

## Soil pH and Buffer pH

Soil pH This is a measure of the soil acidity or alkalinity and is sometimes called the soil "water" pH. This is because it is a measure of the pH of the soil solution, which is considered the active pH that affects plant growth. Soil pH is the foundation of essentially all soil chemistry and nutrient reaction and should be the first consideration when evaluating a soil test. The total range of the pH scale is from 0 to 14. Values below the mid-point (pH 7.0) are acidic and those above pH 7.0 are alkaline. A soil pH of 7.0 is considered to be neutral. Most plants perform best in a soil that is slightly acid to neutral (pH 6.0 to 7.0). Some plants like blueberries require the soil to be more acid (pH 4.5 to 5.5), and others, like alfalfa will tolerate a slightly alkaline soil (pH 7.0-7.5).

The soil pH scale is logarithmic, meaning that each whole number is a factor of 10 larger or smaller than the ones next to it. For example if a soil has a pH of 6.5 and this pH is lowered to pH 5.5, the acid content of that soil is increased 10-fold. If the pH is lowered further to pH 4.5, the acid content becomes 100 times greater than at pH 6.5. The logarithmic nature of the pH scale means that small changes in a soil pH can have large effects on nutrient availability and plant growth.

Buffer pH (BpH) This is a value that is generated in the laboratory, it is not an existing feature of the soil. Laboratories perform this test in order to develop lime recommendations, and it actually has no other practical value.

In basic terms, the BpH is the resulting sample pH after the laboratory has added a liming material. In this test, the laboratory adds a chemical mixture called a buffering solution. This solution functions like extremely fast-acting lime. Each soil sample receives the same amount of buffering solution; therefore the resulting pH is different for each sample. To determine a lime recommendation,

the laboratory looks at the difference between the original soil pH and the ending pH after the buffering solution has reacted with the soil. If the difference between the two pH measurements is large, it means that the soil pH is easily changed, and a low rate of lime will suffice. If the soil pH changes only a little after the buffering solution has reacted, it means that the soil pH is difficult to change and a larger lime addition is needed to reach the desired pH for the crop.

The reasons that a soil may require differing amounts of lime to change the soil pH relates to the soil CEC and the "reserve" acidity that is contained by the soil. Soil acidity is controlled by the amount of hydrogen ( $H^+$ ) and aluminum ( $Al^{+++}$ ) that is either contained in, or generated by the soil and soil components. Soils with a high CEC have a greater capacity to contain or generate these sources of acidity. Therefore, at a given soil pH, a soil with a higher CEC (thus a lower buffer pH) will normally require more lime to reach a given target pH than a soil with a lower CEC.

### ***Soil Colloids***

During physical and chemical weathering processes in which rocks, minerals, and organic matter decompose to form soil, some extremely small particles are formed. Colloidal-sized particles are so minuscule that they do not settle out when in suspension. These particles generally possess a negative charge, which allows them to attract positively charged ions known as cations. Much like a magnet, in which opposite poles attract one another, soil colloids attract and retain many plant nutrients in an exchangeable form. This ability, known as cation exchange capacity, enables a soil to attract and retain positively charged nutrients (cations) such as potassium ( $K^+$ ), ammonium ( $NH_4^+$ ), hydrogen ( $H^+$ ), calcium ( $Ca^{++}$ ), and magnesium ( $Mg^{++}$ ). Also, because similar charges repel one another, some of the soluble negatively charged ions (anions), such as nitrate ( $NO_3^-$ ) and sulfate ( $SO_4^{=}$ ), are not bonded to soil colloids and are more easily leached than their positively charged counterparts.

Organic colloids contribute a relatively large number of negative charges per unit weight compared with the various types of clay colloids. The magnitude of the soil's electrical charge contributed by colloids is an important component of a soil's ability to retain cationic nutrients in a form available to plants.

### ***Cation Exchange Capacity***

The ability of a soil to retain cations (positively charged ions) in a form that is available to plants is known as cation exchange capacity (CEC). A soil's CEC depends on the amount and kind(s) of colloid(s) present. Although type of clay is important, in general, the more clay or organic matter present, the higher the CEC.

