Effects of SULFUR on Five Annual Grassland Species

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Differences in yield, sulphate-sulfur (SO_4-S) concentration, and total sulfur (S) uptake were found among five competing annual grassland species growing at different levels of available S at Hopland. Yield response of subclover, soft chess and ripgut to S fertilization increased as the season advanced, but the concentration of total S and SO_4-S in the plants decreased. Sulfur deficiency was indicated by the SO_4-S concentration in each of the species where no S had been applied. The SO_4-S concentration in subclover at flowering gave the best single indication of S status when all levels of available S were considered. Where no S was applied, there was little or no uptake of S after the first harvest date, but where S was applied, it continued to be absorbed by subclover, soft chess and ripgut up to the third harvest. The increase over the check was much greater for subclover than for any of the other species.

IN CALIFORNIA, sulfur (S) ranks a close third to nitrogen (N) and phosphorus (P) as a major plant nutrient which must be supplied to maintain crop production. While a great many areas of S deficiency are now known through field plot studies, it is important to know the S status of each field so that it can be fertilized properly. One approach is to first determine the minimum SO_4-S concentration required in plant tissue for maximum growth of a given crop. A comparison between the SO_4-S value obtained from crop samples and that known to be required for good growth would indicate the S status of the field.

The SO_4-S concentration, as related to growth, has been reported for a number of crops. Sulfur deficiency in perennial ryegrass has been found to occur when the SO_4-S concentration in the tissue was 320 parts per million (ppm) or less. The critical concentration of SO_4-S in recently matured sugar beet leaf blades was found to be about 250 ppm. In a greenhouse study, the critical SO_4-S concentrations for immature subclover (*Trifolium subterranean* L.) with from one to five flowers per runner was found to be about 170 ppm. No significant difference appeared among the critical concentrations in the leaflets, petioles, and stems. The critical concentration of SO_4-S in flowering subclover growing in the field was found to be about 170 ppm.

Further work was needed to determine the relation of SO_4-S concentration in several competing pasture species to total production. Under pasture conditions, competition among species is very important and should be considered where fertilizers are under study. The purpose of this investigation was to determine the effect of increasing levels of available S on yield, concentration of SO_4-S, and total S uptake for five competing annual grassland species at three growth stages. The relation of total yield to SO_4-S concentration in each of the species was of particular interest.

The five species chosen for this study are common in the annual pastures of the north coastal area of California. Subclover is a high-producing legume, well adapted to the area, and is very important in increasing pasture production. Soft chess (*Bromus mollis*), ripgut (*B. rigidus*), and filaree (*Erodium botrys*) are important resident annuals found in almost every pasture in the area. Medusahead (*Elymus caput-medusa* L.), a range weed notably unpalatable after heading, tends to utilize late moisture and crowd out more desirable species.

Eighteen pounds of Holcumb clay loam known to be deficient in S were placed in each of sixty two-gallon glazed pots. Each pot was fertilized at the rate of 50 lb N, 87 lb P and 110 lb potassium (K) per acre. The N was applied as calcium nitrate ($Ca(NO_3)_2$) and the P and K as potassium phosphate (KH_2PO_4). Five S levels (0, 5, 10, 20, and 30 lb per acre) were applied as sodium sulfate (Na_2SO_4). There were 12 pots for each S treatment, thus making it possible to harvest four pots from each treatment at each of three harvest dates (February 14, March 23, and April 19, 1961). The surface of each pot was divided into five areas. Each area was seeded to one of five species on November 14, 1960, and thinned to three plants. After each species was clipped, it was oven-dried, weighed, and ground in a Wiley mill.

The relation found to exist between total production at the final harvest and SO_4-S concentration in each of the five species on the same date is shown in graph 1. The curve for soft chess had no sharp break or clearly defined critical value, and the SO_4-S values were generally higher for soft chess than for the other four species. Subclover was lowest in SO_4-S compared to the other species at the 0-, 5-, and 10-lb S rates and about equal to soft chess at the 30-lb S rate. This resulted in the curve for subclover having a relatively sharp break, and giving a critical value of slightly less than the 170 ppm previously established for subclover. The SO_4-S values of ripgut, medusahead and filaree gave curves intermediate between soft chess and subclover.

