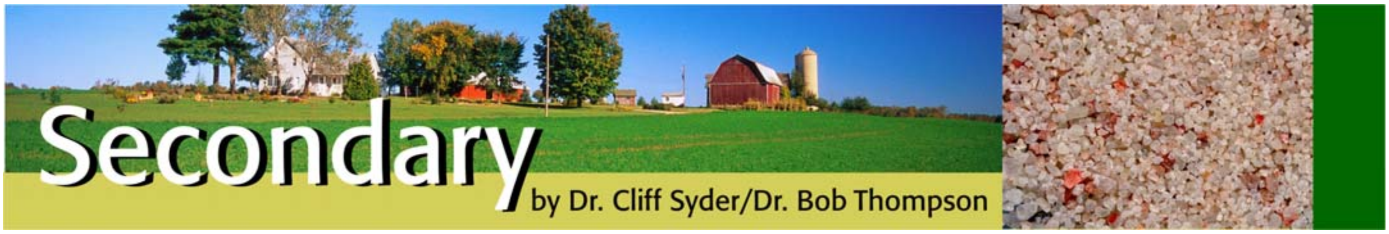


SECTION CONTENTS:

- **Secondary Nutrients**
- **Calcium**
- **Magnesium**
- **Sulfur**
- **Research**

The Sometimes Forgotten Secondary Nutrients Calcium—Magnesium—Sulfur

Three of nature's products — calcium, magnesium and sulfur— are very important in the industrial world. Calcium, is a constituent in cement and concrete. As such, it helps form the foundation for virtually all of our homes, offices, factories, and many of our highways and airports. It is also a key element, along with phosphorus, in bone development. Magnesium, in its metallic form, is the lightest of all building or structural metals. Sulfur is just as important industrially. Its many uses range from its use in producing sulfuric acid to a component of protein building blocks.

In addition to being important commercially, calcium, sulfur and magnesium are also vital to plant and animal existence. They are three of the 16 essential plant nutrients.

Table 8.1: Essential Plant Nutrients

To produce at optimum yields, all crops must have an adequate supply of all of the 16 essential plant nutrients. If one or more is lacking in the soil, crop yields will be reduced even though an adequate amount of the other 13 elements are available. This is somewhat analogous to the fact that a wooden bucket will hold no more water than its shortest stave. Crop yields may be limited by the element that is in shortest supply.

Carbon	Calcium	Boron	Iron
Oxygen	Magnesium	Copper	Molybdenum
Hydrogen	Sulfur	Chlorine	Zinc
Nitrogen	Phosphorus	Potassium	Manganese

Increased Need for Calcium, Magnesium and Sulfur

In today's agriculture with the emphasis on higher crop yields, there is an increased need for calcium, magnesium and sulfur. Some of the factors responsible for this increased need are:

1. Increased use of higher analysis fertilizers.
2. Increased crop yields.
3. High crop utilization of calcium, sulfur and magnesium.
4. Decreased use of sulfur containing insecticides and fungicides.
5. Government restrictions on sulfur emissions to the atmosphere.
6. Many soils are acidic and need limestone, which provides calcium.
7. Many soils are deficient in sulfur and magnesium.
8. Increased awareness of sulfur and magnesium needs.

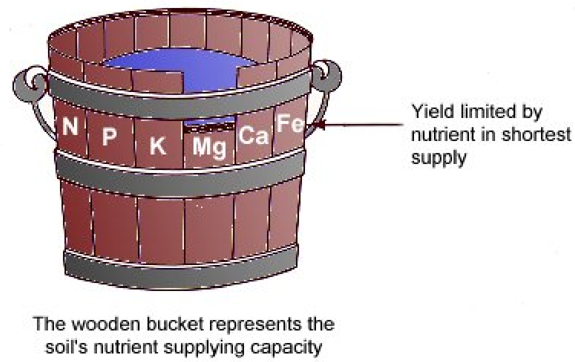


Figure 8.1 The Law of the Minimum

Increased Use of Higher Analysis Fertilizer Materials

To produce high analysis bulk blended or fluid fertilizers, magnesium and sulfur free fertilizer materials, such as Diammonium Phosphate, Urea, Ammonium Nitrate, Nitrogen Solutions, Phosphoric Acid and Muriate of Potash are often used. The nutrient content of these materials clearly indicates the lack of sulfur and magnesium. Ordinary superphosphate (20% P_2O_5) and triple superphosphate (45 to 46% P_2O_5) contain calcium in addition to phosphorus. The typical percentage by weight is 14 to 20 percent.

Table 8.2: Nutrient Content of High Analysis Fertilizer Materials

	NUTRIENT CONTENT - Percent					
MATERIAL	N	P_2O_5	K_2O	Ca	Mg	S
Anhydrous Ammonia	82	0	0	0	0	0
Diammonium Phosphate	16-21	46	0	0	0	0
Urea	46	0	0	0	0	0
Ammonium Nitrate	33	0	0	0	0	0
N-Solutions	21-49	0	0	0	0	0
Phosphoric Acid	0	52-60	0	—	0	0
Triple Superphosphate	0	45-46	0	14	0	0
Muriate of Potash	0	0	60-62	0	0	0

Increased Crop Yields

Crop yields have dramatically increased during the past ten years. For instance, some farmers are now producing 200 bushels or more of corn per acre, whereas ten years ago a corn yield of 150 bu/acre was considered good. Corn producing at 200 bu/acre will utilize about 65 lb/acre of magnesium and 33 lb/acre of sulfur. In contrast, when the corn yield is 120 bu/acre, the magnesium and sulfur utilization drops to 30 and 20 lb/acre, respectively.

High Crop Utilization of Calcium, Magnesium and Sulfur

Calcium, magnesium and sulfur are generally referred to as secondary elements; however, they play no secondary role in plant nutrition. They are just as essential for plant nutrition as any of the other 13 essential plant nutrients.