The CEC of a soil might be compared to the size of a fuel tank on a gasoline engine. The larger the fuel tank, the longer the engine can operate and the more work it can do before a refill is necessary. For soils, the larger the CEC, the more nutrients the soil can supply. Although CEC is only one component of soil fertility, all other factors being equal, the higher the CEC, the higher the potential yield of that soil before nutrients must be replenished with fertilizers or manures.

When a soil is tested for CEC, the results are expressed in milliequivalents per 100 grams (meq/100 g) of air-dried soil. For practical purposes, the relative numerical size of the CEC is more important than trying to understand the technical meaning of the units. In general, soils in the southern United States, where physical and chemical weathering have been more intense, have lower CEC's (1-3 meq/100 g) than soils in the northern United States, where higher CEC's are common (15-25 meq/100 g) because weathering has not been as intense. Soils in warmer climates also tend to have lower organic matter levels, and thus lower CEC's than their northern counterparts.

Soils high in clay content, and especially those high in organic matter, tend to have higher CEC's than those low in clay and organic matter. The CEC of soils in Maryland generally ranges from 1-2 meq/100 g for coarse-textured Coastal Plain

soils to as high as 12-15 meq/100 g for certain Piedmont and Mountain soils. The CEC of most medium-textured soils of the Piedmont region ranges about 8-12 meq/100 g.

There are many practical differences between soils having widely different CEC's. It has already been mentioned that the inherent fertility (exchangeable nutrient content) of soils varies in direct relationship to the magnitude of the CEC. Another important CEC-related property is soil buffering capacity, that is, the resistance of a soil to changes in pH. The higher the CEC, the more resistance soil has to changes in pH. The CEC and buffering capacity are directly related to the amount of liming material required to produce a desired change in pH. Higher CEC soils require more lime than those with low CEC's to achieve the same pH change.

If CEC is analogous to the fuel tank on an engine, soil pH is analogous to the fuel gauge. The gauges on both a large and a small tank might read three fourths full; but, obviously, the larger tank will contain more fuel than the smaller tank. If a soil test indicates that two soils, one with a low CEC and the other with a high CEC, have the same low pH, indicating that they both need lime, the one with the higher CEC will require more liming material to bring about the desired pH change than will the one with the lower CEC. The reason for this difference is that there will be more exchangeable acidity (hydrogen and aluminum) to neutralize in the high CEC soil than in the lower CEC soil. Thus, a soil high in clay or organic matter will require more liming material to reduce soil acidity (and raise the pH) than a low organic matter sandy soil will.

### **3 Soil pH and Percent Base Saturation**

Soil pH is one of the most important characteristics of soil fertility because it has a direct impact on nutrient availability and plant growth.

The pH scale is a logarithmic expression of hydrogen ion  $[H^+]$  concentration in the soil solution. Mathematically, pH equals  $-\log [H^+]$  (the negative logarithm of the hydrogen ion concentration). The pH scale ranges from 0 to 14. A soil pH value of 7.0 is neutral. At pH 7.0, the hydroxyl ion  $[OH^-]$  and the hydrogen ion  $[H^+]$  concentrations exactly balance one another. At pH values below 7.0, soils are acidic because the  $[H^+]$  ion concentration is greater than the  $[OH^-]$  ion concentration. At pH values above 7.0, soils are basic because there are more  $[OH^-]$  than  $[H^+]$  ions. Most agricultural soils in Maryland have a pH range between 4.5 and 7.5. Although there are some exceptions, the preferred pH range for most plants is between 5.5 and 7.0. Legumes prefer higher pH's (pH values of 6.2-7.0) than do grasses (pH values of 5.8-6.5).

Because the pH scale is logarithmic rather than linear, the difference in acidity between each pH value varies by a factor of 10, not 1. Therefore, a soil with a pH of 5.0 is 10 times more acid than a soil with a pH of 6.0. A soil with a pH of 4.0 will be 100 times more acid than a soil with a pH of 6.0 and 1,000 times more acid than a soil at pH 7.0. This is an extremely important factor to consider when developing liming recommendations to correct acid soils.