If SO_4-S concentration in plant tissue is to be used to indicate the S status of a pasture, the relation of SO_4-S concentration in the plants at various stages of maturity to total production at the final harvest must be considered. The SO_4-S values for subclover at three dates, as related to combined production of all species at the final harvest are given in graph 2. Subclover was chosen to illustrate this relationship because N was not limiting, and SO_4-S concentration in this plant was considered to be the best indicator of the S status of the soil when the plants were at the flowering stage. Where no S was applied, the SO_4-S concentration was 100 ppm on February 14, indicating low S at an early date, and decreased by only 60 ppm by April 19. However, subclover that had an SO_4-S concentration of 1,400 ppm February 14 became deficient by April 19 when the SO_4-S concentration dropped to 140 ppm. The total yield at this level of SO_4-S in the subclover was 42 grams (g) per pot compared to 45 g where S was not limiting.

Where S was applied at 10 lb per acre, the SO_4-S concentration in subclover decreased at the rate of 28 ppm per day between February 14 and March 23. Under greenhouse conditions it would be difficult to tell what the level of SO_4-S at any given date early in the season should be to prevent S deficiency at maturity, because the values were changing so rapidly. Under the variables of climate, soils and grazing pressures found under field conditions, the problem is even more difficult.

It was concluded that SO_4-S concentration in the plant indicates the S status of that plant at the time the sample is taken. Work is now under way to extend this information into the field. From the practical viewpoint it now appears that a low-producing stand of subclover should be sampled when the clover is flowering. If S is low then, the field should be fertilized the next autumn. Samples taken from pastures very low in S early in the season would have low SO_4-S values, but from pastures where S supplies were just below critical levels, samples taken early in the season appear to have little value. In the subclover-producing area of California, most pastures are too wet for equipment operation during the winter months, and best responses to fertilization have resulted from early fall applications.

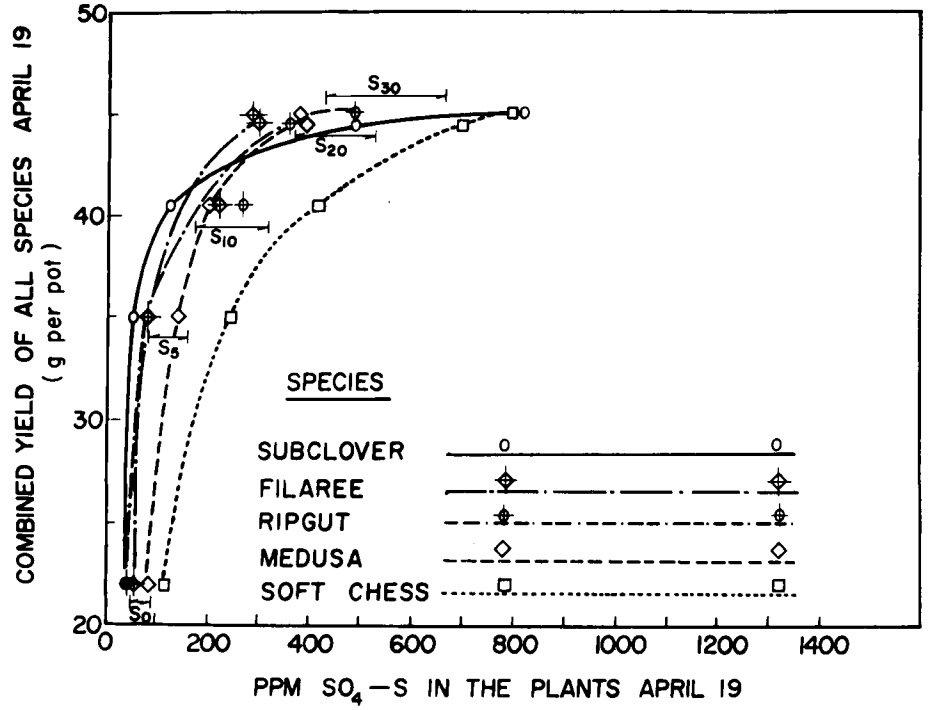
The fact that subclover is a relatively poor competitor for S when supplies are low was indicated by low subclover yields, low SO_4-S, and low organic S concentrations where no S was applied. In contrast, subclover had the capacity to absorb and utilize more S than the grasses when it was available, as indicated by its greater percentage increase in yield and S uptake as the rate of S applied increased. Application of 30 lb S per acre increased ripgut by 72% at the first harvest. No other species increased significantly at this date. At the third harvest, 30 lb S per acre increased the yield of ripgut 129% and that of subclover 313% compared to the untreated plots. The combined yield of the five species was increased at each harvest date by the application of S. However, the 20- and 30-lb S rates inhibited total growth early in the season, but not at the last harvest.

