MACRO AND MICRO NUTRIENTS OF SOIL

Introduction:

Fertile soil is essential to obtain the best growth and productivity from vegetables and flowers. Plants need different amounts of seventeen essential elements to grow. Soils are rarely fertile enough to supply adequate quantities of all the elements needed for best plant growth. Most soils do not contain enough Nitrogen for optimum plant growth. Vegetables and other shallow rooted plants also usually grow better with additional Phosphorus and sometimes Potassium. These three elements, and any other elements that a soil may lack, can be supplied with an appropriate fertilizer and compost. Fertilizers may be either organic or inorganic often called chemical materials. Compost and similar organic amendments are a source of plant nutrients, but usually do not provide enough Nitrogen for optimum plant growth. Plants require seventeen essential elements for growth. If any one of these elements is missing, a plant will not grow, even if all the other elements are present in their required amounts. The elements which plants require in relatively large amounts are called macronutrients. The primary macronutrients are Nitrogen (N), Phosphorus (P), and Potassium (K). The secondary macronutrients are Calcium (Ca), Magnesium (Mg), and Sulphur (S). Essential elements which plants need in relatively small amounts are called Micronutrients. The Micronutrients are Boron, Chlorine, Copper, Iron, Manganese, Molybdenum, Zinc, and Nickel. Composting organic matter such as grass clippings and tree leaves is an excellent way to provide micronutrients.

Hence, in this episode the following aspects are going to be seen:

- Macronutrients of Soil
- Micronutrients of Soil
- Micronutrient Deficiency Symptoms.
- Nutrient Root Contact
- Soil Sampling and Testing

1. MACRONUTRIENTS OF SOIL.

Essential elements used by plants in relatively large amounts for plant growth are called macronutrients. The major macronutrients are nitrogen (N), phosphorous (P), and potassium (K). Calcium (Ca), magnesium (Mg), and sulphur (S) are also macronutrients. All six nutrients are important constituents in soil that promote plant growth. Concentrations of these macronutrients in the soil are generally determined before the site is disturbed in order to complete a site reclamation plan.

Nitrogen: Nitrogen is important for growth because it is a major part of all amino acids, which are the building blocks of all proteins, including enzymes, which control virtually all biological processes. A good supply of nitrogen stimulates root growth and development, as well as the uptake of other nutrients. Plants deficient in nitrogen tend to have a pale yellowish green colour called as chlorosis, have a stunted appearance, and develop thin, spindly stems.

Much of the nitrogen reserve is stored in the soil as organic matter and most of this organic fraction is found in the upper soil horizons. At surface mines, the upper soil horizons are usually removed and stockpiled prior to disturbance. The storage of top soil allows for relatively rapid conversion of organic nitrogen to soluble nitrate (NO_3^-) and is subject to leaching or conversion to nitrogen gas is known as denitrification which volatilizes out of solution into the atmosphere. Thus, when stored top soil is spread on a disturbed landscape, nitrogen reserves may be depleted or altered by several chemical and biological phenomena and the healthy cycling of nitrogen through the ecosystem inhibited or prevented. Tilling is generally not necessary to incorporate the nitrogen into the soil because of the leaching ability of nitrogen. Although, it is often tilled in since nitrogen fertilizer is often incorporated with other macronutrient fertilizer which do need tillage.

Nitrogen in soils can be in various different forms. In most soils, nitrate is the common ionic form of plant-available nitrogen, but this element may also exist as ammonium (NH_4^+) or nitrite (NO_2^-) as well as other ions. Nitrogen is also incorporated in organic matter and microbes. When organic matter decomposes by microbial processes or when the microbes themselves die and decompose, nitrogen is released in various forms into the soil solution. There are various different methods that are used to measure total nitrogen as well as methods that measure organic nitrogen, NH_4^+, NO_3^-, and NO_2^- separately. The Kjeldahl method is the most commonly used method for measuring total nitrogen.

