Using DRIS to assay nutrients in subclover

Correction of a DRIS-indicated sulfur deficiency resulted in a significant subclover yield increase per acre.

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It works well in diagnosing phosphorus and sulfur status

Procedures for diagnosing the nutrient status of crops by tissue analysis generally require the sampling of particular plant parts at particular stages of development. In this way, differences in nutrient composition due to age and type of tissue are avoided. This approach is applicable to pasture crops but is made more difficult by grazing, which affects plant growth and nutrient concentration. Concentrations of nitrogen, phosphorus, potassium, and sulfur are affected in a similar way by plant age (concentration decreases with age), plant part (concentrations are usually higher in younger tissue), or defoliation (concentrations are often higher in grazed plants). The ratios of these nutrients therefore do not change as much through time or with plant part sampled as do the individual nutrient concentrations. The Diagnosis and Recommendation Integrated System (DRIS) takes advantage of these characteristics, making sampling time and plant part less critical.

DRIS assesses the nutrient status of crop and forage plants by comparing ratios of important element concentrations in the tissue being assayed with the same ratios (called reference norms) from high-producing crops. These comparisons are made simultaneously on several ratios by computing a DRIS index for each nutrient being studied (see indices in box). From these indices, nutrients are ranked in order of those most limiting to yield, the most negative index indicating the most deficient nutrient, and the highest positive value indicating the most abundant nutrient. The total of these indices, added together whether they are positive or negative numbers, indicates the degree of nutrient balance; the lower the total, the more nearly the nutrients are in balance. (Further details are given by M.E. Sumner in "Diagnosing the Sulfur Requirements of Corn and Wheat using Foliar Analysis," *Soil Sci. Soc. Am. J.* 45:87-90. 1981, and C.A. Jones in "Proposed Modifications of the Diagnosis and Recommendation Integrated System [DRIS] for Interpreting Plant Analyses," Commun. in Soil Sci. Plant Anal., 12[8]:785-794. 1981.)

Reference norms for the use of DRIS are available for corn, wheat, soybeans, alfalfa, sugarcane, potatoes, pineapples, sorghum, and rubber trees. Pasture plants are not on this list, in part because suitable yield, response, and analytical data are less common for pasture than for crops. Large responses, however, to nitrogen, phosphorus, sulfur, and sometimes potassium and calcium have been observed on California's annual grasslands, and subclover has supplied the nitrogen needs of many pastures. Having a method of assaying the nutrient status of sub-

TABLE 1. *Diagnosis and Recommendation* Integrated System (DRIS) foliar diagnostic reference norms for subclover*

Parameter	Norm value	Standard deviation
P/N	0.091	0.022
N/S	14.438	3.910
K/N	0.751	0.184
Ca/N	0.317	0.130
Mg/N	0.093	0.152
P/S	1.291	0.386
K/P	8.507	2.244
Ca/P	3.647	1.416
Mg/P	1.008	0.398
K/S	10.510	2.615
Ca/S	4.695	2.516
Mg/S	1.314	0.690
K/Ca	2.641	1.036
K/Mg	9.839	4.761
Mg/Ca	0.312	0.161

*Nutrient concentrations were expressed as % of dry matter.

TABLE 2. DRIS indices, yield, and nutrient concentration in subclover as affected by phosphorus and sulfur fertilization on a Yorkville soil, Hopland, California