Soil pH also reflects percent base saturation (% BS) of the CEC. This term refers to the relative number (percentage) of the CEC sites on the soil colloids that are occupied by bases such as calcium ( $Ca^{++}$ ), magnesium ( $Mg^{++}$ ), and potassium ( $K^+$ ). In general, at pH 7.0 the base saturation is 100 percent. By rule of thumb, for every one-half unit drop in soil pH, the % BS declines by about 15 percent (pH 6.5 = 85 percent BS, pH 6.0 = 70 percent BS, pH 5.5 = 55 percent BS, and so forth). This information can be useful to calculate the approximate amounts of available nutrients present in a soil at a given pH. Ag-Lime Recommendations

To predict how much liming material (calcium and/or magnesium carbonate) will be necessary to change the pH of a soil from one level to another, other information is needed in addition to the soil's pH. It is also necessary to estimate the soil's buffering capacity, that is, the soil's ability to resist a change in pH.

There are several ways to estimate a soil's buffering capacity so that a liming recommendation can be developed. One of the simplest techniques for Maryland soils is to determine soil texture. Research has shown that, with just a few exceptions, for soils within a particular physiographic region, a positive direct relationship exists between soil texture and the CEC. Thus, as soil texture varies from coarse to fine on the Coastal Plain (for example, from sand to silt loam to loam to clay loam), CEC and buffering capacity increase. Simplified tables and equations have been developed to estimate the amount of liming material needed to achieve a desired pH goal when the current soil pH and texture are known.

Another technique that some soil-testing laboratories use to develop an ag-lime recommendation is known as the lime requirement test. With this procedure, in addition to determining the normal water pH, a second pH measurement, known as the buffer pH, is required. For a normal water pH reading, the soil is allowed to equilibrate in distilled water. A pH meter is used to measure how much the soil changed the pH of the unbuffered distilled water. The buffer pH differs in that the soil is allowed to equilibrate in a specially prepared solution that has previously been buffered to a known pH. The buffer solution, as well as the soil, resists changes in pH. A pH meter is used to determine how much the soil was able to overcome the resistance of the buffer solution to a change in pH.

The buffer pH technique directly reflects the soil's buffering capacity and the result can be used in a formula to calculate the amount of ag-lime required to achieve the desired change in pH.

### ***Nutrient Availability and Soil pH***

Nutrient availability is influenced strongly by soil pH. This is especially true for phosphorus, which is most available between pH 6.0 and 7.5. Elements such as iron, aluminum, and manganese are especially soluble in acid soils. Above pH 7.0, calcium, magnesium, and sodium are increasingly soluble.

Phosphorus is particularly reactive with aluminum, iron, and calcium. Thus, in acid soils, insoluble phosphorus compounds are formed with iron, aluminum, and manganese. At pH levels above 7.0, the reactivity of iron, aluminum, and manganese is reduced, but insoluble phosphorus compounds containing calcium and magnesium can become a problem. To maximize phosphorus solubility and hence availability to plants, it is best to maintain soil pH within the range of 6.0 to 7.5. Over liming can result in reduced phosphorus availability just as quickly as under liming.

In general, the availability of nitrogen, potassium, calcium, and magnesium decreases rapidly below pH 6.0 and above pH 8.0. Aluminum is only slightly available between pH 5.5 and pH 8.0. This is fortunate because, although plants require relatively large quantities of nitrogen, phosphorus, and potassium, aluminum in appreciable quantities can become toxic to plants. If managed properly, soil pH is a powerful regulator of nutrient availability. Manganese, zinc, and iron are most available when soil pH is in the acid range. As the pH of acid soil approaches 7.0, manganese, zinc, and iron availability decreases and deficiencies can become a problem, especially on those soils that do not contain appreciable amounts of these elements. These micronutrients frequently must be supplemented with fertilizers when soil levels are low, when over liming has occurred, or when soil tests indicate a deficiency. There is a delicate balance between soil pH and nutrient availability. It is important that soils be tested regularly and that the pH be maintained in the recommended range to achieve maximum efficiency of soil and fertilizer nutrients.

