SULFUR FERTILIZATION OF ALFALFA IN THE MOUNTAIN VALLEYS OF SOUTHERN IDAHO[1/]

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Areas of S deficiency are still being identified in the Pacific Northwest even though S has been applied to some soils in this region for at least 50 years. Recent studies dealing with the S fertilization of legumes for the Northwest have been conducted by Pumphrey and Moore (1965a, 1965b) in northeastern Oregon; Smith, et al., (1968) in western Montana; Dawson (1969) on pasture legumes in western Oregon; and Koehler (1965), and Roberts and Koehler (1968) in Washington.

Plant and soil analyses both can be used for predicting S deficiencies. Critical levels of total S concentrations ranging from 0.20 to 0.24 percent have been established for alfalfa (Pumphrey and Moore, 1965b; Smith, et al., 1968; and Ensminger and Freney, 1966). Several procedures have been proposed and evaluated for estimating the available S status of soils (Spencer and Freney, 1960; Williams and Steinberg, 1959; Ensminger and Freney, 1966; and Roberts and Koehler, 1968). In general, the water-soluble SO_4-S in soils has not been a good index of crop yield or S uptake because of changes in SO_4-S levels resulting from air-drying and the inability of water to replace adsorbed SO_4-S. Significant correlations have been obtained between the SO_4-S extracted by a 500 ppm P — KH_2PO_4 solution and plant growth or S uptake in greenhouse studies (Spencer and Freney, 1960; Fox, et al., 1964). However Fox, et al. (1964) indicate little reason to choose either water or a P-solution for extracting SO_4-S from relatively unweathered soils. This would indicate that very little adsorbed SO_4-S was present in these soils.

Exploratory studies identified S deficiency as a major factor limiting forage production in some of the mountain valleys of southern Idaho. Field experiments were established to evaluate soil and plant S levels and the need for S fertilization.

METHODS AND MATERIALS

Sixteen experiments were established on existing alfalfa stands in Camas, Custer, and Teton Counties of Idaho from the fall of 1969 to the spring of 1971. The experiments in Custer and Teton Counties were sprinkler-irrigated, whereas those in Camas County were nonirrigated. Soil samples were taken by one-foot increments to a three-foot depth where possible when each experiment was begun. In general, the alfalfa was not actively growing at the time of

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soil sampling. The soil samples were air-dried, sieved through a 2-mm sieve, and extracted for 30 minutes with 0.0322 M KH_2PO_4 (500 ppm P) in a 1:3 soil:solution ratio. The SO_4-S in the soil extracts was determined by the methylene blue method of Johnson and Nishita (1952). The ranges and average concentrations of SO_4-S for the respective soil depths are shown in Table 1.

Table 1. Ranges and average concentrations of KH_2PO_4-extractable SO_4-S by soil depth and county (1969-1971).

Idaho County		SO_4-S at soil depths of: 0 - 12 in.	13 - 24 in.	24 - 36 in.
		ppm		
Camas (11)*	Range	1.5 - 3.1	0.8 - 2.1	0.8 - 2.7
	Average	2.2	1.2	1.3
Custer (2)*	Range	4.3 - 7.4	1.4 - 5.9	---
	Average	5.8	3.6	(20)
Teton (3)*	Range	2.7 - 3.0	1.2 - 1.8	---
	Average	2.9	1.6	---

* Number of experimental sites

Fertilizer treatments were broadcast on the surface at the beginning of each experiment. Sulfur was applied as gypsum at rates of 20 to 60 lbs S per acre. Each experiment also contained P and K fertilizer variables; however no yield responses were measured from either.

Forage yields were measured and samples for chemical analyses were taken at 0.1 bloom. All irrigated experiments were harvested twice and the nonirrigated experiments once. The plant samples were oven-dried at 60° C, ground, and wet-ashed. Total S was determined turbidimetrically on the plant digests according to Chesnin and Yien (1950), as modified by Tabatabai and Bremner (1971). Total N, including NO_3-N, was determined by micro-Kjeldahl (Bremner, 1965).

