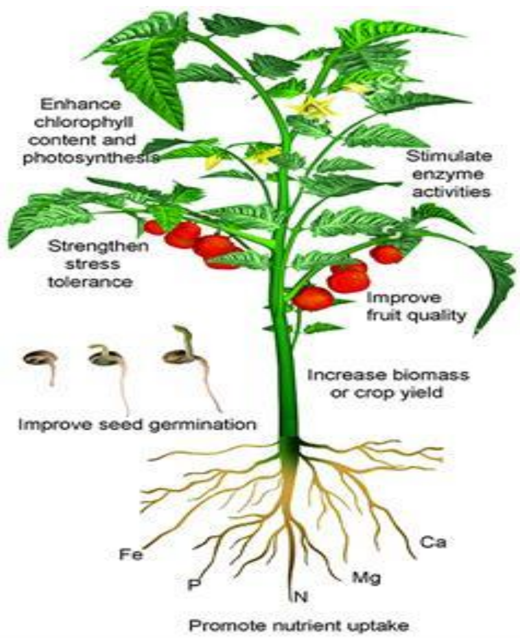
Core Course XII: Plant Physiology

Course Code: BOTACOR12T

- ***Plant nutrition :*** Plants use inorganic minerals for nutrition. Complex interactions involving weathering of rock minerals, decaying organic matter, animals, and microbes take place to form inorganic minerals in soil. Roots absorb mineral nutrients as ions in soil water. Many factors influence nutrient uptake for plants. Ions can be readily available to roots or could be "tied up" by other elements or the soil itself. Soil too high in pH (alkaline) or too low (acid) makes minerals unavailable to plants.



- ***Fertility or nutrition :*** The term "fertility" refers to the inherent capacity of a soil to supply nutrients to plants in adequate amounts and in suitable proportions. The term "nutrition" refers to the interrelated steps by which a living organism assimilates food and uses it for growth and replacement of tissue. Previously, plant growth was thought of in terms of soil fertility or how much fertilizer should be added to increase soil levels of mineral elements.

  Most fertilizers were formulated to account for deficiencies of mineral elements in the soil. The use of soilless mixes and increased research in nutrient cultures and hydroponics as well as advances in plant tissue analysis have led to a broader understanding of plant nutrition. Plant nutrition is a term that takes into account the interrelationships of mineral elements in the soil or soilless solution as well as their role in plant growth. This interrelationship involves a complex balance of mineral elements essential and beneficial for optimum plant growth.

- ***List of essential mineral, non- mineral and beneficial elements:***

Essential Minerals

- **Nitrogen(N),**
- **Phosphorus(P),**
- **Potassium(K),**
- **Calcium(Ca),**
- **Magnesium(Mg),**
- **Sulfur(S),**
- **Boron(B),**
- **Chlorine(Cl),**
- **Iron(Fe),**
- **Manganese(Mn) ,**
- **Zinc(Zn),**
- **Copper(Cu),**
- **Molybdenum(Mo),**
- **Nickel(Ni).**

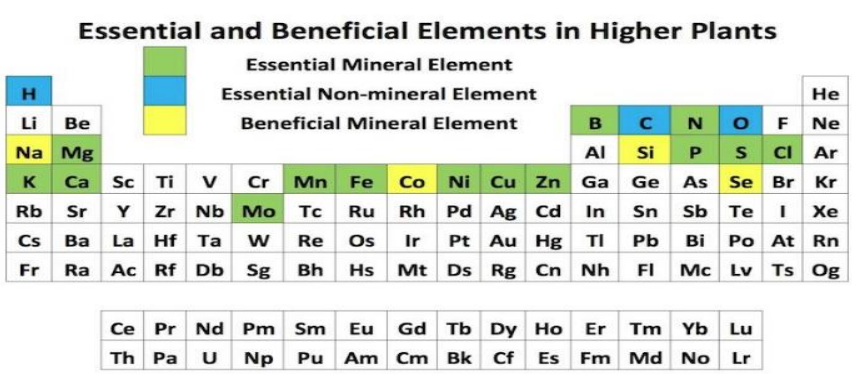
Beneficial Elements

- **Silicon(Si),**
- **Sodium(Na),**
- **Cobalt(Co),**
- **Selenium(Se)**

Essential non-mineral elements

- **Hydrogen(H),**
- **Oxygen(O),**
- **Carbon(C).**

Out of all of the many natural elements, essential mineral elements, essential non-mineral elements, and beneficial elements are not randomly scattered, but instead cluster in several groups on the periodic chart.



