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Effect of SO_4-S Fertilization on Se Concentration of Alfalfa (*Medicago sativa* L.)[1]

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ABSTRACT

Selenium is not required for plant growth, but is necessary for the prevention of white muscle disease and other low-Se related animal disorders. Areas in the Pacific Northwest that produce forages low in Se are nearly identical to those known to be S deficient. While SO_4-S has been shown to inhibit SeO_4-Se uptake by plants, the effect of S fertilization on Se uptake by plants growing on low-Se soils where other forms of Se may exist has not been evaluated. This was examined on eight alfalfa (*Medicago sativa* L.) experimental sites where S fertilization was a variable in southern Idaho. Yields were measured, and plant samples were taken from the first harvest of alfalfa (0.1 bloom) and analyzed for total Se and S, and Se uptake.

Sulfur fertilization significantly reduced forage Se concentrations at four of the eight experimental sites. Forages at seven sites contained less than 0.1 ppm Se before S fertilization, which was further reduced by the S fertilization. The decrease in Se concentration mainly reflected a dilution effect caused by a growth response to the S fertilization. No direct relationship was apparent between forage Se and S levels. This study showed that S fertilization of S-deficient, low-Se soils to increase forage production may increase the incidence of Se deficiency in animals. Thus ranchers, cattlemen, and agronomists should become aware of this potential problem and provide protective measures against Se deficiency in their livestock.

Additional index words: **S deficiency, Animal nutrition, Se uptake.**

CONSIDERABLE evidence has accumulated in the last decade that dietary Se is required to prevent white muscle disease in livestock (2, 10, 18). Minimal dietary Se concentrations range from 0.03 to 0.10 ppm Se, depending upon vitamin E level, sulfulamino acids, and antioxidants. Some investigators have suggested 0.10 ppm Se in dry forages as a minimal safe level for preventing white muscle disease and other low Se-related disorders, whereas dietary Se levels above 3 to 5 ppm are toxic to livestock.

Factors influencing Se uptake by plants are: 1) plant species, 2) chemical forms of Se present, 3) soil physical and chemical factors, and 4) interaction with other ions, particularly S. Early work by Hurd-Karrer (11, 12) showed that S compounds decreased Se uptake by promoting increased S uptake. Later studies showed that SO_4-S strongly inhibited SeO_4-Se absorption and partially inhibited SeO_3-Se absorption (15, 20). These findings have been used in numerous attempts to reduce Se toxicity to plants and animals on seleniferous soils (16, 23).

An additional aspect of the S-Se antagonism is the possible effect of S fertilization on Se uptake by plants growing on soils low in available Se. Gissel-Nielsen (9) showed that plant uptake of applied Se was highest where a fertilizer low in S was used. In the Pacific Northwest, the areas of S deficiency (4) are nearly the same as those that produce forages containing less than 0.10 ppm Se (6, 8). To evaluate the effect of S fertilization on the Se concentration of forages, we collected alfalfa (*Medicago sativa* L.) samples from a S fertilization study in progress and analyzed them for Se (22).

METHODS AND MATERIALS

The experimental sites were located in mountain valleys in the Idaho counties of Camas, Custer, and Teton. These valleys are at elevations of 1520 to 1850 m, have 60 to 90 frost-free days, and receive 180 to 380 mm of annual precipitation, mostly as snow. Soils are acid to slightly alkaline and formed from a variety of parent materials. The soil series, suborder classification, and some physical and chemical characteristics of the 0 to 30-cm soil layers for each of the experimental sites are shown in Table 1. Soil pH was determined with a glass electrode on a saturated soil paste and organic matter was determined by the method of Walkley and Black (21). Soil SO_4-S was extracted by 0.1 *M* LiCl and determined by the methylene-blue reduction method (13). Plant available soil Se was not determined; however, these areas have been identified as producing forages low in Se (8). Experiment 6, 7, and 8 were sprinkler irrigated; the remainder were not, although moisture was not limiting for the first harvest.

Sulfur was applied as gypsum (Table 2) the fall before sampling on the nonirrigated sites and in the spring of the sampling year on the irrigated sites. Forage samples were obtained and yields were measured from the first harvest at 0.1 bloom.

Table 1. Selected soil physical and chemical characteristics of the 0 to 30-cm soil layer for each experimental site.