RESULTS AND DISCUSSION

Sulfur fertilization increased forage yields on 11 out of 16 experimental sites. Yields were lowest in Camas County, and many sites were extremely S deficient. Poor stands were common and accounted for most of the low yields where nutritional needs were adequate, e.g., Camas-305 (Table 2) as compared with Camas-311 where the stand was satisfactory. Yields were greater in Custer and Teton Counties because two cuttings were harvested. Only one cutting was obtained from Teton-317 because of an early harvest by the grower.

Table 2. Effect of S fertilization on alfalfa forage yields in selected experiments (1970-71).

Location	Soil SO_4-S (0-12 in.)	Year	Alfalfa Yield — S fertilization (lbs S/A) 0	20	30	40	60
	ppm		T/A				
Camas-304	1.7	1970	0.66	0.87	--	--	--
		1971	1.46	1.67	--	--	--
Camas-305	2.2	1970	0.14	0.90	--	--	--
Camas-309	1.5	1970	0.42	--	--	0.75	--
		1971	0.52	--	--	1.88	--
Camas-311	1.9	1971	0.81	1.71	--	--	2.48
Custer-315*	7.4	1971	4.01	--	4.02	--	--
Teton-317	2.9	1971	1.01	1.71	--	--	1.71
Teton-318*	3.0	1971	3.69	4.27	--	--	4.03

* Two cuttings

The relative yield of forage [(yield without S ÷ yield with S) × 100] versus the SO_4-S extracted by the P-solution from the top 12 inches of soil (Figure 1) indicated that 4 ppm of SO_4-S was required for a yield potential of 90% of maximum. In the 14 experiments that had a SO_4-S soil test level below 4 ppm, three failed to respond significantly to S fertilization. The regression relationships did not change when the SO_4-S extracted to 36 inches was included, but it did increase the SO_4-S level required for a 90% relative yield by approximately 2 ppm SO_4-S (8 lbs SO_4-S/acre) with each additional 12-inch increment (Figure 2).

The relationship between the P-extractable SO_4-S in the top 12 inches and the total S uptake by the first cutting is shown in Figure 3. Increasing amounts of S were taken up as the SO_4-S soil test level increased. This reflected both increased growth and S concentration in the plant. Including the SO_4-S extracted to 36 inches did not improve this relationship but gave regression curves similar to those shown in Figure 2. It appears that the P-solution extracted more SO_4-S than was available for plant growth, since 2 ppm SO_4-S is equivalent to approximately 8 lbs SO_4-S per acre-foot of soil.

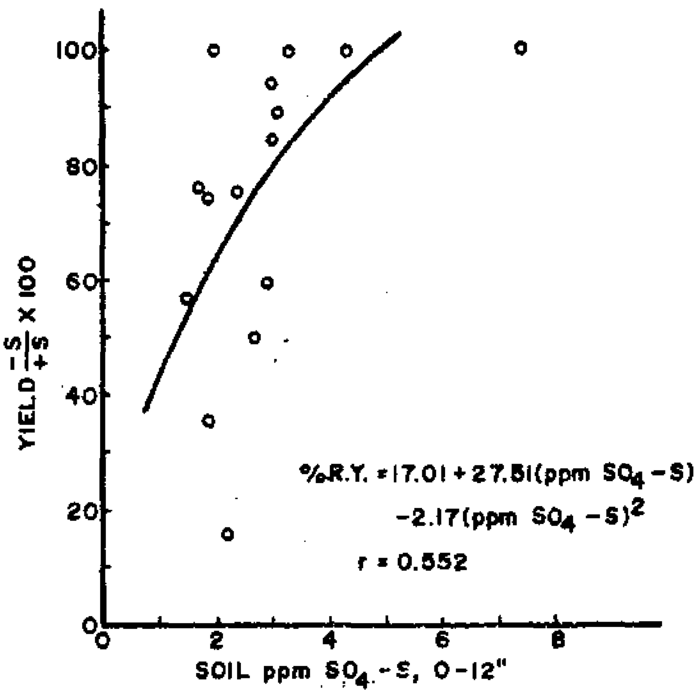

Fig. 1. The relationship between 0.0322 M KH_2PO_4 extractable soil SO_4-S and relative yield of alfalfa [(yield without S ÷ yield with S) × 100]. Significant at the 5% level.

