Phosphorus and Sulfur Fertilization of Established Subclover in Western Oregon

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PHOSPHORUS AND SULFUR FERTILIZATION
OF ESTABLISHED SUBCLOVER IN WESTERN OREGON

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ABSTRACT

Several rates of P and S separately and together were applied to established grass-subclover pastures in six western Oregon counties. Soil and plant analyses were made in order to determine their value as a means of predicting whether or not P actually was needed and, if so, the amount or rate of P and S to be applied for an optimum subclover response. Levels of soil P and clover P and S for adequate plant growth are suggested based upon pasture responses.

ABBREVIATIONS

B	boron
Ca	calcium
K	potassium
Mg	magnesium
Mo	molybdenum
N	nitrogen
P	phosphorus
pH	soil acidity
S	sulfur
SMP	buffer test

INTRODUCTION

Subterranean subclover has become the mainstay of dryland improved pastures in western Oregon both in association with perennial grasses such as perennial ryegrass or tall fescue and with resident annual grasses.

Maintenance of forage productivity and subsequent animal productivity depends on keeping a vigorous component of subclover in the stand. A number of management factors are very important including grazing, soil fertility, and soil acidity. This bulletin addresses some aspects of soil fertility on established pastures.

Phosphorus (P), sulfur (S), and molybdenum (Mo) are the nutrient elements most frequently limiting normal subclover growth in western Oregon. Potassium (K) and boron (B) are sometimes deficient in hill pasture soils. After the main limiting fertility factors during the establishment phase of a pasture have been determined, fertilizer needs usually normally will be for P, S, and sometimes Mo.

In western Oregon, a number of experiments over a 25-year period have firmly established the need for P. Soil test values which diagnose whether a P deficiency does, in fact, exist have been determined. Cooper (1958) found that subclover responds to added P when soil test values are less than 12 ppm[1] and P in petioles and leaves of subclover at early bloom stage is less than 0.25 percent. Subsequently, Jackson et al. (1964) reported that on a red hill soil (Olympic series) with a pH of 5.5 and soil P value of 15 pounds per acre[1] subclover responded equally well to either added P or lime.

Lime is known to increase P availability to plants. Later, Jackson (1972) showed that subclover on Douglas County soil (Nonpareil series) with pH values of 5.8 to 5.9 containing only 1 to 3 ppm[1] P did not respond to phosphorus. In Linn and Polk counties, on soils with 2.5 to 6 ppm P, subclover yields were greatly increased with 40 and 80 pounds P_2O_5 per acre.

After a number of years of adding P, a buildup can occur (Ayres 1976; Ayres et al. 1977). These workers in Australia found essentially no P response on soils with a history of P fertilization (26 to 35 ppm) but a good P response on medium P soils (15 ppm[2]).

Maintenance of clover in the stand is quite important both for the potential of fixing high amounts of N and because the nutritive value of forage containing clover and grass is superior to grass alone. Some Australians are concerned that P fertilized pastures may become grass dominant (Ayres et al. 1977; Curll 1977a, 1977b; Kohn 1974). Under medium soil P levels, clover can grow but apparently does not fix enough N for the grasses to grow with the same vigor. After P fertilization, clover increases. Then grass increases and suppresses clover. Sheep may hasten the process since they will selectively graze clover over grass at certain times of the year (Curll 1977a).

However, Curll (1977b) presented data to show direct grass responses to added P. When such composition changes occur, forage nutritive value varies substantially throughout the year. Kohn (1974), Ayres (1976), and Ayres et al. (1977) all reported that P fertilized forage which becomes grass dominant after at least one year of fertilization is less digestible during summer than unfertilized forage. More winter regrowth usually takes place, however, so less feeding is necessary.

Although soils may accumulate P, tests do not always show it (Curll 1977a and 1977b). In both of Curll's studies, P application over a 3 year period did not increase soil test values for P. This can lead to an inconsistent relationship between soil and plant tests for P and response from added P (Curll and Smith 1977). Can soil and plant tests on P predict how much P is needed? Curll and Smith (1977) and Montgomery and Rubenis (1978) suggest that soil and plant values can indicate non-responsive sites (those having sufficiently high P values) but cannot be used consistently to predict plant response to P fertilizer.

Sulfur also is needed in an adequate amount. Much effort in western Oregon is being made toward defining S requirements (Drlica and Jackson 1979). Plant analysis is effective in diagnosing need for sulfur but soil tests are not. At the University of California Hopland Field Station in northern California on a Laughlin gravelly loam, Jones (1964) determined that maximum subclover-annual grass yields occurred when 40 pounds S per acre was applied annually, that 20 pounds per acre was sufficient for maximum winter growth, and that 80 pounds per acre was necessary for maximum subclover growth.

Subsequently, Jones and Ruckman (1966) comparing sources of S (elemental and gypsum), found that carryover effects on subclover growth were superior with the elemental form although initial sulfur uptake was better with the sulfate form (gypsum). They recommended alternate year fertilization with elemental sulfur.

