symptoms may be identified, although S
readily apparent. B deficiency is accompanied by a red coloration of the leaves near the growing point when the plant is well supplie
low, yellowing of alfalfa leaves occurs.
2. Deficiencies are actually relative, and a deficiency of one nutrient may be related to an excessive quantity of another. For example,
quantities of Fe, provided that soil Mn is marginally deficient. Also, at a low level of P supply, the plant may not require as much N co
once the first limiting factor is eliminated, the second limiting factor will appear (Liebig's law of the minimum).
3. It is often difficult to distinguish among the deficiency symptoms in the field, as disease or insect damage can resemble certain micr
damage can be confused with deficiency in alfalfa.
4. A visual symptom may be caused by more than one factor. For example, sugars in corn combine with flavones to form anthocyanin
accumulation may be caused by an insufficient supply of P, low soil temperature, insect damage to the roots, or N deficiency.

Nutrient deficiency symptoms appear only after the nutrient supply is so low that the plants can no longer function properly. In such cases, it

long before the symptoms appeared. If the symptoms are observed early, it might be corrected during the growing season. Since the objectiv
quickly as possible, with some nutrients and under some conditions this may be accomplished with foliar applications or side dressings. Usua
would have been obtained if adequate nutrients had been available at the beginning. However, if the problem is properly diagnosed, the defic

Hidden Hunger

Hidden hunger refers to a situation in which a crop needs more of a given nutrient yet has shown no deficiency symptoms. The
symptom zone but still considerably needed for optimum crop production. With most nutrients on most crops, significant respon
recognizable symptoms have appeared.

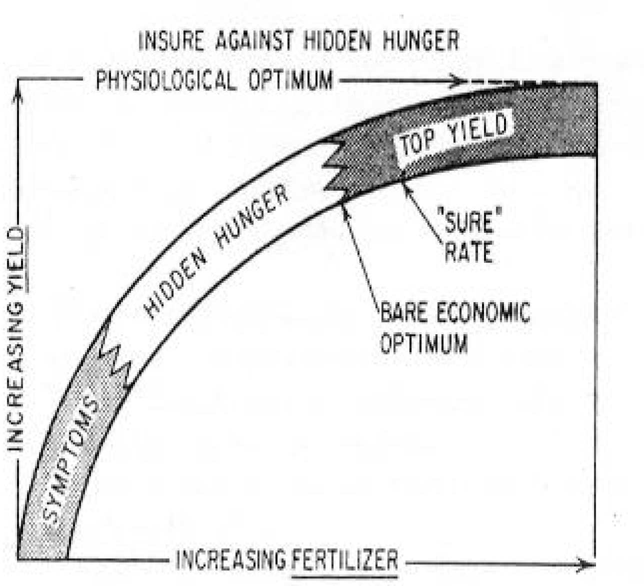

Figure. Hidden hunger is a term used to describe a plant that shows no obvious symptoms, yet the nutrient content is not sufficient to give the
Phasphate Institute, Atlanta, Ga.

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The question, then, is how best to eliminate hidden hunger. Testing of plants and soils is helpful for planning or modifying plant
subsequent crops. In both approaches, careful consideration must be given to past management practices.

Generalized Visual Leaf and Plant Nutrient Element Deficiency and Excess Symptoms

Element/status	Visual symptoms
Nitrogen (N)	
Deficiency	Light green leaf and plant color with the older leaves turning yellow, leaves that will eventually growth is slow, plants will be stunted, and will mature early.
Excess	Plants will be dark green in color and new growth will be succulent; susceptible if subjected to and subjected to drought stress, plants will easily lodge. Blossom abortion and lack of fruit set
Ammonium toxicity	Plants fertilized with ammonium-nitrogen (NH4- N) may exhibit ammonium-toxicity symptoms, and reduced plant growth. Lesions may occur on plant stems, there may be a downward cupp of the conductive tissue at the base of the stem with wilting of the plants under moisture stress occur 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, partic
Excess	Phosphorus excess will not have a direct effect on the plant but may show visual deficiencies 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 easil 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 emerging leaves stick together. Fruit quality will be affected with the occurrence of blossom-er
Excess	Plants may exhibit typical Mg deficiency symptoms, and when in high excess, K deficiency ma
Magnesium (Mg)	
Deficiency	Older leaves will be yellow in color with interveinalchlorosis (yellowing between the veins) sym 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 color of the entire plant with the older leaves being light green to intensifies.
Excess	A premature senescence of leaves may occur.
Boron (B)	
Deficiency	Abnormal development of the growing points (meristematic tissue) with the apical growing poi stunted and dying. Rowers and fruits will abort. For some grain and fruit crops, yield and quali
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 infes
Excess	Premature yellowing of the lower leaves with burning of the leaf margins and tips. Leaf absciss easily wilt.
Copper (Cu)	
Deficiency	Plant growth will be slow and plants stunted with distortion of the young leaves and death of th
Excess	An Fe deficiency may be induced with very slow growth. Roots may be stunted.
Iron (Fe)	
Deficiency	Interveinalchlorosis will occur on the emerging and young leaves with eventual bleaching of th the entire plant may be light green in color.
Excess	A bronzing of leaves with tiny brown spots on the leaves, a typical symptom frequently occurri
Manganese (Mn)	
Deficiency	Interveinalchlorosis of young leaves while the leaves and plants remain generally green in colo 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 chlo instances, leaf margins are rolled and growth and flower formation are restricted.
Excess	Not of common occurrence.
Zinc (Zn)	
Deficiency	Upper leaves will show interveinalchlorosis with an eventual whiting of the affected leaves. Lea torted with a rosette form.
Excess	An Fe deficiency will develop.

Terms:

Chlorosis is a physiological disorder that occurs to deficiency of mineral elements (eg; Mn, K, Zn, Fe, Mg, S and N). Leaves or plant parts l

Mottled is surface marked with coloured spots (anthocyanin develops) eg. Due to deficiency of N, Mg, P, S.