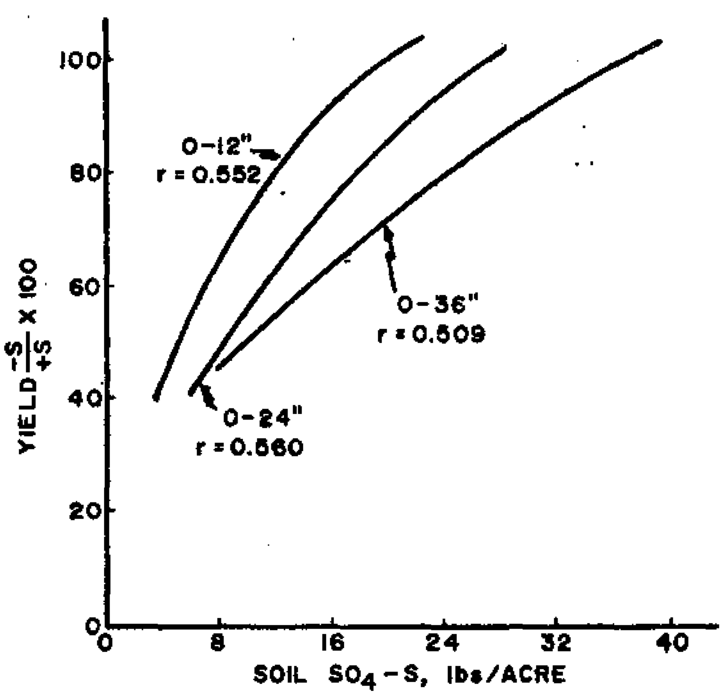

Fig. 2. The calculated regression curves for the relationships between 0.0322 M KH_2PO_4 extractable soil SO_4-S for the indicated soil depths and the relative yield [(yield without S ÷ yield with S) × 100].

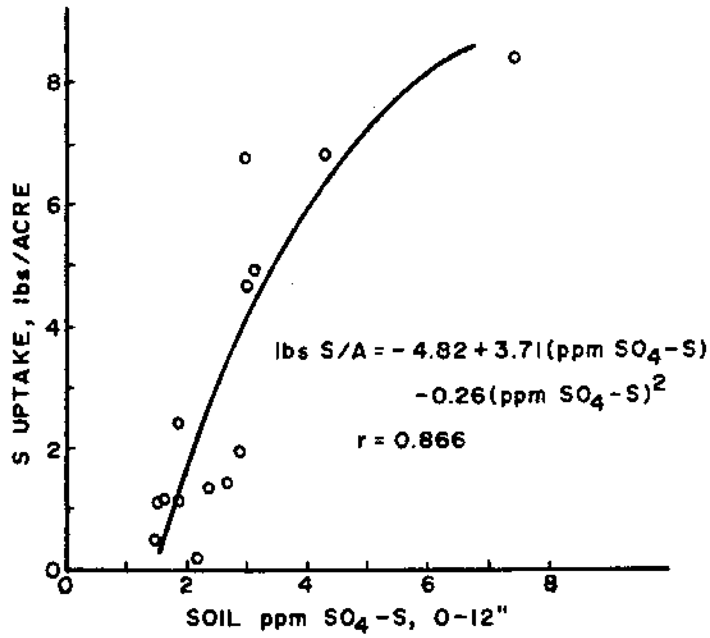

Fig. 3. The relationship between 0.0322 M KH_2PO_4 extractable soil SO_4-S and total S uptake per acre by first cutting of alfalfa. Significant at the 1% level.

