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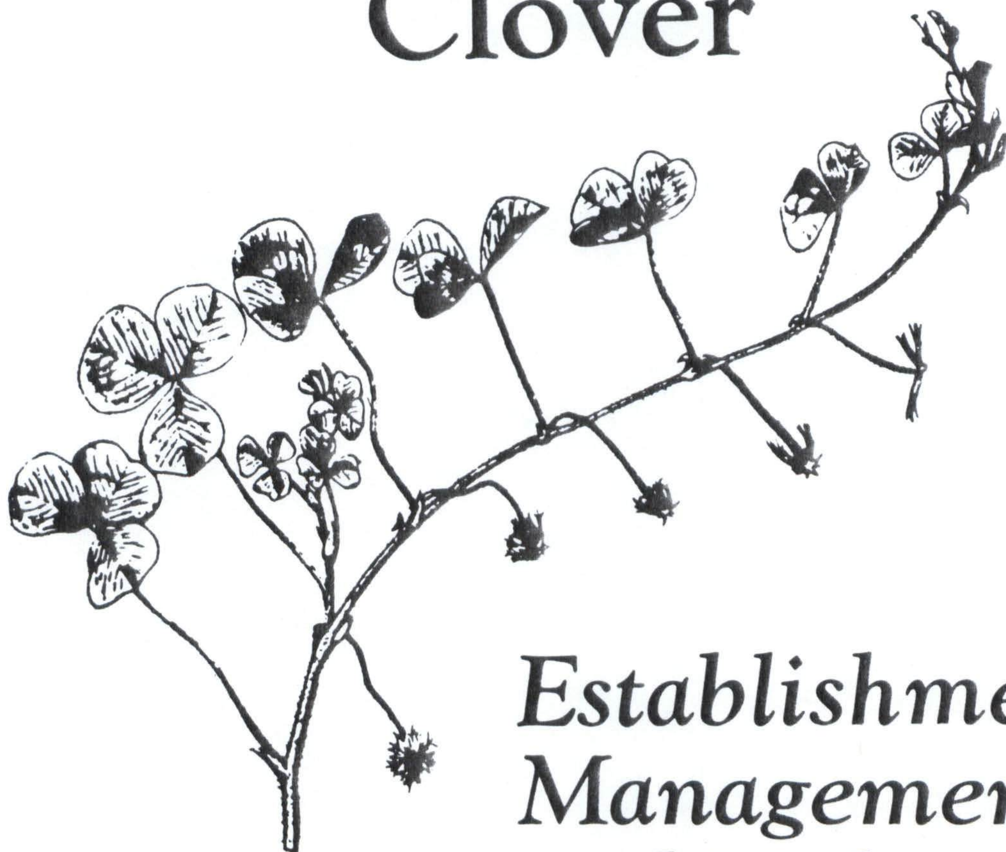
Subterranean Clover



Establishment, Management, and Utilization in Texas

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CHAPTER 5

Nutrient Requirements of Subterranean Clover

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Introduction

A major contribution of subterranean clover to pastures is the fixation of nitrogen (N) through symbiosis with *Rhizobium trifolii* in root nodules. Estimates of N made available for the following crop vary up to 100 or more pounds of N per acre per year. Because subclover can utilize N fixed from the atmosphere, its requirement for fertilizer N is negligible. However, optimum N fixation occurs only in actively growing plants supplied with adequate amounts of the other 15 plant essential elements. This chapter treats the nutritional requirements of subclover for optimum growth and N fixation.

Literature Review

The most obvious and important limitation to subclover production is water. Too much or too little water restricts clover growth and activity of nitrogen-fixing bacteria. Nutritional deficiencies, especially of phosphorus (P), potassium (K), sulfur (S), magnesium (Mg), calcium (Ca), and selected trace elements can seriously limit N fixation by a direct effect on the host plant.

Soil acidity may be more critical to the growth of rhizobia than for that of subclover. Australian data indicate that subclover flourished at pH 4.5, although rhizobia failed to grow (16). However, recent research at TAES-Overton indicates that subclover cannot tolerate soil acidity at pH 5.1. At or below pH 5.5, soil aluminum (Al) and manganese (Mn) become more available for plant uptake. Excessive soil concentrations of these elements can be toxic to clover plants. Soil acidity can be neutralized by limestone application to increase the pH to 6.0 or above (24). Soils adequately limed with a high Mg limestone should contain sufficient calcium (Ca) and Mg for clover production.

