NUTRIENT SCREENING FOR ALFALFA RESPONSE

V. A. Haby, J. V. Davis, and A. T. Leonard

SUMMARY

Alfalfa (*Medicago sativa*) production on Alfisols and Ultisols in the East Texas Timberlands is hindered by a number of problems which include soil acidity and nutrient deficiencies. This greenhouse-pot study nutrient screening technique was conducted to determine response of 'Cimarron' alfalfa to the main effects of phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sulfur (S), zinc (Zn), copper (Cu), boron (B), and molybdenum (Mo) in a randomized complete block design with 4 replications. Three selected rates of each nutrient were applied to soil from the Ap (0-6") horizon of the Darco series (loamy, siliceous, thermic, Grossarenic Paleudult). Soil incorporated treatments consisted of a check with no nutrients applied, all nutrients applied at the 1x rate, and all nutrients applied at the 2x rate. In addition, the zero and the 2x rates of each individual nutrient were tested at the 1x rate of the other 8 nutrients. All nutrients except Mo contributed to increased yield in various cuttings. Calcium as $Ca(OH)_2$, and S, P, K, and Zn affected alfalfa yield most strongly. Zinc decreased yield. This study suggested that limestone, P, K, and S should be applied to the field for alfalfa production on the Darco soil.

INTRODUCTION

Livestock, dairy, and horse producers in the East Texas Timberlands are dependent on interstate shipment for alfalfa hay. In addition, this area lacks a warm season perennial legume which could be grown in association with Coastal bermudagrass. Coastal bermudagrass interseeded with alfalfa could improve forage quality while reducing the requirement for fertilizer N on soils which have a high leaching potential for ground water contamination by NO_3. Soil problems prohibiting alfalfa production in this region include soil infertility and acidity. The objectives of this study were to determine the most yield limiting nutrients for alfalfa production on the Darco soil, and to determine the rates of each nutrient to apply in future field studies with alfalfa.

PROCEDURES

Soil was collected from the Darco series Ap horizon (plow depth) and air dried. Plant essential nutrient elements and rates studied, including source, and percent concentration are shown in Table 1. The mass of each nutrient applied to 9 kg (19.84 lb) of soil is presented in Table 2. Treatments 1, 2, and 3 were all nutrients applied at the zero rate, at the 1x rate, and at the 2x rate, respectively. Each individual nutrient was tested at its zero and 2x rate with all other nutrients applied at their 1x rate. A treated soil mass of 2.2 kg (4.85 lb) was placed into 15.2 cm (6 inch) diameter plastic pots. The soil was saturated to field capacity for 1 d to allow the chemicals to begin to equilibrate. 'Cimarron' alfalfa was seeded into the pots and thinned to 10 plants per pot. The pots were watered daily as needed. Greenhouse temperature was set at 20°C. The first harvest was collected 85 d after seeding. Succeeding harvests were collected at 30 day intervals. Data were statistically analyzed using micro SAS.

RESULTS

Soil test data indicate that the Darco soil Ap horizon was deficient in N, P, K, Mg and B (Table 3). Calcium tested in the moderate level. Sulfur and the micronutrient cations tested high. Soil pH indicated moderate acidity.

Statistical analysis of alfalfa dry matter showed that P, K, S, B, and Ca as $Ca(OH)_2$ contributed to significant yield increases ($P \leq 0.05$) in harvest 1 (Table 4). At harvest 2, all plant nutrients but Mo significantly increased yield. At harvest 3, Mg and B along with Mo ceased to have an effect on yield. Analysis of nutrient effects on total alfalfa yield indicated that the B effect on harvest 1 carried through to the total, while the effect of Mg on harvest 2 did not. Regression equations for each harvest and the total are presented in Table 5. Multiple correlation coefficients indicated that 68% or more of the variation in yield at all cuttings was accounted for by the nutrients indicated as significant in Table 4.

The effect of the variable P and K rates on alfalfa yield for individual harvests when the rate of other nutrients which significantly affected yield (probability level ≤ 0.01) was held constant at the 1x rate is shown in Fig. 1 and 2, respectively. Response to P was essentially linear and indicated that the rates selected for this study were inadequate to maximize yield. Response to K was quadratic and indicated that maximum yield was attained in the range of 75 to 100 kg K ha^{-1} (67 to 89 lb K/ac) for harvests 1 and 3. For harvest 2, yield appeared to be maximized at 125 kg K ha^{-1} (112 lb K/ac).

Total yield response of alfalfa to K, P, S, and Ca is indicated in Fig. 3. Total yield was maximized by approximately 100 kg K (89 lb/ac), 60 kg S (54 lb/ac), and 1250 kg Ca ha^{-1} (1115 lb/ac) as $Ca(OH)_2$. Total yield response to P was linear.

