How Plant Nutrients React in Soils

---- Roy S. Rauschkolb and Robert J. Zasoski[1/]

Plants use the sun's energy, water, air and nutrients from the soil to manufacture all the materials needed for growth, development and reproduction; the excess material produced or absorbed is stored in the cells of the plant.

We depend on these plant functions for our food and fiber. Since thirteen of the nutrient elements required by plants must be supplied from the soil, it should be clear why it is important to understand how nutrients react in soils.

Although soils tend to be an obscure part of any landscape, they are often responsible for the changes in native vegetation that may be found. Soils provide:

- A continual and adequate supply of nutrients,
- Aeration of the plant's roots,
- Mechanical support,
- A reservoir of water.

It is the role soil plays on various changes and reactions of nutrient elements and how that influences a continual and adequate supply that is the subject of discussion.

There are thirteen nutrients essential for growth that plant roots must absorb from the soil solution. These elements are listed in Table 1. They undergo various chemical, physical and biological reactions which influence their movement through soils and their availability to plants.

The principal reactions are:

- Adsorption on clay minerals, and
- Precipitation as insoluble compounds.

Clay minerals play a major role in regulating nutrient supply and movement. They are extremely small particles with a platelike crystalline structure. Because of their size and chemical make-up, they have highly reactive surfaces

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TABLE 1. THE RELATIVE EXTENT THAT PLANT NUTRIENTS ARE ASSOCIATED WITH BIOLOGICAL, CHEMICAL AND PHYSICAL SOIL REACTIONS.

Nutrient	Chemical Symbol	Forms Utilized	Cation Adsorption	Anion Adsorption	Precipitation as Relatively Insoluble Inorganic Forms	Incorporation in Organic Forms	Mineral Entrapment	Relative Mobility
Nitrogen	N	$NH_4^{\oplus}$	high			slight to moderate	moderate to high	Immobile
		$NO_3^{\ominus}$		none to slight		slight to moderate		Mobile
		$H_2PO_4^{\ominus}$						
Phosphorus	P	$HPO_4^{\ominus\ominus}$		moderate	high	slight to moderate		Immobile
Potassium	K	$K^{\oplus}$	high				moderate to high	Immobile
Sulfur	S	$SO_4^{\ominus\ominus}$		slight to moderate	slight	slight to moderate		Mobile
Calcium	Ca	$Ca^{\oplus\oplus}$	high		slight			Immobile
Magnesium	Mg	$Mg^{\oplus\oplus}$	high		slight			Immobile
Zinc	Zn	$Zn^{\oplus\oplus}$	high		high			Immobile
Iron	Fe	$Fe^{\oplus\oplus\oplus}$	high		high			Immobile
Manganese	Mn	$Mn^{\oplus\oplus}$	high		high	moderate		Immobile
Copper	Cu	$Cu^{\oplus\oplus}$	high		high	moderate		Immobile
Boron	B	$H_3BO_3^{\circ}$		moderate		slight to moderate		Mobile
Molybdenum	Mo	$HMoO_4^{\ominus}$		moderate	high			Immobile
Chlorine	Cl	$Cl^{\ominus}$		none to slight				Mobile

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which have an electrical charge associated with them. The electrical charge was demonstrated by use of a battery and two metal rods. The negatively charged clay particle was attracted to the positively charged metal rod.

When plant nutrients are dissolved in soil water, they form ions with either a positive or negative charge. The positively charged ones are called cations and the negatively charged ones are called anions. Because of the attraction of the cations to the negatively charged clay surface, that phenomena is called cation exchange and the amount of cations that can be held is the capacity of the clay; hence, the term "Cation Exchange Capacity". This is an important concept in soil chemistry because it accounts for the movement of positively charged elements in soils and regulates their supply to plants. Potassium is an example of a nutrient whose movement and supply is regulated by the exchange reaction with clay.

The negatively charged elements are actually repelled from the negative clay surfaces and are free to move through the soil with soil water when present in the soil solution. Sulfur in the sulfate form is an example of a nutrient element that can move in soils with water.

The two forms of nitrogen, the ammonium cation and the nitrate anion, move differently through soils. The difference in movement demonstrates the concept of nutrient mobility. See Table 1 for the relative mobility of the plant nutrients in soils.

Not all of the negatively charged plant nutrients are mobile in soils. Some undergo reactions which remove them from the soil solution. The predominate reaction is the formation of compounds which dissolve very little in soil water. Phosphorus is an example of an immobile plant nutrient whose movement and supply to plants is regulated by the formation of relatively insoluble compounds.

The anions which do not form very insoluble compounds such as chloride, and the nutrient with no net electrical charge such as borate are not well regulated by soils. Their movement and supply to plants are influenced by the amount of water moving through the soil.

The soil is a reservoir of plant nutrients that undergo reactions such as adsorption and precipitation, which regulate their mobility in soils. Through a knowledge of these reactions and the forms of nutrients in fertilizer materials, you can achieve proper placement of the right nutrient in the right amount for more efficient utilization of a resource.

The goal of fertilization is the intelligent replacement of plant nutrients. Whether the source of the nutrient is organic or inorganic, it is through informed use that we can provide high quality food and fiber at lowest cost and prevent unwanted environmental changes.

Other publications and slide programs available through Agricultural Extension which may be of help are:

What on Earth are Soils	Slide Set
Organic and Inorganic Fertilizers and Soil Amendments	AXT-357
Soil and Water Management for Home Gardners	AXT-111
Soil Analysis	OSA- 98
Plant Tissue Analysis as a Guide to Fertilization	OSA-112
Zinc Fertilization of Field and Vegetable Crops	OSA-123