THE SULFUR-SUPPLYING POWER OF CERTAIN RED RIVER VALLEY SOILS

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Sulfur (S) is an essential element for the growth of plants. Sulfur deficiency in crops in the United States has increased during recent years. This has possibly resulted from: (a) the increasing use of sulfur-free fertilizers; (b) the decreasing use of sulfur as a pesticide; and (c) increasing crop yields which require greater amounts of plant nutrients (1). Little is known concerning the sulfur status of soils in the Red River Valley. Painter (6) analyzed sweet clover, brome grass and crested wheat grass forage grown at Fargo for sulfate sulfur (SO_4-S), and found that while the sweet clover contained relatively large amounts of sulfate, some of the grass samples contained no measurable amounts. Rehm and Caldwell (7) recently studied the sulfur supplying capacity of Minnesota soils, and reported that the soils of the Red River Valley, in comparison to those in the state as a whole, were intermediate in their capacity to supply sulfur to plants.

Plant analysis provides a convenient way to evaluate the sulfur supplying power of soils. According to Humbert and Ulrich (4) sulfur deficiency is unlikely if the sulfate-sulfur content of the blades of recently mature, dried sugar beet leaves exceeds 250 parts per million (ppm). These workers also indicated that sugar beet leaf blades showing sulfur deficiency contained 50 to 200 ppm sulfate-sulfur. Reports concerning levels of sulfate adequate for healthy growth of crops such as wheat and corn are sparse. Some plant testing laboratories use the total sulfur content of the ear leaf of corn as an index of sulfur status. Other researchers consider this method unsatisfactory since the amount of sulfur required is proportional not to the weight of the plant, but to the amount of organic nitrogen (N), mainly protein, to which the sulfur contributes in a fixed proportion (2). These workers suggested that the total nitrogen/total sulfur ratio provides a more reliable basis for diagnosis. When the N/S ratio becomes greater than approximately 16, protein formation is impaired. Stewart and Whitfield (8) found that if the ratio of total nitrogen/total sulfur was less than 17, wheat plants contained enough sulfur for satisfactory nutrition.

During 1967 and 1968 plant material from fertilizer and management experiments with wheat, corn and sugar beets in the Red River Valley was available for plant analysis. This report evaluates the sulfur status of these plant samples.

EXPERIMENTAL METHODS

Plant tissue samples were obtained at several growth stages from corn, grown in six field experiments in 1967 and 1968, in which enough nitrogen fertilizer was supplied to prevent nitrogen deficiency. In another experiment samples of Chris wheat also were collected at two growth stages from check and nitrogen fertilized plots. Addition of nitrogen fertilizer more than doubled the yield of grain and straw. The plant samples were dried at 70°C and analyses for total sulfur and sulfate were made (5). Total nitrogen was determined to include nitrate.

In a series of field experiments during 1968, young but fully developed sugar beets were har-

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vested in July and August. The leaves were separated into blades and petioles (leaf stems) before estimating sulfate and nitrate. Plant nitrate was determined on samples of water extracts of the finely ground material by steam distillation in the presence of Devarda's alloy and magnesium oxide (3).

RESULTS

I. Corn and wheat samples:

The plant analysis data for the corn and wheat samples are given in Table 1. The addition of nitrogen fertilizer to the Embden soil increased the nitrogen/sulfur ratio of wheat. However, all the nitrogen/sulfur ratios are markedly lower than 16. The corns samples with one exception also had nitrogen/sulfur ratios lower than 16. Of interest was the markedly higher sulfate contents of the corn growing on the Fargo soil. Corn growing on this soil in the absence of nitrogen fertilizer was not nitrogen deficient.

II. Sugar beet samples:

Data showing the sulfate contents of the blades and petioles from the July and August samplings are given in Table 2. The sulfate-sulfur contents of the blades of all samples at both harvest dates greatly exceed 250 ppm. There was a marked

Table 1: Contents of total nitrogen (N), total sulfur (S) and sulfate-S (SO_4-S) in selected plant parts of wheat and corn grown in field experiments in southeastern North Dakota during 1967 and 1968.

Soil series[1]	Crop[2]	Plant part[3]	Stage of growth	Fertilizer N, lbs/acre	Tissue composition N,%	S,%	SO_4-S, ppm	Total N / Total S
Embden	Wheat-1968-(a)	Whole plant	Early stem extension	0	3.29	0.272	700	12.1
				100	4.09	0.298	700	13.7
		Heads	Anthesis	0	1.66	0.139	450	11.9
				100	1.98	0.151	430	13.1
		Stems (minus heads)	Anthesis	0	1.55	0.140	460	11.1
				100	1.97	0.145	370	13.6
Eulin	Corn-1968-(b)	6th leaf	1-foot	100	4.15	0.283	520	14.7
			Silking	100	2.89	0.208	530	13.9
Hamar	Corn-1968-(b)	6th leaf	1-foot	100	4.11	0.295	500	13.9
			Silking	100	2.85	0.163	160	16.8
Fargo	Corn-1968-(b)	6th leaf	1-foot	100	4.28	0.419	1,760	10.2
			Silking	100	2.58	0.215	730	12.0
Gardena	Corn-1968-(c)	6th leaf	Silking	100	2.73	0.193	330	14.1
Tiffany	Corn-1967-(c)	6th leaf	Silking	100	2.94	0.208	410	14.2
		Stover	Early dent	100	0.86	0.090	380	9.9
Hecla	Corn-1967-(c)	6th leaf	Silking	100	2.29	0.151	240	15.8
		Stover	Early dent	100	0.71	0.057	150	12.4

[1]The soils in descending order were located in the vicinities of Colfax, Walcott, Wyndmere, Fargo, Barney, Barney and Colfax respectively.
[2]a, b and c refer to Chris wheat, No. Dak. Exp. B564 corn, and P.A.G. 45 corn respectively.
[3]The leaf analyzed at the silking stage was the one below and opposite the ear.

