UNDERSTANDING THE BASICS

Mineral fertilizers are a concentrated source of nitrogen, phosphorus and potassium. The amount of each is listed on the label.

As a grower, you want to choose the nutrient sources and application strategies that will meet the nutrient demands of your crops without wasting resources. Knowing what nutrients are needed by which crops, and understanding how those nutrients move through soil, water and the atmosphere, will help you get it right.

This chapter will help you learn more about:

- the nature of nutrients
- how crop nutrients move through nutrient cycles
- nutrients required by crops
- alkaline and acidic soils
- why crops may not be able to use all the nutrients you apply
- what happens to the fertilizer and other nutrients you apply
- how to diagnose deficiency symptoms.

WHAT ARE NUTRIENTS?

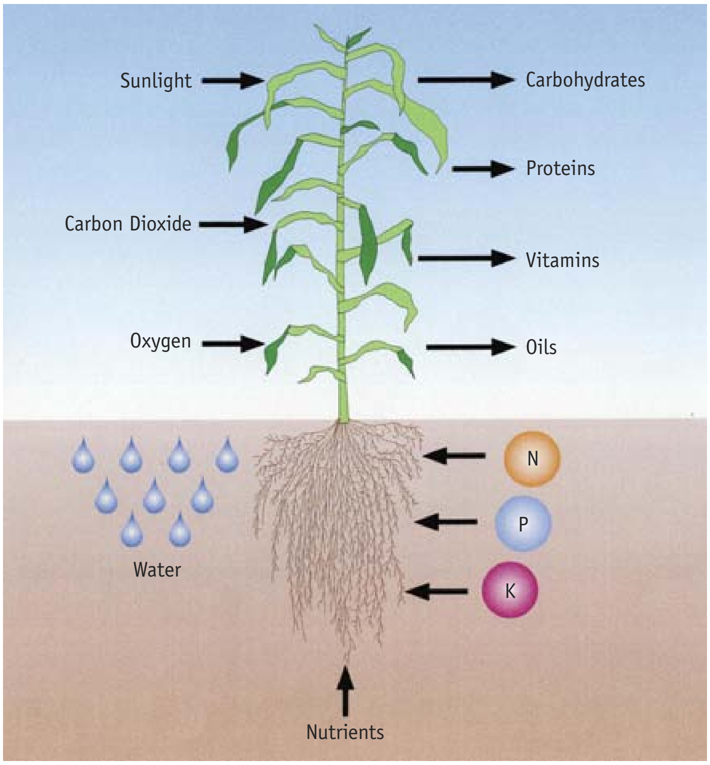
Plant nutrients are chemical elements, or simple compounds formed from them, needed by plants for proper growth and development. The most common elements in plants are carbon, hydrogen, and oxygen, which are obtained from air and water. All other nutrients are obtained from soil.

Six nutrients are required by crops in relatively large amounts. These are often referred to as **macronutrients**. The other nutrients are required in quite small amounts – often less than one kilogram per hectare per year. These are called **micronutrients**.

Mineral fertilizers are a concentrated source of nitrogen, phosphorus and potassium. The amount of each is listed on the label.

Nutrients exist in either **organic** or **inorganic** (mineral) form. Organic compounds are produced by living organisms and contain carbon. Inorganic compounds are derived from the breakdown of organic compounds or from chemical reactions. For example, protein is an organic form of nitrogen; ammonium and nitrate are inorganic or mineral forms.

Nutrients are naturally present in soil in inorganic forms, as the result of the weathering of soil minerals. Inorganic nutrients taken up by living organisms may be converted to organic forms that make up the tissue of plants, animals, and micro-organisms. Organic forms of nutrients in living organisms return to inorganic forms when these organisms die and decompose.



Green plants convert light, water air and plant nutrients into forms that people and animals can use. Without this process, the nutrients would be inaccessible.

ESSENTIAL NUTRIENTS FROM SOIL

MACRONUTRIENT	SYMBOL
Calcium	Ca
Magnesium	Mg
Nitrogen	N
Phosphorus	P
Potassium	K
Sulphur	S
MICRONUTRIENT	**SYMBOL**
Boron	B
Chlorine	Cl
Copper	Cu
Iron	Fe
Manganese	Mn
Molybdenum	Mo
Nickel	Ni
Zinc	Zn

Nutrient and Soil Management: Plants Need Both!

Nutrients are essential for plant growth and reproduction, but they are only one of the essential inputs needed by crops.

Your soil's ability to support plants and to supply water, oxygen, and warmth to plants is also important. A lack of any one of these directly affects plant growth, and can impair your crop's ability to use nutrients present in the soil. Take another look at your present soil management program: if it considers only the amount of nutrients available to crops, it's probably unsatisfactory.

For available nutrients to be used efficiently, soil must have good structure, proper drainage, and good moisture-holding capacity. See Best Management Practices books, *Soil Management*, *Field Crop Production*, and *Horticultural Crops*, for more information.

Crops cannot obtain sufficient nutrients from soil that is in poor physical condition.

Crops also take up nutrients they don't need, but animals do, such as:

Cobalt	**Co**
Iodine	**I**
Chromium	**Cr**
Sodium	**Na**
Selenium	**Se**

Soil organisms can temporarily tie up available nitrogen in the soil, leaving crops at a loss.

THE NUTRIENT CYCLE

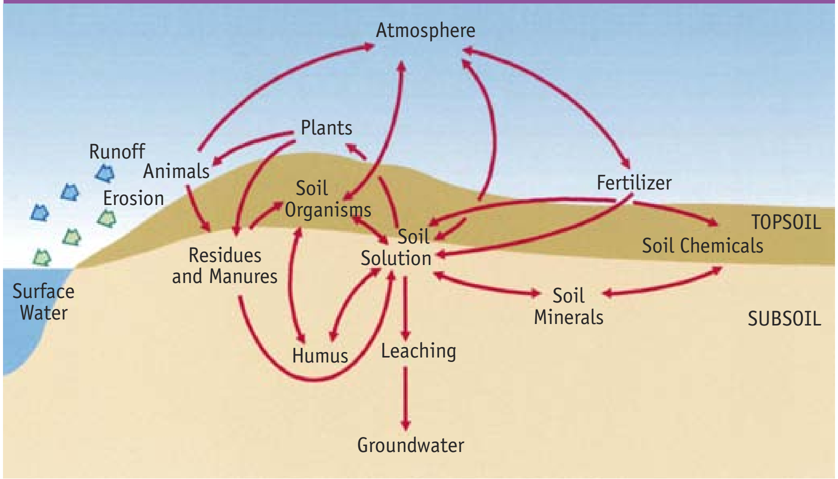
Nutrients are constantly cycling through different forms in the soil. As they react, nutrients are used by plants, lost from the soil, or converted to unavailable forms.

A basic understanding of the nutrient cycle is a cornerstone of a sound nutrient management program. It will involve learning the various forms in which nutrients exist, what influences the availability of specific nutrients, and how they're lost from the cycle.