Table 1. Soil conditions inducing nutrient deficiencies for crop plants

Nutrient	Conditions inducing deficiency
N	Excess leaching with heavy rainfall, low organic matter content of soils, burning the crop residue
P	Acidic condition, calcareous soils
K	Sandy, organic, leached and eroded soils; intensive cropping system without addition of fertilizer
Ca	Acidic, Alkali, or sodic soils
Mg	Similar to Calcium
S	Low organic matter content of soils ; use of N and P fertilizers containing no sulfur, burning the crop residue

Fe	Calcareous silt and clays, high organic matter, calcareous soils
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 soil
B	Sandy soils, naturally acidic leached soils, alkaline soils with free lime
Mo	Highly podzolized soils ; well drained calcareous soils

Source: http://www.plantstress.com/Articles/min_deficiency_i/impact.htm

Table 2. Range in nutrient content commonly found in soils

Nutrient	**Normal range**	
	Per cent (%)	**Parts per million (ppm)**
Nitrogen	0.02-0.50	200-5000
Phosphorus	0.01-0.20	100-2000
Potassium	0.17-3.30	1700-33000
Calcium	0.07-3.60	700-36000
Magnesium	0.12-1.50	1200-15000
Sulphur	0.01-0.20	100-2000
Iron	0.50-5.00	5000-50000
Manganese	0.02-1.00	200-10000
Zinc	0.001-0.025	10-250
Boron	0.0005-0.015	5-150
Copper	0.0005-0.015	5-150
Chlorine	0.001-0.10	10-1000
Cobalt	0.0001-0.005	1-50
Molybdenum	0.00002-0.0005	0.2-5

Nutrient mobility in soil

Very Mobile – (prone to leaching) nitrate Nitrogen, sulfateSulfur, Boron

Moderately Mobile – Ammonium Nitrogen (Ammonium Nitrogen is temporarily immobile), Potassium, Calcium, Magnesium, Molybdenum

Immobile – Organic Nitrogen, Phosphorus, Copper, Iron, Manganese, Zinc (Chelated forms of Copper, Iron, Manganese and Zinc are mobile and resistant to leaching)

Nutrient mobility in plants

Very mobile – Nitrogen, Phosphorus, Potassium, Magnesium (Deficiency symptoms appear first in older leaves and quickly spread throughout the plant)

Moderately mobile – Sulfur, Copper, Iron, Manganese, Molybdenum, Zinc (Deficiency symptoms first appear in new growth but do not readily translocate to old growth)

Immobile – Boron, Calcium (Calcium is very immobile)

Table 3. Ranges of the major elements and micronutrients in mature leaf tissue generalized as deficient, sufficient or excessive for various plant species

Essential elements	% Deficient	% Sufficient or Normal	% Excessive or Toxic
Major Elements			
Nitrogen (N)	<2.50	2.50 - 4.50	>6.00
Phosphorus (P)	<0.15	0.20 - 0.75	>1.00
Potassium (K)	<1.00	1.50 - 5.50	>6.00
Calcium (Ca)	<0.50	1.00 - 4.00	>5.00
Magnesium (Mg)	<0.20	0.25 - 1.00	>1.50
Sulfur(S)	<0.20	0.25 - 1.00	>3.00
Micronutrients	**ppm**	**ppm**	**ppm**
Boron (B)	5 - 30	10 - 200	50 - 200
Chlonne (Cl)	<100	100 - 500	500 - 1,000
Copper (Cu)	2 - 5	5 - 30	20 - 100
Iron (Fe)	<50	100 - 500	>500
Manganese (Mn)	15 - 25	20 - 300	300 - 500
Molybdenum (Mo)	0.03 - 0.15	0.1 - 2.0	>100
Zinc(Zn)	10 - 20	27 - 100	100 - 400

Flowchart for the identification of deficiency symptoms

Indicator Plants

Deficiency	Crop
Nitrogen	Maize , Sorghum ,Leguminous plants
Phosphorus	Tomato ,Maize, Lucerne, Cereals, Duranta
Potassium	Maize, Lucerne , Cotton, Potatoes, Banana, Cucurbits
Sulpur	Lucerne , Clover , Cereals, Tea
Zinc	Maize, Tomatoes , Potatoes, Beans, Citrus
Copper	Citrus
Iron	Ornamental plants, Ixora, Acacia, Eucalyptus, Gooseberry, Securmanis
Boron	Lucerne, Coconut, Guava
Manganese	Citrus
Molybdenum	Cauliflower, Cabbage

		
Sorghum: Nitrogen deficiency	Maize: Phosphorus deficiency	Cotton: Potassium deficiency
		
Rice: Sulphur deficiency	Tomato: Zinc deficiency	Sugarcane: Fe deficiency
		
Lime: Copper deficiency	Guava: Boron deficiency	

Sampling of plant material

Sampling techniques vary with the crop. In some cases, such as cereal crops, leaf samples are taken. In a few cases, for example suspected boron deficiency in sugar beet, the roots should be sampled.

In any sampling of plant material great care should be taken to avoid soil contamination. This is true when sampling for major element analysis but it is critically important when trace element analysis is concerned because the contaminating soil may contain very much more of some trace elements than does the crop and a false result will be obtained.

It is essential to take a representative sample of the crop. One or two whole plants taken from an area may be completely unrepresentative. Samples should be taken from 50-100 plants in a given area. The advisory services, if called in may wish to take samples themselves, or may advise on which part of the plant to sample.

If a deficiency or toxicity condition is suspected in only a part of a field, 'good' and 'poor' areas should be sampled for comparison in the laboratory. Leaves or other parts of the plant, of the same age or growth stage, should be taken at the same time.

It is extremely important to use containers for transporting the samples which will not contaminate them. Tins, other metal containers and even some paper bags can cause serious contamination of the sample. The best container is a clean polythene bag. After taking the sample, labels should be attached, the bag sealed and transferred to the laboratory as quickly as possible.

The basic principle behind this technique is that the nutrient concentration of plants is related to the amount of nutrient element available in soil. General range of nutrient content in fully developed leaves of vegetable crops is given in table. If the nutrient level in the tissues falls below the critical concentration, the soil may be deficient in that element for optimum plant growth.