Phosphorous: Phosphorous enhances many aspects of plant physiology, including the fundamental processes of photosynthesis, nitrogen fixation, flowering, fruiting and maturation. Root growth, particularly development of lateral roots and fibrous rootlets, is encouraged by phosphorous. Phosphorous uptake by plants is about one-tenth that of nitrogen and one-twentieth that of potassium. Its deficiency is generally not as easy to recognize in plants as are deficiencies in many other nutrients. A phosphorous-deficient plant is usually stunted, thin-stemmed, and spindly, but its foliage is often dark, almost bluish green. Thus, unless much larger, healthy plants are present to make a comparison, phosphorous-deficient plants often seem quite normal in appearance. In severe cases, phosphorous deficiency can cause yellowing and senescence of leaves

Potassium: Of all the essential elements, potassium is the third most likely, after nitrogen and phosphorous, to limit plant productivity. For this reason, it is commonly applied to soils as fertilizer and is a component of most mixed fertilizers. Potassium is known to activate 80 different enzymes responsible for such plant and animal processes as energy metabolism, starch synthesis, nitrate reduction, photosynthesis, and sugar degradation. Potassium plays a critical role in reducing the loss of water from leaves and increases the ability of the roots to take up water from the soil. It also helps plants adapt to environmental stresses. Good potassium nutrition is linked to improved drought tolerance, improved winter hardiness, better resistance to certain fungal diseases, and greater tolerance to insect pests. Potassium deficiency is relatively easy to detect compared to deficiencies in phosphorous. The tips and edges of the oldest leave begin to yellow and die, so that the leaves appear to have been burned on the edges.

The original sources of potassium are the primary minerals, such as mica and potassium feldspar. At any one time, most soil potassium is in primary minerals and non exchangeable forms. In relatively fertile soils, the release of potassium from these forms to the exchangeable and soil solution forms that plants can use directly may be sufficiently rapid to keep plants supplied with enough potassium for optimum growth. Conversely, in non fertile soils, the levels of exchangeable and solution potassium may have to be supplemented by outside sources, such as chemical fertilizers, poultry manure. Without these additions, the supply of available potassium will likely be depleted over a period of years and the productivity of the soil will likewise decline.

2. MICRONUTRIENTS OF SOIL

In addition to macronutrients, there are various trace elements that are necessary for plant growth. These trace elements are needed in smaller quantities than macronutrients. If a trace element is required for plant growth it is called a micronutrient. These include aluminium, arsenic, boron, cadmium, chlorine, copper, iron, lead, manganese, sodium, zinc and others.

Iron: Iron is taken up by plants as either ferrous cation or ferric cation. Iron is involved in photosynthesis, respiration, chlorophyll formation, and many enzymatic reactions.

Boron: Boron is taken up by plants primarily as boric acid and borate. Boron plays an important role in the movement and metabolism of sugars in the plant and synthesis of plant hormones and nucleic acids. It also functions in lignin formation of cell walls.

Manganese: The primary form of manganese uptake is manganous ion. Manganese is a component of enzymes and is also involved in photosynthesis and root growth. Additionally, it is involved in nitrogen fixation.

Zinc: The Zinc cation is the predominate form taken up by plants. Zinc is a component of many organic complexes and DNA protein. It is also an important enzyme for protein synthesis. Also, zinc is involved in growth hormone production and seed development.

Molybdenum: Molybdenum is primarily taken up as molybdate ion. It is involved in nitrogen fixation and nitrification.

Copper: Copper is taken up as cupric ion. Copper is also a component of enzymes, some of which are important to lignin formation in cell walls. It is also involved in photosynthesis, respiration, and processes within the plant involving nitrogen.

3. MICRONUTRIENT DEFICIENCY SYMPTOMS

Some micronutrients have characteristic deficiency symptoms. However, symptoms can be easily confused with other nutrient deficiencies, salinity, disease, drought, herbicide injury or other physiological problems. Visual symptoms alone are not a reliable method of determining a micronutrient, problem, but they are useful indicators when used with other diagnostic tools.

Boron: This deficiency results in stunted growth of young plants. The youngest leaves are affected first. They will be misshapen, thick, brittle and small. Because boron is not easily transferred from old to young leaves, older leaves usually remain green and appear healthy. Often dark brown, irregular lesions appear, followed by pale yellow chlorosis of young leaves. Stems are short and growing points may die. In canola, the symptoms of a boron deficiency can be confused with a sulphur deficiency. In alfalfa, boron deficiency symptoms include death of the terminal bud, rosetting, yellow top and poor flowering.

When a boron deficiency is moderate, seed yield is often reduced without any evidence of severe deficiency symptoms during vegetative growth.

Chlorine: Chlorine deficiencies are very rare; therefore, symptoms are seldom observed. Symptoms may include stubby roots, some chlorosis of new leaves and plant wilting.