In a field experiment to examine the effects and longevity of applying several forms of S to established subclover pastures in Douglas County, Oregon, Kiemnac et al. (1981) compared one application of several particle sizes of elemental sulfur to annual applications of gypsum and finely ground elemental S (< .25 mm). They found similar results to those of Jones and Ruckman (1966).

Particle sizes of elemental S from 0.5 to 2 mm applied at 176 kg/ha in 1974 showed residual effects on yield in 1980. S uptake in clover is more rapid with either finely ground sulfur or gypsum than the > 0.5 mm sizes of elemental S. The authors recommended a mixture of finely ground (< 0.25 mm) and coarsely ground material (> 1.0 mm) for effectiveness over a period of years.

In Oregon, sulfur fertilization also can result in a shift in pasture composition (McCarthy 1976). At low rates (20 pounds S per acre), clover percentage was optimum. At higher rates, the clover percentage was lower compared with grass although not as low as without S. This was because high S rates increased N fixation and this increased growth of grass. Sulfur can be effectively cycled through the soil-plant-animal system (Dawson and McGuire 1972). They suggested that 10 pounds S per acre annually was sufficient to stimulate optimum subclover responses if intensive grazing was used.

As mentioned, plant analyses can be effectively employed to diagnose deficiencies of P and S. Jones et al. (1972) reported that clover plants should be at least 120 days old to be analyzed for P. Young plants have higher P needs, as much as 0.7 percent. These workers concluded that 0.11 percent P in the leaves and petioles of 120 day plants were sufficient for optimum growth.

In Australia, Ozanne et al. (1969) found a range of 0.12 to 0.20 percent P in healthy 92-day old clover leaves and petioles (flowering stage). Jones et al. (1980) developed S diagnostic criteria for subclover as a function of age of plant and time since defoliation. They also evaluated several methods of assessing plant sulfur statistics. Their data indicated that for `Mt. Barker´ subclover approximately 0.20 to .21 percent S was the critical level (90 percent maximum yield) in the last three fully expanded leaves when plants were 60 and 77 days old.

However, when ages advanced to 109 days and 133 days, the critical levels were .09 and .07 percent, respectively. Also, when plants were defoliated and regrowth leaves examined, critical levels were in the 0.20 percent S range and remained higher than unclipped levels for plants of the same age. This suggests that grazed plants will contain and/or need a higher concentration of S than ungrazed plants of the same age.

In a Douglas County experiment (Nonpareil and Oakland soils) on subclover, Drlica and Jackson (1979) concluded that plants with less than 0.25 percent P and 0.20 percent S would benefit from fertilization. They stressed that sampling must occur before mid-April and before plants flower to any extent. From the same experiment, McCarthy (1976) showed hay stage subclover to have S concentrations of 0.10, 0.12, 0.13, 0.15, 0.18, and 0.23 percent for 0, 10, 20, 40 80, and 160 pounds per acre rates of S fertilization, respectively.

The objectives of this study were to determine the value of soil and plant testing as a means of predicting the amount or rate of P needed for an optimum subclover response and to determine the absolute need, or lack of need, for P. Could levels of P in the surface soil of established subclover-grass pastures and levels of both P and S in leaves and petioles of subclover be used successfully as tools in determining how much of each of these nutrients would be needed?

STUDY LOCATIONS

In the fall of 1976, established subclover-grass pastures (12 on 9 ranches in 5 counties) were selected for study. Extension agents in Coos, Jackson, Josephine, Lane and Polk counties[3] were actively involved in these experiments. Douglas County was not included since extensive research on this subject was already underway. Appendix Table 1 provides selected soil test characteristics at the beginning of the experiment. All sites except one had P levels less than recommended in the then-current fertilizer guide. Fertilization histories and past forage production varied greatly. Generally, those sites which had been fertilized recently with P and S were under better management and had yielded more forage.

MATERIALS AND METHODS

A composite sample of soil was obtained from the surface two inches of each pasture because previous soil testing had confirmed that P levels in the two inches of soil of established pastures were more representative of P available to subclover roots than in the more customary six inches of surface soil. Gillingham et al. (1980) found that from 85 to 92 percent of uptake in New Zealand hill pastures occurred from within the surface 7 cm (2.75 inches) with most from the surface 3 cm (1.25 inches).

Six single application treatments were applied in four replications to 3 x 5 foot plots during the fall of 1976. Treatments were:

(1) Control, no fertilizer.

(2) 40 pounds P_2O_5 (17.5 pounds P) plus 50 pounds S per acre.

(3) 80 pounds P_2O_5 (35 pounds P) plus 50 pounds S per acre.

(4) 160 pounds P_2O_5 (70 pounds P) plus 50 pounds S per acre.

(5) 160 pounds P_2O_5 (70 pounds P).

(6) 50 pounds S per acre.

The source of P was treble superphosphate (45% P_2O_5) and the source of S was Agri-Sol (95% S). Materials were hand broadcast on each plot.