Different plant parts of the same plant contain different concentrations of the same nutrient. Nutrient concentration again varies with the stage of the crop. So, leaf samples for analyses should be selected on the basis of physiological age, i.e., developmental stage. Stages of leaf sampling for the vegetable crops have been presented in table. It is important that the sample must be free from diseases, insect damage and physical or chemical injury. Leaf near the fruit should not be sampled as the nutrients, it might have contained, are often translocated to the fruits.

Table . Sampling procedures for collecting leaf and plant tissue for a plant analysis (Plank, 1979)

Stage of growth	Plant part to sample	Number of plants to sample
Field crops		
Maize*		
Seedling stage (less than 30 cm)	All the above ground portion	20-30
Prior to tasseling	The entire leaf blade fully developed below the whorl	15-25
or		
From tasseling and shooting to silking	The entire leaf blade at the ear node (or immediately above or below it)	15-25
* Sampling after silking occurs is not recommended		
Soybeans or Other Beans*		
Seedling stage (less than 30 cm)	All the above ground portion	20-30
or		
Prior to or during initial flowering	The leaflets on 2 or 3 fully developed leaves at the top of the plant	20-30
* Sampling after pods begin to set not recommended.		
Small Grains (including rice)*		
Seedling stage (less than 30 cm)	All the above ground portion	50-100
or		
Prior to heading	The 4 uppermost leaf blades	
* Sampling after pods begin to set not recommended.		
Hay Pasture, or Forage Grasses		
Prior to seed head emergence or at the optimum stage for best quality forage	The 4 uppermost leaf blades	40-50
Alfalfa		
Prior to or at 1/10 bloom stage	Mature leaf blades taken about 1/3 of the way down the plant	40-50
Clover and Other Legumes		
Prior to bloom	Mature leaf blades taken about 1/3 of the way down from top of the plant	40-50
Cotton		
Prior to or at first bloom or when first squares appear	Youngest fully mature leaf blades on main stem.	30-40
Tobacco		
Before bloom	Uppermost fully developed leaf blade	8-12
Sorghum		
Prior to or at bloom stage	Leaflets of mature leaves from both the main stem and either cotyledon lateral branch	15-25
Peanuts (Groundnuts)		
Prior to or at bloom stage	Leaflets of mature leaves from	40-50

	both the main stem and either cotyledon lateral branch		
Potato	Fourth to sixth leaf from growing tip	Early growth (35-40 days after planting)	20-30
Tomato	Fourth to sixth leaf from growing tip	Early bloom	20-25
Chilli and Sweet pepper	Young mature leaves	Early fruit set	20-25
Cauliflower	Young mature outside leaves	Button stage of curd	10-20
Cabbage	First mature leaf from central whort	Prior to heading	10-20
Broccoli	Young mature leaves	First bud formation stage	10-20
Brussels sprouts	Young mature leaves	Mid growth	10-20
Watermelon, Muskmelon, Cucumber, Pumpkin, etc.	Mature leaves near the base portion of plant on main stem.	Early growth prior to fruit set	20-30
Beans (French bean, Cowpea, Lima bean, Hyacinth bean, etc.)	Two to three fully developed leaves at top of the plant	Initial flowering	20-30
Pea	Leaves form third node down from top of the plant	Initial flowering	30-60
Root crops (Carrot, Radish, Beet, Turnip)	Young from third node down from top of the plant	Initial flowering	20-30
Bulb crops (Onion, Garlic etc.)	Young mature leaves from centre	Prior to bulbing	20-30
Celery	Petiole of youngest fully elongated leaf	Midgrowth (30-35 cm tall)	10-20
Lettuce (leaf type)	Midrib of wrapper leaf	Heading	30-40
Lettuce (leaf type)	Youngest mature leaf	Midgrowth	30-40
Leafy greens (Palak, Spinach, etc.)	Youngest mature leaf	Midgrowth	30-40
Sweet potato	Fourth to sixth leaf from the growing tip	Prior to root enlargement	20-30
Asparagus	Top 10 cm of the new fern branch	Midgrowth of the ferm	20-30
Sweet com	Entire leaf at the ear node		

	Tasseling	20-30
FRUITS AND NUTS		
Apple, Apricot, Almond, Prune, Peach, Pear, Cherry		
Mid season	Leaf blade near base of current year's growth or from spurs	50-100
Strawberry		
Mid season	Youngest fully expanded mature leaves, without petioles	50-75
Pecan		
6 to 8 weeks after bloom	Leaflets from terminal shoots, (taking the pairs from the middle of the leaf)	30-45
Walnut		
6 to 8 weeks after bloom	Middle leaflet pairs from mature shoots	30-35
Grapes		
End of bloom period	Petioles from leaves adjacent to fruit clusters	60-100
Raspberry		
Mid season	Youngest mature leaves on laterals or "primo" canes (without leaf petioles)	20-40
Ornamentals and Flowers		
Ornamental trees		
Current year's growth	Fully developed leaves (without petioles)	30-100
Ornamental Shrubs		
Current year's growth	Fully developed leaves	30-100
Turf		
During normal growing season	Leaf blades. Clip by hand to avoid contamination with soil or other material	½ liter of material
Roses		
During flower production	Upper leaves on the flowering stem, without petioles	20-30
Chrysanthemums		
Prior to or at flowering	Upper leaves on flowering stem	20-30
Carnations		
1. Unpinched plants	4th or 5th leaf pairs from base of plant	20-30
Pinched plants	5th or 6th leaf pairs from top of primary laterals	20-30
Poinsettias		
Prior to or at flowering	Most recently mature, fully expanded leaf blades	15-20

Taking plant samples for analyses of nutrient content

1. **Mailing Kit.** Many laboratories have plant analysis mailing kits. Instructions for sampling and submitting samples should be followed specifically.
2. **What to sample.** The sampling procedures for collecting leaf and plant tissue for analysis is shown in Table 3.4. When no specific sampling instructions are given for a particular crop, the general rule of thumb is to sample the upper, recently matured leaves. The recommended stage of growth to sample is just prior to the beginning of the reproductive stage for many plants. Roots from total plant sample should be removed. It is well to take a soil sample from the same area at the same time.
3. **Comparison samples.** Where a deficiency is suspected, take samples from normal plants in an adjacent area as well as from the affected plants. Take a soil sample from each area also.
4. **Washing to remove contaminants.** Dusty plants should be avoided but if dust is present, brushing or wiping with a clean damp cloth may be sufficient. If not, rinse briefly in running water while the material is still fresh.

