DRIS Evaluation of the Nutritional Status of Crisphead Lettuce

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Abstract. Diagnosis and Recommendation Integrated System (DRIS) norms were derived for crisphead lettuce (*Lactuca sativa* L.) from field fertility experiments conducted over the past 20 years on mineral and organic soils in Florida. Preliminary testing indicates that DRIS diagnoses generally agree with diagnoses using the sufficiency range approach, with the advantage of predicting the degree of nutrient limitation. DRIS also appeared to correctly predict a response to K where sufficiency ranges currently used did not. Overall, DRIS appears to be a useful adjunct to the sufficiency range approach currently used to diagnose nutritional deficiencies in crisphead lettuce.

The Diagnosis and Recommendation Integrated System (DRIS) method of interpreting nutrient content of plant tissue has received considerable attention since being detailed by Beaufils (1973). The DRIS approach stresses nutrient balance and provides a means for comparing the degree to which various nutrients limit yield, either as a result of deficiency or excess (Walworth and Sumner, 1987). Because the DRIS approach uses nutrient ratios, it is sometimes less sensitive than the sufficiency range (SR) approach to differences caused by leaf position, tissue age, climate, soil conditions, and cultivar effects. However, a shortcoming of using nutrient ratios is that DRIS may indicate a nutrient limitation for a nutrient that is low relative to others, even though the nutrient may not be limiting yield (Beverly et al., 1984). The incorporation of nutrient concentrations in the DRIS evaluation has been proposed and used as a means of minimizing these erroneous diagnoses (Hallmark et al., 1987; Parent and Granger, 1989).

The DRIS approach has been found to provide reliable diagnosis for agronomic crops (Elwali and Gascho, 1984; Sumner, 1977; Walworth et al., 1986) and for orchard crops (Beverly et al., 1984; Parent and Granger, 1989). However, the possibility of using the DRIS approach for fast-growing short-season leafy vegetables, such as crisphead lettuce, has not been evaluated. The objectives of this work were to derive DRIS norms for crisphead lettuce and perform a preliminary evaluation of the DRIS approach as a tool for diagnosing nutrient deficiencies in lettuce.

The data used for this investigation consisted of 3316 observations from numerous lettuce field fertility experiments conducted between 1971 and 1989 on both mineral and

organic soils in southern Florida. About 20% of the observations came from experiments conducted on mineral soils, and 80% of the observations came from experiments conducted on organic soils (Histosols). Details of experimental procedures are presented elsewhere (Sanchez and Burdine, 1988; Sanchez et al., 1988, 1990).

The outermost sound leaf was collected from several plants in each plot in each experiment during the growing season (generally early to midgrowth). The leaves were dried at 60°C and ground for analysis. From 1972 to 1983, N was determined by steam distillation after micro-Kjeldahl digestion. During this same period, P was determined calorimetrically, K and Na by flame-emission spectroscopy, and Ca, Mg, Fe, Zn, Mn, and Cu by atomic absorption spectroscopy, after digestion with $\text{HNO}_3/\text{HClO}_4$ acid. During this period, B was determined using the quinalizarin method (McDougall and Biggs, 1952). In 1984, our laboratory changed to a $\text{H}_2\text{O}_2/\text{H}_2\text{SO}_4$ digestion (Wolf, 1982), after which time N was determined colorimetrically and B by inductively coupled plasma spectroscopy. Comparisons of digestion methods before the change was made indicated that both methods gave similar results.

Because quality is often the overriding factor determining the market value of lettuce, we used a combined yield-quality index to separate superior and inferior subpopulations rather than yield alone. Lettuce yields were assigned a rating ranging from 1 through 5 for marketable yield levels of 0 to 14, 15 to 28, 29 to 42, 43 to 56, and >56 $\text{Mg}\cdot\text{ha}^{-1}$, respectively. The quality of lettuce was rated from 1 to 5 as very poor, poor, fair, good, and excellent, respectively. The lettuce was rated based on head firmness, head size, and the presence of marketing defects, such as tipburn, cracked stems, rib-biness, and rib discoloration (U.S. Dept. Agr., 1973). A yield-quality index was calculated as the multiple of the yield and quality ratings. Marketable yields >50 $\text{Mg}\cdot\text{ha}^{-1}$ are generally only obtainable in the winter-spring (January to March) growing period when the