- **ESSENTIAL ELEMENTS:** A chemical nutrient that is vital for the successful growth and development of an organism. The term essential mineral element (or mineral nutrient) was proposed by **Arnon and Stout (1939**). They concluded three criteria must be met for an element to be considered essential. These criteria are:

a) A plant must be unable to complete its life cycle in the absence of the mineral element.
b) The function of the element must not be replaceable by another mineral element.

c) The element must be directly involved in plant metabolism. These criteria are important guidelines for plant nutrition but exclude beneficial mineral elements.

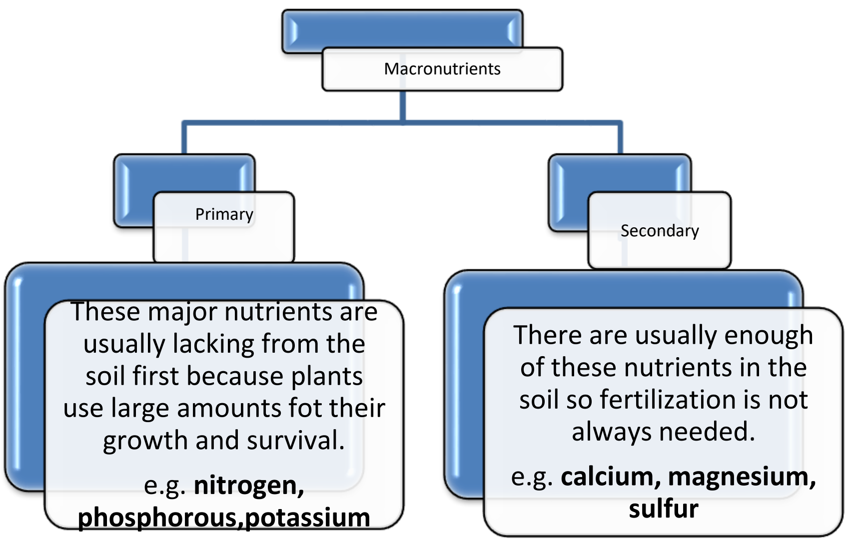
It may be of two types—

1) **Mineral Elements**
2) **Non- mineral Elements**

1. Mineral Elements: Majority of the elements that are essential for growth and development of plants comes from soil. These elements are further divided into categories-

I. Macronutrients
II. Micronutrients

- **Macronutrients:** Six essential elements are required in relatively large quantities (1000 mg/kg of dry matter) and are referred to as macronutrients. Such minerals are nitrogen, phosphorous, potassium, calcium, magnesium, and sulfur .



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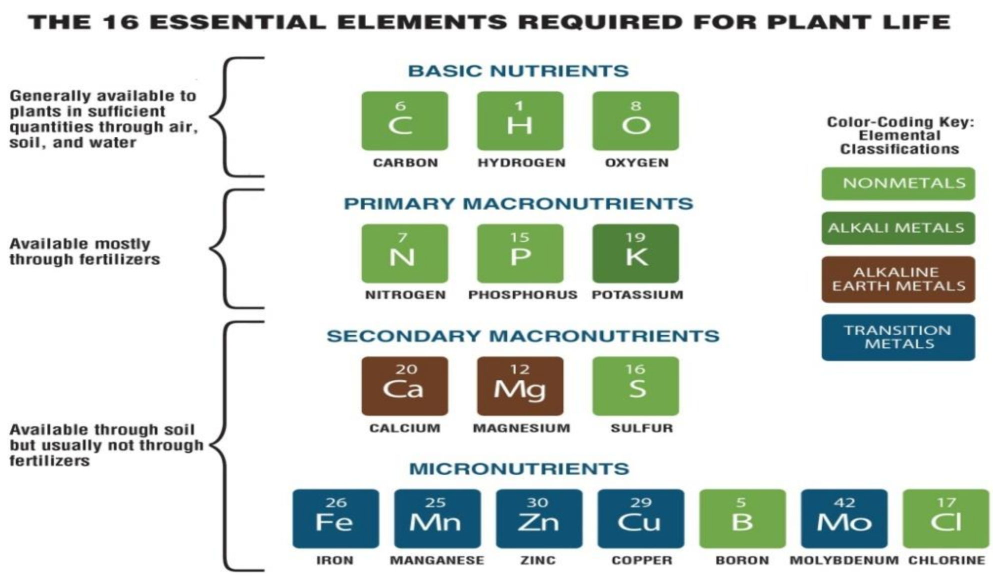
- **Micronutrients:** micronutrients are those elements essential for plant growth which are needed in only very small quantities (equal to or less than 100mg/kg of dry matter).
These elements are sometimes called minor elements of **trace elements**. (Any chemical element required by living organisms in minute amounts (that is less than 0.1 percent by volume [1,000 parts per million]), usually as part of a vital enzyme (a cell-produced catalytic protein).
e.g. Boron , copper, manganese, nickel, sodium, molybdenum, iron, chloride, zinc.