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**Soil as a source of plant nutrients - Essential and beneficial elements, criteria of essentiality**

**Learning objective :**

To understand the importance of soil fertility

To study the essential nutrients in plant growth

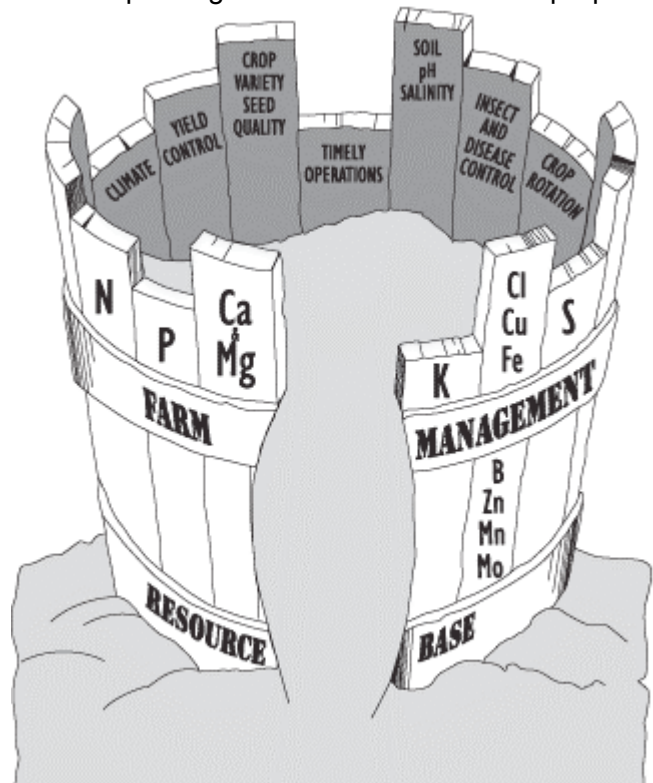
Crops depend on extrinsic and intrinsic factors for their growth and environment to provide them with basic necessities for photosynthesis. These essential plant growth factors include:

- light
- heat
- air
- water
- nutrients
- physical support

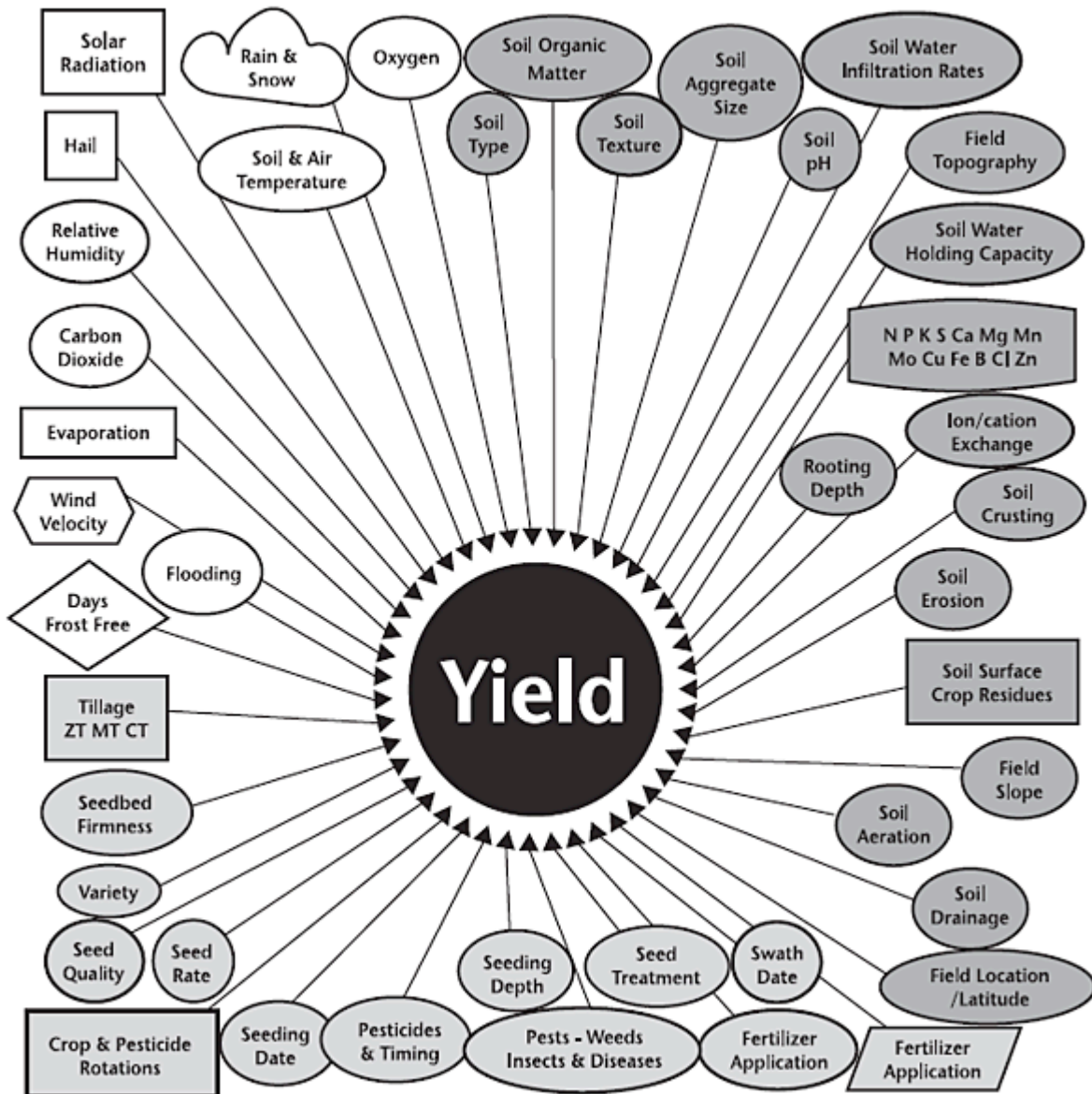
If any one factor, or combination of factors, is in limited supply, plant growth will be adversely affected. The importance of each of the plant growth factors and the proper combination of these factors for normal plant growth is best described by the principle of limiting factors. This principle states: "The level of crop production can be no greater than that allowed by the most limiting of the essential plant growth factors." The principle of limiting factors can be compared to that of a barrel having staves of different lengths with each stave representing a plant growth factor.

Crop yield and quality depends upon the essential growth factors and the many interrelated soil, plant, environmental and agronomic factors or variables. Within this system, some of these factors cannot be controlled; others can be controlled and are manageable.

Soil is one of the key factors affecting plant growth as observed in the figure. The major functions of the soil are to provide plants with nutrients, water and oxygen.







### Crop Production Factors

FAO has listed seven important soil qualities which affect crop growth as given below.

Soil Qualities	Soil Characteristics
SQ1 Nutrient availability	Soil texture, soil organic carbon, soil pH, total exchangeable bases
SQ2 Nutrient retention capacity	Soil Organic carbon, Soil texture, base saturation, cation exchange capacity of soil and of clay fraction
SQ3 Rooting conditions	Soil textures, bulk density, coarse fragments, vertic soil properties and soil phases affecting root penetration and soil

		depth and soil volume
SQ4	Oxygen availability to roots	Soil drainage and soil phases affecting soil drainage
SQ5	Excess salts.	Soil salinity, soil sodicity and soil phases influencing salt conditions
SQ6	Toxicity	Calcium carbonate and gypsum
SQ7	Workability (constraining field management)	Soil texture, effective soil depth/volume, and soil phases constraining soil management (soil depth, rock outcrop, stoniness, gravel/concretions and hardpans)

Soil fertility is the key to sustainable agriculture. Soil fertility is defined in several ways.

### Soil fertility

“Soil fertility is the ability of the soil to supply essential plant nutrients during growth period of the plants, without toxic concentration of any nutrients”. i.e “**the capacity of soil to supply nutrient in available to crop**”.

### Soil productivity

“Soil productivity is ability of soil to produce a particular crop or sequence of crops under a specified mgt system” i.e **the crop producing capacity of soil**”.