Nutrients exist in soil in many forms, of which only a few are useful to plants. Regardless of whether you apply nutrients to soil in organic form (e.g., manures) or in inorganic form (e.g., commercial fertilizers), they must be in an inorganic form to be taken up by plants.

In soil that isn't frozen, chemical and biological activity is continually changing nutrients from one form to another, although a rough balance exists among them. Look at the nutrient cycle illustration for a general idea of the cycle through which nutrients flow.

NUTRIENT CYCLE



Bacteria in nodules on the roots of legume plants supply the plants with nitrogen.

SOIL COMPONENTS

Soil Solution

The mixture of soil moisture and the materials dissolved in it is called the **soil solution**. Only a small proportion of the total nutrients in soil are in solution. Most of the nutrients are either attached to soil particles or part of the organic matter.

The soil solution is the key component of the cycle for all nutrients, because they must be dissolved in water before they can be taken up by plants.

Soil Organic Matter and Organisms

Healthy soil is filled with many living organisms, ranging from bacteria to earthworms. These organisms are essential to the nutrient cycle because they break down organic matter, releasing its nutrient content. (See the Best Management Practices book, *Soil Management*, for much more information on this subject.)

At times, soil organisms can compete with plants for nutrients. Under some conditions, soil micro-organisms that break down residues low in nitrogen can temporarily consume much of the available nitrogen in soil, preventing its immediate use by plants. This nitrogen is, however, released again as the micro-organisms themselves die and decompose. The temporary tie-up of nitrogen can affect crop yields if it occurs at a time of high crop demand.

The bacteria associated with legume crops fix nitrogen from the air. The residues of alfalfa and clovers, in particular, can add large amounts of nitrogen to the soil. When such residues break down quickly, a large flush of nitrate-nitrogen can be released into the soil. If nitrate-nitrogen is not used by plants, much of it can be leached into groundwater.

CATION EXCHANGE

Fertile soils have the ability to provide nutrients when crops require them. In most cases, fertile soils have a relatively high clay plus organic matter content in the topsoil (e.g., clay loams). Clay and humus are able to hold more nutrients than other soil particles.

Because clay and humus particles are negatively charged, nutrients that are positively charged, called **cations**, are drawn to their surface. Nutrients held in this way resist leaching, but can be removed by plant roots.

They can also exchange places with other cations from the soil solution. This replacement of one cation by another is called **cation exchange**. The soil's ability to hold onto and exchange certain nutrients for plant growth is known as the **cation exchange capacity (CEC)**.

Exchangeable nutrients are readily available to plants and represent an important reserve, especially for calcium, potassium, and magnesium. A small amount of nitrogen in the ammonium form is also held by cation exchange.

Cation exchange capacity is the soil's ability to hold and exchange particular nutrients for plant growth.

Cations often "compete" for space on soil exchange surfaces.

WEATHERING, MINERALS AND CHEMICAL COMPOUNDS

The natural fertility of the soil on your farm was determined by two key factors:

- the type of rock from which the soil was derived
- the conditions under which the soil was formed.

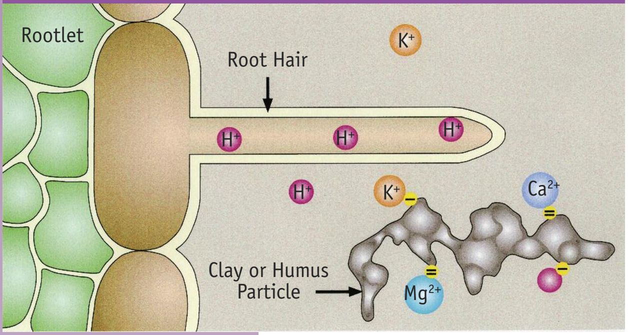
As a result, different soil types vary greatly in fertility and related properties.

Originally, most of the nutrients in soil (except nitrogen) were part of the chemical structure of rock. Over many thousands of years, various natural forces, together known as **weathering**, have broken down the rock and its minerals, releasing some of their nutrient content in forms that plants can use. Slowly, weathering continues to release small amounts of nutrients from these sources.

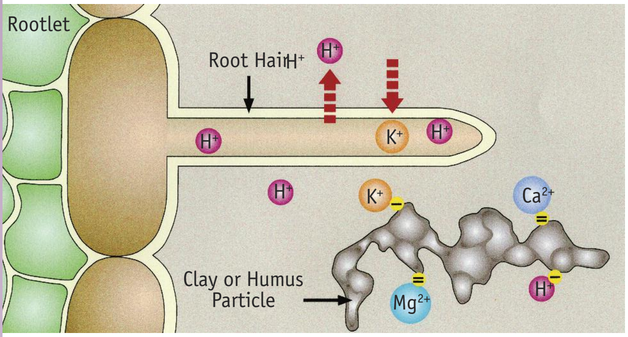
Many of the chemical reactions that occur in soils remove nutrients from soil solution. Some of these reactions produce compounds that are insoluble in water and thus unavailable to plants. Nutrients in these compounds remain unavailable until other reactions break the components down.

The pH of your soil influences which chemical reactions occur, and therefore which compounds are produced. The pH also affects the solubility of the compounds. Thus, the availability of most nutrients changes if the soil pH is changed.

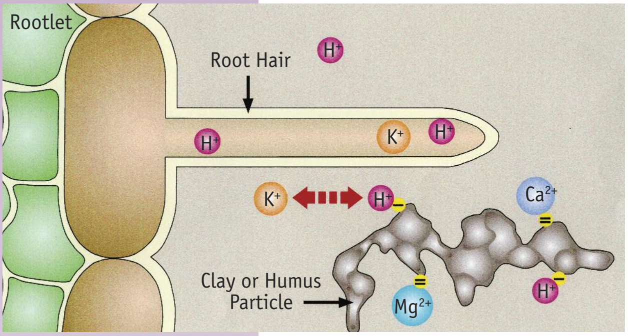
CATION EXCHANGE AND NUTRIENT UPTAKE



Nutrient cations are in the soil solution and attached to soil particles.



When a root absorbs a nutrient cation from the soil solution, it releases a hydrogen ion.

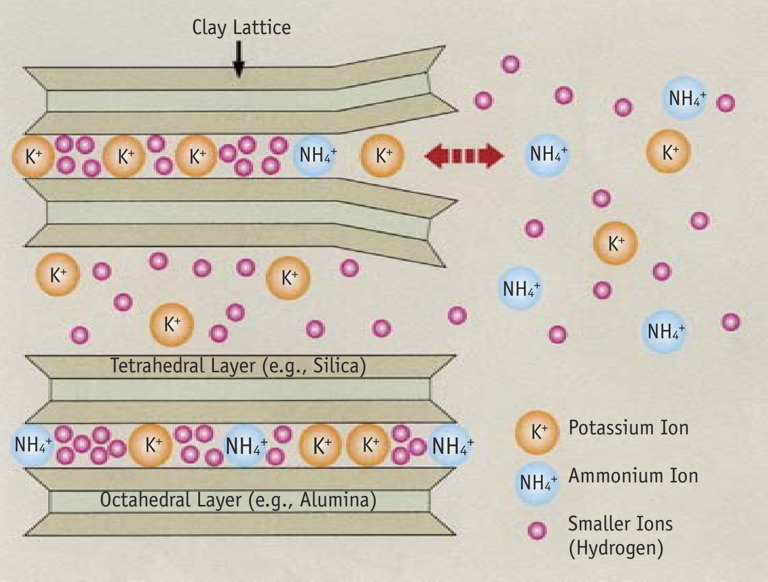


The hydrogen ion is then exchanged with the nutrient cation (K^+) from the soil particle.