Table 1. DRIS norms for lettuce.^z

Nutrient ratio	Mean	SD
N	3.87	0.87
N : P	9.06	3.04
N : Mg	8.18	3.18
10 N : Mn	1.09	0.64
P	0.47	0.17
100 P : K	5.56	2.59
P : Mg	1.00	0.49
P : Na	2.86	2.36
1000 P : Fe	3.42	2.01
1000 P : Zn	9.24	3.79
100 P : Mn	1.67	1.50
100 P : B	1.39	0.83
K	9.64	3.11
K : N	2.62	1.19
0.1 K : Mg	1.95	0.73
10 K : Mn	2.96	2.22
10 K : B	3.75	1.21
Ca	1.62	0.57
10 Ca : N	4.41	2.09
10 Ca : K	1.93	1.12
Ca : Mg	3.23	1.34
100 Ca : Mn	4.62	3.98
100 Ca : B	5.35	2.46
Mg	0.54	0.24
100 Mg : Mn	1.43	1.15
100 Mg : B	1.63	0.60
Na	0.20	0.13
100 Na : N	5.45	3.85
100 Na : K	1.88	1.57
10 Na : Ca	1.64	0.95
10 Na : Mg	4.34	3.61
1000 Na : Fe	2.21	1.56
1000 Na : Zn	4.55	2.80
1000 Na : Mn	4.62	3.76
1000 Na : B	6.53	4.46
Fe	174.5	97.2
0.1 Fe : N	4.62	2.88
0.1 Fe : K	2.09	1.41
0.01 Fe : Ca	1.18	0.70
0.01 Fe : Mg	3.68	2.66
Fe : Zn	3.23	1.62
Fe : Mn	4.35	2.93
Fe : B	5.45	4.28
Zn	58.2	35.8
0.1 Zn : N	1.56	1.38
Zn : K	6.80	4.06
0.1 Zn : Ca	4.29	3.36
0.01 Zn : Mg	1.24	0.85
Zn : Mn	1.61	1.33
Zn : B	1.97	1.83
Mn	53.1	38.7
Cu	9.6	5.7
Cu : N	2.55	3.27
0.1 Cu : P	1.83	1.43
Cu : K	1.04	1.13
Cu : Ca	6.60	7.19
0.1 Cu : Mg	2.07	2.47
0.1 Cu : Na	5.17	11.93
100 Cu : Fe	6.41	10.33
10 Cu : Zn	1.60	1.44
10 Cu : Mn	3.30	4.21
10 Cu : B	1.92	1.65
B	31.3	9.6
B : N	8.48	2.97
10 B : Mn	5.71	3.42

^zN, P, K, Ca, and Mg concentrations are in percent dry weight and Fe, Zn, Mn, and Cu concentrations are in milligrams per kilogram dry weight.

weather is cool and irradiance is relatively high. Limiting yields in the range of 40 to 56 $\text{Mg}\cdot\text{ha}^{-1}$ are more frequent; hence, a yield-quality index of 16 was used to separate the subpopulations.

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The nutritional data were expressed in all possible ratios and reciprocal ratios. Additionally, actual concentrations of nutrients (i.e., N/dry matter) were included on the basis of recent evidence indicating that their inclusion may reduce the number of erroneous diagnoses of deficiencies. The mean, standard deviation, and variance were calculated for each nutrient concentration and all ratios between nutrient concentrations for both populations. The form of expression (N : P vs. P : N) with the greater variance ratio (s^2 superior/ s^2 inferior) was selected (Table 1). Equations used in the calculation of DRIS indices are described in detail elsewhere (Sumner, 1977; Walworth and Sumner,

1987). SRS currently used in southern Florida to diagnose nutrient deficiencies of lettuce (Table 2) were used to compare DRIS to the SR approach. These SRS closely agree with the common ranges found in lettuce leaves, as reported by Geraldson et al. (1973).

The diagnostic accuracy of DRIS and the SR approach was evaluated using two separate factorial experiments conducted in southern Florida. A nutrient was considered deficient by DRIS when its index was more negative than the DM index (Hallmark et al., 1987; Walworth et al., 1986). For brevity, only the progressive diagnosis (treatment 1 and other treatments indicated by SR or DRIS diagnosis) are shown. The first evaluation

compared the response of lettuce to P and K fertilization (Table 3). Both the DRIS and SR approach correctly diagnosed the significant ($P < 0.01$) linear response to P and K fertilizer. The second evaluation compared the response of lettuce to N, P, K, and S (Table 4). In southern Florida, S is often applied as an acidifying amendment primarily to increase the availability of Mn (Sanchez, 1990). Both the SR and DRIS evaluation of the $N_0P_0K_1S_0$ treatment diagnosed a P and Mn deficiency, indicating the need for the $N_0P_1K_1S_1$ treatment. After this addition, both SR and DRIS indicated a need for additional P ($N_0P_2K_1S_1$ treatment), although no response was obtained. This observation suggests that SR and DRIS diagnostic norms for P may be too high. However, after addition of the second P treatment, DRIS correctly diagnosed a K deficiency; whereas the SR approach did not. It is possible that current SR values used for K are too low. Although many investigators have reported K sufficiency ranges from 3% to 5%, recent studies have indicated that lettuce produced in Florida may require a K leaf concentration $>5\%$ (Beverly, 1984; Sanchez et al., 1988). However, even setting the lower end of the SR at 6% would not have identified the K limitation in this study. Nutrient balance may be a major factor influencing the K nutritional status of lettuce. Furthermore, the K requirements of lettuce may be confounded by the level of Na (Costigan and Mead, 1987). While we had the data base to integrate Na into the DRIS norms, we, unfortunately, did

Table 2. Sufficiency ranges of nutrients in the outermost sound leaves of lettuce.