These rates were selected in accordance with recommendations of about 200 pounds of single superphosphate (approximately 17.5 pounds P and 24 pounds S) per acre per year for P levels of 20 to 40 ppm in the surface 6 inches.

Exclosures excluded grazing during the growing seasons. In some locations, complete exclusion was not accomplished but partial experimental use was still possible. On sheep ranches, exclosures were opened during the 1977-78 winter. Also, old 1977 material was rotary mowed to try to provide better germination conditions for subclover.

Leaves and petioles of subclover in the pre-bloom stage were collected in each treatment during early-mid April 1977 and 1978. P, S, and, for some samples, N was determined at the OSU Soils Laboratory. After the 1977 and 1978 growing seasons, soil samples from the surface two inches were obtained and tested for pH, SMP, P, K, Ca, and Mg by the OSU Soils Laboratory (Berg and Gardner 1978). Soil samples were composited by treatment; clover samples were not.

Total herbage production was determined by hand clipping either two 2.4 square foot circular rings (1977) or 2-square foot, open-ended rectangular frames (1978) to approximately 0.5 inch height at hay stage.

Times varied from approximately May 10 to June 10 for clipping. Herbage was dried in a forced air oven at 70° C and yields expressed as oven dry weight. Subclover percent by dry weight was estimated before clipping. Two observers did the estimates when possible.

Plant P and S, forage yield, and percent subclover data were analyzed for significant differences from fertilizer treatment by analysis of variance (Steel and Torrie 1960) for each location.

RESULTS AND DISCUSSION

Although treatments were applied at 12 locations on 9 ranches in 5 counties, a combination of droughty conditions in 1977 and unsuccessful plot fence maintenance resulted in incomplete data being collected at 6 locations. More complete data and analysis were possible for the remaining 6 locations on 6 ranches in 5 counties. These are presented in Tables 1 through 6.

Jackson-Josephine Counties

Extreme drought in 1977 made data collection impossible. Soil P levels were higher at the beginning of the experiment at these locations compared to other locations (Appendix Table 1). No P response was expected nor was one observed in 1978. However, dramatic responses to sulfur occurred on an Agate soil series near Eagle Point (Table 1). During spring 1978, subclover showed marked S deficiency signs in the check and $P_{70}S_0$ treatments. Good stands of clover occurred in all treatment plots but clover S levels were significantly ($p < .05$) greater where 50 pounds per acre S had been applied (Table 1). No increase in clover P levels was observed, although addition of P_{70} in 1976 did cause a 10 to 15 ppm increase in soil P levels two years later.

The more vigorous clover component in the S treatments resulted in significantly improved ($p < .01$) total herbage yield (Table 1). Based on observed results, a clover S level of 0.12 percent in leaves and petioles in mid-April was sufficient for adequate growth. No minimum or threshold clover P level can be estimated from these plot data; amounts were 0.24 to 0.32 percent which falls into the adequate range as suggested by Drlica and Jackson (1979).

At two Josephine County sites with high residual P, strong S responses were noted. At one, clover was S deficient at 0.08 to 0.10 percent S, but apparently adequate at 0.11 to 0.13 percent S, since deficiency symptoms were not evident. No significant P changes in clover from P_0 to P_{70} were observed. At the other site, clover S on the check and $P_{70}S_0$ were 0.16 to 0.19 percent but 0.21 to 0.24 percent S where 50 pounds of S per acre was applied. These were significantly different ($p < .05$).

<u>Coos-Curry Counties</u>

Data from a location east of Langlois on an Orford silty clay loam are shown in Table 2. P content of clover leaves and petioles was not improved by addition of P, nor were herbage yields significantly affected in 1977 or 1978. However, a small but significant increase ($p < .05$) in percent clover in the herbage occurred in the plots receiving P. The S concentration in clover was significantly increased ($p < .05$) in both years by addition of S, but sulfur deficiency symptoms were not evident. Soil P levels were higher for the P_{70} treatment compared to the lower P application rates.

In both years, neither P nor S singly stimulated percent clover. But a gradual increase in percent clover with increased rate of P and S occurred with the highest rates different from the check and single element treatments. P levels in clover did not consistently increase with increasing rate of P. On the other hand, S levels were positively influenced by S fertilizer independent of the rate of P. This suggests that the check levels of S were deficient (0.09 percent in 1977 and 0.14 percent in 1978). A clear-cut S threshold was not evident, but at above 0.15 percent no S response would be expected.

No association could be noted between P contained in clover leaves and petioles and in soil samples. On the basis of these results, P levels of 15 to 20 ppm in this soil were high enough to provide adequate clover growth and maintain adequate P and S in the clover leaves and petioles.

At the Bandon site, although both P and S had been applied at 20 pounds per acre annually through fall 1975, significant yield responses to P and S were obtained. But P and S levels in clover were not affected by P and S fertilizers in 1977 (Table 3). Although the plot was mowed in fall 1977 and the gate left open to sheep, clover did not reestablish in 1978 and no plant data were collected in 1978.