When phosphorus is expressed in the comparable elemental form P instead of P_2O_5 (multiply P by 2.3 to convert to P_2O_5), the magnesium, sulfur, calcium and phosphorus values are very similar as shown below:

Table 8.3: Comparison of Total Ca, Mg, S and P Crop Uptake

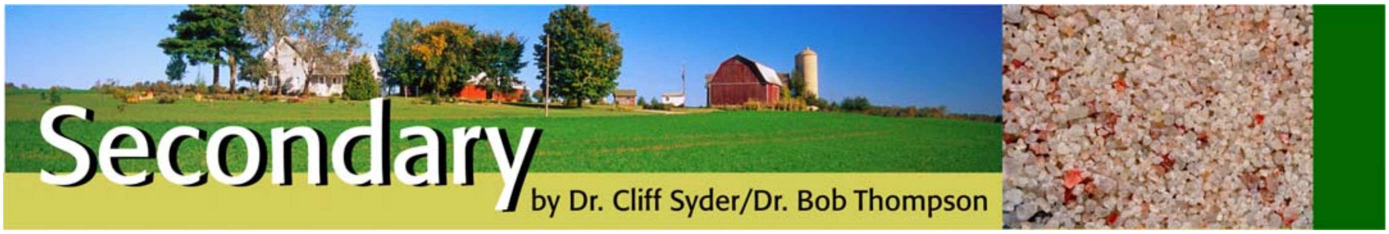
		Nutrients Taken Up, lb/acre			
Crop	Yield/Acre	Ca	Mg	S	P
Corn	180 bu	44	58	30	44
Soybeans	60 bu	26	27	25	29
Wheat	70 bu	18	21	18	20
Alfalfa	8 tons	175	40	40	35
Fescue	3.5 tons	30	13	15	26
Tomatoes	800 cwt	30	36	54	37
Oranges	540 cwt	80	22	21	44
Peaches	600 bu	N/A	33	N/A	17
Onions	400 cwt	4	58	33	35
Cotton	1,000 lb lint	76	21	24	21
Peanuts	4,000 lb	20	25	21	17
Hybrid bermudagrass	8 tons	52	26	44	41
Rice	7,000 lb	20	14	12	26
Sugarbeets	25 tons	N/A	67	37	14

Decreased Use of Sulfur Containing Pesticides

Many of the insecticides and fungicides previously used for controlling insects and diseases in crops have been replaced by sulfur free compounds.

Government Restrictions on Emissions to Atmosphere

The amount of sulfur dioxide (SO_2) that can be returned to the atmosphere from coal burning furnaces is now restricted by government regulations. Most of the sulfur is now removed from natural gas used in home heating and in industry. Also, catalytic converters in new automobiles remove most of the sulfur that was previously returned to the atmosphere when sulfur containing gasoline was burned in automobiles. As a result of these government restrictions, less sulfur is being returned to the soil by rainfall.



Calcium

Calcium is a low-key essential nutrient that carries a heavy load in plant growth. Too often, it takes a back seat as soil fertility programs are developed for many high yield and high quality crops. Peanut and tomato growers are probably exceptions in their emphasis on good calcium nutrition.

Functions of Calcium in Soil

In soil, calcium replaces hydrogen (H) ions from the surface of soil particles when limestone is added to reduce soil acidity. It is essential for microorganisms as they turn crop residues into organic matter, release nutrients, and improve soil aggregation and water holding capacity. Calcium helps enable nitrogen fixing bacteria that form nodules on the roots of leguminous plants to capture atmospheric nitrogen gas and convert into a form that plants can use.

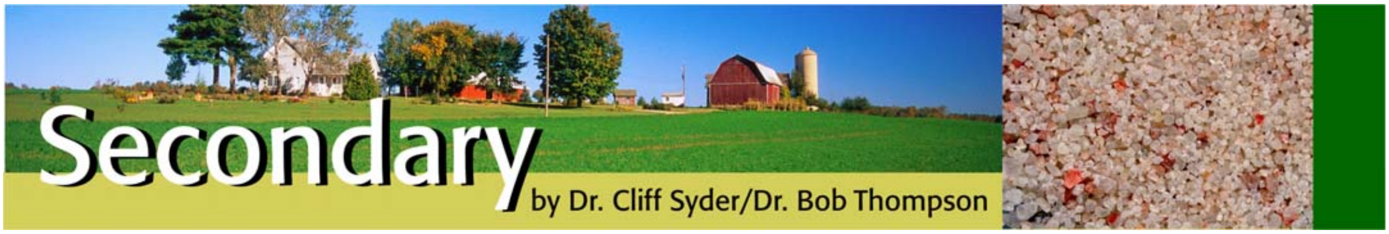
Functions of Calcium in Plants

Calcium improves the absorption of other nutrients by roots and their translocation within the plant. It activates a number of plant growth-regulating enzyme systems, helps convert nitrate-nitrogen into forms needed for protein formation, is needed for cell wall formation and normal cell division, and contributes to improved disease resistance. Calcium, along with magnesium and potassium, helps to neutralize organic acids, which form during cell metabolism in plants.

Calcium Deficiency

Calcium is taken up by plants as the divalent cation, Ca^{++}. Calcium deficiency is not likely for most crops when the soil is properly limed to adjust soil pH to optimum levels for crop production. As soils become more acidic, crop growth is often restricted by toxic soil concentrations of aluminum and/or manganese; not a calcium shortage. Soil testing and a good liming program are the best management practices (BMPs) to prevent these problems.

Calcium deficiencies can occur and they need to be avoided or corrected. Symptoms of deficiency include: (1) Slow root development. Roots may develop a dark color and in severe cases the growing point may die. (2) New leaf growth may slow and leaf tips may stick together. Remember that calcium does not readily translocate within the plant so deficiency symptoms will appear on the new growth. (3) Poor nodulation by nitrogen fixing bacteria on leguminous plant roots. Ineffective nodules are white to grayish green inside while healthy nodules have dark pink interiors. (4) Blossom end rot in tomatoes. Calcium and proper water management improve plant



resistance to this problem. (5) Aborted and shriveled fruit on peanuts. A shortage of calcium at "pegging" results in a high percentage of "pops". (6) Darkened plumule or "black heart" in peanut seed. This reduces yield, quality and crop value. (7) Pod rot diseases on peanuts. Pods are predisposed to fungus infections when calcium is deficient or out of balance with Mg and K.