Properly inoculated subclover plants growing in fertile soil should never suffer from N deficiency. However, N fixed by rhizobia is in the reduced form. When the plant takes up this N, it must secrete an equivalent amount of hydrogen ions into the soil (17). Thus, legumes excrete acidity that will eventually result in their death in acid soils unless liming is practiced. In addition, when legumes are grazed, cut, or frosted, they shed roots which decompose and release N which is taken up by grasses and weeds, allowing them to compete more vigorously for sunlight, water, and plant nutrients (24). Nitrogen mineralized by organic decomposition has an effect similar to fertilizer N and is usually a losing proposition for legumes, especially when they are grown in association with grasses.

Without P, N is seldom fixed in appreciable amounts by clover plants. Next to N, P is the most limiting nutrient for clover production. Jones and Ruckman (12) reported subclover yield increases averaging 2,600 lbs/A for the first 2 years following application of 100 lbs P/A (230 lbs P_2O_5/A). Yield increases had declined to 1,300 lbs/A in the 5th and 6th years of their study. Donald and Williams (4) estimated that 0.76 lbs of N were fixed per pound of superphosphate applied to subclover pastures in New South Wales. Varietal differences in P uptake can be significant in subclover (10). Clover stems contain lower concentrations of P than petioles and leaves (13). Critical P level was defined as percent P in the clover when lack of P limited clover yields to 95 percent of those obtained with adequate P. Leaves of subterranean clover clipped one, two, three, and four times over a 120-day period contained critical P concentrations of 0.11, 0.18, 0.23, and 0.28 percent, respectively, when the harvest at the end of 120 days following planting was analyzed (13). Defoliation prior to sampling can increase P critical levels for subclover (18). This indicates that the high P levels usually associated with legumes are required only if they are used intensively. Research in Oregon by Drlica and Jackson (5) showed that the P concentration of subclover not receiving P was approximately 0.22 percent from mid-March to mid-April and dropped to 0.18 percent in mid-May. Phosphorus fertilized clover contained 0.28 percent P from mid-March to mid-April and 0.25 percent in mid-May.

The K requirement of subclover is less readily understood. Critical levels have been almost impossible to determine. Literature values for legumes range from 0.8 to 4.0 percent, and may be related to the cation balance with Ca and Mg. It appears that higher rates of K fertilization increase the K content, but do not necessarily increase clover yield. Kimbrough et al., (15) showed that on a whole plant basis, the K level required for optimum alfalfa growth changed drastically with age at cutting.

Secondary nutrients required for clover growth include Ca and Mg, mentioned earlier, and S. In acid soils, Ca will rarely become deficient before plants are damaged by acid soil toxicities. In alkaline soils, both Ca and Mg usually occur in adequate supplies for plant growth. Magnesium could become deficient in acid soils heavily limed with calcitic limestone (Ca only) and fertilized with high rates of K. However, research documentation of Mg deficiencies in clover were not found.

Sulfur requirements of subclover have been documented. Drlica and Jackson (5) reported that treatments supplying 60 lbs P_2O_5 plus 40 or more lbs S/A increased yield 45 percent over those treatments receiving only P. Response of legumes to S fertilization has been frequently observed in western Oregon (8). Jones and Ruckman (12) reported relatively small responses of subclover to S the first 2 years. In the third, fourth, and fifth years there was a definite response to S applied with P or P plus molybdenum (Mo). Jones et al., (14) reported the amount of applied S required to reach maximum yield for first-time clipping increased with time from 2.5 ppm at 60 days to 20 ppm at 133 days. Yield response to S increased with decreasing clipping frequency. Thomas (24) reported that the S requirement of legumes was related to N. A fairly good relation is a N:S ratio of 15:1 by weight. Adequate S is necessary for protein synthesis and is required to maintain yield and forage quality in subclover (1, 8, 11). Total S values near 0.22 percent have been reported as critical levels in subclover in Australia (2, 3). Critical S values for subclover under field conditions have not been established in the United States (9).

