

Uptake and utilization of sulfur by range clovers are increased by sulfur fertilization but may be limited by low temperatures, according to controlled-environment tests. If the level of available sulfur in the soil is low, higher temperatures do not appear to aid in plant uptake of sulfur. A form of sulfur with a high degree of availability would be best for greatest plant response in warm spring months—although leaching losses may occur in the event of excessive rainfall. Uptake and utilization of fertilizer sulfur was notably greater for subterranean clover than for rose clover.

Temperature effects on utilization of

SULFUR FOR RANGE CLOVERS

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GERMINATION AND GROWTH of annual range plants are usually rapid after the first substantial rain in the fall, but as the temperature drops, plant growth slows notably. Nitrogen fertilizer applications have been shown to increase forage production under cool growing conditions. Phosphorus fertilization may help to increase growth and stimulate some annual legumes at relatively low growth temperatures. However, application of sulfur fertilizer has not resulted in rapid plant responses.

Sulfate sulfur not taken up by plants is subject to considerable leaching in years of above-average rainfall, particularly on coarse-textured soils. A common recommendation in Australia is to use different sources of sulfur under different rainfall conditions: elemental sulfur for high-rainfall areas to avoid leaching losses and give longer carryover; and gypsum in low-rainfall areas where leaching is less of a problem and relatively fast availability is desired.

Since most of the leaching of sulfur occurs during the rainy winter months, when both temperatures and plant growth rates are low, this study was designed to determine the effect of temperature on sulfur uptake and the efficiency with which legume species take up sulfur. Rose clover (*Trifolium hirtum* All.) and subterranean clover (*T. subterraneum* L.) were used in the study because they are recommended for reseeding sulfur-deficient annual rangelands in California. Previously germinated seeds were planted in No. 2 cans filled with Vista sandy loam—a soil that has shown a sulfur response in field tests—at a rate of eight plants per can. Thirty-six cans were planted with each species.

Clovers were grown for 35 days in the uniform environment of a plant growth

chamber set for a 14-hour daylength; temperature at 65°F; light intensity of 1000 foot-candles at plant height; and relative humidities of 55 to 70% during the light period and 85 to 95% in the dark period. During the entire study plants were weighed and irrigated to the calculated field capacity—on alternate days at first and daily when plants became larger.

At the end of the preliminary growth period, clover plants of each species were randomized into three groups and placed in separate growth chambers set at 50, 60 and 70°F. The photoperiod and light intensity remained at 14 hours and light intensity at 1000 foot-candles. Replicate positions were maintained in the same relative location in each growth chamber. After soil temperatures matched the growth-chamber air temperature, sulfur fertilizer was applied at 5, 20 and 80 pounds per acre. (Sulfur was added as 100 ml of appropriate strength K_2SO_4 solution plus 2 microcuries of S^{35} -labeled H_2SO_4 in HCl solution.) The daily irrigations served to further distribute the applied sulfate through the soil in the cans.

Analysis

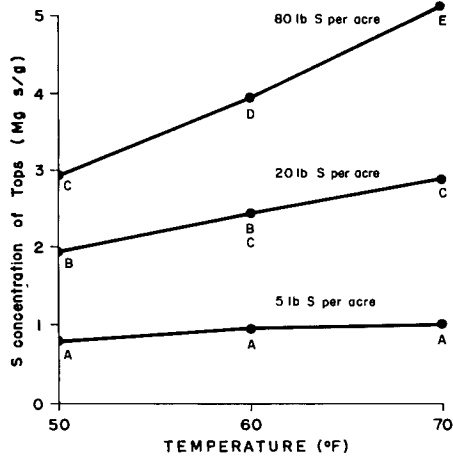
Plants were removed from the three growth chambers after 10 days and harvested. Roots were washed free from the soil, both tops and roots were oven dried for 48 hours, weighed on an analytical balance and analyzed in the radioisotope laboratory for fertilizer sulfur content. Tops and roots were wet-ashed by nitric-perchloric digestion, evaporated to near dryness, and then brought to a uniform volume of 100 cc with distilled water.

After thorough shaking, 2-ml aliquots were pipetted into planchets, and dried for counting with an internal gas-flow counter. Gross counts were adjusted for background, coincidence loss, and self-absorption.

During the 10-day period the clover plants were in the three growth chambers, temperature was the only factor that significantly altered the yield of tops and roots (see table). The top yield at 60°F was 19% greater than at 50°F. This increase was significant. However, the top yield at 70°F was only 11 per cent greater than the yield at 60°F and not significant. Root yields increased 31 per cent from 50 to 60°F, a significant amount, but when grown at 70°F there was 7 per cent less weight than at 60°F. There were no significant differences between the two species in top or root weights.

Concentration in tops

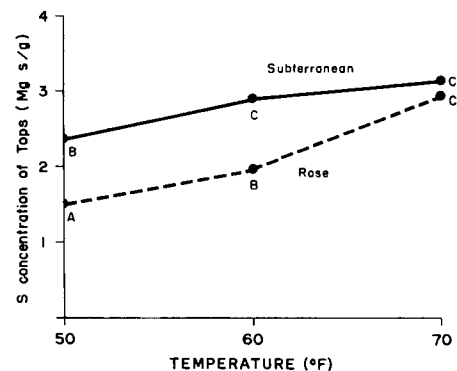
The concentration of fertilizer sulfur in the tops of the two clovers was significantly affected by temperature, sulfur fertility rates, and the interaction of temperature and sulfur rates (see graph 1). At the lowest sulfur fertility rate, the concentration of fertilizer sulfur was near 1 mg per gram of tissue at each temperature. The fertilizer sulfur content of plants fertilized at the 20-lb-sulfur-per-acre rate was 1.97 mg of sulfur per gram of tissue at 50°F and increased linearly with increasing temperature. The greatest effect of temperature on fertilizer sulfur concentration occurred with plants fertilized at the rate of 80 pounds of sulfur per acre. At 50°F the fertilizer sulfur con-



Graph 1. Concentration of sulfur in clover tops from applied sulfate as a function of temperature and sulfur-fertilization rates. Points with the same letter do not differ significantly at the .05 level.

centration was 2.94 mg per gm of tissue and increased linearly to 5.11 mg per gram at 70°F.