Under field conditions, equal space for each species would not be provided initially as it was in the pots. However, the fact that subclover continued to increase in yield with increasing S, even though the pot was dominated by ripgut, is significant. Previous experiments have indicated that in the absence of outside sources of S, grasses in a grass/legume association would be almost completely dominant as they compete intensively with legumes for S and could utilize almost all the mineral N and S made available by the mineralization of the organic matter. If a little S is applied, grasses may respond within the limit imposed by nitrogen deficiency. In the case of clover, previous work indicates that S deficiency greatly restricts growth and N fixation, but as the supply of S is increased, the growth is not restricted by the lack of N, as in the case with the grasses. Thus the SO_4-S concentration remains low in the clover until some factor other than N limits growth.

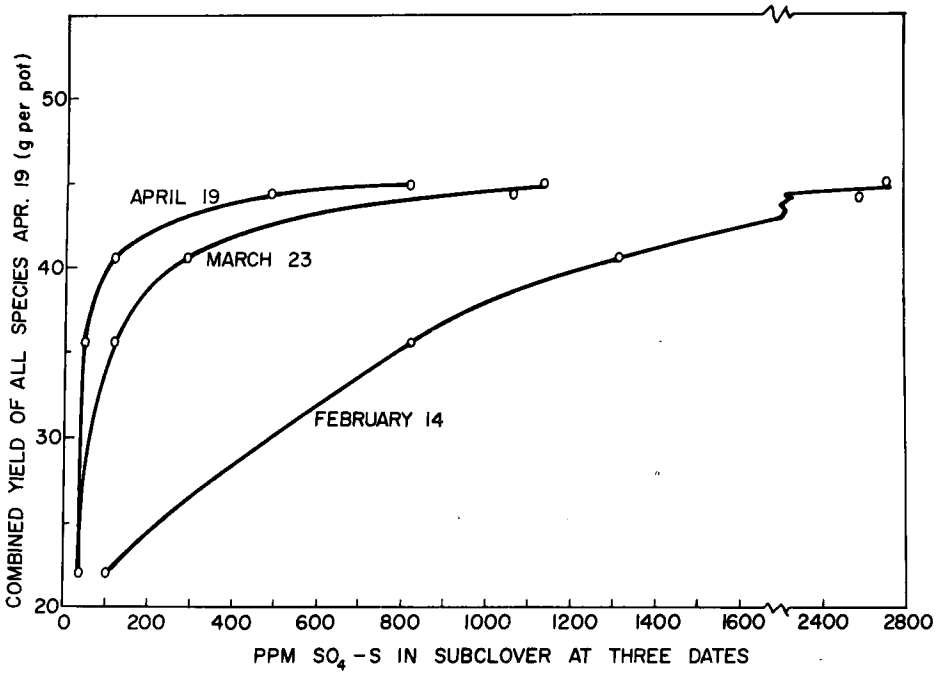
Other workers also have shown that where S levels are satisfied, pasture legumes have a competitive advantage over the grasses. After fertilization with S and P the proportion of *Medicago* increased from less than half to 85%, in previous tests. Grazing also has been shown to be advantageous to subclover and soft chess, but detrimental to ripgut and medusahead. Grazing, plus the addition of S where it is needed, could be helpful in establishing a proper balance among these species.

GRAPH 1. RELATION OF SO_4-S CONCENTRATION IN FIVE ANNUAL GRASSLAND SPECIES APRIL 19, 1961 TO COMBINED YIELD OF ALL SPECIES ON SAME DATE.

(Statistical significance for SO_4-S concentration at 5% level, for each S rate is indicated by the horizontal arrows.)



GRAPH 2. RELATION OF SO_4-S CONCENTRATION IN SUBCLOVER AT THREE DATES TO COMBINED PRODUCTION OF ALL SPECIES AT LAST HARVEST.



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