Not all nutrients increased yield. Increasing rates of Zn significantly lowered alfalfa yield on this soil (Fig. 4 and Table 5).

DISCUSSION

Results of this greenhouse nutrient screening test verify that the Darco soil is infertile. To have a chance to effectively produce alfalfa on this soil would require the application of P, K, S, B, and Ca as a liming material. The use of only the Ap horizon limits the application of greenhouse test results to the field, however. Sulfur which had a strong effect on increasing alfalfa yield, increases in concentration with depth in the Darco soil at this location. Over 800 lb S/ac were measured in the top 7 feet of this soil. This does not preclude the application of S as a starter fertilizer prior to seeding alfalfa.

TABLE 1. PLANT NUTRIENTS, APPLICATION RATES, SOURCES, AND CONCENTRATION

Nutrient	Application Rates			Sources	Conc.
	-------------kg ha^{-1}†------------				%
P	0	56	112	Phosphoric acid	17.48
K	0	75	150	Potassium chloride	46.0
Ca	0	775	1550	Hydrated lime	62.9
Mg	0	33.5	67	Magnesium chloride	11.95
Zn	0	3.4	6.7	Zinc chelate	14.5
B	0	1.12	2.24	Boric acid	39.65
S	0	33.6	67.2	Sodium sulfate	58.0
Cu	0	1.12	2.24	Copper chelate	22.57
Mo	0	0.21	0.42	Sodium molybdate	14.2

†kg ha^{1} x 0.8923 = lb/ac

TABLE 2. MASS OF EACH NUTRIENT APPLIED TO THE SOIL FOR 4 REPLICATIONS OF EACH TREATMENT

Treatment	B	Ca	K	Mg	Cu	Mo	P	S	Zn
	g/9 kg								
1 Check	0	0	0	0	0	0	0	0	0
2 All 1x	.033	8.628	.732	1.444	.040	.003	1.141	.765	.122
3 All 2x	.066	17.256	1.463	2.888	.079	.006	2.281	1.529	.243
4 0 B	0	8.628	.732	1.444	.040	.003	1.141	.765	.122
5 2x B	.066	"	"	"	"	"	"	"	"
6 0 Ca	.033	0	"	"	"	"	"	"	"
7 2x Ca	"	17.256	"	"	"	"	"	"	"
8 0 K	"	8.628	0	"	"	"	"	"	"
9 2x K	"	"	1.463	"	"	"	"	"	"
10 0 Mg	"	"	.732	0	"	"	"	"	"
11 2x Mg	"	"	"	2.888	"	"	"	"	"
12 0 Cu	"	"	"	1.444	0	"	"	"	"
13 2x Cu	"	"	"	"	.079	"	"	"	"
14 0 Mo	"	"	"	"	.040	0	"	"	"
15 2x Mo	"	"	"	"	"	.006	"	"	"
16 0 P	"	"	"	"	"	.003	0	"	"
17 2x P	"	"	"	"	"	"	2.281	"	"
18 0 S	"	"	"	"	"	"	1.141	0	"
19 2x S	"	"	"	"	"	"	"	1.529	"
20 0 Zn	"	"	"	"	"	"	"	.765	0
21 2x Zn	"	"	"	"	"	"	"	"	.243

TABLE 3. PLANT AVAILABLE NUTRIENT LEVELS IN DARCO SOIL†

		Macro and Secondary Nutrients					
	pH	NO_3-N	P	K	Ca	Mg	S
		ppm					
Value	5.9	1	1	95	508	64	75
Rating		VL	VL	L	M	L	H

	Micro Nutrients and Salinity						
	Zn	Fe	Mn	Cu	B	Na	EC
	ppm						dSm^{1}
Value	0.34	9.37	25.7	0.17	0.03	55	
.01							
Rating	H	H	H	H	L	. VL	L

†Procedures used in the Texas Agric. Ext. Service Laboratory (Johnson et al., 1984).

TABLE 4. ANOV FOR ALFALFA RESPONSE TO APPLIED NUTRIENTS

Element	Cut 1	Cut 2	Cut 3	Total
P	***	***	***	***
P^2	***	***	NS	***
K	***	***	***	***
K^2	***	***	***	***
Ca	***	***	***	***
Ca^2	**	***	**	***
B	**	*	NS	**
B^2	***	*	NS	**
S	***	***	***	***
S^2	NS	***	**	***
Mg	NS	**	NS	*
Mg^2	NS	**	NS	*
Cu	NS	***	**	**
Cu^2	NS	**	**	**
Zn	NS	***	***	***
Zn^2	NS	*	**	**
Mo	NS	NS	NS	NS
Mo^2	NS	NS	NS	NS
R^2	0.86	0.86	0.80	0.88
C.V.	4.71	8.24	7.73	5.76