5. **What not to sample.**

    1. Diseased or dead plant material, damaged by insects, or mechanically injured.
    2. Plants stressed severely by cold, heat, moisture deficiency or excess.
    3. If roots are damaged by nematodes, insects or diseases.

6. **The questionnaire.** This is the means of communication between the sample and the laboratory. Completion of the questionnaire is important if the interpreter is to evaluate properly the analysis and make a recommendation.
7. **Packaging the plant tissue.** Partially air dry and put in a clean paper bag or envelope. Do not put in polyethylene bags or tightly sealed containers, since this permits molding.

Selection of the tissue to be tested in various plants and interpretation of the analyses under the varying environmental conditions of any given plant and conditions of any given plant are much more complex. Since the plant is a dynamic system growing in a dynamic soil system and subject to other ecological influences, many factors will influence the level of the soluble or unassimilated nutrients in a given plant at any given time. Some of the most pertinent of these which should be considered in the interpretation of the tests are: first general performance and vigor of the plant; Second, level of other nutrients in the plants; third, occurrence of insect damage, disease or other known disturbances; forth, climatic condition at the time of testing; and fifth, time of day at which tests are made. In other words, the plant diagnostician must be well versed with the physiology of the plant if he is to make most effective use of plant – tissue tests.

Rapid tissue test for nutrients

The crop growth and productivity is conditioned by many factors of which, the nutrient status (Content) of plant parts such as leaf, stem, etc play a critical role. Moreover the leaf and stem are considered as the indicator parts of plants for assessing the nutrients content of plant. Each crop plant requires the essential element at a specific concentration at different growth stages and it is known as 'critical level'. When the nutrients content of plant depletes below the critical level the plants may exhibit some symptoms. The requirement or otherwise the availability of nutrients can be assessed by i) plant diagnosis ii) soil analysis and iii) plant analysis by two methods a) by qualitative test and b) by quantitative estimation. Based on the plant or soil tests, the required nutrients can be applied for crops to sustain the growth and rectify the deficiency disorders. The rapid tissue test would pave way for rectifying the nutritional problems for quick recovery, however the quantitative estimation of both plant and soil for nutrients concentration will be more useful and economic for applying fertilizers either as basal or foliar and would be the long term strategy to cope up with nutritional problems.

On dry weight basis, the normal healthy cultivated crop plant will have the foliar concentration of essential elements. Nevertheless it will vary depends up on the variety, type of soil, growth stage and other environmental and cultural operations.

Nitrogen	:	1.0 to 3.0 %	Iron	:	20 to 100 ppm
Phosphorus	:	0.05 to 1.0 %	Zinc	:	15 to 50 ppm
Potassium	:	0.8 to 1.2 %	Manganese	:	2.0 to 10 ppm
Calcium	:	0.3 to 0.6 %	Copper	:	10 to 20 ppm
Magnesium	:	0.2 to 0.4 %	Boron	:	5 to 15 ppm
Sulphur	:	0.2 to 0.3 %	Molybdenum	:	0.5 to 5.0 ppm

For rapid tissue test to assess the nutrient status, different parts of plant should be taken as indicator tissue and some of the representative crops are furnished below:

Crops	Nutrients					
	N	P	K	Ca	Mg	S
Cereals	Stem/Midrib	Leaf blade	Leaf blade	Leaf lamina	Leaf lamina	Leaf blade
Pulses	Petiole	Leaf blade	Leaf blade	Leaf lamina	Leaf lamina	Leaf blade
Oil seeds	Petiole	Leaf blade	Leaf blade	Leaf lamina	Leaf lamina	Leaf blade
Cotton	Petiole	Petiole	Petiole	Petiole	Petiole	Petiole
Banana	Leaf lamina	Leaf lamina	Leaf lamina	Leaf lamina	Leaf lamina	Leaf lamina
Papaya	Petiole	Petiole	Petiole	Petiole	Petiole	Petiole
Vegetables	Petiole, Leaf blade	Petiole Leaf blade	Petiole, Leaf blade	Petiole, Leaf blade	Petiole, Leaf blade	Petiole, Leaf blade

Fruit trees

Either leaf blade/mid rib/leaf lamina can be taken.

Ornamentals, Tea, coffee, etc.,

The leaf blade should be taken.

Micronutrients:

The leaf lamina/ leaf blade/ mid rib portion of leaf can be taken.

Procedure for tissue test

1. Nitrogen

Reagent: 1-% diphenylamine in conc. sulphuric acid**.**

Small bits of leaf or petiole are taken in a petridish and a drop of 1% diphenylamine is added. The development of blue colour indicated the presence of nitrate – nitrogen. The degree of colouration indicates the amount of nitrogen present in that leaf.

Dark blue : Sufficient Nitrogen
Light blue : Slightly deficient Nitrogen
No colour : Highly deficient Nitrogen

2. Phosphorous

Reagents: (1) Ammonium molybdate solution, (2) Stannous chloride powder.

Eight gm ammonium molybdate is dissolved in 100 ml of distilled water. To this, add 126 ml of conc. Hydrochloric acid (Hcl) and volume is made up to 300 ml with distilled water. This stock solution is kept in an amber coloured bottle and at the time of use it is taken and diluted in the ratio of 1:4 using distilled water.

A tea spoonful of freshly chapped leaf bits are taken in a test tube and 10 ml of ammonium molybdate reagent is added and kept for few minutes. After shaking, a pinch of stannous chloride is added. Colour development is observed.

Dark blue : Sufficient Phosphorus

Bluish green : Slightly deficient Phosphorus

No colour : Highly deficient Phosphorus

3. Potassium

Reagent: (1) Sodium cobalt nitrate reagent, (2) Ethyl alcohol (95%).

