Preliminary Nitrogen, Phosphorus, and Potassium DRIS Norms for Pineapple

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Abstract. Diagnosis and Recommendation Integrated System (DRIS) norms for pineapple [*Ananas comosus* (L.) Merr.] were developed from 1185 observations of previously published leaf nutrient composition and yield. The data were divided into high-yielding (> 60 t·ha⁻¹, 650 observations) and low-yielding (< 60 t·ha⁻¹, 535 observations) sub-populations and the norms derived by standard DRIS techniques. The validity of the norms was tested using independently published sets of data from factorial experiments in which yield responses to N, P, and K had been obtained. In the case of most data sets, the new DRIS norms were able to make correct diagnoses where critical values failed to make any diagnoses for N, P, and K. Thus, the DRIS approach revealed nutrient deficiencies in the range normally considered to be sufficient. Increased precision is found in the evaluation of nutrient balance in the DRIS approach, which is ignored in the case of critical values.

Various workers (Godfrey-Sam-Aggrey, 1970; Kanapathy, 1958; Marchal et al., 1972; Pennock, 1944; Su, 1969) have diagnosed nutrient problems in pineapple based on leaf and soil analyses or a combination of both. The critical values or lower limits of sufficiency ranges used by these workers vary between 1.0% and 1.7% for N, 0.08% and 0.23% for P, and 1.8% and 4.2% for K. These ranges are too wide for use as diagnostic criteria if accuracy in revealing nutrient problems is desired. Although the importance of nutrient balance in determining yield and quality of crops has been known for some time, no means of readily quantifying it was available until the introduction of the Diagnosis and Recommendation Integrated System (DRIS) (Beaufils, 1973). The major advantage of this approach lies in its ability to minimize the effect of leaf age on diagnosis, enabling one to sample over a wider range of tissue age than permissible under the critical value approach. In addition, it gives a ranking of relative balance among nutrients in a tissue by means of indices that can have positive or negative values, with zero indicating balance. Furthermore, once DRIS norms have been established for a particular crop from a representative data bank incorporating all the variation likely to occur in the areas where the crop is cultivated, they are generally applicable to the crop wherever it might be grown (Beaufils, 1973). Thus,

assessment of the nutritional status of plants can be easily made. Although, in pineapple, most diagnoses have been made using critical values, Langenegger and Smith (1978) reported using DRIS based on a rather limited data base, with limited verification of their norms.

The objective of the present study is to develop DRIS norms for pineapple from a large data set, and to validate and compare their efficacy with the critical value approach using independent data.

A data bank comprising 1185 observations of leaf nutrient concentrations and yields of pineapple fruit was developed as described previously by Sumner (1977a). The observations used came from the following countries: Philippines (Coronel, 1976; Eligio, 1978), Cameroon (Gaillard, 1971), Australia (Jorgensen, 1969; Jorgensen and Page, 1969), Honduras (A. McKay, personal communication), Ivory Coast (Lacoeuilhe, 1979; Lacoeuilhe and Guerot, 1976), South Africa (Langenegger and Smith, 1978), Taiwan (Su, 1957, 1958; Su and Li, 1962), Puerto Rico (Ramirez and Tejera, 1983; Samuels et al., 1955, 1958; Samuels and Gandia-Diaz, 1960), India (Rao et al., 1977; Subramanian et al., 1977), and Venezuela (Antoni and

Leal, 1979). The norms and their coefficients of variation (cv) were developed by standard DRIS procedures (Sumner and Beaufils, 1975), using a fruit yield, based on many years of pineapple-growing experience, of 60 t·ha⁻¹ as the cutoff between low- and high-yielding sub-populations. The cutoff yield should be positioned in such a way that the high-yielding sub-population reflects conditions that are deemed to be desirable (Beaufils, 1973). However, Letzsch and Sumner (1984) have shown that the actual cutoff value used for maize has little effect on the norms developed as long as it is not too low. DRIS indices were calculated using the standard formulae (Beaufils, 1973). The norms developed were tested by the progressive diagnosis technique described previously (Beaufils, 1973; Sumner, 1977a). They involve using published data from a factorial experiment to validate the accuracy of a diagnosis. This is done by starting with the control plot, diagnosing the most-limiting nutrient using the DRIS indices, and then proceeding to test whether a yield response was obtained in the treatment in which the limiting nutrient was applied. This process is continued until all available treatment combinations have been exhausted. Similar diagnoses were conducted using the critical values suggested in a particular study, as well as the mean of critical and lower values of the sufficiency range.

The norms developed from the data base are presented in Table 1 and compared to those developed independently from a limited data base (Langenegger and Smith, 1978) composed of 39 observations with high yields. In addition, norms obtained as the average of the published critical values or lower limits of the sufficiency range are also presented (Dalldorf and Langenegger, 1978; S.F. du Plessis, personal communication; Glennie, 1977; Godfrey-Sam-Aggrey, 1970; Kanapathy, 1958; Lacoeuilhe, 1987; Langenegger and Smith, 1978; Marchal, 1971; Marchal et al., 1972; Pan, 1957; Reuter and Robinson, 1987; Samuels et al., 1955, 1958; Samuels and Gandia-Diaz, 1960; Steyn, 1961; Su, 1957; Subramanian et al., 1977). The agreement among different sets of norms is good for N, but the values for P and K were slightly higher than, but within the range of, previously published critical values. Because of the larger data base used in the development of the present norms, they are more

Table 1. DRIS norms for pineapple from various sources.