H^+	hydrogen ion
K^+	potassium ion
Ca^{2+}	calcium ion
Mg^{2+}	magnesium ion
$^-/^=$	negative charges on clay or humus particle

Fixation of potassium or ammonium-nitrogen by clay particles can be a problem in regions with high clay contents, such as the Ottawa Valley.

FIXATION OF AMMONIUM AND POTASSIUM BY CLAY



THE ROLE OF SUBSOIL AND SOIL PARENT MATERIALS

Generally speaking, subsoil is much lower in fertility and contributes a much smaller proportion of the nutrients taken up by plants than does topsoil. Several factors contribute to this:

- most of the plant root system is in the topsoil
- nutrients have not been added to the subsoil
- the availability of many nutrients is reduced in alkaline parent materials as found in most of southern Ontario
- there is less organic matter in subsoil
- fewer nutrients have been released in subsoil because subsoil is less subject to weathering than topsoil.

Nevertheless, subsoils can be an important source of nutrients, especially during dry weather. When plants obtain most of their water from subsoil, they must also obtain nutrients there. Nutrients taken from the subsoil by deep-rooted plants are added to the topsoil when the residues from those plants decay.

Deep-rooted crops move some nutrients such as potassium to the topsoil.

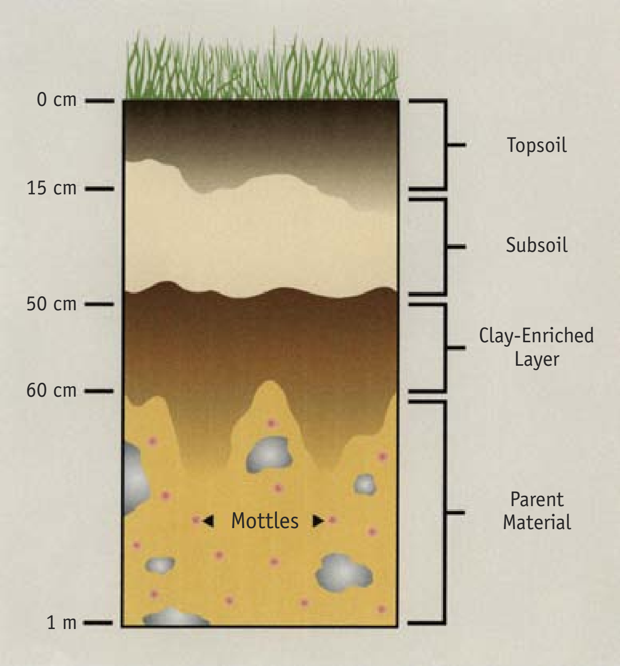
ADDITIONS TO SOIL

Residues, Manures, and Other Organic Materials

Many of the nutrients taken up by plants are returned to the soil in their residues. Livestock manures return most of the nutrients contained in feeds. These and other organic materials, like sewage or paper biosolids, composts and other organic wastes, are important reserves of nutrients.

Nutrients in organic form are held in the soil and are gradually released in available forms as the organic matter decomposes. Some of the nutrients in organic materials are immediately available; more become available over time. Manure, for example, can continue to release nutrients for several years.

The availability of crop nutrients from organic sources is related to the ratio of carbon to nitrogen. The closer this ratio is to soil (12:1), the sooner and more likely organic forms of nitrogen will become available as crop nutrients following application.



Subsoils are less fertile than topsoil.

Organic matter that has rotted and become stable is known as **humus**. Humus forms an important part of a soil's ability to hold nutrients.

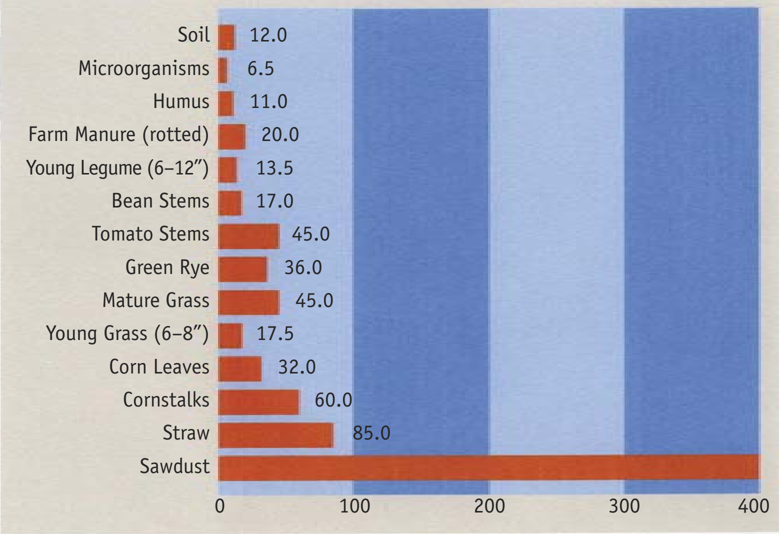
Soil Organic Matter: Finding the Right Balance

Soil organic matter plays crucial roles in maintaining soil structure and increasing the soil's capacity to hold onto water and nutrients. Building up organic matter levels will help you do both. However, the release of nitrogen and other nutrients that are sequestered in organic forms depends on the breakdown of organic matter.

The trick is finding the right balance between the stable organic compounds that stay in the soil for the long term, and the active fraction of organic matter involved in nutrient cycling.

Organic material with a chemical composition that's high in carbon relative to nitrogen content (i.e., a C:N ratio greater than 30:1) can tie up (immobilize) the available N in the soil, temporarily limiting its availability for crop growth. Over time, soil microbes use up the carbon and reduce the material's C:N ratio, eventually making its N available to crops.

CARBON-TO-NITROGEN RATIOS OF COMMON MATERIALS



Returning organic matter to the soil helps complete the nutrient cycle.

Rain and snow add both nitrogen and sulphur compounds to the soil.

Fertilizers

Nutrients in most commercial fertilizers are in a soluble form. They enter the soil solution directly and become available to plants almost immediately. In the year of application, however, plants capture only a portion of the nutrients applied.

Because the addition of nutrients to the soil solution shifts the balance in the nutrient cycle, some nutrients are converted to less-available forms until the balance is re-established.

Of the nutrients applied in fertilizers, crops in the year of application typically take up:

- 50–70% of nitrogen
- 10–30% of phosphorus
- 20–60% of potassium.