Take 5 gm cobalt nitrate and mix with 30 gm of sodium nitrate in 80ml of distilled water. To this, 5ml of glacial acetic acid is added. The volume is made up to 100 ml distilled water. Dilute reagent prepared (5 ml) with 15 mg sodium nitrate to 100 ml using distilled water.

Finally cut leaf bits are taken in a test tube and 10 ml diluted reagent is added and shaken vigorously for few a minutes and kept for 5 minutes. Then add 5 ml of ethyl alcohol reagent, allowed to stand for 3 minutes. The solution is observed for the formation of turbidity.

No turbidity : Deficiency of Potassium
Slightly turbidity : Moderate deficiency
High turbidity : Sufficient Potassium

4. Calcium

Morgan's Reagent: 30 ml of glacial acetic acid and 100 grams of sodium acetate are dissolved in a little of distilled water

Procedure: 0.5 g of finally cut plant material is taken into a glass vial (both of healthy plant and deficient plant in different vials) and 5 ml of Morgan's reagent is added in test tube. After allowing it to stand for 15 minutes, 2 ml of glycerin and 5 ml of 10% ammonium oxalate is added and the solution is shaken for 2 minutes. The turbidity resembling after 15 minutes indicate the amounts of calcium in normal plant tissue.

5 .Magnesium

Reagents
(1) 5% pure sucrose solution
(2) 2% Hydroxylamine hydrochloride
(3) Titan yellow
(4) Sodium hydroxide

150 mg of Titan yellow is dissolved in 75 ml of 95% ethyl alcohol and 25 ml distilled water. This solution is stored in darkness.

Procedure

To a tea spoonful of finely cut material, following reagents are added in sequence. One ml of 5 % sucrose solution, 1 ml of 2 % Hydroxylamine hydrochloride and 1 ml of Titan Yellow. Finally solution was made alkaline with 2 ml of 10% NaoH. Red colour indicates the presence of magnesium and yellow colour indicates absence or traces of Magnesium.

6 .Iron

Finely cut leaf materials (0.5g) are taken into a glass vial and 1ml of con. Hcl is added in it. After 15 minutes, 10ml of distilled water and 2-3 drops of con HNO3 are added. 10 ml of this solution is pipetted out into a specimen tube after 2 minutes and 5ml of 20% ammonium thiocynate is added and stirred. Further, 2 ml of amyl alcohol is added, shaked well and allowed to stand for few minutes. The intensity of red colour in amyl alcohol layer indicates the quantity of iron.

PHYSIOLOGICAL DISORDERS IN FIELD CROPS

Identification of Physiological Disorders in Agricultural Crops

Crop	Malady	Corrective measure
Rice	Severe chlorosis of leaves	1%super phosphate and 0.5% ferrous sulphate
Rice	Irregular flowering and chaffiness multiple deficiency of nutrients	1% super phosphate and magnesium sulphate.
Rice	Tip drying and marginal scoring and browning	1%super phosphate and 0.5% zinc sulphate.
Maize	Chlorosis	A spray solution containing 0.5% ferrous

		sulphate and 0.5% urea.
Maize	'White bud' yellowing in the bud leaves only	0.5% zinc sulphate spray with 1% urea.
Maize	Tip drying and marginal scoring pinkish colouration of lower leaves	1% super phosphate and 0.5% zinc sulphate.
Maize	Marginal scorching and yellowing.	0.5% ferrous sulphate and 1%urea
	Irregular drying of tips and margins	25 kg of zinc sulphate / ha
Sorghum	Chlorosis of younger leaves	Spray of 0.5% ferrous sulphate with 0.5%urea and 0.5% ammonium sulphate
Cowpea	Water soaked necrotic spots on leaf surface. Root growth very much restricted in 10-12 days old seedling	Spray containing sulphate and zinc sulphate 0.1% and 0.1% urea
Groundnut	Chlorosis of terminal leaves	0.5% ferrous sulphate and urea 1%

Leaf chlorosis in rice

Maize: Marginal scorching

Leaf chlorosis in pulses

Terminal leaf chlorosis in groundnu

Disease or disorder: How do I tell the difference? Part 1

Learn how to identify disorders to ease your scouting in the greenhouse and field. A prerecorded webinar on vegetable diagnostics is now available at the Online IPM Academy.

Lina Rodriguez Salamanca, Michigan State University Extension - December 22, 2014

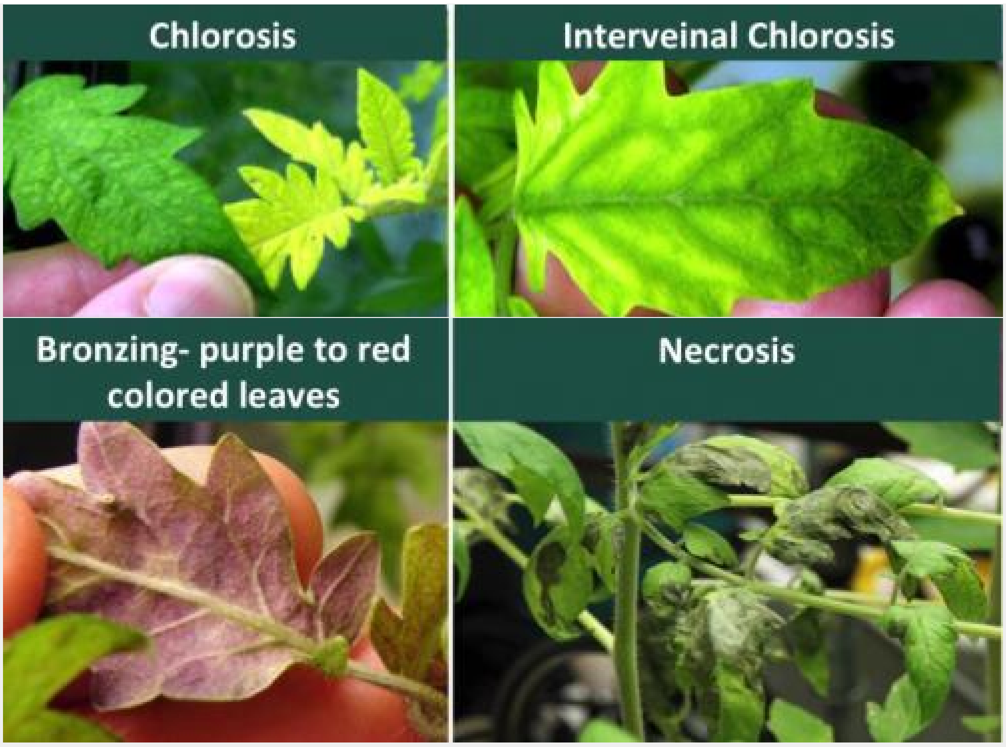
Phosphorus deficiency on tomato leaf. Photo credit: Robert Kosinski, Clemson University

