Agri Articles
(e-Magazine for Agricultural Articles)
Volume: 02, Issue: 04 (JULY-AUGUST, 2022)
Available online at http://www.agriarticles.com
©Agri Articles, ISSN: 2582-9882

Secondary Plant Nutrients: Calcium, Magnesium and Sulphur

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Abstract
Calcium, magnesium and sulphur, are known as secondary macronutrients because they require small amounts compared to primary nutrients (N, P and K), and are required in huge quantities for crops. After major nutrients, sulphur is the most critical nutrient as it's crucial for the development of plant. It is a structural element of protoplasm and crucial for the synthesis of certain amino acids, protein, & oil. Ca is a structural component of the cell wall & rich in foliage. Just at plant terminals and root tips, it inhibits cell progress and stimulates nitrate-nitrogen uptake. Magnesium is a crucial component of chlorophyll and plays an essential role in the synthesis of proteins & plants metabolism. Magnesium is less important to plants than calcium. Deficiency of any nutrient shows visible symptoms on plants surface & stunt the plant growth.

Introduction
The secondary plant nutrients are calcium (Ca), magnesium (Mg) and sulphur (S). Soil contains Ca and Mg as exchangeable, as $CaCO_3$ and dolomite forms. These three nutrients, Ca, Mg, and S, are added indirectly to the soil through fertilizers as carriers of the primary nutrients and through soil amendments. For example, single super phosphate (SSP), a phosphatic fertilizer, contains both Ca and S; ammonium sulfate, a nitrogenous fertilizer, also contains S. Likewise, dolomite, an acid soil amendment, can supply Ca, Mg and gypsum an alkali soil amendment, can supply calcium and sulphur to the soil. Because of the frequent occurrence of their deficiency in soils, secondary nutrients are gaining paramount importance in agriculture for achieving high and sustainable crop yields.

Nutrient	Discoverer and year	Plant uptake form	Average conc. in plant tissue
Calcium (Ca)	C. Sprengel, 1839	Ca^{+2}	0.5%
Magnesium (Mg)	C. Sprengel, 1839	Mg^{+2}	0.2%
Sulphur (S)	Sachs and Knop, 1860	So_4^{2-}	0.1%

The Functions of Calcium
- It is a part of the cell wall as calcium pectate. The cell membranes' integrity is maintained.
- It facilitates the growth of meristems and functioning of the root tips. It protects the root cells against ion imbalance, low pH and toxic ions like Al^{3+} etc.
- It neutralizes the charges on the acidic molecules of phosphoric acid and organic acids, *viz*. citric acid, maleic acid, oxalic acid, etc., which as un-dissociated acid molecules are injurious to plant growth.
- • It participates in mitosis (cell division) and contributes to chromosomal structure maintenance. It encourages the incorporation of nitrogen into organic compounds,

especially proteins. High Ca levels may be necessary as a prerequisite for symbiotic leguminous plants to become sensitive to *Rhizobium* infection.
- It activates phospholipase, arginine kinase, amylase and ATPase enzymes.

The Functions of Magnesium

- Magnesium is constituent of chlorophyll as Mg-porphyrin with one atom of Mg bound to four pyrrole rings.
- Magnesium is the powerhouse behind photosynthesis in plants.
- Without Mg chlorophyll cannot capture sun energy that is needed for photosynthesis.
- Mg is required to give leaves their green color.
- It activates critical enzymes, including ribulose bisphosphate carboxylase (RuBisCO) and phosphoenolpyruvate carboxylase (PEPC) both having a role in carbon fixation.
- Essential constituent of polyribosomes.
- It promotes uptake and translocation of phosphorus and movement of sugars within the plants.
- Mg brings about significant increases in the oil content of several crops.
- Mg involved in carbohydrate metabolism and synthesis of nucleic acids.

The Functions of Sulphur

- Sulphur is the essential constituent of S-containing amino acids, viz. cysteine ($C_3H_7NO_2S$), cystine ($C_6H_{12}N_2O_4S_2$) and methionine.
- All nitrogenases have an iron (Fe) and sulphur-containing cofactor that includes an iron-sulphur cluster at the active site, in most of the proteins, this Fe-S cluster also contains Mo.
- As a constituent of Ferredoxin-containing nitrogenase, sulphur takes part in the biological nitrogen fixation (BNF) and other electron transfer reactions.
- Several biologically active compounds like vitamins - thiamine and biotin, lipoic acid, acetyl co-enzyme A and glutathione contain S as an essential part.
- It is involved in the synthesis of glucosides in mustard oil.
- It plays a major role in improving the oil quality in oilseed crops.
- Although not a constituent, sulphur is required for the synthesis of chlorophyll.