**All the productive soils are fertile but all the fertile soils may not be productive**

Sometimes even if the soil is fertile, they are subjected to drought or other unsatisfactory growth factors or management practices.

### History of development of soil fertility

**Francis Bacon** (1591- 1624) suggested that the principle nourishment of plants was water and the main purpose of the soil was to keep plants erect and to protect from heat and cold.

Jan Baptiste **Van Helmont** (1577 – 1644) was reported that water was sole nutrient of plants.

**Robert Boyle** (1627 – 1691) an England scientist confirmed the findings of Van Helmont and proved that plant synthesis salts, spirits and oil etc from H<sub>2</sub>O.

**Anthur Young** (1741 – 1820) an English agriculturist conducted pot experiment using Barley as a test crop under sand culture condition. He added charcoal, train oil, poultry dung, spirits of wine, oster shells and numerous other materials and he conducted that some of the materials were produced higher plant growth.

**Priestly** (1800) established the essentiality of O<sub>2</sub> for the plant growth.

J.B. Boussingault (1802-1882) French chemist conducted field experiment and maintained balance sheet. He was first scientist to conduct field experiment. He is considered as **father of field experiments**.

**Justus Von Liebig (1835)** suggested that

- a. Most of the carbon in plants comes from the CO<sub>2</sub> of the atmosphere.
- b. Hydrogen and O<sub>2</sub> comes from H<sub>2</sub>O.
- c. Alkaline metals are needed for neutralization of acids formed by plants as a result of their metabolic activities.
- d. Phosphorus is necessary for seed formation.
- e. Plant absorb every thing from the soil but excrete from their roots those materials that are not essential.

The field may contain some nutrient in excess, some in optimum and some in least, but the limiting factor for growth is the least available nutrient. **The law of Mn**, stated by **Liebig in 1862**, is a simple but logical guide for predicting crop response to fertilization. This law states that, “the level of plant production cannot be greater than that allowed by the most limiting of the essential plant growth factors”. The contributions made by Liebig to the advancement of agriculture were monumental and he is recognized as the **father of Agricultural chemistry**.

J.B. Lawes and J. H. Gilbert (1843) established **permanent manurial experiment** at Rothemsted Agricultural experiment station at England. They conducted field experiments for twelve years and their findings were

- a. Crop requires both P and K, but the composition of the plant ash is no measure of the amounts of these constituents required by the plant.
- b. No legume crop require N. without this element, no growth will be obtained regardless of the quantities of P and K present. The amount of ammonium contributed by the atmosphere is insufficient for the needs of the crop.
- c. Soil fertility can be maintained for some years by chemical fertilizers.
- d. The beneficial effect of fallow lies in the increases in the available N compounds in the soil.

**Robert Warrington England** showed that the nitrification could be supported by carbon disulphide and chloroform and that it would be stopped by adding a small amount of unsterilized soil. He demonstrated that the reaction was two step phenomenon. First NH<sub>3</sub> being converted to nitrites and the nitrites to nitrates.

### **Essential and Beneficial elements**

“A mineral element is considered to be essential for plant growth and development if the element is involved in plant metabolic functions and the plant cannot complete its life cycle without the element”.

There are seventeen essential elements required for plant growth viz., **C, H, O, N, P, K, Ca, Mg, S, Fe, Mn, Zn, Cu, B, Mo, Cl, Ni,**

The following is the essentiality criteria described by Arnon and Stout (1939)

1. A plant must be unable to complete its life cycle in the absence of the mineral element.
2. The function of the element must not be replaceable by another mineral element.
3. The element must be directly involved in plant metabolism.