The results suggest that soil test P values of 25-30 ppm are adequate for subclover pastures on this soil. Since no clover response to added P or S occurred, levels of 0.23 to 0.25 percent P and approximately 0.15 percent S are considered adequate.

The third Coos-Curry site was four miles northwest of Coquille on a Dement silt loam with a dense stand of subclover, perennial ryegrass, and annual grasses. Although the plot was open to sheep grazing after

1977 data were collected, good clover reestablishment did not occur in 1978, and thus, no herbage yield data were obtained that year.

In spite of the low level of extractable P in the soil in fall 1976 (6 ppm), a significant yield increase from added P did not occur in 1977. The application of P at 35 and 70 pounds per acre significantly increased ($p < .01$) the percent P in clover leaves and petioles in 1977 but no difference occurred in 1978 (Table 4). Percent S in clover did not vary significantly in either year.

No herbage yield differences were observed in 1977 among treatments. Results at this location suggest that 0.25 percent P and 0.16 to 0.18 percent S in clover leaves and petioles are adequate for vigorous clover growth. Soil test P levels of 15 to 20 ppm appear adequate for pasture production on this soil.

<u>Willamette Valley</u>

Data from two Polk County sites on Willakenzie and Coburg soils showed responses of clover-grass to P but not to S (Tables 5 and 6). A good stand of subclover, perennial ryegrass, and 'Fawn' tall fescue occurred on a Willakenzie silty clay loam site. The pasture had received 22 pounds of P and 25 pounds of S per acre two years before the experiment.

During the 1977 and 1978 growing seasons, observations suggested that a P but not an S response was occurring at the Polk County locations. The clover was somewhat less vigorous in the check and S only plots. In 1977, clover made up 23 percent of the herbage in June on plots treated with P but only 12.5 percent on the check and S only plots. In 1978, the same relative responses occurred.

Percent P and S values in clover were not raised greatly with added P and S, but several differences did occur (Table 5). In both years, clover in P_{70} treatments contained significantly more ($p < .05$) P than all other treatments. Considerably more soil P was present in P_{70} and it may have been more available than that in other treatments. The S content was not different in 1977 but it was in 1978; clover in the S treatments contained 0.03 to 0.04 percent more S (Table 5).

Yields were significantly improved ($p < .05$) by all P treatments in 1977 but not in 1978 (Table 5). Less clover was present in 1978, which may have affected the level of response. Overall yields were not greatly different in the two years.

Soil P levels rose in relation to the amount of P added, although the trend was not linear (Table 5). In 1978, two years after application, the levels were still above the check for P_{35} and P_{70} but not for P_{17}.

The slight but significant yield increase in 1977 at all P rates was associated with both the slightly higher level of P in clover and more P in the soil (Table 5). The same association appeared to occur in 1978. Some depletion in soil P content from year to year occurred. There was an approximate 5 ppm decline for 17 pounds P per acre.

On the basis of the results on Willakenzie soil, some response to P could be expected at soil P levels below 20 ppm and clover P contents at 0.26 percent or below. Since no yield or uptake S response occurred with S, the observed levels of 0.16 to 0.17 percent S probably are still above the threshold level.

Subclover, perennial ryegrass, and annual grasses occupied a Coburg silty clay loam site. No fertilizer was applied for several years before the experiment. Cattle had been concentrated on the site, however, and the soil contained 16 ppm P in the upper two inches in 1976 (Table 6).

P and S deficiency symptoms in subclover were not noted in either year. However, P uptake was significantly greater on P_{70} plots than on all others in 1977 and significantly greater for all P than non-P treatments in 1978 (Table 6). For S, no differences occurred in 1977 but significant increases were observed for all treatments containing S in 1978. Subclover was not dense on any plot in 1977 or 1978 and did not appear to respond to fertilizer treatment. Herbage yields in 1977 varied with level. Yields without P were 5,500 and 6,050 pounds per acre (check and S only). With P, regardless of rate, yield only varied from 6,900 to 7,150 pounds per acre. Yield results could not be obtained in 1978. Early in that season (April), forage in the P plots appeared to be growing faster.

Soil P was moderately high to start with, perhaps a reflection of cattle concentrations. However, levels were raised with P_{70} in 1977 and all P rates in 1978 (Table 6). Since clover populations were not high in 1977, probably none of the slight increases in yield with P could be attributed to clover. P was probably not limiting for clover growth. In fact, 0.33 and 0.34 percent P are well above the level suggested as threshold by Drlica and Jackson (1979). Although clover percent S was improved in the second year, no S deficiency symptoms were noted, nor was the percent clover in the herbage increased. This would suggest that 0.17 percent S was above the threshold in leaves and petioles. Some 16 to 18 ppm in the upper two inches of soil appears adequate for normal clover growth.