Scouting your vegetables in the greenhouse and field will help you identify potential issues early on. In most cases, the earlier you detect an issue, the more effective the management tactics can be. But what are the differences between a disease and a disorder? Among the webinars Michigan State University Extension is offering at the Online Integrated Pest Management (IPM) Academy, the webinar titled "What is wrong with my vegetable plants?" discusses the differences between vegetable diseases and disorders.

Since vegetable transplant production will start soon, let's focus on how to pinpoint disorders in the greenhouse. The nutrients plants require are available as soluble salts. Nitrate, ammonium, potassium, calcium, magnesium, chloride and sulfate contribute to the soluble salts in greenhouse growing media. The substrate can be charged with nutrients but sometimes it is not. Guidelines for soluble salt content can be found in the MSU Extension article "Diagnosing plant problems – don't forget about pH and soluble salt content" and the MSU Extension bulletin E1736, "Greenhouse growth media: Testing and nutrition guidelines." Electrical conductivity (EC) is a measure of the soluble salts and indicates salt accumulation in the growing media.

On the other hand, the pH of the media influences the availability and uptake of nutrients. Vegetable transplants grown in media with inadequate pH (lower or higher than optimum) can develop nutrient deficiencies or toxicities. Monitor growth media and irrigation water pH frequently. Closely monitor nutrient and soluble salt content weekly, or twice a week if possible, by randomly selecting plug trays throughout the facility. This proactive approach is very important in maintaining your greenhouse fertility plan when needed while preventing nutrient deficiency and toxicity. Consider investing in a portable instrument that allows you to measure pH, EC and meters for nitrate-N and K petiole sap testing and nutrient solutions.

The most common disorders in vegetable transplants are nutritional disorders related with pH, soluble salts and irrigation. The symptoms associated with nutrient imbalances include chlorosis, necrosis, change in color of the foliage and stunting.



Symptoms of nutritional deficiency in tomatoes. Top symptoms are nitrogen deficiency, bottom symptoms are phosphorous deficiency. Photo credit: Robert Kosinski, Clemson University

Chlorosis is a yellowing due to breakdown of plant's chlorophyll, or because its production is disrupted. Necrosis or cellular death results in tissue turning dry and brown to black. Necrosis usually occurs first along the leaf margins, but can expand over time. Anthocyanin and other pigment concentration changes and as a result, leaf bronzing can occur. Stunting is a noticeable delay in growth. When nutrient deficiencies occur, one or a combination of symptoms arise, for example stunting can be associated with off-color (dark green or yellow).

Preventative management tactics are the best approaches to managing disorders. Plan ahead your fertility management strategy and design adequate watering schedules to keep the nutrients in the media available to the plants while decreasing the potential for nutritional deficiencies or toxicities. Once transplanted in the field, avoid overwatering vegetable seedlings. The article “Don’t overwater your vegetable seedlings” will walk you through some considerations.

If symptoms arise in the greenhouse or the field, it is important to be able to recognize diseases on vegetable transplants in the greenhouse. On occasion, some symptoms observed may be the result of a pathogen. Disease symptoms also include chlorosis, necrosis and stunting. If you have additional questions, find an MSU Extension expert or collect and send samples to MSU Diagnostic Services. Remember, correct diagnosis is the first step to effective disease management.

Do not miss the chance to learn more about IPM basics, scouting guides and more at the Online IPM Academy. Accommodations for persons with disabilities may be requested by contacting Erin Lizotte with MSU Extension at taylo548@msu.edu to make arrangements. Requests will be fulfilled when possible.

Disease or disorder: How do I tell the difference? Part 2

Recognizing diseases on vegetable transplants in the greenhouse can improve your scouting. A prerecorded webinar on vegetable diagnostics is available at the Online IPM Academy.

Lina Rodriguez Salamanca, Michigan State University Extension - December 22, 2014

Scouting your vegetable plants in the greenhouse and field will help you identify potential issues early on. In most cases, the earlier you detect an issue, the more effective the management tactics can be. But what are the differences between a disease and a disorder?

Let’s focus identifying diseases in the greenhouse. There are multiple pathogens that cause damping off in seedlings, including *Pythium spp.*, *Phytophthora* spp. and *Rhizoctonia spp*. Damping off is a term that describes when a pathogen infects the roots and parts close to the soil line, delaying growth but ultimately resulting in seedling death.

Symptoms of damping off. Rhizoctonia damping-off, blight and rot (Rhizoctoniasolani) on watermelon seedlings (top left) and Chinese cabbage seedlings (top right). Damping off on cotton seedlings in the field (bottom). All photo credits: Gerald Holmes, California Polytechnic State University at San Luis Obispo, Bugwood.org

Vegetable transplant diseases will depend on the crop. The table below lists the most important diseases on vegetable transplants in Michigan. Click on the disease name and the link will direct you to a symptom image to help with scouting.

