Essential Secondary Elements: Sulfur
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SULFUR (S), like calcium (Ca) and magnesium (Mg), is essential for all plants and animals and is classed as a secondary element because it is required in smaller amounts than the major elements but in much greater quantities than the micronutrients.

Deficiencies of S may occur in Michigan, although to date no well-defined localities or situations have been identified. Some predict that deficiencies are likely in the future because S levels in air and water are decreasing.

Sulfur in Animals

Sulfur is a part of every animal cell and all fluids. Feed of plant origin containing S amino acids is the major source of S. In the metabolic process, inorganic S compounds are produced and excreted. Thus, manure is likely to contain significant amounts of S.

Ruminants such as cattle, sheep and goats can utilize inorganic S. Microorganisms in the rumen convert inorganic S into S amino acids which are absorbed farther along the digestive tract.

Table 1. Total Sulfur Content of Field Crops.[1]

Crop	Yield/ acre	Total S lbs.
Alfalfa hay	4 T	19
Barley grain	80 Bu	6
Barley straw	2 T	8
Corn grain	150 Bu	10
Corn stover	4.5 T	14
Navy Bean seed	40 Bu	4
Oats grain	80 Bu	5
Oats straw	2 T	9
Potato tubers	600 Bu	8
Soybean seed	40 Bu	4
Sugarbeet roots	20 T	13
Wheat grain	60 Bu	5
Wheat straw	2 T	9

[1] *Calculated from several sources.*

Sulfur in Plants

Sulfur is also a part of every plant cell and is absorbed from soil primarily as the sulfate (SO_4^{--}) ion.[1] It moves easily within a plant and is closely associated with nitrogen (N) since both are involved in the synthesis of S amino acids. Two S amino acids, cysteine and methionine, combine with other amino acids to produce plant protein.

Sulfur is also a part of several other organic compounds of plant origin. It is present in glycosides which give the characteristic odors and flavors to mustard, onion and garlic. Since S is essential for the formation of nodules on legumes, nitrogen fixation does not occur in the absence of this element.

The S requirement of most crops is relatively low, as reported in Table 1. Even with the highest yields, crops grown in Michigan utilize less than 40 pounds per acre. The data suggest that legumes have higher S requirements than nonlegumes and that most S is associated with vegetative parts and not seed.

Chemical analysis of plant tissue provides a clue to the nutrient status of a crop. The percent S values in Table 2 represent the "sufficiency range" concept. Values outside of the range are indicative of potential problems. Values within the range are considered adequate for even the highest yield. The values shown were derived from several sources and therefore are tentative.

Procedures for precise chemical evaluations of S in any material at best are tricky. If other than recommended plant parts and sampling time are used, interpretation of test results becomes increasingly difficult.

Plant nutrient deficiency symptoms for S have been identified in Michigan only on field beans. In growth chamber and greenhouse studies, the symptoms on most crops have been similar to those of nitrogen (N) deficiency. A light green color over most of the plant is the first noticeable symptom. As the deficiency increases, yellowing of leaves at the base of a plant

[1] *An electrically charged form of the element.*

Table 2. Sulfur Sufficiency Ranges.[1]

Crop	Sampling notes	Sufficiency range percent S
Alfalfa	Above ground parts — 14 inches to bud stage	0.26 — 0.70
Barley	Above ground parts — preheading stage	0.16 — 0.75
Corn	Center section ear leaf at silking time	0.19 — 0.90
Navy beans	Most recently matured trifoliate — 30 days to bloom	0.16 — 0.80
Oats	Above ground parts — preheading stage	0.16 — 0.75
Potatoes	Most recently matured leaves — mid-season	0.16 — 0.80
Soybeans	Most recently matured trifoliate — 30 days to bloom	0.16 — 0.80
Sugarbeets	Most recently matured leaves — mid-season	0.19 — 0.60

[1] *From several sources.*

Table 3. Average Sulfate Sulfur Level in Plow Layer of Soils in Southern Michigan.[1]

Dominant profile texture	Soil management group symbol	Natural drainage conditions[2]		
		(a)	(b)	(c)
			Pounds/ acre[3]	
Clay and clay loam	1 & 1.5	23	32	23
Loam and sandy loam	2.5 & 3	16	20	38
Loamy sand and sand	4 & 5	11	13	36

[1] *For more details, refer to MSU Research Report 286.*
[2] *(a) well drained; (b) somewhat poorly drained; (c) poorly drained.*
[3] *Equivalent to 2 million pounds of soil material.*

and sometimes at the tip of leaves may be noticed. On the average, when such symptoms are observed, it is safe to assume that they are probably caused by shortages of N. Green plant tissue testing for nitrate (NO_3^-) helps to determine the cause of the symptoms.