Nutrient	Sufficiency range	Source of data
N (%)	4.0–5.0	Beverly (1984); Slater and Goodall (1956)
P (%)	0.35–0.60	Beverly (1984); Grant Lipp and Goodall (1958a); Sanchez et al. (1988)
K (%)	4.8–8.0	Beverly (1984); Grant Lipp and Goodall (1958b); Sanchez et al. (1988)
Ca (%)	1.2–2.0	Ashkar and Ries (1971); Vlamis (1949)
Mg ²⁺ (%)	0.4–0.8	Sanchez et al. (1988)
Fe ²⁺ (ppm)	80–200	Sanchez et al. (1988)
Zn (ppm)	30–60	Berry (1971); Boawn and Rasmussen (1971)
Mn (ppm)	25–130	Vlamis and Williams (1973)
Cu (ppm)	5–10	Adams et al. (1978); Davis and Beckett (1978)
B (ppm)	20–60	McHarque and Calfee (1933)

*We did not have and were unable to locate data where Fe and Mg concentrations were actually determined on Fe- and Mg-deficient plants. Therefore, for these nutrients, the ranges represent those commonly found in healthy lettuce leaf tissue.

Table 3. Progressive diagnoses of response of lettuce to P and K fertilizer.

Treatment ²		Factor	N	P	K	Ca	Mg	Fe	Zn	Mn	Cu	Dry matter	Yield (Mg·ha ⁻¹)	Indicated treatment
0	0	Concentration ^y	5.00	0.34	4.69	1.88	0.55	152	40	31	12	---	27.8	
		DRIS index	8	-5	-15	3	4	0	0	0	3	2		P ₁ K ₁
		SR diagnosis	0	L*	L	0	0	0	0	0	0	---		P ₁ K ₁
1	1	Concentration	5.08	0.33	4.16	2.19	0.56	120	47	22	10	---	29.2	
		DRIS index	11	-4	-21	8	5	0	1	-3	1	2		P ₂ K ₂
		SR diagnosis	0	L	L	0	0	0	0	0	0	---		P ₂ K ₂
2	2	Concentration	4.91	0.35	4.48	2.06	0.52	118	38	30	9	---	38.7	
		DRIS index	8	-3	-15	4	4	0	0	0	0	2		More K and P
		SR diagnosis	0	L	L	0	0	0	0	0	0	---		More K and P

²Treatments were three P rates (0, 118, and 236 kg·ha⁻¹) and three K rates (0, 223, and 446 kg·ha⁻¹) applied in factorial combination.

^yN, P, K, Ca, and Mg concentrations are in percent dry weight and Fe, Zn, Mn, and Cu concentrations are in milligrams per kilogram dry weight.

*Low (L) tissue concentration or 0, no limitation.

Table 4. Progressive diagnoses of lettuce response to N, P, K, and S.

Treatment ²		Factor	N	P	K	Ca	Mg	Fe	Zn	Mn	Cu	Dry matter	Yield (Mg·ha ⁻¹)	Indicated treatment
0	0	Concentration ^y	4.87	0.29	7.43	1.84	0.46	238	50	19	14	---	15.8	
		DRIS index	7	-12	0	3	0	7	0	-7	2	0		N ₀ P ₁ K ₁ S ₁
		SR diagnosis	0	L*	0	0	0	0	0	L	0	---		N ₀ P ₁ K ₁ S ₁
0	1	Concentration	4.76	0.34	7.35	2.26	0.56	188	43	38	14	---	28.9	
		DRIS index	3	-6	-1	4	0	0	-1	0	3	-2		N ₀ P ₂ K ₁ S ₁
		SR diagnosis	0	L	0	0	0	0	0	0	0	---		N ₀ P ₂ K ₁ S ₁
0	2	Concentration	4.68	0.37	6.67	1.78	0.47	157	42	38	17	---	27.6	
		DRIS index	3	-3	-4	0	0	0	-2	0	7	-1		N ₀ P ₂ K ₂ S ₁
		SR diagnosis	0	0	0	0	0	0	0	0	0	---		None
0	2	Concentration	4.85	0.42	7.57	1.89	0.48	190	51	29	14	---	35.6	
		DRIS index	1	0	-1	0	0	0	0	0	1	-1		None
		SR diagnosis	0	0	0	0	0	0	0	0	0	0		None

²Treatments were three N rates (0, 34, and 68 kg·ha⁻¹), three P rates (0, 74, and 279 kg·ha⁻¹), three K rates (84, 181, and 279 kg·ha⁻¹), and two S rates (0 and 2240 kg·ha⁻¹) applied in factorial combination.

^yN, P, K, Ca, and Mg are in units of percent dry weight and Fe, Zn, Mn, and Cu are in units of milligrams per kilogram dry weight.

*Low (L) tissue concentration or 0, no limitation.

not have data to evaluate the relationship between K and Na in the nutrition of lettuce.

Overall, these evaluations indicate that DRIS is a useful tool in diagnosing the nutritional status of lettuce. Additional testing of these norms across various plant growth stages, in lettuce-producing areas outside Florida, and for other nutrient responses in Florida is needed.

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