*, **, ***Significant at $P \leq 0.10$, 0.05, and 0.01 levels, respectively.
NS = not significant

TABLE 5. REGRESSION EQUATIONS AND CORRELATION COEFFICIENTS

Harvest	Equation No.	Equation
1	1	$\hat{Y} = 5.341 - 0.601\ B + 0.283\ B^2 + 0.000272\ Ca + 0.0171\ K - 0.0000820\ K^2 + 0.0168\ P - 0.0000340\ P^2 + 0.0141\ S$ $R^2 = 0.79$ C.V. = 5.3
2	2	$\hat{Y} = 3.266 + 0.114\ S - 0.000975\ S^2 - 0.267\ Ca + 0.0169\ K - 0.0000585\ K^2 + 0.00154\ Ca - 0.000000561\ Ca^2 - 0.177\ Zn + 0.0179\ P - 0.0000291\ P^2$ $R^2 = 0.77$ C.V. = 9.8
3	3	$\hat{Y} = 5.483 + 0.039\ S + 0.0194\ K - 0.000101\ K^2 + 0.00123\ Ca - 0.185\ Zn + 0.00973\ P$ $R^2 = 0.68$ C.V. = 8.9
Total	4	$\hat{Y} = 13.572 + 0.190\ S - 0.00136\ S^2 + 0.0437\ K - 0.000182\ K^2 + 0.00438\ Ca - 0.00000155\ Ca^2 - 0.428\ Zn + 0.0424\ P - 0.0000551\ P^2$ $R^2 = 0.81$ C.V. = 6.6

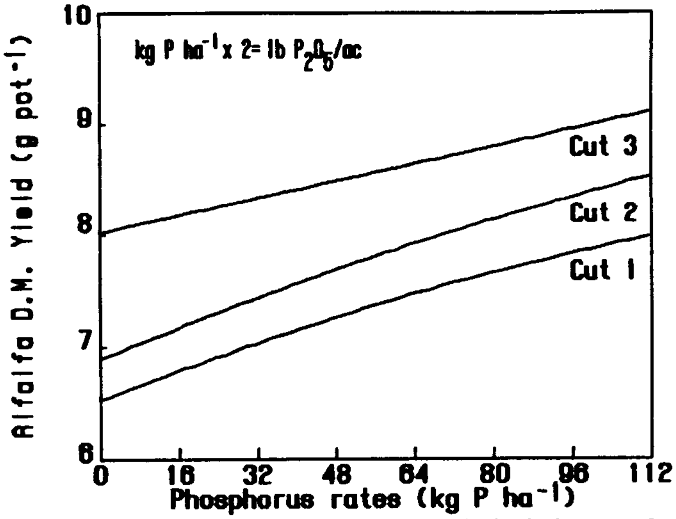

Fig. 1. Alfalfa response to P predicted for each harvest by Eq. 1, 2, and 3 in Table 5.

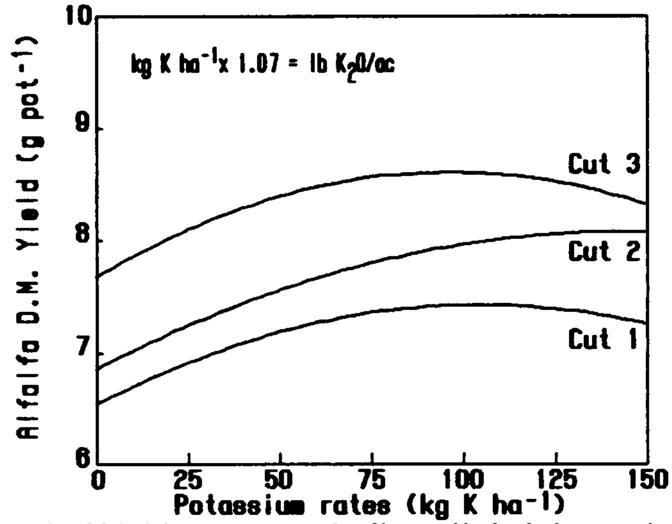

Fig. 2. Alfalfa response to K predicted for each harvest by Eq. 1, 2, and 3 in Table 5.