Site No.	Series	Suborder classification	pH	Organic matter	SO_4-S
				%	ppm
1	Riceton l	Typic Argixeroll	5.6	2.01	2.46
2	Simonton l	Typic Argixeroll	5.8	1.52	0.50
3	Simonton gl	Typic Argixeroll	5.6	1.38	1.59
4	Riceton l	Typic Argixeroll	5.5	1.69	2.08
5	Riceton l	Typic Argixeroll	5.6	1.80	0.85
6	Gini gl	Typic Haplargid	7.4	1.42	2.34
7	Bereniceton sil	Xeric Torriorthent	7.6	2.98	6.62
8	Tetonia sil	Pachic Cryoboroll	6.4	2.38	1.54

Table 2. Effect of SO_4-S fertilization on dry matter yields, Se concentrations and uptake, and S concentration of alfalfa.

Experimental site No.	Fertilizer SO_4-S	Forage yield	Forage composition: Se		Forage composition: S
	kg/ha	mt/ha	ppm	mg/ha	%
1	0	2.46 a*	0.079 a*	194 a*	0.112 a*
	34	3.47 a	0.018 b	62 b	0.195 b
2	0	0.31 a	0.080 a	25 a	0.068 a
	22	2.02 b	0.055 a	111 b	0.184 b
3	0	1.16 a	0.051 a	58 a	0.070 a
	45	4.21 b	0.026 b	109 b	0.156 b
4	0	3.90 a	0.022 a	86 a	0.142 a
	22	4.37 a	0.025 a	109 a	0.216 b
5	0	1.81 a	0.032 a	58 a	0.065 a
	22	3.83 b	0.023 b	88 ab	0.116 b
	67	5.56 c	0.019 b	106 b	0.175 c
6	0	4.21 a	0.163 a	686 a	0.186 a
	34	4.61 a	0.108 b	496 a	0.229 a
7	0	4.46 a	0.087 a	388 a	0.221 a
	34	4.90 a	0.114 a	558 a	0.229 a
8	0	2.20 a	0.024 a	54 a	0.098 a
	22	3.83 b	0.011 a	42 a	0.234 b
	67	3.90 b	0.020 a	78 a	0.264 b

* Means followed by same letter within an experiment are not significantly different at the 0.05 level.

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The plant samples were oven-dried at 55 C, ground, and analyzed for Se (1) and S (19). All plant data are given on an oven-dried basis and are the averages of four replications. Other essential nutrient elements were maintained at adequate levels.

RESULTS AND DISCUSSION

The Se concentrations in the alfalfa ranged from very low to adequate levels for animal nutrition (Table 2). Using 0.10 ppm as the minimal concentration of Se in forages required for normal animal nutrition, forages from seven of the eight experimental sites were low enough to cause possible Se deficiencies in animals, and of these, forages from three sites contained less than 0.05 ppm Se before S fertilization. Only the alfalfa from site 6 had an adequate level of Se for animal nutrition using this criteria. Sulfur fertilization significantly reduced the Se concentration in four experiments. This reduction was independent of the initial Se concentration. There was a nonsignificant increase in Se concentration from S fertilization on site 7. An earlier study showed that SO_4-S increased Se concentration in alfalfa on a low Se alkaline soil well-supplied with SO_4-S (7). A similar mechanism may be operative here.

Sulfur fertilization tended to increase total Se uptake (mg/ha) on all sites except 1 and 6 (Table 2). Factors responsible for this difference may include a greater proportion of SeO_4-Se forms and a lack of plant-available forms of Se in soil horizons below the zone of SO_4-S enrichment on sites 1 and 6. Most of the decrease in the Se concentration resulted from a dilution effect since yields were generally increased by S fertilization. However, the dilution effect appears to have been modified by increased root growth in areas of plant-available Se and by SO_4-S inhibition of Se absorption.

No relationship was shown between plant S and Se levels. However, there may be a relationship on a given site, but no conclusions can be drawn from our limited data. Also, there were no apparent relationships between plant Se levels and soil textures or organic matter levels. Plant Se levels were higher at the higher soil pH's, particularly at sites 6 and 7. Selenate forms of Se are favored by higher pH's and are absorbed by plants in greater amounts than selenite forms (5), which may partially account for the greater amounts of Se in the forages on these two sites. In addition, the level of plant-available Se may be naturally higher in these soils or may have been altered by past P fertilization practices (17).

Our data help explain earlier observations that the incidence of white muscle disease was higher in areas where gypsum was being applied to increase forage yields (10, 18). Also of possible concern is the relative level of S compared to that of Se in forages. Studies have shown that high dietary S levels may interfere with the biological availability of Se (3). While most of the reported studies were not with indigenous S, the increased level of plant S resulting from S fertilization may aggravate the problem of low Se levels in animal nutrition.