Sulfur toxicities are unknown except when produced experimentally with nutrient solutions.

Sulfur dioxide (SO_2) may be a pollutant of the air which can cause considerable damage to vegetation. Sulfur dioxide damage bears no resemblance to symptoms of S deficiency. Interestingly, SO_2 of the atmosphere, when present in nontoxic quantities, is a source of S for plants. It is readily absorbed by leaves and rapidly converted to SO_4^{--}. In this form, it moves easily within the plant.

Sulfur in Soil

Most S in soil is in the organic form and therefore concentrated in the plow layer. Organic S is not available to plants and must be transformed into SO_4^{--} before it can be utilized. This process is microbial and progresses most rapidly in moist, well-drained, warm soils.

Several testing laboratories now have methods for evaluating SO_4^{--} levels in soil. The threshold levels used frequently in the Great Lakes area is between 12 and 14 pounds per acre. Data in Table 3 show average available SO_4^{--} levels in Michigan to be low, especially in sandy, well-drained soils. Despite this situation, recent field research with S-containing fertilizer failed to demonstrate a strong need for supplemental S.

Sulfur in Water

Very little information is available on the S content of Michigan waters. The Michigan Department of Natural Resources evaluated SO_4^{--} levels in selected streams and found great variation with years, seasons and sites. Average levels are reported in Table 4. These data illustrate that irrigation water from many streams can be a good source of S, providing that ample water is used.

Sulfur levels in pond, lake and well waters in Michigan are not well known. Thus, if there is need to know the S-supplying potential of water from a specific source, chemical analyses is advised.

Sulfur in Manure

Livestock manure is a good source of S, as suggested in Table 5. The S content of manure varies with kind, age and feeding programs. However, 10 tons of manure will generally supplement the natural supply of the soil to such an extent that S deficiencies should not develop.

Table 4. Average Dissolved Sulfate Sulfur Levels in Michigan Rivers.[1]

River	County	Dissolved sulfate ppm	Sulfur lbs. per acre foot
Sturgeon	Houghton	5.1	4.5
Escanaba	Delta	16.8	14.9
Pine	Charlevoix	22.0	19.6
Elk	Antrim	10.0	8.9
Cheboygan	Cheboygan	11.2	10.0
Thunder Bay	Alpena	12.7	11.3
Flint	Saginaw	63.0	56.0
Cass	Saginaw	81.0	72.0
Rouge	Wayne	30.0	26.7
Raisin	Monroe	81.0	72.0
St. Joseph	Berrien	43.0	38.2
Grand	Ottawa	85.0	75.6
Muskegon	Muskegon	32.5	28.9

[1] *From Michigan Department of Natural Resources, Bureau of Water Management.*

Table 5. Average Sulfur Content of Three Rates of Livestock Manure.[1]

Source	Tons of manure/acre		
	1	5	20
	Pounds of Sulfur		
Chicken — no litter	6.2	31.0	124.0
Chicken — old floor litter	3.3	16.5	66.0
Dairy Cows	1.0	5.0	20.0
Fattening Cattle	1.7	8.5	34.0
Hog	2.7	13.5	54.0
Horse	1.4	7.0	28.0
Sheep	1.8	9.0	36.0

[1] *Calculated from several sources.*

Sulfur in Municipal Sludges and Waste Water

Very little information is available on S levels in municipal sludges and waste waters. Sulfur levels of sludges from municipalities in the United States, Canada, Sweden, England and Wales ranged between 0.58 and 1.47 percent.