Vegetable transplant diseases in Michigan

Tomatoes/Peppers

Disease name	Bacterial pathogen
Bacterial Speck	*Ps. syringaepv tomato*
Bacterial Spot	*X. campestrispvvesicatoria*
Bacterial canker	*Clavibactermichiganensis* subsp. *michiganensis*
Disease name	**Fungal pathogen**
Early blight	*Alternariasolani*
Graymold	*Botrytis cinerea*
Leaf mold	*Fulviafulva*
Disease name	**Oomycete pathogen**
Late blight	*Phytophthorainfestans*
Disease name	**Viral pathogen**
Tobacco mosaic virus (TMV)	Tobacco mosaic virus (TMV)
Cabbage-cole crops	
Disease name	**Bacterial pathogen**
Bacterial leaf spot	*Ps. syringaepvmaculicola*
Bacterial blight	*Ps. syringaepvalisalensis*
Black rot	*X. campestrisipvcampestris*
Disease name	**Fungal pathogen**
Damping off and wire stem	*Thanatephoruscucumeris*
Alternaria leaf spot/head rot	*Alternariabrassicae*
Dark leaf spot	*Alternariabrassicicola*
Disease name	**Oomycete pathogen**
Downy mildew	*Peronosporaparasitica*
Damping off	*Phytophthora or Pythium*
Celery	
Disease name	**Bacterial pathogen**
Bacterial leaf spot	*Ps. syringaepvappi*
Disease name	**Fungal pathogen**
Early blight	*Cercosporaapii*
Anthracnose	*Colletotrichumacutatum*
Disease name	**Oomycete pathogen**
Damping off, root rot	*Pythium spp.*

Preventative management tactics are the best approach to manage diseases. Planting pathogen-free seed and managing irrigation will keep fungal and bacterial diseases to a minimum for vegetable transplants.

To eradicate seed-borne bacterial pathogens, use hot water and chlorine treatments on vegetable seeds. “Hot Water and Chlorine Treatment of Vegetable Seeds to Eradicate Bacterial Plant Pathogens” and “Hot Water Treatment of Vegetable Seeds to Eradicate Bacterial Plant Pathogens in Organic Production Systems” by Ohio State University’s Sally Miller will provide the steps necessary to treat seed properly for conventional and organic production systems. Treatment is a function of time and chlorine concentration. Care must be taken to avoid seed damage. It would be best to practice on small seed lots and understand the procedure before moving into larger batches.

Early morning irrigation and increased airflow will minimize leaf wetness conducive to disease development on high-density plug trays. Once transplanted in the field, avoid overwatering vegetable seedlings.

If symptoms arise in the greenhouse or the field, make sure you consider the fertility program and have learned to recognize disorders on vegetable transplants in the greenhouse. If you have additional questions, find an MSU Extension expert or collect and send samples to MSU Diagnostic Services. Remember, correct diagnosis is the first step to effective disease management.

Learn more about IPM basics, scouting guides and more at the Online Integrated Pest Management (IPM) Academy. Among the webinars Michigan State University Extension is offering at the Online IPM Academy website, the webinar titled “What is wrong with my vegetable plants?” discusses the differences between vegetable diseases and disorders. Accommodations for persons with disabilities may be requested by contacting Erin Lizotte with MSU Extension at taylo548@msu.edu to make arrangements. Requests will be fulfilled when possible.

Interpreting A Plant Analysis

SESL Australia

Interpreting a plant analysis is not easy. Although the association between nutrient uptake and plant growth is well studied, we still don’t have enough data for a number of crops, particularly at the seedling stage, and for concentrations at or near toxic levels.

Figure 1 shows a typical relationship between the nutrient concentration in a plant and yield. The steep slope in the deficient zone shows that the range in concentration between deficiency (with visible symptoms) and the critical concentration (no visible symptoms) is small. For some elements and some plants, the techniques needed to detect these small differences have not yet been developed.

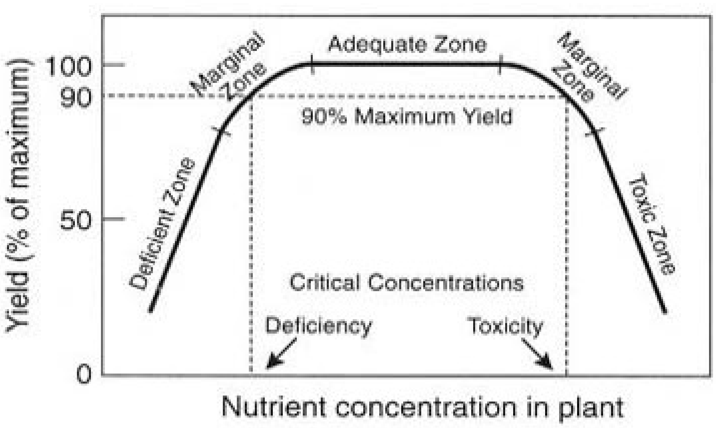


Figure 1. Idealised relationship between nutrient content of a plant and yield.

Critical values

A **critical value** is the concentration below which deficiency occurs. But without a corresponding upper value, it is not very helpful.

A **standard value** is determined from the analysis of large numbers of samples collected from normal crops. Being a single value, it too offers limited usefulness.

Ranges of concentrations give values classified as, for example, low, adequate and high. The effects of time of sampling, cultivar, soil moisture, temperature and light can significantly affect the relationship between nutrient concentration and plant response. Therefore, even a defined sufficiency range may not apply to all situations or environments.

Tissue concentrations can be affected by differences in plant growth. Under normal conditions, nutrient uptake determines plant growth in a predictable way during most of the crop's growth. However, exceptional conditions can cause nutrient accumulation or dilution. Thus, it is essential that the time of sampling, stage of growth and crop history be taken into account when a plant analysis is interpreted.

Even plants within the same species will vary in their ability to take up nutrients. The difference is genetic in origin. But much research is still needed on the effect of genotype on plant nutrient contents.

Nutrient interactions

Interactions or the balance between nutrients within a plant are critical. Varying one nutrient from deficiency to excess can alter the concentrations of other nutrients.

An appropriate interpretation of a plant analysis can be done by comparing the nutrient concentration against a sufficiency range: whether it is less than, greater than or within the sufficiency range. Soil test data and cultural practice information can help explain insufficient or excess concentrations.