The proportion of nutrients taken up from organic materials in the year of application is even lower.

Some of the unused nutrients will become available in succeeding years and will be reflected in your soil test.

Regular application of phosphorus or potassium at rates above crop removal often causes the levels of these nutrients in the soil to increase. This eventually reduces the need for these nutrients to be applied.

Much of the nitrogen released during manure decomposition will be tied up and later released by soil microbes – and not always when the crop requires it. The challenge is to account for this effect when determining nutrient application rates.

Atmosphere

Dust, smoke particles, and other air pollutants fall with the rain and snow, adding trace amounts of most nutrients to the soil. Acid rain and snow also contain significant amounts of nitrogen and sulphur.

In southern Ontario, rainfall adds about 18 kilograms per hectare (16 lb/ac) of nitrogen to the soil, annually. The amount of sulphur received in precipitation each year ranges 8–13 kg/ha (7–12 lb/ac), with a similar amount received by dry deposition (dust and fine particles).

Waterlogged soils lead to the loss of nitrate as nitrogen gas to the atmosphere.

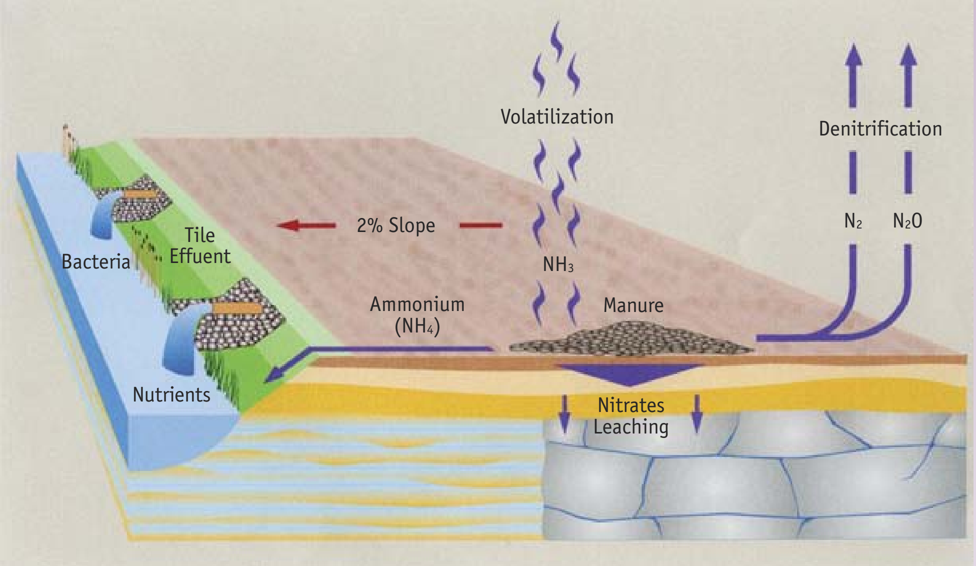
Atmospheric ammonia can be added to the soil after interacting with water vapour and acidic compounds to form ammonium. Ammonia and sulphuric acid can form fine particulate aerosols – better known as smog – in the atmosphere.

Proper nutrient management minimizes the losses of nutrients from organic sources to the air, surface water and groundwater.

Losses from Soil

Nutrients in harvested crops are used by livestock and people. If their wastes are returned to cropland, the cycle is completed with relatively little loss – with the exception of nitrogen.

Nutrients are lost from this cycle when they are released into the atmosphere, surface water, or groundwater.



Wind erosion is one way that nutrients become “lost” from the nutrient cycle.

SUMMARY OF NUTRIENT LOSSES FROM THE NUTRIENT CYCLE

PROCESS	**DETAILS**
VOLATILIZATION	• defined as the loss of free ammonia (NH_3) to the atmosphere • manure-based ammonium (NH_4^+) will readily convert to ammonia • manure with higher levels of NH_4^+ will more readily produce NH_3 • rate of loss depends on temperature, humidity, wind speed, soil moisture, pH, vegetative cover, rainfall and infiltration – loss is greatest in warm, sunny, dry weather • loss increases with surface exposure – incorporation reduces loss
DENITRIFICATION	• in saturated soils, nitrates will be converted by microbes to nitrogen gas (N_2) • in semi-saturated soils and storages, nitrates will be converted by microbes to nitrous oxide (N_2O) • nitrogen (organic and ammonium) that converts to nitrate (nitrification) is also subject to denitrification
RUNOFF AND EROSION	• surface-applied manure is at risk of runoff • manure-based P and N nutrients will be transported with eroding materials and runoff • rates of runoff and erosion increase with slope, low infiltration rates, compacted or frozen soils, low vegetative or crop cover, intense rainfall or snowmelt
LEACHING	• involves the movement of soil solutions and their solutes out of the soil profile/rooting zone • for this to happen, there must be a high concentration of nitrates (and/or bacteria) in the rooting zone and a net movement of water through the soil profile • sandy and gravelly soils with high water tables are at greatest risk • prime sources of nitrate are: ○ improperly stored manure (e.g., uncovered solid or composted manure on bare soil) ○ nitrate fertilizers ○ mineralized legumes and applied manure
TILE EFFLUENT	• is the mass flow to tile of land-applied liquids through cracks and continuous macropores • nutrients (N, P and K) and pathogens can end up in surface waters • this is more of an issue with soils that have not been tilled prior to land application
IMMOBILIZATION	• nutrients are tied up by soil microbes in soil • soil microbial populations are large and diverse enough to remove available nitrogen from soil solutions before plants can use them • depends on the ratio of carbon to nitrogen (C:N) in crop residues or organic materials added to the soil ○ if high carbon/low nitrogen material such as straw or sawdust bedding is added to soil, the microbes will tie up available nitrogen ○ in time the microbes will run out of food, die, and release the nitrogen following mineralization
FIXATION	• phosphate is very reactive in soil: combines with calcium, magnesium, iron, manganese or aluminum, and becomes attached to the soil particles • a small amount remains in solution at any given time • much of the phosphate remains in a reserve form and is released into solution to replenish what's been removed by plants

NUTRIENTS IN SOILS AND PLANTS

In this section, you'll learn about the type, function, and deficiency symptoms of the macronutrients and micronutrients essential for crop growth.

This should help you diagnose and predict crop problems as they relate to nutrient deficiency.

THE MACRONUTRIENTS

Nitrogen (N)

Regardless of how nitrogen is applied to the soil, much of it will eventually be converted to the nitrate (NO_3^-) form. Plants take up most of their nitrogen as nitrate, in part because it's the most common inorganic form in soil.

Nitrate-nitrogen is very soluble in water and moves with soil moisture. This allows roots to obtain the nitrogen from almost any part of the soil from which they draw water. However, because of its solubility, nitrate-nitrogen also leaches very easily.

The level of nitrate-nitrogen in the soil can change quickly. In warm weather, large amounts can be released by the breakdown of organic matter. In wet weather, nitrate can be lost from well-drained soils through leaching. From saturated soils, it can also be lost due to conversion into nitrogen gas (N_2) by soil bacteria through denitrification.