Other Sites

At one Lane County site, approximately 2.4 tons of lime per acre was applied with the P and S treatments. Both soil pH and SMP[4] buffer values were dramatically improved within two years. Soil pH increased from 5.0 to 5.8 and SMP from 6.1 to 6.8. Clover P values were 0.21 percent with no P and up to 0.28 percent with P_{70} in 1978. Clover S values varied from 0.21 to 0.26 percent with no treatment pattern. Soil P level was increased with P_{70} but not P_{17} or P_{35}. Since no P or S deficiency symptoms were evident in subclover, concentrations of approximately 0.21 percent P and S in leaves and petioles were apparently above the critical level. A soil P level of 16 ppm apparently was high enough because no clover response was observed.

In Polk County, observations at two Steiwer soils sites suggested 18 to 21 ppm P in soil was adequate for clover to make normal growth. Clover P contents without fertilization were 0.25 percent at one site and 0.32 percent at another with no increase observed with the high rate of P. Clover S content without S fertilization was 0.16 to 0.20 percent S and only 0.18 to 0.26 percent S with S_{50} after two years. Such concentrations appeared to be above the critical levels.

On a valley bottom Waldo silty clay loam, observations showed slight but inconsistent increases in clover S from 0.15 percent S with no S to 0.20 percent S with S_{50}. Clover P in 1978 ranged from 0.22 to 0.32 percent where P_{70} was added. Soil P was 11 to 13 ppm without P and approximately 20 ppm when P_{70} was applied. Addition of P_{17} and P_{35}

did not improve soil P in either year. Observations suggested that neither P nor S in amounts above those observed on the check were necessary for adequate clover growth to be expressed at that site.

SUMMARY

A two year experiment (1976 to 1978) was conducted on established subclover-grass pastures at 12 locations in 5 western Oregon counties to assess the effects of a single application of several rates of P and S singly and in combination on forage yields. The objective was to relate soil test P values before fertilization to plant responses to evaluate whether such values could be used as a predictive tool for P application rates. Levels of P and S in subclover leaves and petioles also were evaluated for use as a predictive tool to estimate the need for P and S fertilization.

Table 7 provides an interpretation of the overall responses to the one-time application of P and S. An effect was deemed positive for P if any of the three application rates elicited a response. In most cases, a positive response occurred with the 70 pounds per acre rate, if there was a response.

Drought conditions prevailed in 1977 in Jackson and Josephine counties severely limiting forage growth. Conditions in 1978 were sufficient for full growth expression. P levels in soils were 17 ppm or more in the surface two inches without fertilization (8 ppm at one site in fall 1977) and neither a yield response nor P increase in clover leaves and petioles occurred because of added P. In two of the three soils, S apparently was deficient. On these sites, a minimum level of 0.11 to 0.12 percent S was necessary in leaves and petioles for adequate growth

expression. At the site that was not responsive to S, the level in the plants was 0.16 percent S. In these two counties, S appears to be the limiting soil fertility growth factor.

At the Langlois site in Curry County, observations point to a positive P by S interaction. If soil contained 15 ppm P or more in the surface two inches and clover leaves and petioles contained 0.20 percent P and 0.15 percent S, no additional P or S was necessary. In Coos County at the Bandon site, 16 to 18 ppm P in the soil and 0.15 percent S and 0.25 percent P in clover leaves and petioles occurred in check plots. P and S fertilization did not stimulate clover responses, which suggests these levels were adequate. At the Coquille location in Coos County, responses did not occur from added fertilizer; check levels of soil P (15 ppm), plant P (0.25 percent), and S (0.16 to 0.18 percent) were adequate for full growth expression. Addition of 70 pounds P per acre did increase soil P by variable amounts at the three locations, but plant responses were not strongly affected.

Four soils on five Polk County locations were studied. On a heavy textured Waldo soil (lowland site) with 13 ppm P, no yield response was noted to added P even though soil P increased to 20 to 22 ppm at the P_{70} rate. Slight increases in clover P and S occurred after added P and S, but check amounts of 0.15 percent S and 0.26 percent P appeared to be above critical level. On a relatively well-drained Coburg soil, 16 to 18 ppm P in the surface two inches of soil was adequate for clover growth. Plant P was 0.33 to 0.34 percent in check plots and increased to 0.37 to 0.40 percent P in the P_{70} treatment in both years. Plant S was 0.17 percent or above and no response occurred in any treatment.

On Steiwer soils (two locations), above 16 ppm P occurred in check plots even though management history was quite different. Soil P was raised by added P but no apparent plant response occurred. Percent P was 0.25 and above at one site and 0.32 and above at the other. Clover S concentration was above 0.16 percent at both locations. Apparently, critical levels of P and S are below these amounts.

Study of a good tall fescue-subclover stand on a Willakenzie soil suggested that a P response would be expected when soil P was below 20 ppm and clover P below 0.26 percent since a P response was measured in the first year. No response occurred to S to suggest that 0.16 to 0.17 percent S in clover leaves and petioles is sufficient for normal growth expression.