Calcium deficiencies are most likely to occur in acid, sandy soils from which calcium has been leached by rain or irrigation water. It may also occur in strongly acid peat and muck soils where total calcium is low.

Sources of Calcium

A good liming program is an efficient supplier of calcium to most crops. High quality calcitic limestone is effective when pH adjustments are needed. If magnesium is deficient also, dolomitic limestone may be used, or calcitic limestone may be applied along with a magnesium source such as potassium-magnesium-sulfate (K-Mag). Gypsum (calcium sulfate) provides calcium when soil pH is adequate. Some common sources of calcium are shown below.

Table 8.4: Common Calcium Sources

Material	Ca%	Acid-neutralizing value[1]
Gypsum	22	None
Basic slag	29	50-70
Calcitic limestone	32	85-100
Dolomitic limestone	22	95-108
Hydrated lime	46	120-135

[1] Pure calcium carbonate = 100

Calcium deficiency can be prevented by following several BMPs such as, soil testing on a regular basis and correcting soil acidity with proper liming. Balance the plant nutrition program by keeping calcium, potassium and magnesium available in a balanced supply. An over-abundance of one can lead to a shortage or uptake (antagonism) of another. Also apply calcium for specific plant functions. For example, calcium applied when peanuts begin to set pods can help improve seed development. Team calcium supply with other plant disease resistance management.

Magnesium

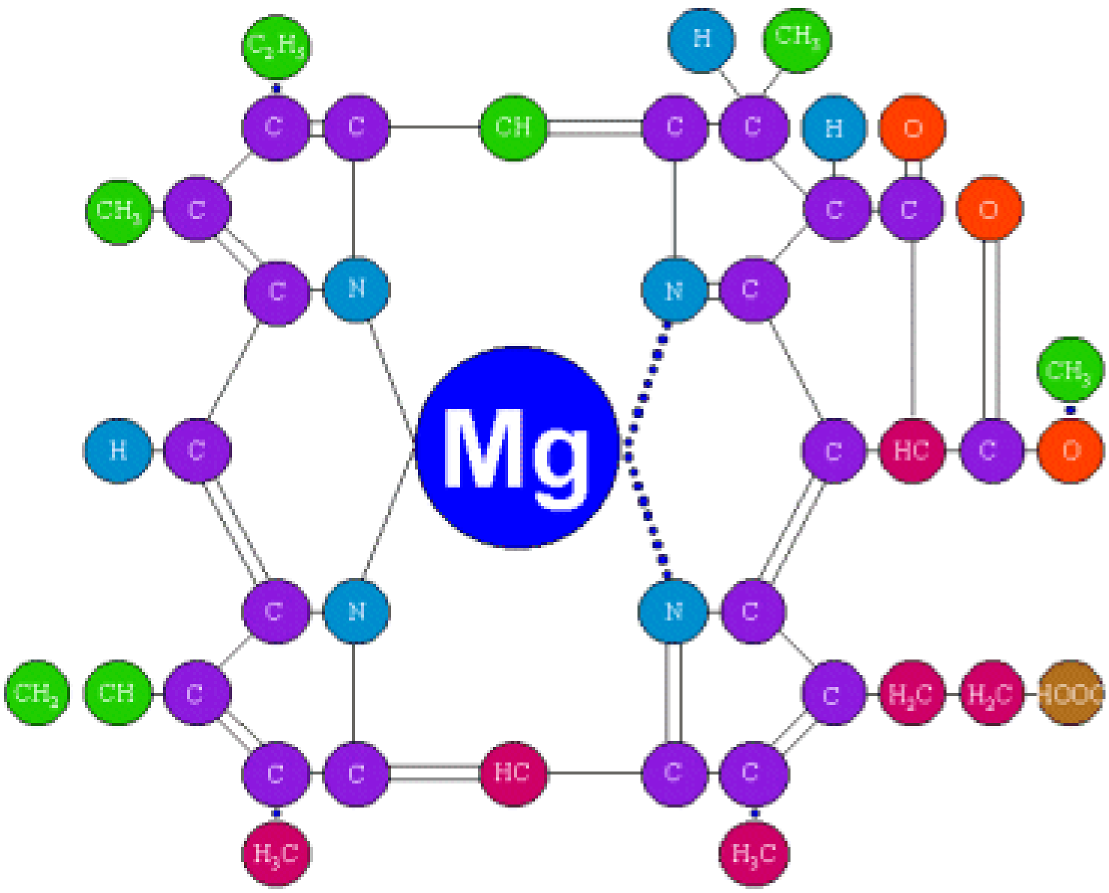
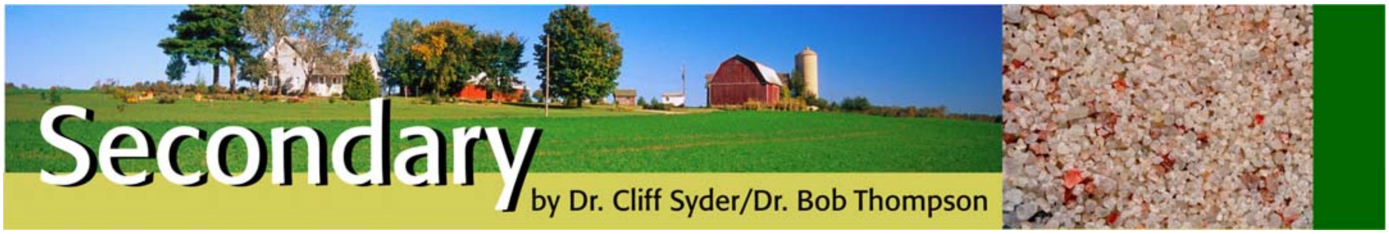


Figure 8.2 Hidden in the Heart of Each Molecule of Chlorophyll is an Atom of Magnesium. Deprive a Plant of Magnesium and its Chlorophyll Molecules (and Plant Life) Cease to Exist.