Fig: A piece of boron carbide

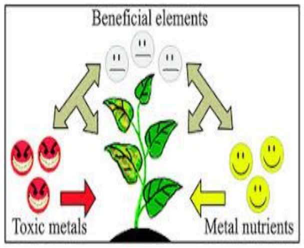
2. Non – Mineral Elements: Elements that are considered as non-mineral elements because they are derived primarily from the carbon-dioxide and water. These elements are carbon, hydrogen, oxygen.



Typical concentrations of nutrient elements sufficient for plant growth:

Element	**Symbol**	**mg/kg**	**percent**	**Relative number of atoms**
Nitrogen	N	15,000	1.5	1,000,000
Potassium	K	10,000	1.0	250,000
Calcium	Ca	5,000	0.5	125,000
Magnesium	Mg	2,000	0.2	80,000
Phosphorus	P	2,000	0.2	60,000
Sulphur	S	1,000	0.1	30,000
Chlorine	Cl	100	--	3,000
Iron	Fe	100	--	2,000
Boron	B	20	--	2,000
Manganese	Mn	50	--	1,000
Zinc	Zn	20	--	300
Copper	Cu	6	--	100
Molybdenum	Mo	0.1	--	1
Nickel	Ni	0.1	--	1

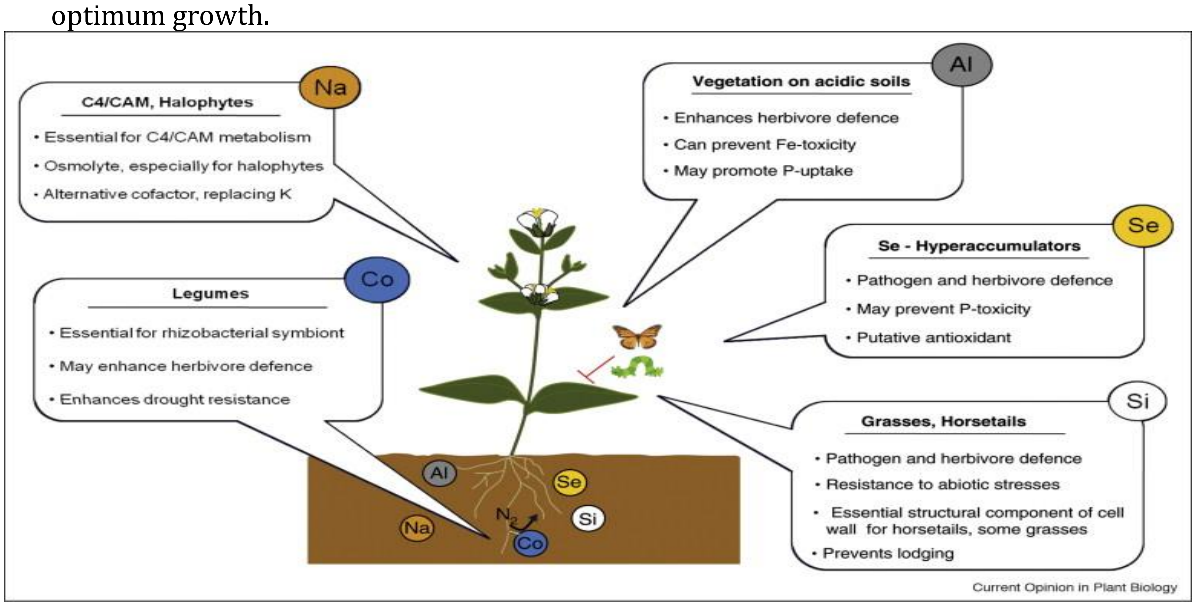
In addition to the essential mineral elements are the **beneficial elements**, elements which promote plant growth in many plant species but are not absolutely necessary for completion of the plant life cycle, or fail to meet **Arnon and Stout's** criteria on other grounds.