At lower temperatures, differences in sulfur concentration were noted between species (see graph 2). Subterranean clover had approximately 2 mg more fertilizer sulfur per gram of tissue at 50 and 60°F than rose clover. At 70°F the uptake of fertilizer sulfur by rose clover was equal to the concentration found in subterranean clover.



Graph 2. Concentration of sulfur from applied sulfate in subterranean and rose clovers at 50, 60 and 70°F. Points with the same letter do not differ significantly at the .05 level.

Concentration in roots

A greater amount of variability was observed in the data for fertilizer sulfur concentration in the roots than in the tops. Each increase in sulfur rate (5 to 20 to 80 lbs per acre) increased the concentration of fertilizer sulfur in the roots approximately 3 mg per gram of root tissue. Subterranean clover contained an average of 6.9 mg of fertilizer sulfur per gram of root tissue as compared with an average of 4.10 for rose clover.

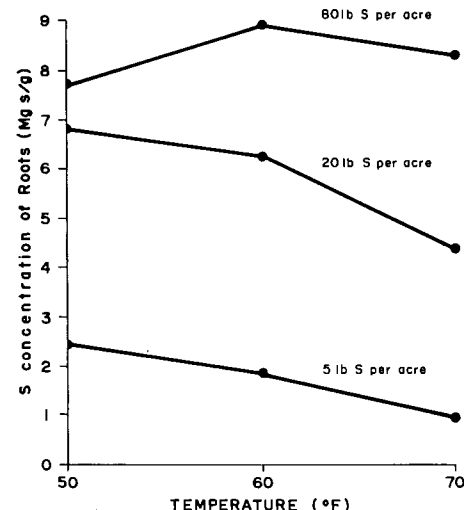
AVERAGE YIELDS OF TOPS AND ROOTS OF *T. HIRTUM* AND *T. SUBTERRANEUM* CLOVERS GROWN FOR 10 DAYS AT 3 TEMPERATURES AND 3 SULFUR LEVELS

Species and sulfur rate per acre	Top weight (g/pot) at			Root weight (g/pot) at		
	50°	60°	70°	50°	60°	70°
<i>T. hirtum</i>	5	.39	.44	.36	.20	.32
	20	.36	.43	.50	.18	.28
	80	.38	.44	.57	.25	.29
<i>T. subterraneum</i>	5	.33	.46	.47	.19	.26
	20	.35	.45	.55	.17	.27
	80	.40	.49	.51	.24	.29
Average for both species		.37	.44	.49	.20	.29
LSD .05 level for temperature		Tops .07		Roots .05		

The concentration of fertilizer sulfur in root tissue was influenced by temperature in a non-linear order. Concentrations were 5.65 at 50°F, 5.97 at 60°F, and 4.86 mg per gram of root tissue at 70°F. The decrease in concentration between 60 and 70°F occurred at each sulfur fertility rate, as shown in graph 3. Thus, the concentration of fertilizer sulfur in the clover roots decreased instead of increasing with higher temperatures, as observed in the tops. Subterranean clover took up more total fertilizer sulfur per plant (both tops and roots) than rose clover during the 10-day period from fertilization to harvest. Subterranean clover plants accumulated an average of 5.05 mg of fertilizer sulfur as compared with 2.09 for rose clover. High temperature apparently slowed the rate of uptake since the average fertilizer sulfur uptake at 50°F was 1.88 mg; at 60, 2.81; and at 70, 2.87 mg.

Relation to field conditions

This study indicates that sulfur uptake and utilization by legumes is increased by sulfur fertilization but may be limited by low temperatures. Under field condi-



Graph 3. Concentration of sulfur from applied sulfate in clover roots as a function of temperature and sulfur-fertilization rates.

tions, it would appear that the change in weather from cool winter to warm spring brings about an increase in the concentration of sulfur in clover tops—along with increased growth at the higher temperatures. As temperature increases, the translocation of fertilizer sulfur from roots to tops increases more than total uptake and may lead to a decrease in fertilizer sulfur concentration in roots.

Subterranean clover not only took up a greater total amount of fertilizer sulfur than rose clover but also had a higher concentration of fertilizer sulfur in both roots and tops. Although not significant, the average fertilizer sulfur uptake values also appeared to be higher for subterranean clover at each temperature, particularly at 50°F, than for rose clover. If the period of uptake had been longer (as under field conditions) it is probable that much larger and more significant differences in sulfur uptake would have been obtained between subterranean and rose clover. Results of this study are not an indictment against rose clover, since it grows in many areas unsuitable for subterranean clover. However, it is possible that rose clover is adapted to lower levels of sulfur fertility, although other studies have shown that it also requires an adequate amount of sulfur for satisfactory production.

When the level of available sulfur in the soil is low, higher temperatures do not appear to aid in uptake of sulfur. Apparently a substantial amount of sulfur is necessary to satisfy the deficit in the soil before it is available to plants. Since roots at 50 and 60°F accumulate sulfur when it is available in the soil, a form of sulfur with a high degree of availability should be used for the greatest plant response in warm spring months. Such a practice might involve the loss of a portion of the sulfur to leaching in years of excessive rainfall.

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