Plant growth is an energy requiring process. During germination alone, a bushel of wheat seed needs about 900 cubic feet of air and produces the same amount of energy needed by a tractor to plow an acre of land. Magnesium is required by wheat, and all other crops, to capture the sun's energy for growth and production through photosynthesis. Chlorophyll, the green pigment in plants, is the site where photosynthesis occurs. Without chlorophyll, plants could not manufacture



food and life on Earth would cease to exist. Magnesium is an essential component of the chlorophyll molecule, with each molecule containing 6.7 percent magnesium. Magnesium also acts as a phosphorus carrier in plants. It is necessary for cell division and protein formation. Phosphorus uptake could not occur without magnesium and vice versa. So, magnesium is essential for phosphate metabolism, plant respiration and the activation of several enzyme systems.

Magnesium in Soils

The Earth's crust contains about 1.9 percent Mg, largely in the form of Mg-containing minerals. As these minerals slowly weather, some Mg is made available to plants. The supply of available Mg has been or is being depleted in some soils through leaching, plant uptake and removal processes. Where Mg is deficient, growers are noticing good responses to fertilization with Mg.

Magnesium availability to plants is often related to soil pH. Research has shown that Mg availability to the plant decreases at low pH values. On acid soils with a pH below about 5.8, excessive hydrogen and aluminum can influence Mg availability and plant uptake. At high pH values (above 7.4), excessive calcium may have an overriding influence on Mg uptake by plants.

Sandy soils with low cation exchange capacity have a low Mg supplying power. Application of high calcium limestone can aggravate a Mg deficiency by increasing plant growth and increasing the demand for Mg. High applications of ammonium and potassium may also interfere with balanced nutrition through competitive ion effects. If soil test levels are below 25 to 50 parts per million (ppm) ..... 50 to 100 lb/acre ..... exchangeable Mg is usually considered low and Mg application is warranted.

Although no ideal basic cation saturation range in soil has been scientifically proven at which crop yields are maximized, a rule of thumb may be used to ensure that Mg is not limiting. For soils with a cation exchange capacity (CEC) higher than about 5 milliequivalents (ME) per 100 grams, it may be desirable to maintain the soil Ca to Mg ratio at about 10 to 1. For example, if soil test results show 2000 lb/acre of Ca, the soil Mg levels should be about 200 lb/acre. For sandy soils with a CEC of 5 ME or less, it may be desirable to maintain the Ca to Mg ratio at about 5 to 1. For example, if a soil has a CEC of 5 ME and contains 800 lb/acre of extractable Ca, the Mg level should be about 160 lb/acre.

Note: In certain forage regions of the U.S., adequate P nutrition is essential for stimulation of adequate Mg uptake by plants and translocation from roots to tops. Low Mg in forages can lead to a condition termed grass tetany or hypomagnesia, associated with low blood serum levels of Mg in cattle. This condition reduces animal performance and sometimes results in death. Beef and dairy producers can help avoid potential Mg deficiency in their animals with adequate P and Mg fertilization.

In contrast, there are other limited areas of the U.S. where certain soils contain much more extractable Mg than K. Fertilization with higher-than-necessary phosphorus rates in these limited areas may induce K-deficiency in crops such as cotton, even if soil test levels indicate that the soil K supply may be adequate. In these exceptional areas, excessive P may stimulate Mg uptake, which can interfere with adequate K nutrition.

Plant Deficiency Symptoms

Magnesium is taken up by the plant as the divalent cation, Mg^{++}. It is mobile within the plant and easily translocated from older to younger tissues. When deficiencies occur, the older leaves are affected first. The deficiency symptoms may include the following: (1) loss of color between the leaf veins, beginning at the leaf margins or tips and progressing inward. This can give the leaves a striped appearance. (2) Leaves may become brittle and cup or curve upward and they may become thinner than normal. (3) Tips and edges of leaves may become reddish-purple in cases of severe deficiency (especially with cotton). (4) Low leaf Mg can lead to lowered photosynthesis and overall crop stunting.

As a rule of thumb, most crops have a critical plant tissue Mg concentration of about 0.2 percent. Some species have a higher total requirement than others: forage legumes and grasses, cotton, oil palm, corn, potatoes, citrus, sugar beets and tobacco need lots of Mg. Some varieties and hybrids of crops such as corn, soybeans, lespedeza, cotton and celery may require more Mg than others.

If Mg deficiencies are detected in growing crops through plant tissue analyses, a soluble magnesium source may be applied and watered into the soil by irrigation or rainfall. This will permit root access and plant uptake. Small amounts of Mg can also be applied to growing crops through foliar fertilization to correct or prevent developing deficiencies. The preferred approach is to soil apply the required amounts of Mg before crops are planted or before they begin active growth.

Sources of Magnesium

There are several sources of magnesium to choose from. The most common sources are shown in the Table 8.5.

Table 8.5: Common Magnesium Sources

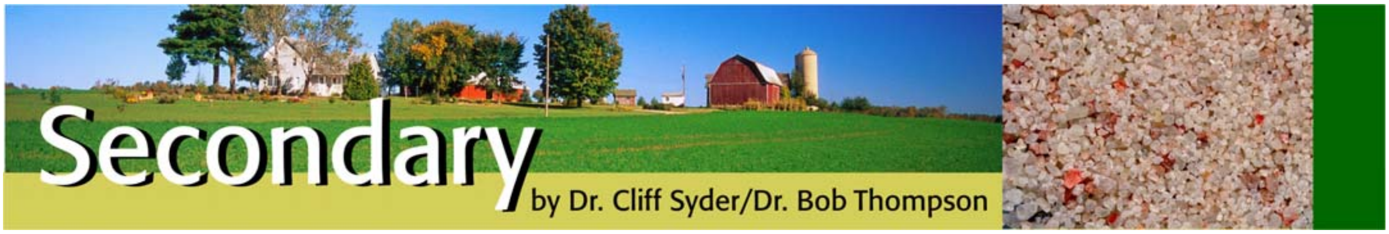
Material	Mg%	Water Solubility
Dolomitic lime	6-12	No
K-Mag	10-11	Yes
Magnesium chloride (solution)	7.5	Yes
Magnesium hydroxide	40	No
Magnesium nitrate	16	Yes
Magnesium oxide	56-60	No
Magnesium sulfate	10-16	Yes