The S concentration in the tops at 0.1 bloom was also related to the relative yield (Figure 4). The regression curve indicates that no response to S fertilization is expected when the S concentration in the tops is greater than 0.20 percent. This value agrees with other published data for a critical S concentration for alfalfa (Punphrey and Moore, 1965b; Ensminger and Freney, 1966).

There was also a significant relationship between the P-extractable SO_4-S in the top 12 inches of soil and the percent S in the alfalfa tops at 0.1 bloom (Figure 5). A value of 5 ppm soil SO_4-S was required to produce alfalfa that contained 0.2% S. This is nearly identical with that required for 100% relative yield in Figure 1, as determined by the regression equation, adding confidence to the latter relationship.

In all cases where there was a yield increase from S fertilization, the N concentration in the plants was also increased (Table 3). Limited data suggest that the concentration of N does not increase after the S concentration reaches 0.20%. Similar results have been reported by Pumphrey and Moore (1965a) and Sorenson, et al. (1968).

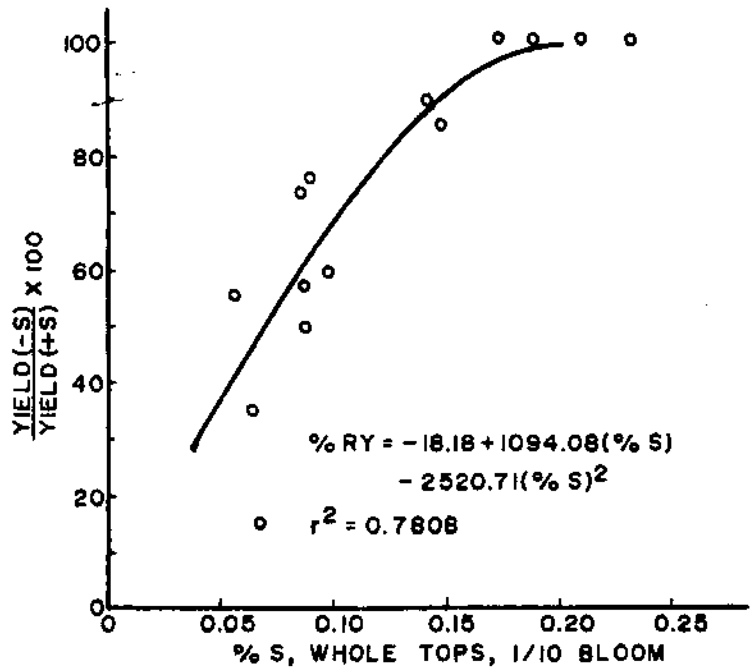

Fig. 4. The relationship between S percentage at 0.1 bloom of the first cutting and the relative yield of alfalfa [(yield without S ÷ yield with S) × 100]. Significant at the 1% level.

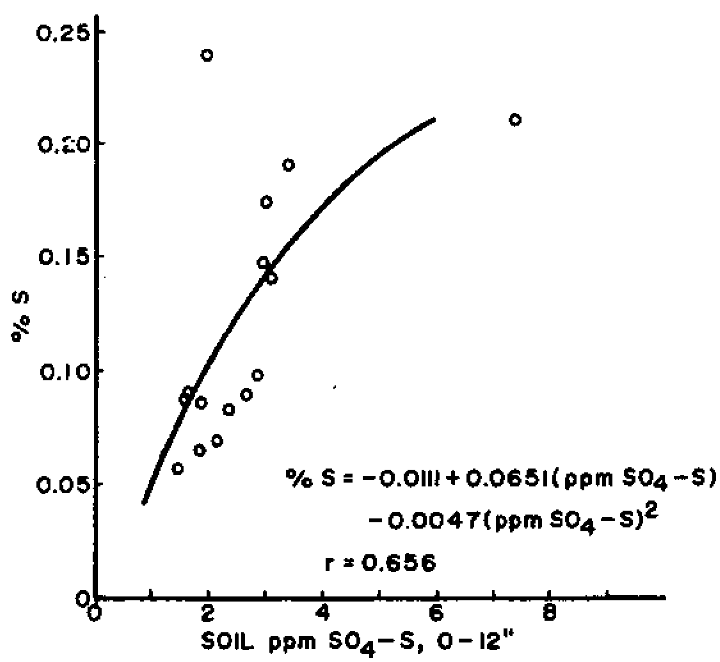

Fig. 5. The relationship between 0.0322 M KH_2PO_4 extractable soil SO_4-S and S percentage at 0.1 bloom. Significant at the 1% level.