Causes of deficiency or excess

Nutrient concentrations can fall outside the sufficiency range for many reasons: low or high soil nutrient levels, low or high soil water pH, improper fertiliser application, soil compaction, nematodes and weather. In most cases, the nutrient concentration found in plant tissue matches the soil level or pH better than the amount of fertiliser applied. The use of a balanced, long-term lime and fertiliser program will give better results than any one lime or fertiliser treatment.

Nutrients

Soil **P** and plant **P** are closely related. **P** uptake can be affected by cool soil temperatures, waterlogging and very low soil pH.

Soil **K** and plant **K** are also closely related.

Soil **Ca** and plant **Ca** are usually positively related, but are affected by fertiliser, weather and soil pH: a higher soil pH reduces the association. Heavy applications of N and K fertiliser will tend to decrease the uptake of Ca.

Plant **Mg** uptake can be reduced by a decreasing soil pH (below 5.4) and an increasing soil K or Ca level. A Mg deficiency can be partially corrected just by liming. This is of primary importance with forages where a high Ca:Mg ratio can promote grass tetany. In this case, the balance between Mg and both K and Ca must be managed. As with Ca, a higher soil pH reduces the association between soil Mg and plant Mg.

In general, as soil pH increases, the availability and, therefore, uptake of **Cu**, **Fe**, **Mn**, and **Zn** decreases. An increasing soil organic matter content intensifies this effect. The primary exception is **Mo**, the availability of which increases with increasing soil pH.

B deficiency is due primarily to insufficient B in the soil. The corrective treatment is to apply B fertiliser can correct it. B toxicity can result from overfertilisation.

Cu deficiency occurs primarily on soils with a high organic matter content and possibly on sandy soils with pH values approaching 7.0. Cu toxicity could occur with the long-term application of large quantities of some animal manures, particularly poultry manure.

Many soil and plant factors can influence the **Fe** level in plants. Deficiency may occur when the soil-water pH is near neutral and the soil is high in organic matter.

Soil-water pH exerts a very strong influence on **Mn** availability in most soils: a pH of <5.4 can lead to toxicity, and a pH of >6.3 can lead to deficiency.

Plant analysis has trouble detecting **Mo** deficiency, particularly in legumes, whose symbiotic root bacteria require higher levels than the plant does. The normal treatment is to sow seed dusted with Mo. pH has an effect too: most legumes respond best at low soil pH (5.2), and respond less well as the pH increases. Therefore, maintenance of the proper soil pH will help eliminate Mo deficiency.

Zn availability is related to both soil pH and soil Zn level. Soil Zn is usually a good indicator of Zn availability, although Zn uptake normally decreases as the soil pH increases. A Zn deficiency can be readily corrected by applying Zn fertiliser.

Al is not a plant nutrient but can affect plant growth. High Al levels in the plant are usually the result of either a very low soil pH (<4.8) or anaerobic soil conditions. As Al does not readily enter the plant, its presence in the plant in high concentrations indicates extreme soil conditions.

Accurate interpretation

This article shows that the interpretation of a plant analysis and an appropriate corrective recommendation can be a complex task requiring skill and sufficient knowledge of the site conditions. Details of the crop, site, weather and site history are essential to an accurate interpretation of the results and appropriate corrective treatments. Without them, accurate evaluation of a plant analysis result is impossible.

DIAGNOSIS AND RECOMMENDATION INTEGRATED SYSTEM (DRIS Method)

Concepts of DRIS

- Concepts of DRIS: DRIS is a new approach to interpreting leaf or plant analysis which was first developed by "Beaufils" (1973) named as Diagnosis and Recommendation Integrated System (DRIS). It is a comprehensive system which identifies all the nutritional factors limiting crop production and increases the chances of obtaining high crop yields by improving fertilizer recommendations. The DRIS method uses "nutrient ratios" instead of absolute and or individual nutrient concentrations for interpretation of tissue analysis.
- There is a set of optimum ratios among the nutrient elements (N/P or N/K or K/P) within a given plant for promoting the growth of the plant. DRIS mainly uses the "nutritional balancing" concept (Relationship among nutrients) in the detection of nutritional deficiencies or excess in the plant. Nutrient balance is a part of the proper interpretation of DRIS system because nutrient interactions to a larger extent determine crop yield and quality. The

nutrient ratios are helpful to obtain special indexes which are called “Nutrient Index” or “Beaufills nutrient Indexes” (BNI).

- The nutrient index values are used to rate the nutrients in order of their need by the plants analyzed. It also measures how far particular nutrients in the leaf or plant are from optimim are used in the calibration to classify yield factors in order of limiting importance. BNI are actually expression of the supplies of nutrients relative to each other. The concentration of each nutrient in the plant has an effect on the index value for each of the other nutrient. An abnormally high concentration of one or more nutrients will decrease the index values of other nutrients.
- There will be positive and negative values for the nutrient index. The nutrients with positive indexes appeared to be in “excess” and nutrients with negative indexes appeared to be “deficient” in plants. DRIS indices can be calculated individually for each nutrient using the average nutrient ratio deviation obtained from the comparison with the optimum value of a given nutrient ratio. DRIS is a mathematical technique to apply plant analysis information (Nutrient concentration) for diagnosing the most limiting nutrient in a production system.
- The evaluation is made by comparing the relative balance of nutrient content with norms established for that crop under high yield conditions. The evaluation is made by comparing the relative balance of nutrient content with norms established for that crop under high yield conditions.

To develop a DRIS for a crop, the following requirements must be met whenever possible.

1. All factors suspected of having effect on crop yield must be defined
2. The relationship between these factors and yield must be described
3. Calibrated norms must be established
4. Recommendations suited to particular sets of conditions and based on correct and judicious use of these norms must be continually refined.

Advantage

- The importance of nutritional balance is taken in to account in deriving the norms and making diagnosis. It helps to quantify the nutrient balance in the plant.
- The norms for nutrient content in leaves can be universally applied to the particular crop.
- Diagnosis can be made over a wide range of stages of crop development.
- The nutrient limiting yield through either excess or insufficient can be readily identified and arranged in order of their limiting importance for yield.