**Beneficial Nutrients/Elements:** Beneficial elements are the mineral elements that stimulate the growth and exhibit beneficial effects at very low concentration or which are essential only for certain plant species or under specific conditions are called as “beneficial elements”.Eg.Na,Va,Co,Si

**D.J.Nicholas coined the term “functional or metabolic nutrient”**

Any mineral element that functions in plant metabolism, whether or not its action is specific. (Cl, Si, Na, Va, Co, Se)

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

**Essentiality of the elements established by**

Carbon	:	Priestly (1800)
Nitrogen	:	Theodore De saussure (1804)
Ca, Mg, K, S	:	Carl sprengel (1839)
Phosphorus	:	Von Liebig (1844)
Iron (Fe)	:	E. Greiss (1844)
Manganese (Mn)	:	J.S. Hargue (1922)
Zinc(Zn)	:	Sommer and Lipman (1926)
Copper (Cu)	:	Sommer, Lipman and Mc Kenny (1931)
Molybdenum (Mo)	:	Arnon and Stout (1939)
Sodium (Na)	:	Brownell and wood (1957)
Cobalt(Co)	:	Ahamed and Evans (1959)
Boron(B)	:	Warring ton (1923)
Chlorine (Cl )	:	Broyer (1954)
Nickel	:	Brown et.al.(1987)

### Classification of Essential Elements

- 1) Based on the amount required by the plant
  - i) Major nutrients – required in large quantities eg. N,P,K
  - ii) Secondary nutrients – required in lesser quantities compared to Major nutrients eg. Ca,Mg,S
  - iii) Micronutrients- required in trace quantities eg. Fe, Mn, Zn, Cu, B, Mo

### Classification based on the role of element in plant system

#### (According to TRUOG, 1954)

- |                                    |                             |
|------------------------------------|-----------------------------|
| Structural Elements                | : C, H, O                   |
| ii). Accessory structural elements | : N. P. S                   |
| iii). Regulator & Carriers         | : K, Ca, Mg                 |
| iv). Catalyst & Activators         | : Fe, Mn, Zn, Cu, Mo, Cl, B |

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### Questions to ponder

- 1) How are the essential elements essential to crops?
- 2) Which elements are considered to be essential for crop growth?
- 3) Why is some nutrient deficiencies exhibited in older leaves, while other nutrient deficiencies show up first on newer leaves?
- 4) What are beneficial elements?
- 5) What is the difference between major and micronutrient?

06.

### Mechanism of nutrient transport in plants

#### Learning objectives

- a. Understand ways in which nutrients in the soil reach plant roots
- b. To know how plant roots absorb nutrients and move inside plants

Nutrients must reach the surface of a root for plant uptake of essential elements to occur. There are three major mechanism of movement of ions from soil to roots. They are

#### Root interception

Root interception occurs when a nutrient comes into physical contact with the root surface. As a general rule, the occurrence of root interception increases as the root surface area and mass increases, thus enabling the plant to explore a greater amount of soil. Root interception may be enhanced by mycorrhizal fungi, which colonize roots and increase root exploration into the soil. Root interception is responsible for an appreciable amount of **calcium** uptake, and some amounts of **magnesium, zinc** and **manganese**. The CEC of roots for monocots is 10 - 30 meq/100 g and takes up monovalent cations more readily and that of Dicots is 40 - 100 meq/100 g and takes up divalent cations more readily. The quantity of nutrients intercepted by roots depends on the soil concentration of nutrients and volume of soil displaced by root system

#### Factors affecting root interception

- a. Anything that restricts root growth
  - i. Dry soil
  - ii. Compaction
  - iii. Low soil pH
  - iv. Poor aeration
  - v. Root disease, insects, nematodes
  - vi. High or low soil temperature
- b. Root growth is necessary for all three mechanisms of nutrient supply, but absolutely essential for root interception to occur

#### Mass flow:

Mass flow occurs when nutrients are transported to the surface of roots by the movement of water in the soil (i.e. percolation, transpiration, or evaporation). The rate of water flow governs the amount of nutrients that are transported to the root surface. Therefore, mass flow decreases as soil water decreases. Most of the **nitrogen, calcium, magnesium, sulfur, copper, boron, manganese** and **molybdenum** move to the root by mass flow. Quantity of nutrients transported is proportional to:

- i. Rate of flow (volume of water transpired)
- ii. Solution concentration of nutrient

Nutrients supplied primarily by mass flow are considered mobile nutrients. e.g. N, S, B