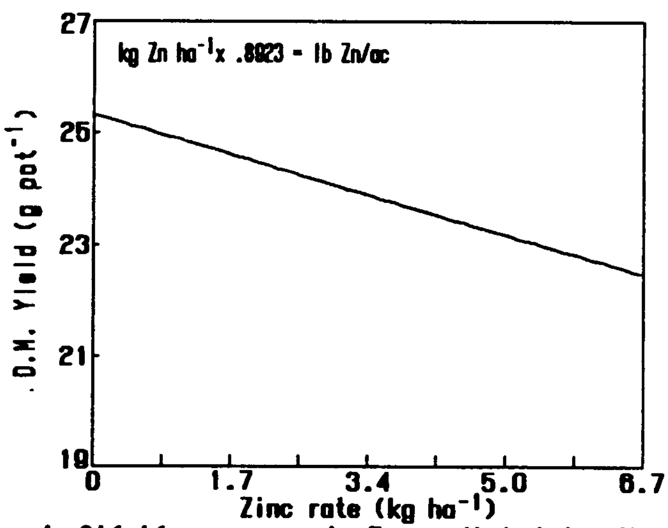

Fig. 4. Alfalfa response to Zn predicted for the total yield by Eq. 4 in Table 5.

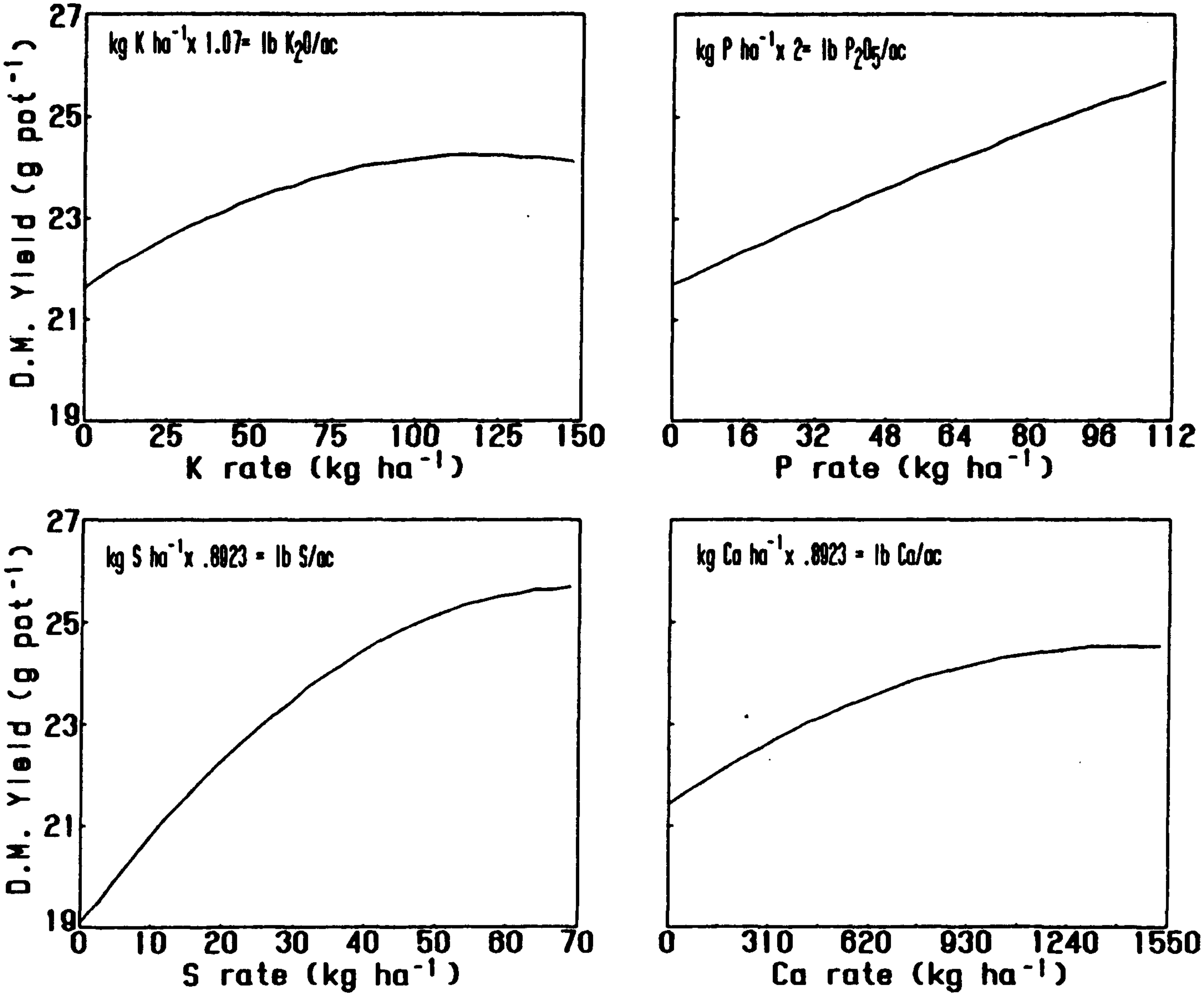

Fig. 3. Alfalfa response to rates of individual nutrients as predicted by equation 4. Nutrients entered into equation 4 were calculated at the 1x rate when not considered for an individual graph.