The data presented in this paper indicate that S fertilization of low-Se soils sometimes reduces the Se levels in forages. Extensive areas in the northeastern and southeastern Coastal States have been shown to produce forages generally low in Se (14) and many of these areas are known to require S fertilization for maximum yields (4). The summer grazing areas at the higher elevations in he Pacific Northwest are also low in Se (8). Sulfur ferilization to increase forage yields on these areas or on areas of winter feed production may increase the incidence of Se deficiency in livestock. Livestock managers should therefore be aware of possible Se deficiencies in young livestock and provide for protective measures.

LITERATURE CITED

1. Allaway, W. H., and E. E. Cary. 1964. Determination of sub-microgram amounts of selenium in biological materials. Anal. Chem. 36:1359-1362.
2. ———, ———, and C. F. Ehlig. 1967. The cycling of low levels of selenium in soils, plants and animals. p. 273-296. *In* Selenium in biomedicine. A.V.I. Publ. Co., Inc., Westport, Conn.
3. Ammerman, C. B., and S. M. Miller. 1972. Biological availability of minor mineral ions: A review. J. Anim. Sci. 35: 681-694.
4. Beaton, J. D., S. L. Tisdale, and J. Platou. 1971. Crop responses to sulphur in North America. Sulphur Inst. Tech. Bull. 18, Washington, D. C. 39 p.
5. Bisbjerg, B., and G. Gissel-Nielsen. 1969. The uptake of applied selenium by agricultural plants. I. The influence of soil type and plant species. Plant Soil 31:287-298.
6. Carter, D. L., M. J. Brown, W. H. Allaway, and E. E. Cary. 1968. Selenium content of forage and hay crops in the Pacific Northwest. Agron. J. 60:532-534.
7. ———, ———, and C. W. Robbins. 1969. Selenium concentrations in alfalfa from several sources applied to a low selenium, alkaline soil. Soil Sci. Soc. Amer. Proc. 33:715-718.
8. ———, C. W. Robbins, and M. J. Brown. 1970. Selenium concentrations in forage on some high Northwest ranges. J. Range Manage. 23:234-238.
9. Gissel-Nielsen. 1971. Selenium content of some fertilizers and their influence on uptake of selenium in plants. J. Agr. Food Chem. 19:564-566.
10. Hartley, W. J., and A. B. Grant. 1961. A review of selenium responsive diseases of New Zealand livestock. Fed. Proc. 20:679-688.
11. Hurd-Karrer, A. M. 1934. Selenium injury to wheat plants and its inhibition by sulphur. J. Agr. Res. 49:343-357.
12. ———. 1935. Factors affecting the absorption of selenium from soils by plants. J. Agr. Res. 50:413-427.
13. Johnson, C. M., and H. Nishita. 1952. Micro-estimation of sulfur in plant materials, soils, and irrigation waters. Anal. Chem. 24:736-742.
14. Kubota, J., W. H. Allaway, D. L. Carter, E. E. Cary, and V. A. Lazar. 1967. Selenium in crops in the United States in relation to selenium-responsive diseases of animals. J. Agr. Food Chem. 15:448-453.
15. Leggett, J. E., and E. Epstein. 1956. Kinetics of sulfate absorption by barley roots. Plant Physiol. 31:222-226.
16. Ravikovitch, S., and M. Margolin. 1959. The effect of $BaCl_2$ and $CaSO_4$ in hindering selenium absorption by lucerne. Emp. J. Exp. Agr. 27:235-240.
17. Robbins, C. W., and D. L. Carter. 1970. Selenium concentration in P fertilizer materials and associated uptake by plants. Soil Sci. Soc. Amer. Proc. 34:506-509.
18. Schubert, J. R., O. H. Muth, J. E. Oldfield, and C. F. Remmert. 1961. Experimental results with selenium in white muscle diseases of lambs and calves. Fed. Proc. 20:689-694.
19. Tabatabai, M. A., and J. M. Bremner. 1970. A simple turbidimetric method of determining total sulfur in plant materials. Agron. J. 62:805-806.
20. Ulrich, J. M., and A. Shrift. 1968. Selenium absorption by excised *Astragalus* roots. Plant Physiol. 43:14-20.
21. Walkley, A., and I. A. Black. 1934. An examination of the Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. Soil Sci. 37:29-38.
22. Westermann, D. T., and S. E. Crothers. 1972. Sulfur fertilization of alfalfa in the mountain valleys of southern Idaho. Ann. Pac. NW Fert. Conf., Proc. 23rd. p. 115-125.
23. Williams, C., and I. Thornton. 1972. The effect of soil additives on the uptake of molybdenum and selenium from soils from different environments. Plant Soil 36:395-406.