Fertilizer		DRIS indices								Percent nutrient in subclover					
P	S	N	P	S	K	Ca	Mg	Sum*	Yield	N	P	S	K	Ca	Mg
lb/acre									*lb/acre*	------	------	------	%	------	------
March 27															
0	0	0	−4	−20	22	−9	11	66	1,771	2.80	0.23	0.13	3.13	0.68	0.36
50	0	−5	9	−20	18	−13	11	76	2,959	2.73	0.33	0.14	3.10	0.62	0.38
200	0	−6	12	−18	11	−8	8	64	3,980	2.81	0.37	0.15	2.96	0.76	0.38
0	20	0	−17	−3	18	−8	10	56	3,672	3.05	0.18	0.20	3.17	0.72	0.36
50	20	−1	1	−4	4	−9	9	28	5,284	3.30	0.32	0.22	2.84	0.78	0.41
200	20	−4	10	−7	1	−9	9	40	5,422	3.15	0.39	0.21	2.67	0.78	0.42
0	80	0	−13	2	12	−10	9	46	4,296	3.23	0.21	0.24	3.09	0.70	0.38
50	80	0	0	1	1	−10	8	20	4,658	3.26	0.30	0.24	2.58	0.71	0.40
200	80	−3	7	2	−1	−10	5	28	5,205	3.40	0.39	0.27	2.71	0.73	0.39
LSD (.05)									658						
April 25															
0	0	−9	−8	−21	16	7	15	76	3,664	1.63	0.15	0.09	1.95	0.75	0.28
50	0	−15	11	−21	9	4	12	72	5,254	1.69	0.25	0.10	2.00	0.78	0.30
200	0	−17	16	−20	3	5	13	74	7,011	1.80	0.30	0.11	1.88	0.88	0.35
0	20	−8	−22	−5	12	10	13	70	6,567	1.74	0.12	0.13	1.90	0.82	0.27
50	20	−7	1	−4	−1	0	11	24	7,674	2.11	0.23	0.16	1.77	0.78	0.33
200	20	−12	10	−8	−4	3	11	48	7,789	2.09	0.30	0.15	1.76	0.93	0.37
0	80	−8	−21	4	5	7	13	58	7,190	1.97	0.14	0.19	1.89	0.88	0.32
50	80	−9	0	4	−7	2	10	32	7,803	2.18	0.24	0.21	1.69	0.90	0.36
200	80	−12	6	4	−6	0	8	36	8,141	2.16	0.29	0.22	1.76	0.87	0.35
LSD (.05)									1,174						

*Sum of indices irrespective of sign.

TABLE 3. DRIS indices, yield, lamb production, and nutrient concentrations in grazed subclover pastures as affected by phosphorus and sulfur fertilization on Sutherlin soil, Hopland

Fertilizer*	DRIS indices								Percent nutrient in subclover					
	N	P	S	K	Ca	Mg	Sum†	Yield	N	P	S	K	Ca	Mg
								lb/acre forage 2/7/85	------	------	------	%	------	------
Feb.														
PoSo	3	−3	−9	9	−6	6	36	1,060	3.21	.25	.17	2.77	.75	.33
PoS+	6	−4	8	6	−12	−4	40	1,750	3.99	.27	.32	2.94	.62	.23
P+So	4	−5	−2	6	−11	8	36	1,676	3.43	.25	.21	2.67	.66	.36
P+S+	6	−5	4	3	−9	1	28	2,992	3.85	.26	.27	2.71	.70	.30
LSD (.05)								694						
								lb/acre lamb gain						
Mar.														
PoSo	3	−1	−12	7	−4	7	34	303	2.81	.23	.14	2.31	.75	.31
PoS+	4	−7	7	8	−9	−3	38	542	3.79	.26	.30	3.07	.71	.25
P+So	5	−2	−7	7	−9	6	36	432	3.35	.26	.18	2.61	.67	.32
P+S+	6	−3	2	2	−6	−1	20	599	3.76	.26	.25	2.65	.79	.28
LSD (.05)								72						
								lb/acre lamb gain						
Apr.														
PoSo	−1	1	−18	8	−2	11	40	303	2.42	.23	.12	2.22	.73	.33
PoS+	2	−10	9	4	−8	3	36	542	3.35	.22	.30	2.66	.71	.30
P+So	−1	6	−13	7	−6	6	40	432	2.54	.28	.14	2.40	.79	.31
P+S+	2	−9	3	2	−3	5	24	599	3.18	.21	.23	2.43	.83	.33
LSD (.05)								72						

*PoSo indicates no phosphorus or sulfur applied. S+ treatments received 88 pounds sulfur per acre, October 1982 and 100 pounds October 1984. P+ indicates an average of three phosphorus treatments: 50 pounds phosphorus per acre, October 1982; 25 pounds phosphorus, October 1982 and 1983; and 12 pounds phosphorus per acre, October 1982, 1983, and 1984.
†Sum of indices irrespective of sign.

