

How Does Your Garden Grow?

Some Information on Soil Fertility



Have you ever planted a seed or seeds in soil and watched in amazement as tiny chutes begin to emerge from the soil and then eventually grow into a healthy, stable plant? Did you know that besides needing water (which is very important!) the type of soil that plants grow in and what actually goes on in soil determines how well plants grow? Five factors determine what types of soil form on Earth and critters that live in the soil are part of the amazing soil forming process:

Parent Material- the primary material from which the soil is formed. Soil parent material could be bedrock, organic material, an old soil surface, or a deposit from water, wind, glaciers, volcanoes, or material moving down a slope. Bedrock is broken down as water, wind, or other weathering processes wear away mineral particles from rocks.

Organisms- Soil is also formed as organic matter (such as leaves and dead plants) decomposes and as critters living in the soil change the chemistry of soil. Each of these parts work together to make soil that plants can grow well in. Fertile soils are those that have enough Nitrogen (N), Phosphorus (P), and Potassium (K), along with other nutrients that plants take up.

Topography- The location of a soil on a landscape can affect how the climatic processes impact it. Soils at the bottom of a hill will get more water than soils on the slopes, and soils on the slopes that directly face the sun will be drier than soils on slopes that do not. Also, mineral accumulations, plant nutrients, type of vegetation, vegetation growth, erosion, and water drainage are dependent on topographic relief.

Climate-heat, rain, ice, snow, wind, sunshine and other environmental forces break down the parent material and affect how fast or slow soil formation processes go.

Time- All of the above factors assert themselves over time, often hundreds or thousands of years.

Soil and plants play a very important part in the survival of humans and animals. Soil protects plant roots from exposure to the Sun's heat at Earth's surface, soil filters pollution that comes from rain and water runoff from farms. Soil is used to build with and on, and soil is what plants need to grow and be supported while growing. Plants are not only used for food but are also used to make fabrics and dyes, medicines and beauty products, fragrances, rubber and building materials, just to name a few.

The most important function of plants involves photosynthesis. Photosynthesis is a process in which all plants and algae as well as certain types of photosynthetic bacteria produce their own food, and in doing so take in carbon dioxide (CO₂) and then release oxygen (O₂) into Earth's atmosphere, which many living species on Earth need to survive.

You will learn here about three important minerals:

**Nitrogen
Phosphorus
Potassium**

Plants must have these nutrients in order to grow healthy and strong.

WHY PLANTS LIKE NITROGEN (N):

Nitrogen (N) helps plants use carbohydrates to gain energy, like certain foods we eat help us to gain energy. Nitrogen controls how plants take their form and how they function inside, and nitrogen helps plants make protein that help them grow strong and healthy. Humans and animals benefit from eating vegetables and plants that are rich in nitrogen because proteins are passed on to humans and animals when they eat vegetables and plants.

THE NITROGEN CYCLE AND HOW NITROGEN MOVES THROUGH THE SOIL:

The nitrogen cycle involves certain processes that change nitrogen into different forms. Organic nitrogen in materials, like dead leaves and plants, are changed into inorganic nitrogen by microorganisms (critters) in the soil. Plants take up

these available forms of inorganic nitrogen (NO₃ and NH₄⁺) so they can grow. Unfortunately, these forms of nitrogen are not always used by plants because they either get onto clay particles in soil, they leach into the groundwater because they cannot be absorbed by the soil, or they change into nitrogen gases that escape into **Earth's atmosphere. Luckily there are specific kinds of**

microorganisms living in the soil that can convert gaseous forms of nitrogen into inorganic nitrogen that plants can use.

When plants die the dead plant matter falls to the ground and certain microbes, yet again, do their job of decomposing dead plant matter (which contains organic N) and changing it into inorganic N that living plants can use! This cycle is continuous. Processes in the nitrogen cycle are: Adsorption/Fixation, Denitrification, Erosion, Immobilization, Leaching, Mineralization, Nitrification, and Volatilization.