On a Lane County low pH soil, (5.0) top dressed lime at 2.4 T/A increased pH to 5.8 to 6.3. Although P_{70} did increase soil P levels, soil without added P (16 ppm) was sufficient for adequate clover growth. Both P and S levels in clover leaves and petioles were 0.21 percent and above regardless of treatments.

MANAGEMENT IMPLICATIONS

The amount or proportion of subclover in a pasture is not just a function of soil fertility. In practice, it probably is more closely related to the intensity of grazing management than any other single factor. Grazing must be managed in accordance with plant needs. In the case of subclover, this means close but not necessarily complete defoliation during summer and early fall before the new crop of seed germinates. Without adequate defoliation, new seedlings will not establish well, and in a short time the stand will diminish.

Once established, subclover and the associated grasses and other plants should be defoliated as uniformly as possible on a periodic basis during the growing season. This should allow high penetration of sunlight into the foliage. When this occurs, subclover has the opportunity to most favorably express itself.

Soil nutrients may be the limiting factors for subclover, but as explained, so also may be the kind of grazing. Therefore, both fertility and grazing are critical and one without the other is unsatisfactory for the optimum amount of subclover in the pasture.

Based on the results of this experiment, soil tests for P taken at the 0-to 2-inch depth in established pastures are adequate as a screening device to determine if sites respond to added P. After a responsive site is identified by a soil test, it is quite difficult, in fact impossible, from a predictability viewpoint to identify an optimum rate of P addition to make from the test alone.

Levels of P and S found in clover leaves and petioles appeared to be a more accurate predictive tool to use as contrasted to soil tests. But the stage of clover growth is quite critical when plant samples are obtained. Concentrations of both P and S are strongly related to stage of maturity and can drop rapidly as plants become more mature. Sampling clover at the rapid spring growth stage before many blooms occur appears to be the optimum time.

Because there did not appear to be a close relationship or even association between soil test values on responsive sites and the response from a particular level of P application, one could conclude, as did Curll and Smith (1977) in Australia, that a test strip of fertilizer be used as an aid in a fertilizer program. However, the levels of both soil P and plant tissue P and S can serve as general guidelines in determining P and S fertilizer application rates on sites similar to those of this experiment.

FOOTNOTES

[1] Modified Olsen's sodium bicarbonate extract (soil:solution 1:10) as conducted in the Oregon State University Soil Testing Laboratory.

[2] P determined with the 'modified' Mehlich method.

[3] Thanks are extended to extension agents Lynn Cannon (Coos), Mike McCarthy and Gary Schneider (Jackson and Josephine), Paul Day (Lane) and Ed Page (Polk).

[4] A soil test to indicate the amount of lime necessary to correct acidic conditions.

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Table 1. Effects of phosphorous (P) and sulfur (S) fertilization on herbage yield, subclover amount, soil analyses and chemical composition of plant samples. Agate soil, Eagle Point, Jackson County, 1978.

P (lbs/Ac)	S (lbs/Ac)	Herbage yield lbs/Ac	Percent clover	Soil P (ppm)	Plant P %	Plant S %
0	0	2900[a1]	30	37	.30	.08[a2]
0	50	6100[b]	70	37	.27	.12[b]
17	50	--	58	36	.24	.10[ab]
35	50	--	39	37	.26	.09[a]
70	50	6700[b]	56	46	.27	.12[b]
70	0	3600[a]	52	54	.32	.09[a]

1/ Means followed by different letters are significantly different, $p < .01$.

2/ Means followed by different letters are significantly different, $p < .05$.

Soil test values - Fall 1976

pH	P	K	Ca	Mg	SMP
	ppm	ppm	meq/100g	meq/100g	
6.1	24	374	13.9	3.3	6.4

Plant analysis values - Spring 1978[1]

K	Ca	Mg	Mn	Mo
%	%	%	ppm	ppm
2.4	1.36	.23	70	8.1

1/ For $P_{70}S_{50}$ treatment.

Table 2. Effect of phosphorous (P) and sulfur (S) fertilization on herbage yield, soil and clover phosphorous levels, clover sulfur content and percent subclover in herbage. Orford silty clay loam, Langlois, Curry County, 1977, 1978.

		1977					1978				
		Yield lbs/Ac	Percent clover	Soil P ppm	Clover P %	Clover S %	Yield lbs/Ac	Percent clover	Soil P ppm	Clover P %	Clover S %
P	S										
lbs/Ac											
0	0	2230	5a1	15	.25	.09a	4240	9a	19	.19	.14a
0	50	3280	9ab	11	.24	.15c	4750	9a	14	.20	.18bc
17	50	3700	16b	13	.26	.13bc	5030	15ab	15	.20	.16ab
35	50	3260	13ab	12	.26	.12ab	4900	19ab	15	.20	.18bc
70	50	4060	18b	23	.28	.15e	5700	24b	20	.24	.18bc
70	0	2980	9ab	20	.28	.11ab	4280	11a	28	.21	.16ab

1/ Means followed by different letters are significantly different, $p<.05$

Soil test values - Fall 1976

pH	P	K	Ca	Mg	SMP
	ppm		meq/100g		
5.2	14	530	4.2	1.7	5.3

Plant ananlysis values - Spring 1977-78 1/

	N	K	Ca	Mg	Mn	Mo
	%				%	
1977	2.38	1.23	.41	.13	73	11.0
1978	--	1.3	1.16	.27	108	5.2

1/ For $P_{70}S_{50}$

Table 3. Effect of phosphorous (P) and sulfur (S) fertilization on selected characteristics of herbage yield, soils and plant chemical content. Etelka-Templeton-Orford soil, Bandon, Coos County, 1977, 1978.