Dolomitic Lime

Dolomitic Lime is an excellent source of lime for magnesium deficient soils because it contains 6-12% Mg; whereas, calcitic lime usually contains less than 1% Mg. However, the magnesium contained in dolomitic lime is in the form of magnesium carbonate which is not water soluble and only slowly available to crops. Its availability is dependent upon particle fineness. The more finely ground the dolomitic lime, the faster its availability to crops. On soils low in magnesium and where dolomitic lime has been used as a liming source, additional water soluble magnesium should be applied in the fertilizer used. For instance, the application of 700 lb/acre of 3-9-18 corn fertilizer, which contains 3% Mg, would supply 21 lb/acre water soluble Mg. This amount of Mg when used in conjunction with dolomitic lime, should supply all of the Mg required by corn producing at 150 bu/acre or more.

Sulfate of Potash Magnesia (K-Mag)

Sulfate of potash magnesia is derived from the mineral, Langbeinite, which contains both magnesium sulfate ($Mg SO_4$) and potassium sulfate (K_2SO_4). The magnesium content is 10-11%. It is water soluble and immediately available to crops. This product is one of the most economical means of supplying water soluble magnesium to crops. Fertilizer manufacturers may use K-Mag as a partial source of potassium in formulating fertilizer analysis and thereby supply water soluble magnesium to crops.



Magnesium Chloride and Magnesium Nitrate

Magnesium chloride ($MgCl_2$) and magnesium nitrate ($Mg(NO_3)_2$) are a water soluble and well suited to use in clear liquids and foliar sprays. Magnesium nitrate has been reportedly used in foliar sprays on citrus in California to correct Mg deficiency.

Magnesium Oxide and Magnesium Hydroxide

Magnesium oxide (MgO) and magnesium hydroxide ($Mg(OH)_2$) are not water soluble and therefore not as quickly available to crops as magnesium sulfate. Their relative availability to crops is somewhat better than Mg in dolomitic lime but less than magnesium sulfate.

Magnesium Sulfate

There are two general forms of magnesium sulfate. Epsom salts which contain about 10% Mg and because it contains considerable amounts of water of hydration, it is completely water soluble. It is most generally used as a foliar application to crops. Its greatest handicap is its cost which is considerably higher than other sources of Mg.

Commercial sources of magnesium sulfate are less hydrated than Epsom salts and contain from 16-18% Mg. Because they are less hydrated than Epsom salts, they are not completely water soluble and therefore not adapted for foliar applications. They are, however, a good source of quickly available magnesium when applied to the soil.

Sulfur

A chain is only as strong as its weakest link. Often overlooked, ... sulfur (S) can be that weak link in many soil fertility and plant nutrition programs. Some of the reasons for the increased observance of sulfur deficiencies and increased sulfur needs were highlighted in the introductory sections of this chapter.

Sulfur in Soil

Sulfur is supplied to plants from the soil by organic matter and minerals, but it is often present in insufficient quantities and at inopportune times for the needs of many high yielding crops. Most S in the soil it tied up in the organic matter and cannot be used by plants until it is converted to the sulfate (SO_4^{-2}) form by soil bacteria. That process is known as mineralization.

Sulfate is mobile in the soil, just as nitrate-nitrogen is mobile, and can be leached beyond the active root zone in some soils with heavy rainfall or irrigation. Sulfate may move back upward toward the soil surface as water evaporates, except in the sandier, coarse textured soils which may be void of capillary pores. This mobility of sulfate-sulfur makes it difficult to calibrate soil tests and to use them as predictive tools for sulfur fertilization needs.

Sulfur tends to be held by clay soil particles more than nitrate nitrogen. When early spring rains occur, soils with a sandy topsoil, but containing relatively high amounts of clay in the subsoil, may have sulfate-sulfur leached out of the topsoil but retained in the subsoil. Therefore, crops grown on these types of soils may show early S deficiency, but as the roots penetrate into the subsoil, the deficiency may disappear. On deep sandy soils with little or no clay in the subsoil, plants will likely respond to sulfur applications.

Sulfur in Plants and Sulfur Deficiency

As mentioned above, sulfur is absorbed primarily in the sulfate form (SO_4^{-2}) by plants. It may also enter the leaves of plants from the air as sulfur dioxide gas. It is part of every living cell and required for synthesis of certain amino acids (cysteine and methionine) and proteins. Sulfur is also important in photosynthesis and crop winter hardiness. Leguminous plants need sulfur for efficient nitrogen fixation. Sulfur is also important in the nitrate-reductase process where nitrate-nitrogen is converted to amino acids.