Micronutrient requirements for subclover in acid soils are thought to include Mo, boron (B), and in heavily limed soils, possibly zinc (Zn). Increasing soil acidity decreased Mo availability, consequently, raising the soil pH by liming increases Mo availability to clovers. Jones and Ruckman (12) indicated little response of subclover to Mo applied alone, but the interaction of Mo with P increased yields. A further yield increase averaged about 4,325 lbs/A over the first 2 years of this study when Mo was applied with P and S. Petrie and Jackson (19) reported the Mo concentration in subclover leaflets and petiole samples was increased from 1.5 to over 25 ppm by application of lime, P, and Mo the first year following treatment with 0.45 lb sodium molybdate/A. The Mo concentration had decreased to below 10 ppm the second season. Although the Mo concentration was as low as 0.1 ppm, yield responses from Mo application were not evident in this study. Molybdenosis, a Mo-induced copper (Cu) deficiency, is caused by Mo concentrations above 10 ppm in clover forage (7).

Reuter et al., (22) reported an average of 200 percent yield increase due to Cu fertilization of subclover in pot culture. Their estimates of critical concentrations of Cu in the youngest open leaf at just adequate Cu supply gave values of about 3 ppm Cu for the cultivars studies. Research by Loneragan et al., (16) indicated that Zn deficiency enhanced P toxicity, but they stated that this will occur more easily in plants grown in sand and water culture than in plants grown on soils with some capacity to react with P. Research by Reuter et al., (21) confirmed that the concentration range of 12-14 ppm Zn in the youngest, open leaf blade is critical for diagnosis of zinc deficiency in subclover. Literature delineating the B requirement of subclover was not found.

Subclover Response to Fertilizers in Texas

Research on subclover plant nutrition in Texas is in its infancy. Most subclover varieties are poorly adapted to Texas' alkaline (high pH) soils, but grow well in slightly acid soils. Read (20) reported that subclover was not adapted to the Blackland prairies of Texas. Research by Evers (6) indicates that subclover grew well at pH 4.0 in a washed sand nutrient solution study, devoid of Al and Mn. Current research by Haby, at Overton, indicates that subclover cannot tolerate a soil pH of 5.1 in a Lilbert loamy fine sand (unpublished).

Dramatic responses of subclover to S fertilization of a Darco soil in a glasshouse study were reported by Rouquette and Keisling (23) (Table 1). Similar responses were observed on the Cuthbert soil where the total yield

Table 1. Subterranean Clover Response to Sulfur on Two Acid Soils From Two Harvests in a Glasshouse Study

Sulfur rate (lbs/A)	Forage Green Weight					
	Darco soil			Cuthbert soil		
	Cut 1	Cut 2	Total	Cut 1	Cut 2	Total
	gms/pot					
0	4.46	3.92	8.38	19.06	14.80	33.86
5	4.20	2.89	7.09	19.52	15.97	35.49
10	6.68	3.76	10.44	19.82	17.49	37.31
20	12.19	6.83	19.02	25.00	20.45	45.45
40	10.63	6.91	17.54	27.96	25.40	53.36
80	15.25	9.47	24.72	27.58	30.41	57.99
Avg.			14.53			43.91

was fourfold larger at the zero S rate. These soils represent the extremes in soil types of East Texas. The Darco (Grossarenic Paleudult) is a deep sandy soil compared to the Cuthbert (Typic Hapludult) which has a shallow sandy A horizon over clay containing angular fragments of ironstone.

The Texas Agricultural Experiment Station Clover Work Group initiated fertilizer research on subclover in 1986. Twelve treatment combinations of P and K were evaluated at Angleton, Beeville, and Yoakum. Total yields at the Yoakum site indicated no response to treatment. Data from the similar treatments at the Angleton and Beeville sites are presented in Table 3.

Results of a glasshouse study being analyzed at Overton, indicate that Mt. Barker subclover yield on a Lilbert loamy fine sand (Arenic Plinthic Paleudult) was increased 130 percent by application of 115 lbs P_2O_5, 67 percent by 2.25 lbs B, 24 percent by 160 lbs K, and 15 percent by 60 lbs Mg/A. Calcium, Mn, Zn, S, and Mo failed to increase subclover forage yield (Haby and Smith, unpublished). Initial soil test levels for P, B, K, and Mg were 3.2, 0.23, 20.8, and 13.4 ppm, respectively. Higher application rates of P, B, and Mg increased the soil test levels, but increased rates of K did not significantly increase soil test K levels. Increasing rates of each of these fertilizers increased the nutrient content of the clover. Successive harvests decreased the plant content of P and K, while Mg remained fairly constant and B content increased. The nutrient concentration in the first harvest forage due to application of 115 lbs P_2O_5/A was 0.29 percent which declined to 0.16 percent by third harvest. The 2.25 lbs/A B rate increased first harvest forage B levels to 29 ppm. This declined to 25.9 ppm by third harvest. The 160 lbs/A K_2O rate increased plant K content to 4.93 percent in the first harvest forage. This had declined to 0.85 percent by third harvest. Forage Mg content remained constant at 0.46 percent through three harvests.