HOW PLANTS TAKE UP NITROGEN

Plants take up nitrogen in forms of nitrate (NO_3^-) and ammonium (NH_4^+). Most plants thrive on equal amounts of these ions but nitrates are more quickly available to plants because they move through the soil solution, whereas ammonium ions become fixed or held on to clay particles, called colloids, because of their positive charge.

WHAT HAPPENS WHEN PLANTS DON'T GET ENOUGH NITROGEN:

Plants deficient in nitrogen have thin, spindly stems and their growth is stunted. Their older leaves turn yellowish-green from nitrogen starvation (chlorosis), while newer leaves are supplied with the available, but limited nitrogen.

WHAT HAPPENS WHEN PLANTS GET TOO MUCH NITROGEN:

Plants that get too much nitrogen have a lot of foliage (leaf) growth but are not strong. Plants that are not strong can get diseases more easily, can be bothered more by bugs, and can eventually fall over and die. An excess amount of nitrogen in plants can affect the amount of sugar and vitamins in fruits and vegetables, making them taste different. More importantly excess nitrogen can build up in plant tissues causing toxicity (poisoning) in livestock and in small children who eat nitrogen rich, leafy vegetables.

WHY PLANTS LIKE PHOSPHORUS (P):

Phosphorus (P) plays an important part in how plants and animals form and in how they function and grow. Phosphorus is known to help plants during photosynthesis, P helps plants respire (breathe), P provides energy transfer and storage, and P also helps plants efficiently use water. Seedlings and roots grow more quickly and vegetable and fruit production is increased when plants get enough phosphorus. Soil phosphorus comes mainly from the weathering of rocks that contain the inorganic mineral Apatite

Because minerals containing P are mostly insoluble and because P is fixed, or held, on to soil particles that erode away during rain storms, plants cannot get enough P. Over the past 100 years, farmers and gardeners have heavily added phosphorus fertilizers to their fields to help plants get more of this nutrient. The main reason phosphorus pollution occurs in the environment is because too much P fertilizer is added to soil, then during rain storms it travels on soil particles, across the land, and into surface waters.

Unfortunately, excess P in the environment has caused and continues to cause pollution in streams, rivers, lakes, and groundwater which is used for drinking water. Aquatic life and wildlife living in and around these waterways also are affected.

HOW PHOSPHORUS MOVES THROUGH THE SOIL AND HOW PLANTS TAKE UP PHOSPHORUS:

Inorganic and organic forms of P are found in soils, with most organic P being located at the soil surface. The same processes for nitrogen also occur for P: organic forms of phosphorus are changed into inorganic forms of P by microbial activity in the soil (mineralization) or when inorganic forms of P are changed into organic forms of P that plants cannot use (immobilization).

Soil pH affects phosphorus availability to plants. In alkaline soils, in arid climates, calcium phosphate (CaPO_4) is dominant. If soil pH gets too high a chemical reaction takes place that fixes the phosphorus and makes it insoluble and unusable by plants. In acid soils aluminum phosphate (AlPO_4), iron phosphate (FePO_4) and sometimes manganese phosphate (MnPO_4) are dominant. If soil pH gets too low a chemical reaction takes place that fixes phosphorus to Al, Fe, or Mn and phosphorus becomes insoluble and unusable by plants.

Other factors that prevent plants from taking up phosphorus include lack of oxygen, low soil moisture, low organic matter, extreme temperatures within soil, soil type, and plant type. Plants living in highly weathered soils use organic forms of phosphorus; plants living in soils that contain organic matter and are less weathered use inorganic forms of phosphorus.

When soil contains enough organic matter (dead leaves and plants) at Earth's surface P cannot become fixed as easily to clay surfaces. Adding organic matter to soil gives plants more time to take up P before P become fixed.

Of all phosphorus in existence on Earth, only 0.01% becomes available for plant use!