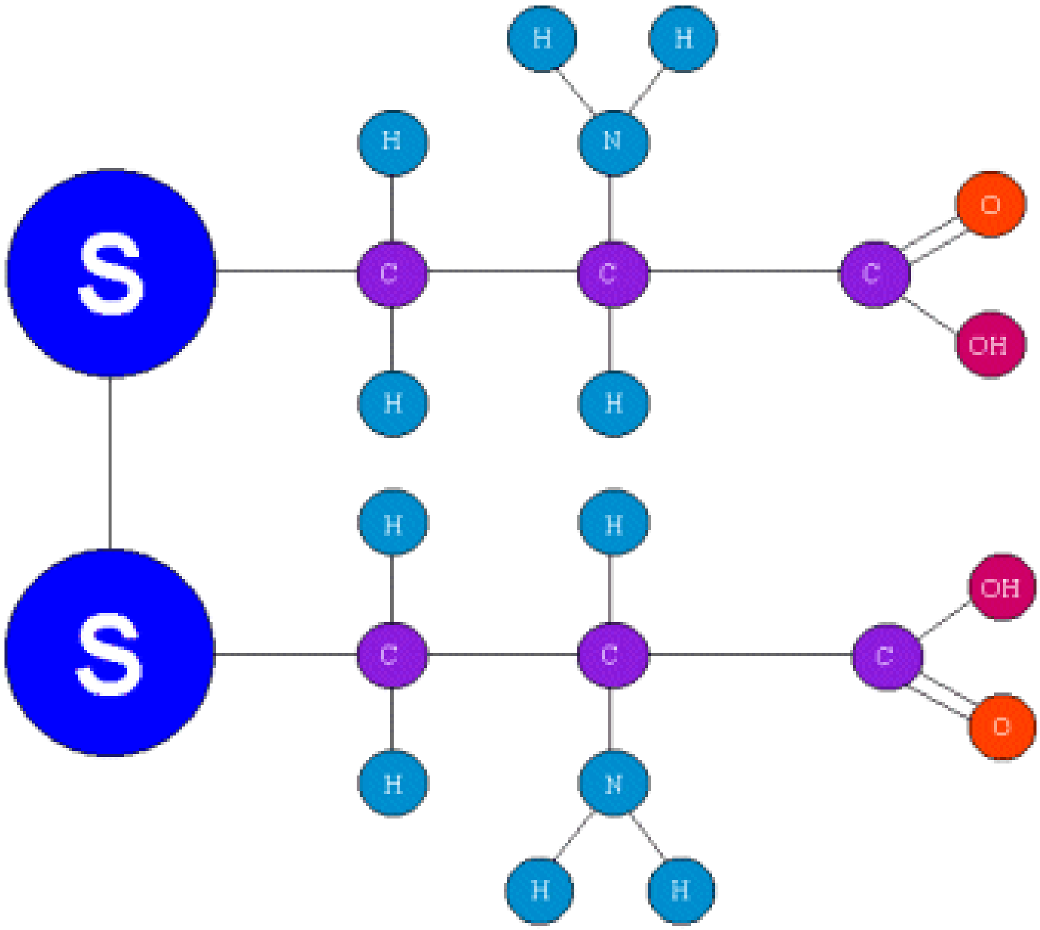
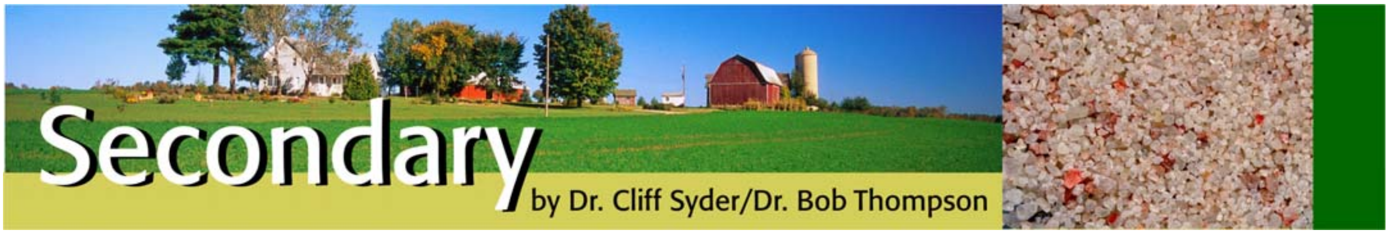


Figure 8.3 Sulphur is Required for the Synthesis of Vitamins, and is a Constituent of Certain Amino Acids Which are the Building Blocks from Which Proteins are Created. Without Proteins, Plants Wither and Die.

In the field, sulfur deficiency and nitrogen deficiency are often easily confused. Symptoms of both deficiencies may appear as stunted plants, with a general yellowing of leaves. Sulfur is immobile within the plant and does not readily move from old to new growth. With sulfur deficiency, yellowing symptoms often first appear in younger leaves, whereas with nitrogen deficiency, the yellowing appears on the older leaves first. In less severe situations, visual symptoms may not be noticeable.



The best way to diagnose a deficiency is with a plant tissue analysis that includes an assay for both sulfur and nitrogen. Sulfur concentrations in most plants should range from about 0.2 to 0.5 percent. Desirable total nitrogen to total sulfur ratios have been considered and range from 7:1 to 15:1. Wider ratios may point to possible sulfur deficiency but should be considered along with actual N and S concentrations in making diagnostic interpretations.

When sulfur is deficient, nitrate-nitrogen may accumulate. This can pose significant health threats to grazing ruminants or those consuming hay high in nitrates. When nitrates accumulate in the plant, seed formation can be inhibited in some crops such as Canola. Balancing sulfur with nitrogen nutrition is important to both plant and animal health.

Crops such as hybrid bermudagrass, alfalfa and corn that have a high dry matter production generally require the greatest amount of sulfur. Also, potatoes and many other vegetables require large amounts of S and have produced best when S is included in the fertility program. Without adequate S fertilization, crops that receive high rates of nitrogen may develop sulfur deficiencies.

Sulfur Sources

Table 8.6: Common Sulfur Sources

Material	S%	Water Solubility	pH Effect
Ammonium sulfate	24	Yes	Lowers
Ammonium thiosulfate	26	Yes	Lowers
Ammonium polysulfide	40-50	Yes	Lowers
Elemental sulfur	>85	No	Lowers
Gypsum	12-18	Yes	None
K-Mag	21-22	Yes	None
Magnesium sulfate	14	Yes	None
Normal superphosphate	12	Yes	None
Potassium sulfate	18	Yes	None
Potassium thiosulfate	17	Yes	—
Sulfur coated urea	10	No	Lowers

Some irrigation waters may contain significant quantities of sulfur. For example, when the irrigation water exceeds about 5 parts per million (ppm) sulfate-S, a sulfur deficiency is unlikely. Most fertilizer sources of sulfur are sulfates and are moderately to highly soluble in water. The most important water insoluble sulfur source is elemental S, which must be oxidized through bacterial action to the sulfate form before it can be utilized by plants. This oxidation is favored by warm soil temperatures, adequate soil moisture, soil aeration, and fine sulfur particle sizes. If elemental sulfur is used, it should be incorporated into the soil well in advance of the crop needs.