Table 3. Effect of S fertilization on N percentage of alfalfa tops at 0.1 bloom in selected experiments (1st cutting only, 1970-71).

		N in alfalfa at S - - -Fertilization rates (lbs S/A)- - -			
Location	Year	0	20	40	60
		%			
Camas-309	1970	3.06	--	3.41	--
	1971	2.23	--	2.51	--
Camas-311	1971	2.45	2.86	--	3.10
Teton-317	1971	2.38	3.11	--	3.05

The rate of S fertilization required for maximum yields depended on year and location. In Camas-304, the plant analysis (Table 4) indicates that 20 lbs S per acre applied in the fall of 1969 was adequate for maximum yields in 1970, whereas 60 lbs S per acre applied in the fall of 1970 was necessary for maximum yields in 1971 in Camas-311. Plant analysis also indicates that S was limiting yields the second year after S application in both Camas-309 and Camas-304 (Table 4). In Teton County, maximum yields were obtained with 20 lbs S per acre on both locations (Table 2) with similar soil test levels; however, there was a greater yield increase in Teton-317 as compared to Teton-318. This difference was largely due to approximately twice as much SO_4-S in the irrigation water applied on Teton-318.

Table 4. Effect of S fertilization on S percentage of alfalfa tops at 0.1 bloom in selected experiments (1st cutting only, 1970-71).

		S in alfalfa at S - - -Fertilization rates (lbs S/A)- - -			
Location	Year	0	20	40	60
		%			
Camas-304	1970	0.09	0.19	--	--
	1971	0.07	0.10	--	--
Camas-309	1970	0.06	--	0.21	--
	1971	0.07	--	0.16	--
Camas-311	1971	0.06	0.12	--	0.18
Teton-317	1971	0.10	0.23	--	0.26

The soils in Camas and Teton Counties are generally susceptible to leaching because of their coarse textures and the large amounts of water moving through the rooting zone in the spring from melting snow. This distributes the SO_4-S throughout the profile as shown in Table 1. Consequently, the S released from organic matter decomposition in the surface layer or added in the irrigation water is the main source of S available to the crop. In contrast, SO_4-S has accumulated at the lower depths of the soils sampled in Custer County because of a lower annual precipitation.

Sulfur available for plant growth may be obtained from several sources such as rainfall, irrigation water, fertilizers, pesticides, and direct absorption from the atmosphere. Contributions from the rainfall and atmospheric sources are low in most of the mountain valleys because of a lack of industry and dense population centers. In addition, most of the irrigation sources contain very little SO_4-S in these areas. Not more than 3 ppm SO_4-S was measured in the irrigation waters used in either Custer or Teton Counties, compared to 14 ppm SO_4-S in the Snake River water at the Milner Diversion for the Twin Falls Irrigation Tract (Carter, 1972).

CONCLUSION

Sulfur fertilization studies on established stands of alfalfa have been conducted the past two years in the southern Idaho counties of Camas, Custer and Teton. Sulfur fertilization increased yields in 11 out of 14 experiments where the P-extractable SO_4-S in the top 12 inches was less than 4 ppm. The S concentration in the plant and the total S uptake at 0.1 bloom was significantly related to the soil SO_4-S. Sulfur fertilization was not beneficial when the plants contained more than 0.20% S in the tops at 0.1 bloom. This critical level agrees with other published data. All sources of S available for plant growth need to be considered when interpreting SO_4-S soil test values and crop response to S fertilization.

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