P	S	1977 Herbage Yield	1977 Soil P	1977 Clover P	1977 Clover S	1978 Soil P
lbs/Ac		lbs.Ac	ppm	%	%	ppm
0	0	7030 a[1]	16	.23	.15	23
0	50	10040 bc	15	.24	.16	26
17	50	8760 b	15	.25	.15	21
35	50	8860 b	24	.25	.15	27
70	50	10920 c	22	.25	.12	29
70	0	11210 c	21	.25	.15	29

1/ Means followed by different letters are significantly different $p < .05$

Soil test values - Fall 1976

pH	P	K	Ca	Mg	SMP
	ppm	ppm	meq/100g	meq/100g	
5.3	12	310	4.2	3.0	5.7

Plant analysis values - Spring 1978[1]

N	K	Ca	Mg	Mn	Mo
%	%	%	%	ppm	ppm
2.07	1.42	.38	.17	46	5.8

1/ For $P_{70}S_{50}$.

Table 4. Effect of phosphorous (P) and sulfur (S) fertilization on selected characteristics of herbage yield, soils and plant chemical content. Dement silt loam, Coquille, Coos County, 1977, 1978.

P (lbs/Ac)	S (lbs/Ac)	1977 Herbage Yield lbs/Ac	1977 Soil P ppm	1977 Clover % P	1977 Clover % S	1978 Soil P ppm	1978 Clover % P	1978 Clover % S
0	0	6430	15	.31 a 1/	.18	20	.25	.23
0	50	6140	12	.30 a	.19	16	.27	.24
17	50	5770	13	.32 a	.19	18	.22	.22
35	50	6570	13	.36 b	.19	21	.27	.24
70	50	6900	18	.38 b	.19	29	.26	.21
70	0	6670	15	.38 b	.16	18	.26	.21

1/ Means followed by different letters are significantly different $p < .05$

Soil test values - Fall 1976

pH	P	K	Ca	Mg	SMP
	ppm	ppm	meq/100g	meq/100g	
5.2	6	530	9.0	7.0	5.3

Plant analysis values - Spring 1977-78 1/

	N	K	Ca	Mg	Mn	Mo
	%	%	%	%	ppm	ppm
1977	4.62	1.4	.36	.11	56	3.3
1978		2.0	1.0	.20	108	4.8

1/ For $P_{70}S_{50}$

Table 5. Effect of phosphorous (P) and sulfur (S) fertilization on herbage yield, soil P level, and subclover P and S levels. Willakenzie soil, Polk County, 1977, 1978.

P	S	1977 Herbage Yield lbs/Ac	1977 Soil P ppm	1977 Clover % P	1977 Clover % S	1978 Herbage Yield lbs/Ac	1978 Soil P ppm	1978 Clover % P	1978 Clover % S
lbs/Ac									
0	0	4210[a] [1/]	17	.23[a]	.21	4160	17	.24[a]	.16[a]
0	50	4120[a]	17	.24[a]	.22	4200	18	.23[a]	.20[b]
17	50	5030[b]	24	.25[a]	.22	4300	17	.26[a]	.20[b]
35	50	5210[b]	29	.26[a]	.20	4210	24	.26[a]	.20[b]
70	50	5200[b]	55	.28[b]	.22	4560	36	.28[b]	.20[b]
70	0	5350[b]	40	.29[b]	.20	5120	38	.28[b]	.17[ab]

1/ Means followed by different letters are significantly different $p < .05$.

Soil test values - Fall 1976

pH	P	K	Ca	Mg	SMP
	---ppm-------		-----meq/100g-----		
5.6	17	672	7.9	2.8	6.2

Plant analysis values - Spring 1977-78 [1/]

	N	K	Ca	Mg	Mn	Mo
	---------------%----------------				---ppm------	
1977	2.81	.78	.69	.12	109	2.1
1978		2.25	1.2	.23	147	.95

1/ For $P_{70}S_{50}$

Table 6. Effect of phosphorous (P) and sulfur (S) fertilization on herbage yield, soil P level, and subclover P and S levels. Coburg soil, Polk County, 1977, 1978.