TABLE 4. DRIS indices, yields, and nutrient concentrations in subclover as affected by phosphorus, sulfur, and molybdenum (Mo) fertilization on Newville soil, Glenn County, California, April 1985

Fertilizer*	DRIS indices								Percent nutrient in subclover					
	N	P	S	K	Ca	Mg	Sum†	Yield	N	P	S	K	Ca	Mg
								lb/acre	------	------	------	%	------	------
Check	4	−9	0	−5	6	4	28	3,770	3.66	0.26	0.23	2.34	1.42	0.36
PS	2	3	7	−13	0	1	26	5,990	4.02	0.38	0.32	2.05	1.25	0.37
PSMo	1	1	11	−12	−2	1	28	5,400	4.14	0.38	0.40	2.22	1.20	0.37

*Phosphorus was applied at 84 pounds, sulfur at 114 pounds, and molybdenum at 4 ounces per acre, September 1984.
†Sum of indices irrespective of sign.

clover growing in these nutrient-deficient pastures would be very helpful.

Our purpose here is to present tentative DRIS reference norms of six nutrients for subclover and to illustrate their use by presenting DRIS indices from several field sites.

Deriving reference norms

We derived reference norms from subclover samples taken from five northern California fertilizer trials. Samples from a Josephine soil site (Typic Haploxerults) near Yorkville were collected in April 1970 in a study of application time and rate with nine phosphorus treatments and four replications. At Hopland, samples were taken in March and April 1984 from a factorial trial on a Yorkville soil (Pachic Argizerolls) with nitrogen, phosphorus, potassium, and sulfur applied in all combinations with three replications. A trial on Sutherlin soil (Ultic Haploxeralfs) tested phosphorus application time and rate with and without sulfur. Results were measured with grazing lambs, and clover samples were taken in February, March, and April 1985. Subclover from a Laughlin soil (Ultic Haploxerolls) was sampled in March and April 1985 where gypsum and elemental sulfur were compared. Samples from a Newville soil site in Glenn County were taken in April 1985.

Yields were converted to relative values, that is, percentages of the highest average treatment yield, because absolute yields varied widely at different stages of growth. Also, some of the plots were clipped to give pounds of forage yield per acre, and some were grazed to give pounds of lamb gain per acre. We used data only where clover on the highest yielding treatment had large leaves and grew vigorously. The subclover leaves were oven-dried at 60°C, ground to pass a 40-mesh screen, and analyzed for nitrogen, phosphorus, sulfur, potassium, calcium, and magnesium.

From the 396 observations in the data base, 100 were segregated as "high-yielding" — having a relative yield of at least 90 percent. The reference norms derived from this high-yielding subclover population (table 1) are preliminary and may be modified as more observations are made in more diverse environmental conditions. However, they represent a range of soil and climatic conditions. The Josephine soil site receives 60 inches of rainfall, the Laughlin, Sutherlin, and Yorkville sites about 38 inches, and the Newville site less than 20 inches.

Examples of DRIS indices

On the Yorkville soil, applications of phosphorus and sulfur together increased April yield by more than 3,600 pounds per acre over the check (table 2); nitrogen gave a smaller response and potassium gave none (not shown). The DRIS indices from subclover samples taken from the check plots in April indicate that the order of deficiency from greatest to least was sulfur, nitrogen, phosphorus, calcium, magnesium, and potassium. Both sulfur and phosphorus were indicated as deficient, and a marked yield response to each was observed. The yield increase was in clover where no nitrogen was applied and in grass where nitrogen was applied. The sulfur and phosphorus indices increased with the application of sulfur and phosphorus, respectively, at the March and April sampling dates. Although there was no yield response to potassium, the levels of this element in clover and the potassium DRIS indices did increase with potassium fertilization (data not shown).