Copper: Copper is not readily transferred from old to young leaves, so older leaves remain darker and relatively healthy and the deficiency symptoms develop on younger leaves. The visual symptoms of a copper deficiency in wheat include yellowing of younger leaves, limpness, wilting, pig tailing or whip tailing or curling of the upper leaves and kinking of the leaf tips. Other signs include excessive tillering, aborted heads, delayed maturity and poor grain filling resulting in a high straw to grain ratio. On copper deficient soils these symptoms tend to occur in irregular patches. Copper deficiency is often associated with the disease stem or head melanosis and an increased incidence of ergot. For barley, the symptoms of a copper deficiency include yellowing, pig tailing, awn kinking, excessive tillering and weak straw. Oats will also show pig tailing. Copper deficiency symptoms have not been well documented for canola or alfalfa.

Iron: Chlorosis of the younger leaves characterizes an iron deficiency. The tissue between the veins gradually turns yellow, while the veins tend to stay green. The tips and margins of some leaves may turn brown and become dry and brittle.

Manganese: In legumes, deficiency symptoms include pale green young leaves and a pale yellow mottling develops in interveinal areas, while the veins remain green. Oats are an excellent indicator crop. Manganese is partly mobile in oats. White to grey flecks or specks first appear and become more severe on mature leaves about halfway up the shoot. If a deficiency persists, symptoms spread to old leaves then to the youngest leaves. The specked condition is referred to as "grey speck" and will appear in the inter-veinal area of the lower half of older leaves and extend toward the tip as symptoms develop.

Molybdenum: Molybdenum deficiency symptoms are similar to those of nitrogen. Since molybdenum deficiencies are very uncommon symptoms are rarely seen.

Zinc: Zinc is partly mobile in wheat and barley. In these crops pale yellow chlorotic areas appear on middle leaves, halfway up the stem. Chlorotic symptoms first develop in the lower half or mid-section of the leaf followed by grey or dark brown necrosis of the leaf. Generally, stems are very short and often fan-shaped with leaves crowded together at the top.

Zinc deficient beans are stunted and older leaves are smaller and narrower. The older leaves may have light blotches between the veins. Younger leaves will have a more normal healthy green colour but may be smaller.

4. NUTRIENT ROOT CONTACT

Nutrients must reach the root surface before uptake by the plant. The three methods by which nutrients reach the root surface are root interception, mass flow, and diffusion. The relative importance of these methods can provide guidance for the most efficient method of application of each micronutrient. Whether one method predominates depends on many factors that include concentration of the nutrient, physical and chemical characteristics of the soil, root system of the plant, water regime in the soil, and transpiration of the plant. A dominant method for a nutrient to reach a root surface is most important when it is deficient because this can guide placement.

Root interception is the growth of the root into contact with ions that are held on the exchange complex of clays and organic matter. Copper and iron are usually held on the exchange complex. This also applies to some extent for zinc. Root interception is important for these essential nutrients.

Mass flow is the movement of soil water and nutrients in solution to the root. Water movement through soils, carrying those ions freely mobile in solution, primarily occurs as a result of a suction gradient, resulting from increased suction at the root surface due to transpiration by the plant. Mass flow is important in getting water-soluble nutrients to plant roots for uptake.

Diffusion is the movement of ions from a higher concentration to one of lower concentration. Diffusive movement of ions does not necessarily involve water movement. Whether nutrients arrive at the root surface by root interception or mass flow and are taken up by the plant, the concentration of those nutrients is lowered and diffusion can occur. Uptake of manganese, zinc and to some extent iron and molybdenum if limiting has been shown to be related to movement by diffusion in the soil.

5. SOIL SAMPLING AND TESTING

Soil tests aid in determining whether a particular nutrient is responsible for poor production and provides the basis for deciding the type and amount of fertilizer needed to correct a nutrient shortage. A soil sample used for laboratory analysis must consist of a composite of a number of samples taken from the field.

The DTPA (diethylenetriamine pentaacetic acid) method is used to extract the metal micronutrients. Hot water is used to extract boron. Either water or sodium nitrate is used to extract chlorine. Analytical results are usually given in parts per million (ppm). No soil test has proven particularly useful in predicting the availability of molybdenum. The micronutrients that are normally tested for boron, copper, iron, manganese and zinc.

Surface soil samples should be taken from both the affected area and an adjacent area of good crop growth for comparison. When a soil sample tests low in a micronutrient, a potential micronutrient deficiency may occur. Some soils with low micro nutrient levels at the surface do not respond to fertilization because they have higher levels of the nutrient in the subsoil.

Conclusion: Knowing the nutrients required to grow plants is only one aspect of successful crop production. Optimum yield also requires knowing the rate to apply, the method and time of application, the source of nutrients to use, and how the elements are influenced by soil and climatic conditions.