Table 2: Sulfate (SO_4) and nitrate (NO_3) contents of blades and petioles of young but fully expanded leaves of sugar beets sampled during July and August 1968.

Soil series[1]	SO_4-S, ppm July Blade	July Petiole	August Blade	August Petiole	NO_3-N, ppm July Blade	July Petiole	August Blade	August Petiole
Bearden	957	244	1,606	298	4,100	20,860	2,350	8,660
Bearden	992	233	1,504	185	4,250	19,370	2,750	8,790
Overly	870	246	1,992	245	4,900	19,850	2,040	7,660
Bearden	916	258	2,273	318	2,980	14,400	3,262	8,540
Glyndon	936	233	2,057	396	4,400	25,430	2,570	10,920
Fargo	2,261	285	6,142	628	4,087	19,082	2,349	9,549

[1]The leaves were collected from experimental plots which were adequately supplied with fertilizer N. The soils in descending order were located in the vicinities of Neche, Neche, Neche, Voss, Johnstown and Casselton respectively. The plant material from the Fargo soil was supplied by Dr. J. C. Zubriski.

tendency for the blade sulfate levels to be higher in the August sampling. This trend was not nearly so marked in the petiole samples. Nitrate, unlike sulfate, decreased during the growing season and accumulated chiefly in the petioles.

DISCUSSION

The results of the plant analysis work with corn, wheat and sugar beets suggest that 12 of the 13 soils in this investigation were providing adequate sulfur for plant growth. The corn leaves at silking from the Hamar site had a total N/total S ratio greater than 16. Several other varieties of corn grown at this site had total N/total S ratios of between 16.1 to 16.7. The sulfur supplying power of the Hamar soil needs further study.

The sugar beet blades had sulfate-sulfur contents much greater than the reported critical level of 250 ppm.[1] The higher sulfate contents at the second sampling may have resulted from the exploitation of sub-soil inorganic sulfate. Alternatively, a lower content of soil nitrate later in the growing season may have resulted in a higher proportion of the available soil sulfate entering the roots between the first and second samplings. Plant nitrate values were generally appreciably lower in August.

The petiole sulfate contents increased between the July and August samplings, but the increase was proportionately lower than that found in the blades. This suggests that the blade of the sugar beet leaf is more sensitive to changes in the availability of soil sulfur than is the petiole.

Soils contain both organic and inorganic reserves of sulfur. Plants are believed to absorb principally sulfate, and consequently the organic sulfur, like the organic nitrogen, must be mineralized before it becomes available to plants. In several of the soils in this experimental work, gypsum was observed within 4 feet of the surface. Once the roots reach the vicinity of a gypsum layer plant sulfur deficiency is unlikely to occur. The occurance of gypsum crystals in the rooting zone of many soils in North Dakota probably insures that such soils are good suppliers of sulfur to plants. Unless a soil is deficient in nitrogen it is likely to be mineralizing adequate sulfur for satisfactory plant growth (8). Large responses to nitrogen fertilizer are now being obtained in North Dakota, and the ability of the soil organic fraction to meet the plant requirements for sulfur is now somewhat questionable. Also, under a continuous cropping system some inorganic sulfur possibly is being immobilized during residue decomposition. In some areas of the U.S., large amounts of sulfur reach the soil in precipitation. However, it is extremely unlikely that any appreciable supply of sulfur enriches the soils in this manner in the rural environment of most of the Red River Valley. An exception may be the Fargo clay soil on which the corn was grown in 1968. This soil is on the main experiment station at Fargo, and sulfur levels in the rainwater there could be appreciable.

[1]The critical concentration was defined as that nutrient concentration where plant growth begins to decrease in comparison with plants above the critical concentration (4).

SUMMARY

The sulfur supplying power of 13 soils, representing 10 soil series from the Red River Valley of North Dakota was studied by means of plant analysis. Plant material (corn and wheat) growing on six of seven of the soils had total-nitrogen to total-sulfur ratios of less than 16. The blades of young but fully developed, dried sugar beet leaves growing on the other six soils contained greater than 250 ppm sulfate-S. The results were interpreted as indicating that the soils, with possibly one exception, were supplying adequate sulfur to meet the plant requirements.

The sulfate content of sugar beet leaves increased as the plants matured, and the levels were substantially higher in the leaf blades. In contrast, the nitrate content of the leaves decreased with increasing maturity, and the accumulation was greater in the petiole portion of leaves.

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