In soil, the nitrogen in urea is converted to ammonium. However, in warm and moist conditions, much of the nitrogen from surface-applied urea can be converted to ammonia (gas) and lost to the atmosphere.

ELECTRICAL CHARGE

COMPOUND	SYMBOL	ELECTRICAL CHARGE
Nitrate	NO_3^-	Negative
Ammonium	NH_4^+	Positive
Ammonia (gas)	NH_3	Neutral

APPROXIMATE AMOUNT OF NUTRIENTS CONTAINED IN CROPS

CROP	YIELD PER ACRE	N lb/ac	P_2O_5 lb/ac	K_2O lb/ac	Ca lb/ac	Mg lb/ac	S lb/ac	Cu lb/ac	Mn lb/ac	Zn lb/ac
Alfalfa, hay	5 tons	364	65	300	135	25	25	0.07	0.55	0.53
Red clover, hay	2.5 tons	160	44	150	70	17	7	0.04	0.54	0.36
Timothy, hay	2.5 tons	90	30	90	20	6	5	0.03	0.31	0.20
Barley, grain	60 bu	60	24	18	1.5	3	4.5	0.04	0.04	0.09
Barley straw	1.5 tons	20	16	55	12	3	6	0.02	0.48	0.07
Corn, grain	150 bu	125	63	44	2	8	10	0.06	0.09	0.15
Corn, stover	4.5 tons	100	40	145	25	20	15	0.05	1.50	0.30
Oats, grain	80 bu	33	11	10	2	3	5	0.03	0.12	0.05
Oats, straw	2 tons	11	7	47	8	8	9	0.03	n.a.	0.30
Rye, grain	45 bu	29	12	9	3	4	10	0.03	0.33	0.04
Rye, straw	2 tons	12	5	32	10	3	4	0.01	0.18	0.09
Wheat, grain	80 bu	48	23	14	2	12	6	0.06	0.18	0.28
Wheat, straw	3 tons	30	5	51	12	6	10	0.02	0.32	0.10
Soybeans, grain	40 bu	78	17	28	7	7	4	0.04	0.05	0.04
Apples	500 bu	30	10	45	8	5	10	0.03	0.03	0.03
Beans, dry	30 bu	75	25	25	2	2	5	0.02	0.03	0.06
Cabbage	20 tons	80	37	130	20	8	44	0.04	0.10	0.08
Onions	7.5 tons	38	17	40	11	2	18	0.03	0.08	0.31
Peaches	600 bu	35	20	65	4	8	6	n.a.	n.a.	0.01
Potatoes	400 bu	80	30	150	3	6	6	0.04	0.09	0.05
Spinach	5 tons	36	15	30	12	5	4	0.02	0.10	0.10
Sweet potatoes	300 bu	45	8	75	4	9	6	0.03	0.06	0.03
Tomatoes	20 tons	80	28	160	7	11	14	0.07	0.13	0.16
Turnips	10 tons	45	23	90	12	6	n.a.	n.a.	n.a.	n.a.
Peanuts	1.25 tons	90	10	15	1	3	6	0.02	0.01	n.a.
Tobacco leaves	1 ton	56	6	120	75	18	14	0.03	0.55	0.07
Tobacco stalks	35	15	50							

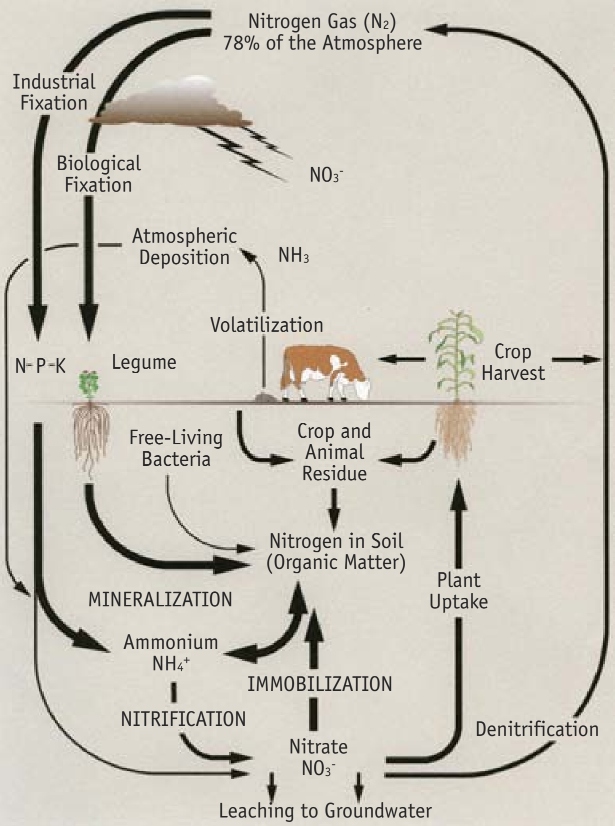
Phosphorus (P)

Phosphates are very reactive in soil, combining with calcium, magnesium, iron, or aluminum and attaching to the soil particles. Only a small amount remains in solution. Phosphates are removed from the solution quickly. But much of the phosphate remains in a reserve form and is released into solution to replenish what's been removed by plants.

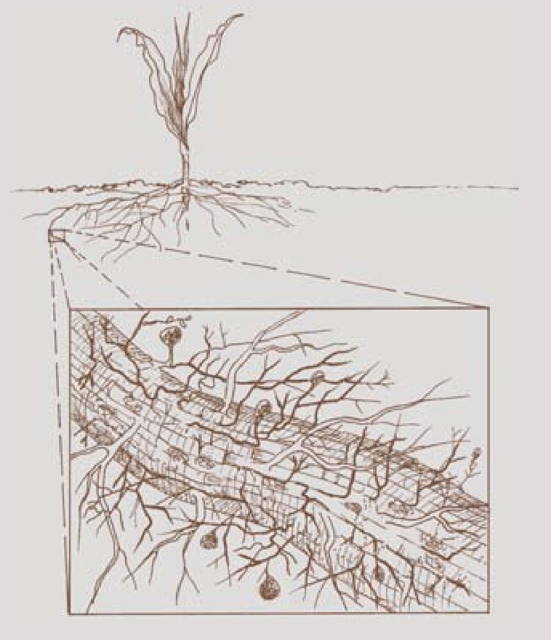
Phosphates move very little within the soil and are unlikely to leach. Phosphorus is lost from soil mainly through soil erosion. Since it doesn't move with soil moisture, it's absorbed only when roots grow to it.

Because low temperatures slow root growth and nutrient absorption, plants are often unable to obtain sufficient phosphorus during cold weather, especially when they are small.

THE NITROGEN CYCLE



In warm, moist conditions, up to half of the nitrogen content of urea left on the soil surface or on crop residues can be lost to the air as ammonia.



VAM, or vascular arbusclar mycorrhizzae, are symbiotic fungi that help crops with nutrient uptake, especially phosphorus.