Ammonium Sulfate ($(NH_4)_2SO_4$)

Ammonium sulfate is sometimes used as a source of nitrogen for crops. Its high sulfur contents (24%) which is in the sulfate form, makes it an excellent source of sulfur for crops. Ammonium sulfate, however, is very acid forming—approximately 3 times more acid forming than other forms of ammonium nitrogen. Consequently, growers using ammonium sulfate as a source of nitrogen and sulfur should apply adequate lime (approximately 15 lbs. of lime for every pound of nitrogen used) to neutralize the acid forming effects of this material.

Ammonium Thiosulfate

Ammonium thiosulfate is primarily used as a source of sulfur and nitrogen for fluid fertilizers. It is completely water soluble and is a good source of sulfate sulfur for crops. Its major drawback is that it is considerably more expensive than other more commonly used sulfate sources. It is also acid forming and leaves an acid residue in the soil.

Ammonium Polysulfide

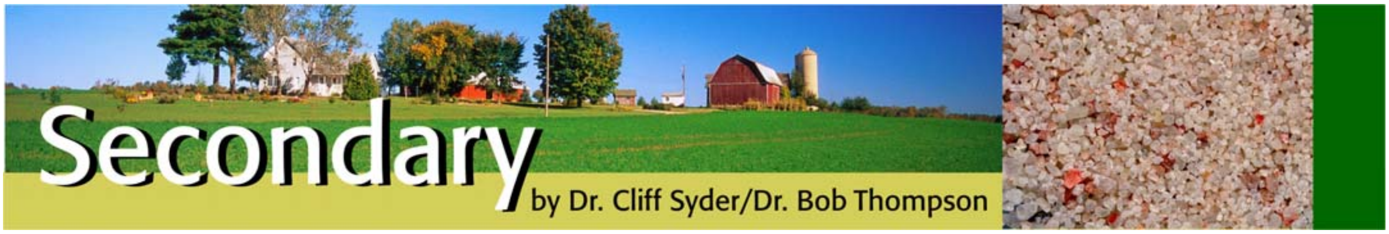
Ammonium polysulfide is a red to black solution with a hydrogen sulfide odor. In addition to its 40 to 50 percent S content, it also contains about 20 percent N. Besides its use as a fertilizer, it is also used for treatment of irrigation water to improve water penetration into soils. It is also used for reclaiming high pH soils. It is normally considered incompatible with phosphate containing liquids. It can be mixed with anhydrous ammonia, aqua ammonia, and urea ammonium nitrate (UAN) solutions.

Elemental Sulfur

Elemental sulfur, although it contains a high percent of S (depending upon the purity) must be converted to sulfate (SO_4)-- in the soil before plants can absorb it. The conversion of elemental S to sulfate is brought about by certain soil organisms and takes from 3 to 6 weeks, depending upon the soil conditions. The finer the sulfur is ground, the faster it converts to sulfate.

Gypsum ($CaSO_4$)

Gypsum, which is calcium sulfate, is commonly used as a source of readily available calcium for peanuts. Although gypsum contains calcium, it has no effect on soil pH. It is an excellent source of sulfate sulfur for crops.



Magnesium Sulfate ($MgSO_4$)

Magnesium sulfate was discussed in the magnesium section of this chapter. As Epsom salts, it is also considered an acceptable water-soluble source of sulfur. Commercial sources of magnesium sulfate are less water soluble and not well suited for foliar applications. They are considered a good supply of quickly available sulfate-sulfur when applied to the soil.

Normal Superphosphate

Normal or ordinary superphosphate is produced by treating phosphate rock with sulfuric acid. The phosphorus in phosphate rock (tri calcium phosphate) is converted to the more available forms of phosphate — di and mono calcium phosphate. The calcium that is removed forms calcium sulfate ($CaSO_4$) which is contained in superphosphate. Therefore, fertilizers containing normal superphosphate as a source of phosphorus also contain considerable amounts of sulfate sulfur. Normal superphosphate contains approximately 12% sulfur, all in the sulfate form.

Potassium Sulfate (K_2SO_4)

Most tobacco fertilizer grades and some vegetable fertilizers contain potassium sulfate as a source of potassium. Potassium sulfate is used as a source of potassium rather than the less expensive form of potassium choloride — to avoid possible excessive amounts of chloride for chloride sensitive crops such as tobacco and some vegetables. Consequently, fertilizers using potassium sulfate as a source of potassium contain considerable quantities of sulfate sulfur.

Potassium Thiosulfate ($K_2S_2O_3$)

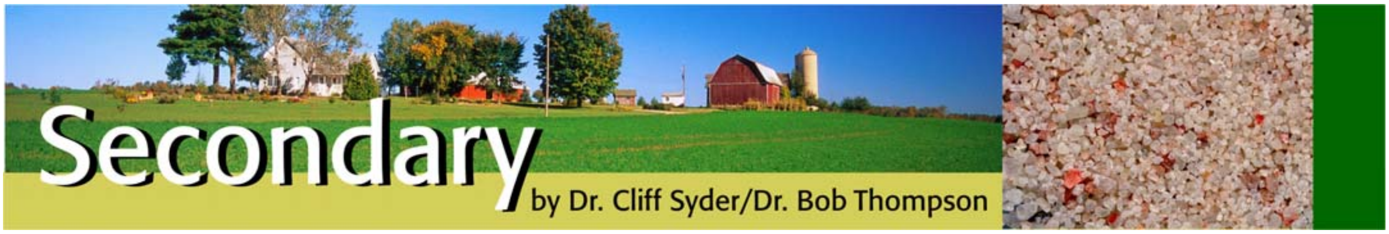
Potassium thiosulfate is considered a relatively new liquid fertilizer product. It is compatible with most liquid fertilizers and may be used in drip irrigation applications and for foliar fertilization.

Sulfate of Potash Magnesia (K-Mag)

Sulfate of potash magnesia (K-Mag) is an excellent and economical source of sulfate sulfur for crops. Since it contains three essential plant nutrients in water soluble forms — potassium, magnesium and sulfur — it can be used as a partial source of potassium in formulating fertilizer grades and also furnish considerable quantities of water soluble magnesium and sulfate sulfur.

Sulfur Coated Urea

A slow release nitrogen material, sulfur coated urea, is produced by coating urea with up to 11% elemental sulfur. The elemental sulfur coating slows down the conversion of urea to ammonium.