It appears that the calcium index is not very useful. The percentage of calcium in the clover increased somewhat from March to April, while the percentage of nitrogen, phosphorus, sulfur, and potassium declined. The ratio of calcium, to the other nutrients thus increased and appeared to change from deficient to sufficient as the season advanced. Furthermore, the calcium index did not increase when this nutrient was applied as triple superphosphate, which had 65 percent as much calcium as phosphorus by weight. The magnesium indices were high at both dates, indicating, as expected, that this Yorkville soil is well supplied with available magnesium.

Some of these indices have more meaning than others. For instance, applying nitrogen did increase total yield, but this increase was in the grass rather than the clover portion. Addition of this nutrient neither increased the nitrogen level nor changed the DRIS index for nitrogen in the subclover.

The Sutherlin soil was clearly sulfur-deficient, as indicated by forage yields, lamb gains, DRIS indices, and sulfur concentrations in the clover (table 3). Levels of phosphorus in the clover appeared adequate in all treatments at each sampling date. There was a significant response to applied phosphorus, however, and the DRIS indices indicated that phosphorus was especially deficient where sulfur was applied. As on the Yorkville soil, the calcium index was misleading. Potassium and magnesium levels appeared to be adequate.

The DRIS indices for subclover samples taken from the Newville soil on April 2 indicate that phosphorus was the most deficient element, followed by potassium, sulfur, nitrogen, magnesium, and calcium (table 4). When phosphorus and sulfur were applied, the yield and DRIS indices for phosphorus and sulfur increased and the indices for potassium decreased, indicating that potassium became the most limiting factor. Whether or not this is true requires further testing.

This is a case where DRIS had a definite advantage over the critical level approach, because the high phosphorus and sulfur values in clover leaves from check plots were above critical levels and suggested that there would not be a response to these elements. The DRIS indices indicated that phosphorus and sulfur were most limiting, and a response was obtained when they were applied.

Conclusions

The DRIS appears to work reasonably well in diagnosing the phosphorus and sulfur status of subclover under field conditions, but the nitrogen and calcium indices do not appear to be very useful. On a soil where the DRIS potassium index of the unfertilized treatment indicated adequate potassium, there was no yield response to applied potassium, but the value of the potassium index increased. Further testing on potassium-responsive soils will be required to establish usefulness of the index. The usefulness of the magnesium levels also awaits further research.

Computing the DRIS indices

DRIS indices in this paper were computed using the following equations:

N Index = [−f(P/N) − f(K/N) − f(Ca/N) + f(N/S) − f(Mg/N)]/X
P Index = [−f(K/P) + f(P/N) + f(P/S) − f(Ca/P) − f(Mg/P)]/X
K Index = [f(K/N) + f(K/P) + f(K/S) + f(K/Ca) + f(K/Mg)]/X
S Index = [−f(N/S) − f(P/S) − f(K/S) − f(Ca/S) − f(Mg/S)]/X
Ca Index = [f(Ca/P) − f(K/Ca) + f(Ca/S) + f(Ca/N) + f(Mg/Ca)]/X
Mg Index = [f(Mg/N) + f(Mg/P) − f(K/Mg) + f(Mg/S) + f(Mg/Ca)]/X
where X = number of functions in the numerator (5) and

f(P/N) = (P/N − p/n)10/sd

where P/N is the actual value of the ratio of %P and %N in the plant being diagnosed; p/n is the value of the reference norm (0.091); sd is the standard deviation of this °norm's population (0.022); and the number 10 is an arbitrary multiplier to make the index a whole number.

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