The total phosphorus in the top 15 centimetres (6 in.) of soil is equivalent to 3000–5000 kilograms per hectare (2700–4500 lb/ac) of P_2O_5. However, less than 1% of the total P is available to crops.

Potassium (K)

Potassium moves in the soil more than phosphorus, but much less than nitrogen. The potassium ion is highly soluble in water and can leach in very sandy (or low CEC) soils.

The minerals that make up clay particles tend to be high in potassium. Many clay and clay loam soils contain an abundance of potassium. Sandy soils commonly are low in potassium.

Calcium and Magnesium (Ca and Mg)

Most of the soils in southern Ontario developed from parent materials that contain a lot of limestone that was ground up and deposited by glaciers during the last Ice Age. In areas west of the Niagara Escarpment and in parts of the Ottawa Valley, dolomitic limestone was predominant and the soils contain significant amounts of calcium and magnesium.

Soils in the clay belts of northern Ontario tend to contain abundant calcium and magnesium.

Soils formed from calcitic limestone tend to be low in magnesium.

Sulphur (S)

The chemistry and fate of sulphur is similar to nitrogen in soil. Sulphur is absorbed by plants as sulphate (SO_4^{2-}) and is prone to leaching. Originally, the soils in Ontario were low in sulphur and required fertilization with it. This is still the case in northwestern Ontario.

Northwestern Ontario aside, sufficient sulphur falls in acid rain and snow to eliminate any need of sulphur fertilization for most crops in the province.

These tomatoes show signs of blossom-end rot (BER). This occurs when there is not enough water in the soil for calcium to move to the developing fruit. This calcium deficiency symptom can be avoided with scheduled irrigations.

Levels of calcium and magnesium tend to be low in sandy soils and in acidic soils. See "Soil and Acidity and Liming" on page 35 for more information.

MACRONUTRIENTS IN SOIL AND PLANTS

NUTRIENT (FORM TAKEN UP BY PLANTS)	HELD IN SOIL BY…	DEFICIENCY SYMPTOMS	SOIL CONDITIONS MOST OFTEN DEFICIENT	EFFECTS OF EXCESS AMOUNT
NITROGEN • nitrate (NO_3^-) • ammonium (NH_4^+)	• organic matter • cation exchange sites (mineral and organic), held as ammonium	• reduced growth, yield, or quality • general yellowing of leaves • grass leaves yellow from tip to base, along midrib • seen in most non-legume crops	• underfertilized soils • waterlogged soils	• excessive vegetative growth • increased lodging • delayed maturity • increased risk of disease
PHOSPHORUS • phosphate ions ($H_2PO_4^-$) (HPO_4^{2-})	• organic matter • soil minerals	• reduced growth, yield, or quality • purple leaves in corn and cereals • seen in most crops	• underfertilized soils • marl soils • low pH soils	• reduced uptake of zinc
POTASSIUM • potassium ion (K^+)	• organic matter • cation exchange sites (mineral and organic)	• reduced growth, yield,or quality • yellow leaves, beginning at edges • increased risk of lodging • increased risk of some diseases • reduced winter-survival in forages • seen in alfalfa, tomatoes, rutabagas	• sands and loams	• reduced uptake of magnesium

MACRONUTRIENTS IN SOIL AND PLANTS (CONTINUED)

NUTRIENT (FORM TAKEN UP BY PLANTS)	HELD IN SOIL BY...	DEFICIENCY SYMPTOMS	SOIL CONDITIONS MOST OFTEN DEFICIENT	EFFECTS OF EXCESS AMOUNT
CALCIUM • calcium ion (Ca^{2+})	• organic matter • cation exchange sites (mineral and organic) • soil carbonates (lime)	• buds do not develop properly • young leaves twisted and yellow • blackhearts in celery • cavity spot in carrots • bitter pit in apples and pears • also seen in grapes, potatoes, tomatoes, cole crops, tobacco	• acidic sandy soils • unirrigated soils	• n.a.
MAGNESIUM • magnesium ion (Mg^{2+})	• organic matter • cation exchange sites (mineral and organic) • soil carbonates (lime)	• yellowing between veins of lower leaves seen in corn, tomatoes, apples, grapes, potatoes, carrots, celery, spinach	• acidic soils • sandy soils • following high rates of potash	• n.a.
SULPHUR • sulphate ion (SO_4^{2-})	• organic matter	• reduced growth, yield, or quality • general yellowing of leaves • seen in forages, cereals, canola	• northwestern Ontario	• n.a.

Secondary and Macronutrient Deficiency Symptoms

In corn, a lack of phosphorus can cause purpling of the leaves.

Most crops yellow and grow poorly if nitrogen is lacking.

Nitrogen deficiency in peaches.

Potassium deficiency on alfalfa leaves.

A lack of potassium causes tomatoes to ripen unevenly.

A lack of calcium can cause blossom-end rot in tomatoes and peppers.

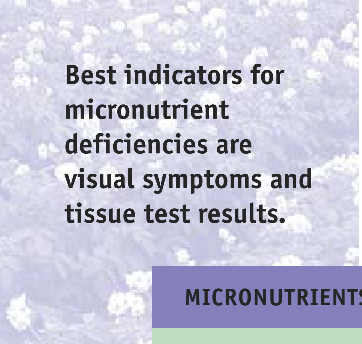
Magnesium deficiency in celery causes yellowing of older leaves.

In corn, magnesium deficiency causes striping of the youngest leaves.

Magnesium deficiency in apples.

For more information about nutrient deficiency and toxicity, please see page 34.

THE MICRONUTRIENTS



Best indicators for micronutrient deficiencies are visual symptoms and tissue test results.

Plant micronutrients, their nutrient cycles, and their roles within plants have not been studied as much as macronutrients. In general, micronutrients are required for the proper functioning of various enzymes and other substances that regulate photosynthesis, respiration, plant growth, and reproduction.

MICRONUTRIENTS IN SOIL AND PLANTS

NUTRIENT	FERTILIZER SOURCES	DEFICIENCY SYMPTOM	SOIL CONDITIONS MOST OFTEN DEFICIENT	EFFECT OF EXCESS AMOUNT
ZINC	• zinc sulphate	• white stripes or patches near base of young leaves • seen in corn	• eroded, high pH soils, high in phosphorus	• excess may interfere with uptake of other micronutrients, causing deficiency
MANGANESE	• manganese sulphate, chelates	• yellowing between veins on young leaves • veins stay dark green • seen in soybean, cereals, beets, tomatoes, muck crops	• soils that were previously poorly drained: muck, marl, eroded, sandy, high pH soils	• on acid soils, excess manganese may reduce root growth • some apple varieties show “measles” on the bark
BORON	• borate	• new growth is stunted and discoloured • flower bulbs may abort • hollow stems cores • seen in alfalfa, cole crops, apples, celery, beets, spinach	• sandy soils • most soils (east of Niagara Escarpment) • dry soil conditions	• necrosis of leaf margins • new growth pale or whitish
COPPER	• copper sulphate	• limp or discoloured leaves • twisted leaf tips • thin pale scales on onions • poor colour in carrots • also seen in winter wheat	• muck soils • coarse sandy soils	• foliar sprays that are too concentrated will damage leaf tissue
MOLYBDENUM	• sodium molybdate	• leaves become yellow between veins • leaves twist and become whiplike • edges of leaves appear scorched • seen in cauliflower, broccoli, onions	• muck soils • acidic sandy soils	• excess molybdenum may cause symptoms that appear like iron deficiency
IRON	• Fe – chelated	• leaves become yellow between the veins • seen in blueberries	• rarely seen in Ontario	

*In addition to these nutrients that are essential for plants, animals require cobalt, sodium, iodine, and selenium.

