Nutrient elements: Arnon's criteria of essentiality – essential, functional and beneficial elements

The criteria of essentiality put forth by Arnon

In the nature there are nearly one hundred and three elements. Of them nearly ninety elements are taken in by the plants. In order to distinguish the elements which are essential from those which may be taken in by the plants but are not essential, Arnon (1954) has laid down the following criteria.

1. The plant must be unable to grow normally or complete its life cycle in the absence of the element.
2. The element is specific and cannot be replaced by another.
3. The element plays a direct role in plant metabolism.

It appears that an element would have to be considered essential even if it has not been possible to demonstrate that it fulfills the second criterion of essentiality. For ex., for many bacteria, diatoms and other algae, vitamin B_{12} is known to be essential, but the essentiality of cobalt per se has not been demonstrated. According to this criterion, molybdenum and chlorine cannot be considered as essential though they are functional in plant metabolism since they can be replaced by vanadium and halides respectively. D.J. Nicholas gave more exact definition of essential elements and advanced the term "functional or metabolic nutrient" to include any mineral element that functions in plant metabolism, whether or not its action is specific.

Element	Essentiality was established by	Year
H, O	---	Since time immemorial
C	Priestly *et al*.	1800
N	Theodore de Saussure	1804
P, K, Mg, S	C Sprengel	1839
Fe	E Gris	1843
Mn	JS Mc Hargue	1922

Zn	AL Sommer and CP Lipman	1926
Cu	AL Sommer, CP Lipman and G Mc Kinney	1931
Mo	DI Arnon and PR Stout	1939
Na	Brownell and Wood	1957
Co	Ahmed and Evans	1959

II. Elements accepted as essential for higher plants only

Ca	C Sprengel	1839
B	K Warington	1923
Cl	Broyer, Carlton, Johnson and Stout	1954

Element	**Group or plant sp**	**Essential requirement**	**Year**
Vanadium	*Scenedesmus Obliquus*	DI Arnon and G. Vessel	1953
Silicon	Diatoms	J.C. Lewin	1962
Iodine	Polysiphonia	L. Fries	1966
Selenium	Astragalus sp.	SF Trelease and HM Trelease	1938
Gallicum	*Aspergillus niger*	RA Steinberg	1938
Aluminium	Ferns	K. Taubock	1942

Terminology

Plant nutrition:

Plant nutrition is defined as the supply and absorption of chemical compounds required for plant growth and metabolism. It is the process of absorption and utilization of essential elements for plant growth and reproduction.

Nutrient:

Nutrient may be defined as the chemical compound or ion required by an organism. The mechanism by which the nutrients are converted to cellular material or used for energetic purposes are known as metabolic processes.

Beneficial elements:

The elements, the essentiality of which for growth and metabolism has not been unequivocally established, but which are shown to exert beneficial effects at very low concentrations are often referred to as beneficial elements, or potential micronutrients. The beneficial effect of these nutrients may be due to the ability of these elements affecting the uptake, translocation and utilization of the essential elements. They may be essential only for certain plant species or under specific conditions. Eg : Silicon, vanadium, cobalt and aluminium.

Functional element:

Nicholas D J (1961) advanced the term functional or metabolic nutrient to include any mineral element that functions in plant metabolism whether or not its action is specific.

To describe the level of nutrient element in plants the following terms are proposed.

1. **Deficient**: When an essential element is at low concentration that severely limits yield and produces more or less distinct deficiency symptoms.
2. **Toxic**: when the concentration of either essential or other element is sufficiently high to inhibit the plant growth to a great extent.

Forms of nutrient elements absorbed by plants

i) Absorbed as single nutrient ion

Nutrient element	**Forms absorbed by plants**
Potassium	K^+
Calcium	Ca^{2+}
Magnesium	Mg^{2+}
Iron	Fe^{2+}
Manganese	Mn^{2+}
Copper	Cu^{2+}
Zinc	Zn^{2+}

Chlorine	Cl^-
Silicon	Si^{4+}
Cobalt	Co^{2+}
Sodium	Na^+

ii) Absorbed in a combined form

Nitrogen	Ammonium (NH_4^+) and Nitrate (NO_3^-)
Phosphorus	$H_2PO_4^-$, $HPO_4^=$
Sulphur	$SO_4^=$
Boron	H_3BO_3, $H_2BO_3^-$, HBO_3^{2-}, BO_3^{3-}
Molybdenum	$MoO_4^=$ (Molybdate)
Carbon	CO_2
Hydrogen	H_2O

Classification of essential nutrients:

Nutrients are chemical compounds needed for growth and metabolic activities of an organism. The essential plant nutrients may be divided into macronutrients (primary and secondary nutrients) and micronutrients.

(A) Macronutrients

Macronutrients or major nutrients are so called because they are required by plants in larger amounts. These are found and needed in plants in relatively higher amounts than micronutrients. They include C, H, O, N, P, K, Ca, Mg and S. C, H and O constitute 90 – 95 per cent of the plant dry matter weight and supplied through CO_2 and water. Remaining six macronutrients are further sub divided into primary and secondary nutrients.

Primary nutrients: Nitrogen, phosphorus and potassium are termed as primary nutrients because the correction of their wide spread deficiencies is often necessary through the application of commercial fertilizers of which these are the major constituents.

Secondary nutrients: Calcium, magnesium and sulphur are termed as secondary nutrients because of their moderate requirement by plants, localised deficiencies and their inadvertent

accretions through carriers of the primary nutrients. For example, the phosphatic fertiliser, single super phosphate (SSP) contains both Ca and S. Similarly, ammonium sulphate, a nitrogenous fertiliser also supplements S.

(B) Micronutrients:

Micronutrient is an element that is required in relatively small quantities but is as essential as macronutrients. These elements have often been called trace elements. They are again classified into micronutrient cations (eg. Fe, Mn, Zn and Cu) and micronutrient anions (eg., B, Mo and Cl) depending upon the form in which they are available.

This above division of plant nutrients into macro and micro nutrients is some what arbitrary and in many cases, the differences between the contents of macronutrients and micronutrients are considerably less well defined. Therefore, classification of plant nutrients according to biochemical behaviour and physiological functions seems more appropriate. The classification of plant nutrients is as below:

Essential plant nutrient	Biochemical functions
1st group	
C, H, O, N, S	Major constituent of organic material, essential elements of atomic groups which are involved in enzymatic processes and assimilation by oxidation – reduction reactions.
2nd group	
P, B, Si	Etherification with native alcohol groups in plants. Involved in energy transfer reactions.
3rd group	
K, Na, Mg, Ca, Mn, Cl	Non specific functions establishing osmotic potentials; enzyme activation, balance of ions, Controlling membrane permeability and electro potentials.
4th group	
Fe, Cu, Zn, Mo	Present predominantly in a chelated form incorporated in prosthetic groups.

Mobile	Partly mobile	Immobile
1. Nitrogen	1.Iron	1.Calcium
2. Phosphorus	2. Zinc	2.Sulphur
3. Potassium	3. Copper	3.Boron
4. Magnesium	4.Molybdenum	

Mobile nutrient:

Mobile nutrients are those when deficient in the plant, move from the matured tissue (older leaves) to the young meristem thus the deficiency symptoms are manifested on the older tissue.

Immobile nutrient:

Immobile nutrients are those which under the situation of deficiency in the soil cannot move from older to younger tissue and hence the deficiency symptoms appear first on the younger leaves.