		1977				1978		
		Herbage Yield lbs./Ac	Soil P ppm	Clover % P	Clover % S	Soil P ppm	Clover % P	Clover % S
P (lbs/Ac)	S (lbs/Ac)							
0	0	5500 a1/	29	.34 a2/	.17	18	.33 a2/	.17 a2/
0	50	6050 a	20	.34 a	.19	20	.33 a	.23 b
17	50	6900 b	28	.33 a	.17	25	.38 b	.24 b
35	50	6890 b	28	.36 a	.17	29	.37 b	.25 b
70	50	7070 b	46	.38 b	.18	37	.37 b	.25 b
70	0	7150 b	56	.39 b	.18	42	.40 b	.18 a

1/ Means followed by different letters are significantly different $p < .01$.

2/ Means followed by different letters are significantly different $p < .05$.

Soil test values - Fall 1976

pH	P	K	Ca	Mg	SMP
	----ppm----		----meq/100g----		
5.1	16	374	5.1	2.1	5.7

Plant analysis values - Spring 1977-78 1/

	N	K	Ca	Mg	Mn	Mo
	----%	----	----	----	----ppm----	
1977	2.98	1.25	.43	.14	132	2.42
1978		2.1	.92	.4	258	2.18

1/ For $P_{70}S_{50}$

Table 7. Summary of responses to P and S fertilization of subclover-grass pastures at 12 western Oregon locations (+ = positive response; 0 = no apparent response).

				Phosphorous				Sulfur		
County	Soil Series	pH	P (ppm)	Yield	% Clover	Concentration in plant	Soil	Yield	% Clover	Concentration in plant
Jackson	Agate	6.1	24	0	0	0	0	+	+	+
Josephine	Manita	6.2	19	0	0	0	+	+	0	+
Josephine	Abegg	5.9	67	0	0	0	0	+	+	+
Curry	Orford	5.2	14	0	0	0	+	0	+	+
Coos	Etelka-Templeton-Orford	5.3	12	+	0	0	+	+	0	0
Coos	Dement	5.2	6[1/]	0	0	0	0	0	0	0
Lane	Veneta	5.0	9	0	0	+	+	0	0	0
Polk	Coburg	5.1	16	+	0	+	+	0	0	+
Polk	Steiwer	5.4	19	0	0	0	+	0	0	+
Polk	Steiwer	5.3	16	0	0	0	+	0	0	+
Polk	Waldo	5.6	9	0	0	0	+	0	0	+
Polk	Willakenzie	5.6	17	+	+	+	+	0	0	0

1/ 0 to 6 inch depth

Appendix Table 1. Soil test values at each experimental site at time of application of fertilizer. Fall 1976.

County	Soil Series	pH	P (ppm)	K (ppm)	Ca (meq/100g)	Mg (meq/100g)	SMP
Jackson	Agate	6.1	24	374	13.9	3.3	6.4
Josephine	Manita	6.2	19	140	13.3	3.4	6.5
Josephine	Abegg	5.9	67	100	3.7	.59	6.7
Curry	Orford	5.2	14	530	4.2	1.7	5.3
Coos	Etelka-Templeton-Orford	5.3	12	310	4.2	3.0	5.7
Coos	Dement	5.2	6 1/	530	9.0	7.0	5.3
Lane	Veneta	5.0	9	250	4.5	1.8	6.1
Polk	Coburg	5.1	16	374	5.1	2.1	5.7
Polk	Steiwer	5.4	19	524	6.9	3.0	6.1
Polk	Steiwer	5.3	16	174	4.0	.69	6.3
Polk	Waldo	5.6	9	116	7.1	2.3	6.1
Polk	Willakenzie	5.6	17	672	7.9	2.8	6.2

1/ 0 to 6 inch depth

Appendix Table 2. Selected chemical characteristics of subclover leaves and petioles in 1977 and 1978 from sites where 70 pounds P and 50 pounds S per acre were applied in Fall 1976.

County	Soil Series	Year	N	K	Ca	Mg	Mn	Mo	N:S
			----------%------------				------ppm-----		
Jackson	Agate	1978	--	2.4	1.36	.23	70	8.13	--
Josephine	Manita	1977	2.64	1.1	.56	.12	44	1.75	23.2
Curry	Orford	1977	2.38	1.23	.41	.13	73	11.0	16.0
		1978	--	1.3	1.16	.27	108	5.2	--
Coos	Etelka-Templeton-Orford	1977	2.07	1.42	.38	.17	46	5.8	13.9
Coos	Dement	1977	4.62	1.4	.36	.11	56	3.3	23.8
		1978	--	2.0	1.0	.20	108	4.8	--
Lane	Veneta	1978	--	1.5	1.38	.18	116	1.4	--
Polk	Coburg	1977	2.98	1.25	.43	.14	132	2.42	16.9
		1978	--	2.1	.92	.4	258	2.18	--
Polk	Steiwer	1978	--	2.5	.87	.24	175	4.5	--
Polk	Steiwer	1978	--	2.6	1.04	.26	136	3.7	--
Polk	Waldo	1978	--	.9	1.07	.25	334	.7	--
Polk	Willakenzie	1977	2.81	.78	.69	.12	109	2.1	13.0
		1978	--	2.25	1.2	.23	147	.95	--