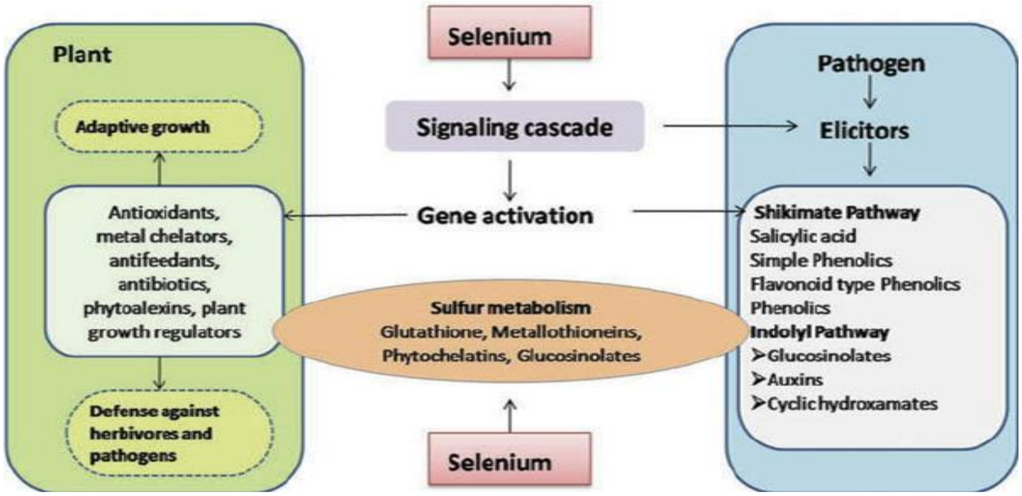
BENEFICIAL ELEMENTS: Beneficial elements are those that can compensate for toxic effects of other elements or may replace mineral nutrients in some other less specific function such as the maintenance of osmotic pressure. The omission of beneficial nutrients in commercial production could mean that plants are not being grown to their optimum genetic potential but are merely produced at a subsistence level.

They are not required by all plants but can promote plant growth and may be essential for particular taxa. These beneficial elements have been reported to enhance resistance to biotic stresses such as pathogens and herbivory, and to abiotic stresses such as drought, salinity, and nutrient toxicity or deficiency. The beneficial elements have not been deemed essential for all plants but may be essential for some. The distinction between beneficial and essential is often difficult in the case of some trace elements.

- Cobalt, for instance, is essential for nitrogen fixation in legumes.
- Silicon, deposited in cell walls, has been found to improve heat and drought tolerance and increase resistance to insects and fungal infections. Silicon, acting as a beneficial element, can help compensate for toxic levels of manganese, iron, phosphorus and aluminum as well as zinc deficiency. A more holistic approach to plant nutrition would not be limited to nutrients essential to survival but would include mineral elements at levels beneficial for optimum growth.



With developments in analytical chemistry and the ability to eliminate contaminants in nutrient cultures, the list of essential elements may well increase in the future.