WHAT HAPPENS WHEN PLANTS DON'T GET ENOUGH PHOSPHORUS:

Plants that don't get enough P have spindly, thin-stems that are weak. Their growth is stunted or shortened, and their older leaves turn a dark bluish-green. The ability of phosphorus deficient plants to produce seeds, flowers, and fruits is diminished. Farmers and gardeners add P fertilizer to soil so their plants won't become unhealthy.

WHAT HAPPENS WHEN PLANTS GET TOO MUCH PHOSPHORUS:

Phosphorus is hard for plants to obtain, let alone get too much of because:

- 1.) inorganic P is scarce in the environment
- 2.) P can quickly become fixed on to soil
- 3.) P gets eroded in rain water runoff to streams, rivers, and lakes.

WHY PLANTS LIKE POTASSIUM (K):

Potassium (K) is very important in the plant photosynthesis process and in helping plants metabolize their food to get energy, like humans and animals do when they eat. Potassium controls water and chemicals inside plants that help plants function well. Potassium also controls the absorption of water into plant pores, like the pores on your skin.

HOW POTASSIUM MOVES THROUGH SOIL AND HOW PLANTS TAKE UP POTASSIUM:

K is found in high levels in most soils, except in those soils containing sand, but the availability of K to plants is low because a large percentage of K is held in mostly unavailable forms to plants. K can be held inside a clay particle as part of the clay's structure, or it can be held outside on the edges or surface of a clay structure because it has a positive charge.

Of all soil K, 90-98% is held in primary mineral structures that are very resistant to most weathering processes, and therefore not easily available to plants. This form of K is known as inorganic structural K. Roots of some plants do have the ability to take up K from solution around these primary minerals, making these minerals dissolve more easily.

Secondary minerals, such as vermiculite and smectite clays, adsorb or fix K on to their edges and in between their crystal layers, making K only slowly available to plants. This form of K is called nonexchangeable K.

More readily available K for plants is found on the surface of clay particles (colloids) where they can exchange places with other similar sized and positive charged ions in the soil solution. These forms of K are called exchangeable K and solution K. K in soil solution is the easiest form of K for plants to take up. The soil solution is, however, subject to loss by leaching.

As plants take up solution K, exchangeable K takes the place of solution K, while another K ion (from nonexchangeable and structural K sources) moves into the position the exchangeable K was once using. In other words, these different forms of K move around (like people do in the game "musical chairs") to replace K used up by plants or to replace K that is lost in the environment.

Plants are known to take up five to ten times more K, as compared to N and P, however; plants cannot take up potassium (and other nutrients) when soil moisture and temperatures are low, when root growth is small, and when enough oxygen is not available. Like phosphorus, potassium is only available to plants in small amounts and is hard for plants to get. Like certain forms of nitrogen and phosphorus, potassium also becomes fixed onto clay particles in soil, making it even harder for plants to obtain..

WHAT HAPPENS WHEN PLANTS DON'T GET ENOUGH POTASSIUM:

Plants lacking in K do not have enough energy to properly grow, their roots are not well formed, and they have weak stems and stalks. The edges of older plant leaves appear "burned", as K deficient plants cannot regulate and use water efficiently. K deficient plants are more easily affected by pests, bugs, and diseases. Also, they cannot survive through winters or droughts (periods of time when water is not available to plants). So, you see, plants that do not get enough of these very important nutrients, (don't forget them- they are N, P, and K!) cannot grow well and eventually can die. But we also must use our knowledge about soils to ensure that nutrients are added to soil in the right amounts and that soil is managed in ways to prevent nutrients from leaving the soil and polluting our groundwater (drinking water), streams, lakes, and rivers.

Information derived from: "The Nature and Properties of Soil" by Nyle C. Brady and Ray R. Weil, Prentice Hall, Inc., 1996, Upper Saddle River, NJ 07458; ISBN: 0-02-313371-6, 11th Edition.