Micronutrient Deficiency Symptoms

In alfalfa, boron deficiency causes reddening and stunting of new growth.

In corn, zinc deficiency causes striping of the youngest leaves.

Leaf tips of copper-deficient plants become twisted and die.

These soybeans are deficient in manganese.

Boron deficiency causes hollow stems in cole crops such as broccoli.

Boron deficiency in celery causes "cat scratches" on the stalks.

A deficiency of any given nutrient can limit crop growth and quality. These are soybeans with a potassium deficiency.

NUTRIENT DEFICIENCY AND TOXICITY

DEFICIENCY

Crops fulfill most of their nutrient requirements from soils. However, soils do not always supply the quantity or balance of nutrients when needed to meet production and quality goals. Nutrient deficiency in a crop is an indicator that the soil nutrient supply is inadequate for any number of reasons, such as:

- some soil types are prone to deficiencies of certain nutrients, because of the way in which the soils were formed
- some crops have a higher requirement for specific nutrients than other crops
- some soils may be depleted in nutrients due to previous cropping practices.

TOXICITY

If available at excessive levels, some nutrients are potentially toxic to plants. For example, the margin between boron deficiency and toxicity is quite narrow, and varies among crops. Cole crops and alfalfa have relatively high requirements for boron. In the year following application, however, boron applied for cole crops may cause damage to sensitive crops such as soybeans, field beans, and cereal grains. Nutrient toxicities may also occur due to pH changes in the soil, which make certain nutrients more available.

Chlorine

Chlorine is present in soil mainly in the form of the chloride ion (Cl-). Chloride is very soluble; much of the chloride in soil remains in the soil solution and is very prone to leaching. Although some compounds containing chlorine are toxic (e.g., chlorine gas and bleach), the chloride ion is not. Fertilizer materials containing chloride can be applied to the soil without damaging results.

However, the chloride ion does contribute to the "salt effect" of fertilizers, and chloride levels in the soil may affect the quality of some specialty crops such as tobacco.

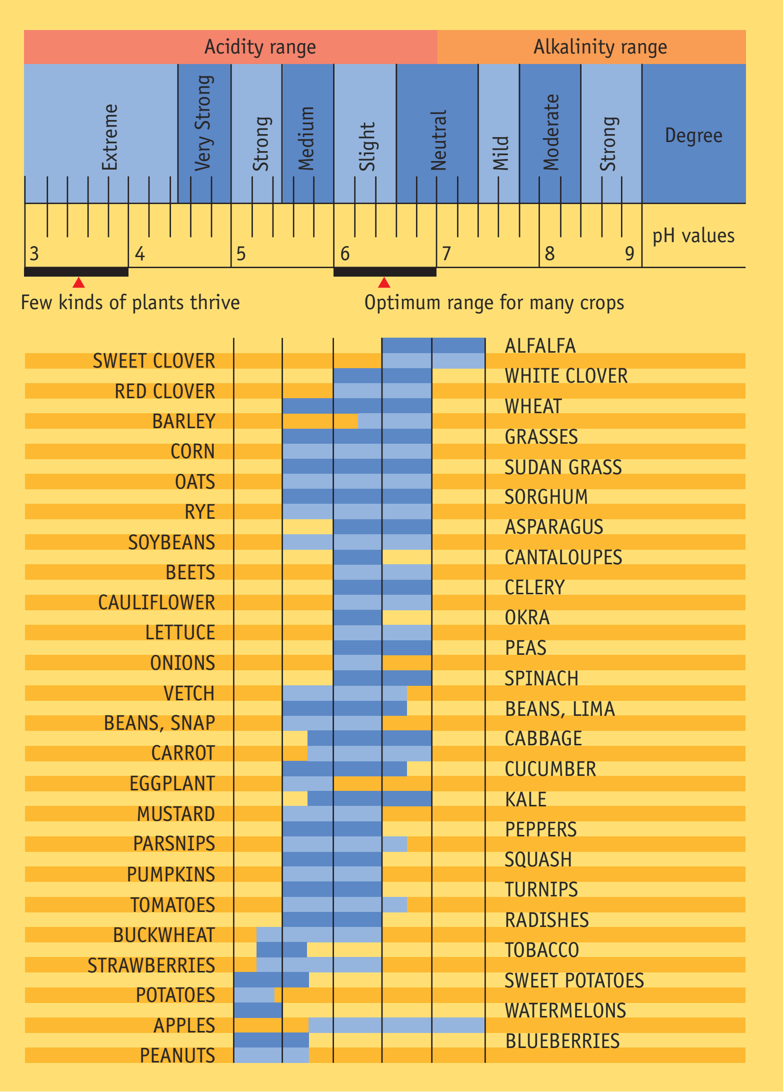
In acidic soils, some nutrients become toxic to some crops such as corn.

SOIL ACIDITY AND LIMING

Your soil's pH – whether it's acidic or alkaline – affects nutrient availability and crop performance.

Soils in Ontario range from slightly alkaline (pH between 7.1 and 8.0) to very acid (pH under 4.0), depending on the type of soil and the way it has been managed. Note: only 10% of the agricultural soils in Ontario have a pH of 6.0 or lower.

PREFERRED pH RANGES FOR CROPS



Why do soils become acidic?

- the acidity of soils increases as a result of uptake of nutrients by plants
- leaching removes nutrients, such as calcium and magnesium, that slow the rate at which soils become acidic
- acids are released when soil organic matter decomposes
- precipitation is normally acidic – in southern, eastern and central Ontario, the effect on soils is more pronounced due to the greater acidity of the rain and snow

Ammonium fertilizers will lower pH.