Deficiency or Toxicity Symptoms on Plant

Sr. No.	Plant nutrient	Type	Visual symptoms
1.	Nitrogen	Deficiency	Light green to yellow appearance of leaves, especially older leaves; stunted growth; poor fruit development.
		Excess	Dark green foliage which may be susceptible to lodging , drought disease and insect invasion, fruit and seed crops may fail to yield
2.	Phosphorus	Deficiency	Leaves may develop purple coloration; stunted plants growth and delay in plant development.
		Excess	Excess phosphorus may cause micronutrients deficiency, especially iron and zinc.
3.	Potassium	Deficiency	Older leaves turn yellow initially around margins and die; irregular fruit development.
		Excess	Excess potassium may cause deficiencies in magnesium and possibly calcium.
4.	Calcium	Deficiency	symptoms appear on the meristem tip portion (top of the plant) and terminal bud is converted into a “Hook” like structure and finally dies.
		Excess	Excess calcium may cause deficiency in either magnesium or potassium.

5.	Magnesium	Deficiency	Lower and older leaves become yellow and the veins remain green (inter-veinal chlorosis).
		Excess	High concentration tolerated in plant; however, imbalance with calcium and potassium may reduce growth.
6.	Sulphur	Deficiency	Initial yellowing of young leaves spreading to whole plant similar symptoms to nitrogen deficiency but occurs on new growth.
		Excess	Excess of sulphur may causes premature dropping of leaves.

Calcium Deficiency Disorder

- Blossom end rot of tomato (BER disease),
- Bitter tips of apple,
- Calyx end rot of grapes (CER),
- Carrot cavity spot

Fig. 1. Blossom end rot of tomato

Fig. 2. Calyx end rot of grapes

Magnesium Deficiency Disorder

- The sand-drown disease of tobacco.
- **Grass tetany** (hypomagnesemia) is an disorder common in cattle grazing on Mg-deficient pastures.

Fig. 3. Sand drown disease of tobacco

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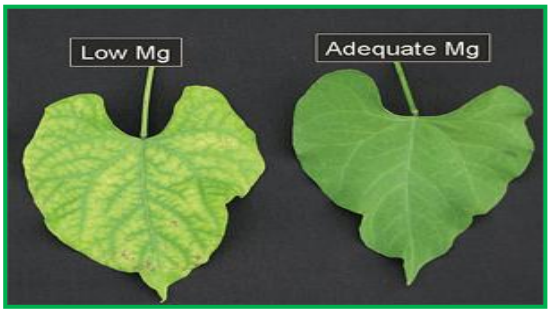

Fig. 4. Mg-deficiency symptom on leave

Sulphur Deficiency Disorder

- Akiochi of rice.
- Tea yellows of tea.

Fig. 5. Akiochi of rice

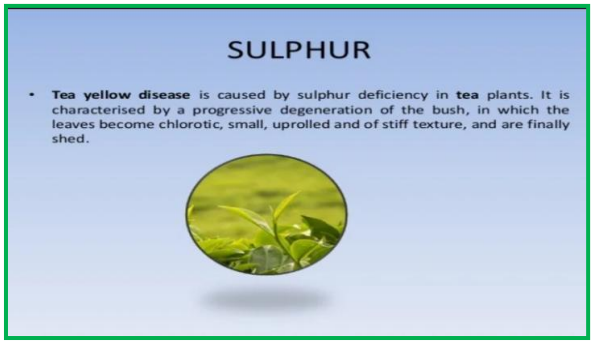

Fig. 6. Tea yellow of tea

Plants Used for Nutrients Deficiency Indicator

S. No.	Nutrients	Indicator plants
1.	Calcium (Ca)	Cauliflower, Cabbage
2.	Magnesium (Mg)	Potato
3.	Sulphur (S)	Lucerne, Clover, Cereals, Tea

Percentage of Nutrients in Different Fertilizers

S. No.	Fertilizer	Ca, Mg and S (%)
1.	Ammonium sulphate	23-24% S
2.	Calcium ammo. nitrate (CAN)	8.1 % Ca, 4.5 % Mg
3.	SSP	18-21% Ca, 12-14% S
4.	TSP	12-14% Ca
5.	Potassium sulphate	18% S
6.	Ammo. phosphate sulphate	15% S
7.	Gypsum ($CaSO_4.2H_2O$)	29% Ca
8.	Bone meal	23% Ca
9.	Magnesium sulphate	9.6% Mg
10.	Magnesium chloride	8-9% Mg

Conclusion

Secondary macronutrients have a significant impact on plant growth and development, which impacts all phases of plant life. The combination and concentration of mineral nutrients present in the soil play a significant role in determining plant growth and development. Because they are somewhat immobile, plants frequently have a difficult time getting enough of these nutrients to meet the requirements of essential cellular functions. Crop fertility or production both are diminished when one or more nutrients are deficient. Small growth, plant tissue loss, or yellowing of the leaves, which lacks a pigment necessary for photosynthesis, are all signs of nutrient deficiency. A major impact of nutrient scarcity on agriculture is seen in decreasing crop yields or the superiority of low-cost plants. While plants act as producers that support almost all food webs, their removal also contributes to a decline in overall biodiversity. Nevertheless, surplus or deficit of secondary macronutrient can harmfully influence the overall enlargement and routine of plants.

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