The sulfur coating is gradually oxidized to sulfate sulfur allowing the urea nitrogen to become slowly available to crops. The sulfur in sulfur-coated urea is comparable in availability to crops to elemental sulfur.

Research and Demonstration Results of Applying S & Mg

The fact that magnesium and sulfur are essential for plant growth means little unless a grower is assured of increased crop yields and profits though the application of adequate sulfur and magnesium on soils deficient in these elements. he following tables indicate the yield responses of various crops to Mg and S on soils deficient in these elements.

Table 8.7: Corn Response to Sulfur - Wisconsin

Sulfur lb/acre	Yield bu/acre	N to S Ratio in Plant
0	124.5	14:1
50	136.0	10.9:1

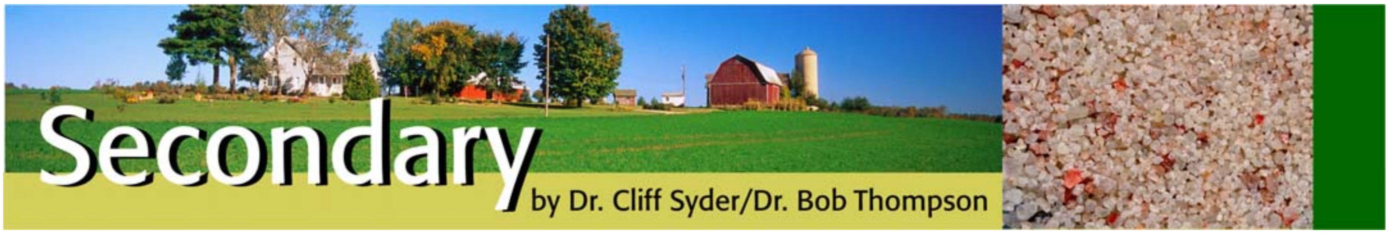
Table 8.8: Alfalfa Response to Sulfur - Nebraska

Sulfur lb/acre		Yield ton/acre
0		3.6
50		4.3

Table 8.9: Sulfur Increases Coastal Burmudagrass Yield and Nitrogen Recovery - Arkansas

N rate, lb/acre	Sulfur applied	Yield ton/acre	--------- Nitrogen ---------	
			Uptake, lb/acre	Recovery, %[1]
0	No	2.4	81	—
	Yes	2.6	88	—
200	No	4.6	186	93
	Yes	5.2	223	112
400	No	5.1	236	59
	Yes	6.1	306	76

[1] (N uptake/N applied) x 100



When sulfur is limiting forage and hay production, it may also be reducing the nitrogen use efficiency. Balanced nitrogen and sulfur management can improve forage and hay production and contribute to a more economic and environmentally acceptable enterprise.

Table 8.10: Seedcotton Yield Response to Sulfur on Sandy Loam Soil - Alabama

Sulfur Rate	Three-Year Average Seedcotton Yield
lb/acre	lb/acre
0	1216
10	1402
20	1526
40	1481

Table 8.11: Effect of Magnesium with and without Sulfur on Seedcotton Yields on a Sandy Loam Soil - Alabama

Treatment	Seed cotton Yield
	lb/acre
Check	1621
20 lb/acre Mg, as magnesium chloride	1924
20 lb/acre Mg + 20 lb/acre S as ammonium sulfate	2347
20 lb/acre S, as K-Mg-sulfate	2311

These two Alabama studies with cotton showed that seedcotton yields may be increased by more than 25 percent with the addition of sulfur. At least 20 pounds of sulfate sulfur were needed on this soil to increase yields the greatest amount. The results also showed that when 20 lb/acre of Mg were provided with the S, yields were further increased in this soil.

Table 8.12: Influence of Calcitic Lime, Dolomitic Lime and Calacitic Lime Plus K-Mag on Bahiagrass Yields on a Deep Sandy Loam Soil - Arkansas

Treatment	Three-Year Total Dry Matter Yield	Increased Grazing
	lb/acre	animal-unit-months
Control	16,227	—
Calcitic lime	18,101	3.7
Dolomitic lime	20,636	8.2
Calcitic lime + 200 lb/acre K-Mag	21,988	10.3

This Arkansas study clearly showed that magnesium increased yield and the potential for increased grazing. Application of finely pulverized dolomitic lime caused a significant yield increase, but the addition of K-Mag with the calcitic limestone resulted in the highest yields.

Table 8.13: Magnesium Demonstrations, Corn - Georgia

	Average Yield Increase (Bu/acre) From	
COUNTY	30 lb/acre Mg ($MgSO_4$)	30 lb/acre Mg (K-Mag)
Colquitt	51	33
Crisp	10	2
Irwin	12	15

In this demonstration, the addition of 30 lb/acre Mg increased corn yields an average of 20 bu/acre in three locations. Either source of magnesium sulfate or sulfate of potash magnesium (K-Mag), was effective in increasing corn yields.

Table 8.14: Influence of Magnesium Sources on Irish Potato Yields - Rhode Island

Mg Source	Yield Increase Over No Added Mg
Dolomitic lime	35%
K-Mag	53%

This experiment indicates that although dolomitic lime is an excellent source of lime for building up soil Mg levels, it should be supplemented by a more soluble source of Mg such as K-Mag.

Magnesium and Sulfur Recommendations

Generally, sulfur and magnesium recommendations vary from state to state. They range from no recommendation to a blanket recommendation from 10-30 lb/acre.

Most states depend on soil test results for making magnesium recommendations and a blanket recommendation for sulfur by crops.

It should be emphasized that yield goal, soil types and soil and plant analysis results should be considered in making magnesium and sulfur recommendations.

Adequate supplies of all essential plant nutrients are essential for high crop yields and profits. We should not allow magnesium and sulfur to be the limiting factors in achieving high, profitable crop yields.

Links to other sections of the EFFICIENT FERTILIZER USE MANUAL
History • MEY • Soil • pH • Nitrogen • Phosphorus • Potassium • Secondary • Micronutrients • Fluid-Dry • Sampling • Testing • Site-Specific • Tillage • Environment • Appendices • Authors