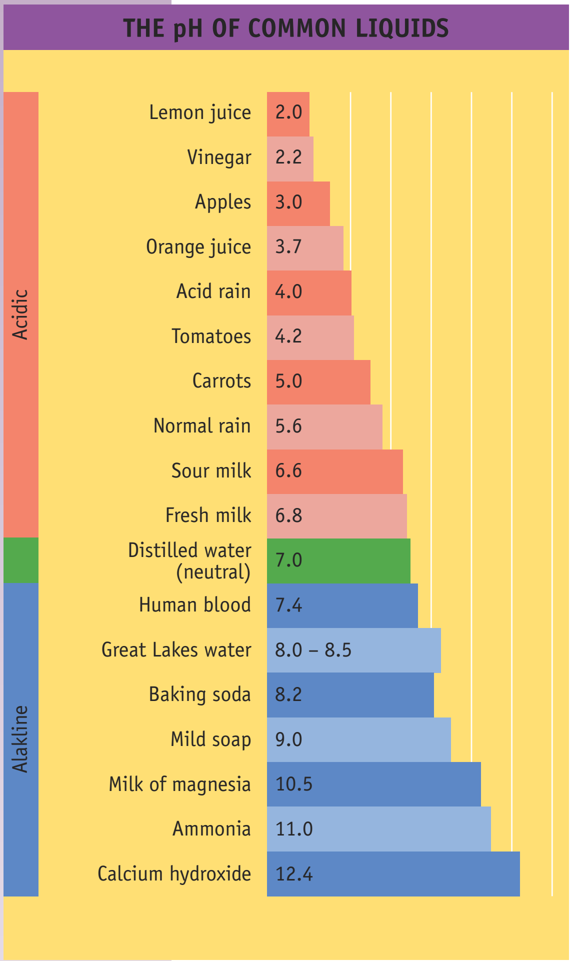
Many soils formed from limestone till contain lime and are naturally slightly alkaline. Because of the presence of lime in these soils, their pH changes very slowly. Soils formed from other types of rock contain little lime and their pH may change relatively quickly. This is especially true for sandy soils.

Soils naturally tend to become more acidic as a result of weathering and fertilizer inputs over time. The application of materials containing ammonium-nitrogen to soil can increase the rate at which susceptible soils become acidic.

✔ **Regularly soil-test fields to monitor changes in soil pH.** See page 56 for details.

The pH of soil does not normally increase. However, the pH of subsoil is often higher than that of topsoil. When topsoil is eroded away or if tillage is too deep, subsoil can be mixed with topsoil and the pH of the plow layer may increase.

When the pH decreases below 5 in mineral soils, growth decreases due to micronutrient toxicity, e.g., aluminum or manganese for apples.


THE pH OF COMMON LIQUIDS


Sandy soils tend to become acidic more quickly than do heavier soils.

EFFECTS OF SOIL pH

As soil is made **more alkaline** (higher pH), the availability of zinc, manganese, boron, copper, and iron is reduced.

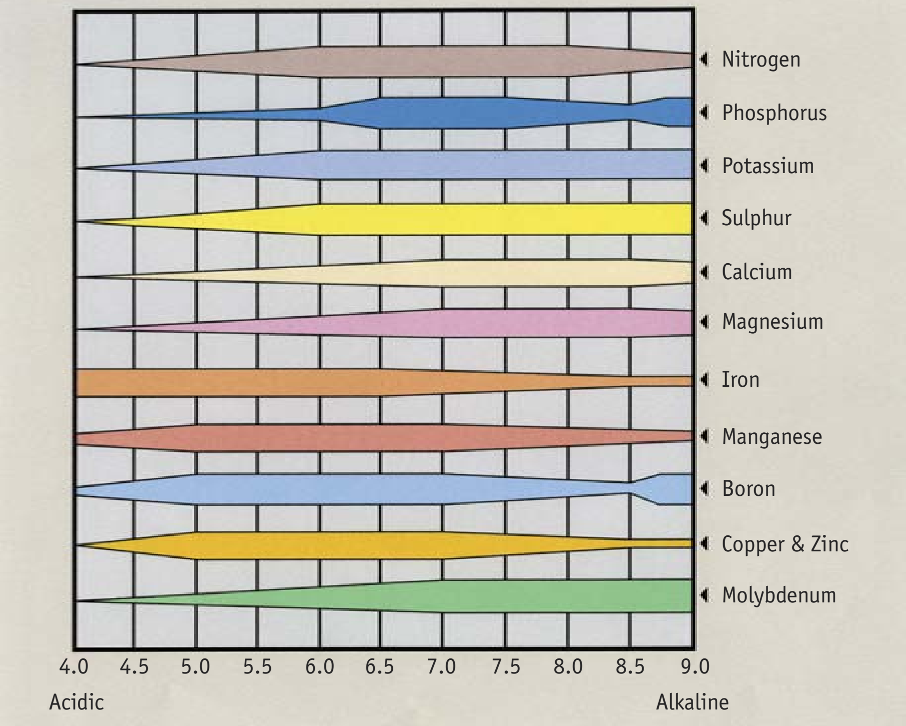
As soil becomes **more acidic** (lower pH):

- phosphorus, potassium, calcium, magnesium, and molybdenum are less available
- iron, aluminum, and manganese are more available, often to toxic levels
- cation exchange capacity of soil organic matter is reduced
- the activity of many soil micro-organisms, including those that fix nitrogen, is reduced.

Most crops do best when the soil pH is over 6.1. Blueberries and cranberries must be grown under more acidic conditions to prevent deficiencies of iron or manganese. Potatoes and tobacco are usually grown in slightly acid soils to reduce disease problems. Most other crops will grow well over a wide pH range, but none needs soil that is alkaline.

Acidic spots often occur unevenly in fields. Sample such areas separately.

EFFECTS OF SOIL pH ON AVAILABILITY OF PLANT NUTRIENTS



CORRECTING SOIL ACIDITY

Raising Soil pH

In Ontario, crushed limestone is the material used most commonly to raise soil pH.

Lime is being added to raise soil pH.

Agricultural limestone is usually a byproduct of aggregate extraction.

Limestone must be finely crushed to be effective. The rocks from which crushed limestone is made differ in their capacity to correct acidity. An index has been developed to combine the effects of these two factors.

Lime recommendations from the Ontario soil test are based on lime with an index of 75. For lime with a different index, rates need to be adjusted. (See Ontario Ministry of Agriculture, Food and Rural Affairs Publication 811, *Agronomy Guide*, for details.)

Recommendations for lime from the Ontario soil test consider the requirements of only the crop indicated on the soil test information sheet. However, you should consider the pH requirements of all crops included in the rotation. Acid soil may be required for certain high-value crops, such as potatoes. Otherwise, application rates for lime should be based on the crop with the higher requirement.

Dolomitic limestone from quarries on the Niagara Escarpment or in the Ottawa Valley contains both calcium and magnesium. Calcitic limestone (from most other quarries in the province) contains little magnesium.

If your soils are low in magnesium, use dolomitic limestone to correct both the acidity and the low magnesium level. On soils with sufficient magnesium, use either calcitic or dolomitic limestone.

The effect of lime moves downward in the soil relatively slowly – about 2 centimetres (1 in.) per year. To correct acidity problems in the entire plow layer, lime must be mixed into the soil. Most uniform mixing will occur where the lime is spread and the field cultivated prior to plowing.

Blueberries need more acidic conditions to prevent deficiencies in iron and manganese.

Lowering Soil pH

Elemental sulphur can be applied to lower the pH of some soils for crops that require acidic conditions. However, if the initial pH of the soil is over 7.0, it's almost impossible to lower the pH, due to the high lime content of the soil.