The following table gives the essentiality of the benefcial elements established by different scientists:

Beneficial element	Plant species	Insect/Pathogen	Reference
Aluminium	Potato (*Solanum tuberosum* L.)	*Phytophthora infestans* (Late blight of potato)	Andrivon (1995)
		Thielaviopsis basicola. Ferraris (Blast rot)	Meyer et al. (1994)
Selenium	Desert princes plume (*Stanleya pinnata* Pursh.)	*Plutella xylostella* (Diamond back moth)	Freeman et al. (2006)
	Indian mustard (*Brassica juncea* L.)	*Pieris rapae* (Caterpillar), *Mesodon ferrissi* (Snail), *Fusarium sp*. (Root stem pathogen) *Alternaria brassicicola* (Leaf pathogen) *Myzus persicae* (Green peach aphid)	Hanson et al. (2003, 2004)
Silicon	Cucumber (*Cucumis sativus* L.)	*Didymella bryoniae Botrytis cineria* (Stem rotting &Stem lesions)	O'Neill (1991)
		Pythium ultimum Pythium aphanidermatum (Root disease)	Cherif et al. (1994)
	Grape (*Vitis vinifera* L.)	*Uncinula necator Oidium tuckeri* (Powdery mildew)	Bowen et al. (1992)
		Oscinella frit (Fruit fly)	Sang-Young et al. (1996)
	Italian ryegrass (*Lolium multiforum* Lam.)	*Oscinella frit* (Fruit fly)	Moore (1984)
	Maize (*Zea mays* L.)	*Sesamia calamistis* (Pink stalk borer)	Setamou et al. (1993)
	Pea (*Pisum sativum* L.)	*Mycosphaerella pinodes* (Leaf spot)	Dann and Muir (2002)
	Rice (*Oryza sativa* L.)	*Magnaportha grisea* (Leaf and neck blast)	Seebold et al. (2001)
		Xanthomonas oryzae pv. oryzae (Xoo) (Bacterial blight)	Chang et al. (2002)
		B. graminis f.sp. *tritici*. *M. grisea* (Blast disease)	Liang et al. (2005)
		Rhizoctonia solani (Sheath blight pathogen)	Zhang et al. (2006)
	Sorghum (*Sorghum bicolor* Moench.)	*Striga asiatica* Kuntze (Witch weed)	Hodson and Sangster (1989)
	Sugarcane (*Saccharum officinarum* L.)	*Leptosphaeria sacchari* (Sugarcane ring spot)	Raid et al. (1992)
		Eldana saccharira (Sugarcane borer)	Meyer and Keeping (2001)
	Wheat (*Triticum aestivum* L.)	*Tribotium castaneum* (Flour beetle)	Setamou et al. (1993)
	Wild rice (*Zizania aquatica* L.)	*Bipolaris oryzae* (Fungal brown spot)	Malvick and Percich (1993)

Classification of plant nutrients based on biochemical behaviour and physiological functions:

Mengel and Kirkby (1987) have divided essential plant nutrients into four groups

- **Group I** includes C, H, O, N and S, which are major constituents of the organic plant materials (carbohydrates, proteins, fats, etc.).
- **Group II** includes P and B, which are involved in biochemical reactions such as esterification.
- **Group III** includes K, Ca, Mg, Mn and Cl. These elements are present in the free ionic state or are adsorbed to indiffusible organic anions (e.g. absorption of Ca^{2+} by the carboxylic group of pectins).
- **Group IV** includes Fe, Cu, Zn and Mo. These elements are predominantly presented as chelates in the plant.

Group	Nutrients	Form in which taken up by plants	Biochemical/physiological functions
I	C	CO_2, HCO_3^-	Major constituents of organic material, essential elements of atomic groups which are involved in enzymatic process, etc.
	H	H_2O	
	O	O_2	
	N	NH_4^+, NO_3^-, N_2 (in fixation)	
	S	SO_4^{-2}, SO_2 (gaseous absorption in leaves	
II	P	$H_2PO_4^{-1}$, HPO_4^{-2}	Esterification with native plant alcohol. Phosphate esters are involved in energy transfer.
	B	$B(OH)_3$	
III	K	K+	Nonspecific functions, involved in establishing osmotic potential. Ca is a component of plant structural parts.
	Mg	Mg+2	
	Ca	Ca+2	
	Mn	Mn+2	
	Cl	Cl-1	
IV	Fe	Fe^{+2}	Present predominantly in a chelated form in prosthetic group, enable electron transport by valency change
	Cu	Cu^{+2}	