Field application of B on split plots of subclover visually improved drought tolerance on a Darco fine sand and, consequently, reseeding of the clover the following year. Clover which received no boron failed to produce seed (Smith, unpublished).

Data from the first year of a field evaluation of subclover response to P and B indicate a significant dry matter yield increase due to application of 1.5 lbs B/A atthe first cutting (Table 2). Response to B was evaluated over all P rates (Haby and Smith, unpublished). Clover yields were increased by increasing rates of phosphorus. Saturated soil conditions in late winter and spring prevented greater yields.

Data from Angleton indicate that 120 lbs P_2O_5/A was needed to significantly increase subclover yield at the zero rate of K_2O. Only 40 lbs P_2O_5/A was needed for a significant yield increase when 40 lbs K_2O/A was also applied. Application of limestone, N, S, B, and a micronutrient treatment had no effect on subclover yield.

At Beeville, 80 lbs K_2O/A was needed in order to obtain a significant response to 120 lbs P_2O_5/A. Hint of a subclover response to S was indicated when 40 lbs P_2O_5/A was applied as superphosphoric acid which contains S (data not shown). However, this response was not noted when the P_2O_5 rate was increased to 80 lbs/A. Subclover did not respond to N, B, Mg, or micronutrients this first year at the Beeville location.

Table 2. Field Response of Subclover to Boron and Phosphorus on an East Texas Acid Soil

Boron rate lbs/A[2]	Dry Matter Yield[1]		
	Harvest 1	Harvest 2	Total
	Pounds/Acre		
0	726 a	1,587 a	2,314 a
1.5	1,059 b	1,594 a	2,653 b
3.0	739 a	1,410 a	2,148 a
4.5	800 a	1,478 a	2,278 a
P_2O_5			
0	194 a	1,122 a	1,317 a
50	747 b	1,534 b	2,282 b
100	932 bc	1,589 b	2,521 bc
200	1,066 cd	1,647 b	2,713 c
400	1,216 d	1,693 b	2,909 c

[1]Yields within individual columns followed by the same letter are not significantly different at the p = 0.05 probability level.

[2]Hot water soluble B tested 0.15 ppm. NH_4OAc-HC1-EDTA P tested 1.8 ppm.

Table 3. Subclover Response to Phosphorus and Potassium at Angleton and Beeville, Texas

Fertilizer N-P_2O_5-K_2O	Dry Matter Yield of Sub Clover[1]	
	Angleton[2]	Beeville[3]
— lb/A —	Pounds/Acre	
0- 0- 0	2,323de	1,716cd
0- 40- 0	2,289e	2,013abcd
0- 80- 0	2,527cde	1,939abcd
0-120- 0	3,290ab	1,790bcd
0- 0-40	2,304de	1,967abcd
0- 40-40	3,184abc	1,730cd
0- 80-40	3,289ab	2,093abcd
0-120-40	3,033abcd	1,812bcd
0- 0-80	2,469cde	1,813bcd
0- 40-80	2,855bcde	2,112abcd
0- 80-80	3,177abc	2,084abcd
0-120-80	3,080abc	2,361a

[1]Yields within sites followed by the same letter are not significantly different at the p = 0.05 probability level.

[2]G. Evers, unpublished, Texas Agric. Ext. Service soil test levels: pH-6.0, P-2 ppm, K-232 ppm.

[3]W. Ocumpaugh, unpublished, Texas Agric. Ext. Service soil test levels: pH-7.6, P-19 ppm, K-272 ppm.

Summary

Preliminary research indicates that subclover grown on East Texas acid sandy soils should be responsive to phosphorus, potassium, sulfur, magnesium, and boron, depending on the soil test levels of these nutrients. Soils which have a pH below 5.5 should be limed to 6.0 or above. This will provide calcium for subclover, increase molybdenum availability, and eliminate the possibility of

aluminum or manganese toxicity. Clover growing on the deeper sandy soils should be more responsive to sulfur application. Research indicates that a combination of phosphorus and potassium can increase subclover production on less acid or alkaline soils. Copper, which increased subclover yields in Australia, has not been studied in Texas.

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