Mineral Nutrition and its Impact on Yield and Quality

FACT SHEET

Mineral nutrition of crops involves the availability and uptake of all nutrients essential to plant growth. The 16 basic chemical elements that are known to be essential to support photosynthesis and plant growth are as follows. Three non-mineral elements carbon, hydrogen, and oxygen which are found in the atmosphere and water and the other thirteen mineral elements which come from the soil are divided into three groups: Major (or primary), secondary and micronutrients.

Major Nutrients
Nitrogen (N)
Phosphorus (P)
Potassium (K)
Secondary Nutrients
Calcium (Ca)
Magnesium (Mg)
Sulphur (S)

Micronutrients
Boron (B)
Chloride (Cl)
Copper (Cu)
Iron (Fe)
Manganese (Mn)
Molybdenum (Mo)
Zinc (Zn)

They are brought together in photosynthesis to provide the structure and catalysts for the conversion of light energy into the chemical energy of Carbohydrates.

$6CO_2$ + 12 H_2O Light Energy $6(CH_2O)$ + $6O_2$ + $6H_2O$

Carbon Dioxide — Water — Mineral Elements — Carbohydrates — Oxygen — Water

In modern production systems too often we do not take into account that each and every element is important to the overall yield and quality of the crop. Mulders chart is a simple example of the complexity of the interaction between these elements and an overall understanding of the relationship of the elements.

In order to breakdown these nutrients into components of crop growth without over simplifying it would be: Chlorophyll production, Yield nutrients, and Quality and Finish.

The elements primarily responsible for chlorophyll production are Carbon, Nitrogen, and Magnesium, which give the structure to chlorophyll. Iron, manganese, copper and zinc assist the chlorophyll in using light energy efficiently to produce carbohydrates, and to ensure that the correct environment is maintained for chlorophyll to remain fully operational in leaf cells under different light conditions.

Iron and Manganese assist the chlorophyll in photosynthesis by channeling or focusing the light energy to give maximum carbohydrate production.

Copper and Zinc actually “buffer” the chlorophyll so that it can operate efficiently at different levels of light intensity.

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Yield nutrients are Phosphorus, Potassium and Calcium. These nutrients drive the photosynthesis, carbohydrate and energy production and build the cells and roots that make up the plant.

When we talk about Quality and Finishing the crop Phosphorus, Potassium, Calcium, Boron and Zinc are the key ingredients.

Carbohydrate Production in Plants is driven by photosynthesis which is the process by which plants convert the energy of sunlight into the chemical energy of organic molecules ***or*** the production of high-energy carbohydrate from low-energy water, carbon dioxide and basic chemical elements.

If we look at nutrition in the steps of growth we again categorize the nutrients by priority nutrients for germination, emergence and early growth. These elements would be Zinc, Manganese, Magnesium, Boron, and Phosphorus.

The plant for the synthesis of IAA requires zinc, which is a growth hormone responsible for all meristimatic growth and cell division. Without high levels of this auxin in the plant root growth, shoot growth and leaf growth are inhibited. Without early zinc levels that stimulate leaf area growth and cell division build the cells to establish the crop potential.

Magnesium has a role in chlorophyll production but is also critical in the production of ATP in the process of phosphorylation and the production of energy and the conversion of inorganic P to sugars and carbohydrates.

Manganese as mentioned earlier plays an important role in the function of chlorophyll but also it has a very direct influence on germination and emergence. A seed that contains good levels of manganese will germinate faster. Also soils that contain adequate levels of Mn will stimulate faster epicotyl or hypocotyls growth and the crop will emerge faster.

The next category Yield and Finish we need Potassium. Potassium is one of the key driving forces of photosynthesis efficiency in plants. The higher the potassium in plant tissue the greater the photosynthetic rate of the plant. Potassium is also the counter ion to nitrogen and for efficient use of NO_3^- the plants requires an adequate supply of K^+. Potassium is required for the uptake and movement of NO_3^- up the xylem and further to movement of sugars to the roots and fruiting components of the plant.

Nitrogen without sufficient supply of potassium will in some cases reduce yield and quality and in many cases open the plant up to more disease and poor quality.

Calcium the major building block of the cell is also a yield-building element because of its importance in the growth of all cell tissue. Calcium is also a secondary messenger within in the plant responsible for stimulation of many enzyme reactions such as calmodulin. This enzyme is key in the activation of protein channels within the root and other cell tissue that take up and transfer nutrients in the process of facilitated diffusion.

Calcium and phosphorus together form pectin's within the plant that hold the cells together and produce a denser plant tissue. Calcium is part of the plants defense mechanism; plants with higher levels of calcium and pectin's are able to resist disease pressure and the penetration of fugal spores.

Maturing the crop Phosphorus, Potassium, Calcium, Boron and Zinc play a major role. Good zinc levels early increase the cell differentiation to give the plant the cell structure to build the finished product. Phosphorus and its role in production of ATP energy and sugars that form the carbohydrates that make the crop.

Potassium is required to convert NO_3^- to amino acids and proteins and is often measured as quality parameters in a crop. Without potassium in the finish of the crop reducing sugars remain high and reduce the quality of the finished product when it is processed.

Calcium levels in the finished product are important for shelf life and storage of the crop. As mentioned earlier calcium and phosphorus make up the pectin's that hold the plant together and give its integrity.

Boron has shown up recently as a major contributing factor to the finish of the crop for a number of reasons. Adequate boron supply is important for the finished shape of the fruit or crop and it is also important for the translocation of sugars from the leaf to the tuber or fruit. In crops that are low in boron cambial cells of the phloem cease to divide but cell elongation continues in the growing zone, and as a result xylem and phloem cells are displaced from their original position, which leads to inactivation of vascular tissue. Inactivation of phloem cells leads to failure of translocation of sugars and carbohydrates to fruits and tubers.

In other circumstances in season when nitrates remain high late in the season a late season boron application may accelerate translocation of nitrogen compounds, increase protein synthesis and stimulate fruiting.

In summary mineral nutrition plays a major role in the overall quality of the crop, but the same factors that effect quality effect yield. Pushing nitrogen to increase yield without attention to the other nutrients or the balance will not only impact on quality but also may not result in and increase in yield. In crop production today where there is an increasing trend towards quality, attention to quality will also result in increased yield and ultimately efficiency.