### Factors affecting mass flow

- a. Soil water content
  - i. Dry soil where there is no nutrient movement
- b. Temperature
  - i. Low temperature reduces transpiration and evaporation
- c. Size of root system
  - i. Affects water uptake and therefore movement
  - ii. Root density much less critical for nutrient supply by mass flow than for root interception and diffusion

### Diffusion:

Diffusion is the movement of a particular nutrient along a concentration gradient. When there is a difference in concentration of a particular nutrient within the soil solution, the nutrient will move from an area of higher concentration to an area of lower concentration. This phenomenon is observed when adding sugar to water. As the sugar dissolves, it moves through parts of the water with lower sugar concentration until it is evenly distributed, or uniformly concentrated. Diffusion delivers appreciable amounts of **phosphorus, potassium, zinc, and iron** to the root surface. Diffusion is a relatively slow process compared to the mass flow of nutrients with water movement toward the root. Nutrients supplied primarily by diffusion are considered immobile nutrients e.g. P, K

### Factors affecting diffusion

- a. Fick's law is given as  $dC/dt = De * A * dC/dX$

$dC/dt$  = diffusion rate (change in concentration over time)

$De$  = effective diffusion coefficient

$A$  = cross sectional area for diffusion

$dC/dX$  = concentration gradient (change in concentration over distance)

Diffusion rate is directly proportional to concentration gradient, diffusion coefficient, and the area available for diffusion to occur

### b. Effective diffusion coefficient

Effective diffusion coefficient  $De = Dw * q * (1/T) * (1/b)$  where

$Dw$  = diffusion coefficient in water

$q$  = volumetric soil water content

$T$  = tortuosity factor

$b$  = soil buffering capacity

- a. Diffusion coefficient in water ( $Dw$ )
  - i. Includes a temperature factor



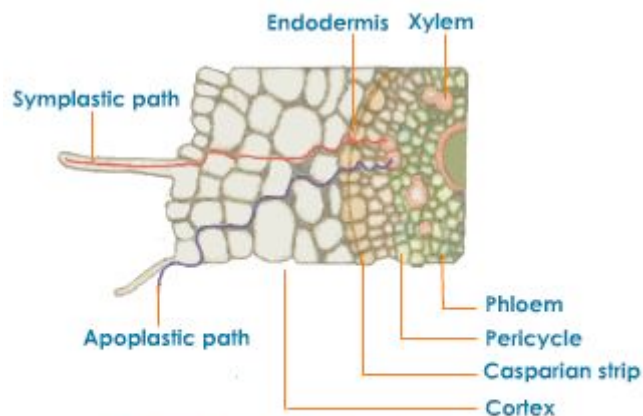
- ii. Colder = slower diffusion
- b. Soil water content
  - i. Drier soil = slower diffusion
  - ii. Less water = less area to diffuse through
- c. Tortuosity
  - i. Pathways through soil are not direct
  - ii. Around soil particles, through thin water films
  - iii. Affected by texture and water content
    - 1. More clay = longer diffusion pathway
    - 2. Thinner water films = longer path
- d. Buffering capacity
  - i. Nutrients can be removed by adsorption as they move through soil, reducing diffusion rate
- c. **How far can nutrients diffuse in a growing season?**
  - a. Diffusion distances are very short
    - i. K ~ 0.2 cm
    - ii. P ~ 0.02 cm
  - b. Size and density of plant root systems is very important for nutrients supplied by diffusion
  - c. Has implications for fertilizer placement

### ***Ion traffic into the root***

Mineral nutrients absorbed from the root has to be carried to the xylem. This transport follows two pathways namely apoplastic pathway and symplastic pathway.

In apoplastic pathway, mineral nutrients along with water moves from cell to cell through spaces between cell wall by diffusion. The ions, which enter the cell wall of the epidermis move across cell wall of cortex, cytoplasm of endodermis, cell walls of pericycle and finally reach the xylem.

In symplastic pathway, mineral nutrients entering the cytoplasm of the epidermis move across the cytoplasm of the cortex, endodermis of pericycle through plasmodesmata and finally reach the xylem.



Anatomical aspect of symplastic and apoplastic pathways of ion absorption in the root hair region