The information on waste waters is even more limited. Therefore, if in the future there is interest in S levels in either sludges or waste water, chemical analysis of representative samples is urged.

Carriers of Sulfur

A large number of well-known materials contain S (Table 6). Depending on the source, the S content of some materials such as gypsum may vary from the values shown. Other materials such as elemental S must be changed in form before they can be utilized by plants. With such materials, application to the soil should be made sometime in advance of planting.

Recommendations

Sulfur recommendations are not generally made for Michigan field crops because research has not demonstrated a strong need. Limited research showed that levels of available S in some soils are low. Therefore, when producing crops with high S requirements, it would be advisable to periodically use test strips across the field and evaluate the essentiality of using supplemental S. Application rates of 20 to 40 pounds of S per acre will correct a deficiency. Soluble sources of S such as potassium sulfate (K_2SO_4), potassium-magnesium sulfate ($K_2SO_4 \cdot 2MgSO_4$), magnesium sulfate ($MgSO_4 \cdot 7H_2O$), or ammonium sulfate[$(NH_4)_2SO_4$] are likely to reflect a growth response sooner than the less soluble forms such as elemental S.

Table 6. Sulfur Carriers.[1]

Carrier	Formula	% S
Ammonium sulfate	$(NH_4)_2SO_4$	23.7
Copperas	$FeSO_4$	12
Copper sulfate	$CuSO_4$	12.8
Epsom salt	$MgSO_4 \cdot 7H_2O$	14.0
Gypsum	$CaSO_4 \cdot 2H_2O$	16.8
Manganese sulfate	$MnSO_4$	14.5
Normal super phosphate	$Ca(H_2PO_4)_2 + CaSO_4 \cdot 2H_2O$	11.9
Potassium-magnesium sulfate	$K_2SO_4 \cdot 2MgSO_4$	22.0
Reax micronutrients	MPP	10.0
Sulfur, elemental	S	30–99.6
Sulfur dioxide	SO_2	50.0
Triple superphosphate	$Ca(H_2PO_4)_2$	1.4
Zinc sulfate	$ZnSO_4 \cdot H_2O$	18.0

[1] *From Fertilizer Handbook, The Fertilizer Institute.*

Summary

Sulfur is an essential secondary element for both plants and animals. Neither deficiencies nor toxicities are common in Michigan. Many Michigan soils test low in S, especially those that are sandy and well drained. Limited information suggests many streams contain significant amounts of S. Livestock manure used at the rate of 10 tons per acre usually contains enough S to satisfy the needs of a high-yielding crop. Municipal sludges and waste waters contain such variable quantities that general recommendations on its use cannot be made. Where S deficiencies are suspected, the use of 20 to 40 pounds of S per acre will correct a deficiency.

MICHIGAN REFERENCES ON SULFUR

1. Cressman, H. K. and J. F. Davis. (1962) Sources of sulfur for corn plants in Michigan and effect of sulfur fertilization on plant growth and composition. Agron. Jour. 54:341-344.
2. Janssen, K. A. and M. L. Vitosh (1974) Effect of lime, sulfur and molybdenum on N_2 fixation and yield of dark red kidney beans. Agron. Jour. 66:736-740.
3. McCool, M. M. (1920) Use of sulfur on soils. Mich. Agr. Exp. Sta. Quart. Bul. 3:26-28.
4. McCool, M. M. and C. E. Millar (1924) Fertilizers and how to use them. Mich. Agr. Col. Ext. Spec. Bul. 113.
5. Robertson, L. S. and M. L. Vitosh (1974) Recent fieldwork on cash crop yields as affected by supplemental sulfur. Mich. Agr. Exp. Sta. Res. Rpt. 265.
6. Robertson, L. S., D. L. Mokma, and D. D. Warncke (1975) Plant-available calcium, magnesium, and sulfur levels in soils used for corn production in Michigan. Mich. Agr. Exp. Sta. Res. Rpt. 286.
7. Vitosh, M. L. (1971) Sulfur response on red kidney beans. Soil Sci. Newsletter, Oct. 15. MSU.
8. Vitosh, M. L. (1973) A survey of sulfur needs in Michigan. Soil Science Newsletter. Aug. 15. MSU.

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