Form of expression	Current study		Derived from critical values ¹		Langenegger and Smith (1978)	
	Norm	cv (%)	Norm	cv (%)	Norm	cv (%)
N	1.43	22	1.43	20	1.52	21
P	0.25	25	0.15	20	0.11	23
K	3.24	26	2.77	20	2.76	26
P/N	0.18	31	0.11	20	0.07	26
K/N	2.30	26	1.94	20	1.70	34
K/P	13.90	40	18.35	20	25.51	33

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²For percent N, P, and K, the norms are the means of published critical values as explained in the text. The values for P/N, K/N, and K/P were obtained arithmetically from percent N, P, and K. Because it was not possible to calculate cv values in this case, a constant value of 20 was assigned arbitrarily.

Table 2. Comparison of diagnoses by the DRIS and critical value approaches using the data of Pan (1957). Arrows represent balance (→) and insufficient (↓) nutrient levels relative to critical values.

Treatment	Concn (%)			DRIS indices			Diagnosis			Total fruit yield (t·ha ⁻¹)
							Critical value ^z	Mean critical value ^y		
	N P K	N	P	K	N	P	K	N P K	N P K	
0 0 0	0.97	0.47	0.64	22	137	-159	K>N>P	↓ → ↓	↓ → ↓	42.7
0 0 1	0.80	0.41	3.57	-46	35	11	N>K>P	↓ → →	↓ → →	60.4
1 0 1	1.50	0.31	2.18	10	13	-23	K>N>P	→ → ↓	→ → ↓	111
1 0 2	1.50	0.34	3.53	-4	7	-3	N>K>P	→ → →	→ → →	105
2 0 2	2.14	0.36	3.95	7	1	-8	K>P>N	→ → →	→ → →	131
0 1 0	0.83	0.42	0.49	29	160	-189	K>N>P	↓ → ↓	↓ → ↓	41.3
0 1 1	0.67	0.54	3.29	-75	70	5	N>K>P	↓ → →	↓ → →	55.5
1 1 1	1.80	0.34	2.80	9	9	-18	K>N=P	→ → ↓	→ → →	107
1 1 2	1.50	0.39	3.67	-7	11	-4	N>K>P	→ → →	→ → →	117
2 1 2	1.87	0.32	3.59	5	2	-7	K>P>N	→ → →	→ → →	124
0 2 0	1.14	0.48	0.47	68	183	-251	K>N>P	↓ → ↓	↓ → ↓	32.8
0 2 1	0.80	0.56	3.38	-61	61	0	N>K>P	↓ → →	↓ → →	62.5
1 2 1	1.57	0.41	2.78	-1	19	-18	K>N>P	→ → ↓	→ → →	97.8
1 2 2	1.64	0.38	3.77	-4	8	-4	N=K>P	→ → →	→ → →	110
2 2 2	1.80	0.32	2.64	12	8	-20	K>P>N	→ → ↓	→ → ↓	134
0 0 0	0.97	0.47	0.64	22	137	-159	K>N>P	↓ → ↓	↓ → ↓	42.7
0 1 0	0.83	0.42	0.49	29	160	-189	K>N>P	↓ → ↓	↓ → ↓	41.3
0 2 0	1.14	0.48	0.47	68	183	-251	K>N>P	↓ → ↓	↓ → ↓	32.8
1 0 1	1.50	0.31	2.18	10	13	-23	K>N>P	→ → ↓	→ → ↓	111
1 1 1	1.80	0.34	2.80	9	9	-18	K>N=P	→ → ↓	→ → →	107
1 2 1	1.57	0.41	2.78	-1	19	-18	K>N>P	→ → ↓	→ → →	97.8
2 0 2	2.14	0.35	3.94	7	1	-8	K>P>N	→ → →	→ → →	131
2 1 2	1.87	0.32	3.58	5	2	-7	K>P>N	→ → →	→ → →	124
2 2 2	1.80	0.32	2.62	12	8	-20	K>P>N	→ → →	→ → →	134

^aPan (1957): N = 1.5%, P = 0.31%, K = 2.9%.

^bMean: N = 1.43%, P = 0.15%, K = 2.77%.

Table 3. Comparison of DRIS and critical nutrient level in making correct diagnoses in pineapple on data of Pan (1957) using the norms derived from the current study, critical nutrient level, and from Langenegger and Smith (1978).

Yield	Norm	Source		Correct response				Percent successful diagnoses
				N	P	K	Total	
Fruit	DRIS	Current study	No. ^a	9.0	0	13.0	22.0	92
			Yield ^b	346	0	425	771	
		Derived from critical value	No.	9.0	0	13.0	22.0	92
			Yield	346	0	425	771	
	Critical level	Langenegger and Smith (1978)	No.	10.0	0	12.0	22.0	92
			Yield	350	0	413	788	
			No.	6.0	0	11.0	17.0	71
			Yield	288	0	403	692	
Plant body ^c	DRIS	Current study	No.	9.0	0	15.0	24.0	100
			Yield	299	0	692	991	
		Derived from critical value	No.	9.0	0	15.0	24.0	100
			Yield	299	0	692	991	
	Critical level	Langenegger and Smith (1978)	No.	10.0	0	14.0	24.0	100
			Yield	320	0	669	989	
			No.	6.0	0	13.0	18.0	79
			Yield	234	0	646	881	

^aNumber of correct diagnoses out of 24 treatments.

^bSum of yield increases (kg·ha⁻¹) over the entire experiment when nutrient levels were diagnosed as insufficient by the appropriate diagnostic method.

^cReference did not give details, but we assumed that it refers to the weight of the aerial vegetative parts.

likely to represent the range of variation experienced in pineapple production areas. However, an independent test of the diagnostic precision of the norms relative to that of the critical values is necessary to support this claim.

A comparison of the diagnostic accuracy of the two approaches is made in Table 2 using independent data from an experiment in which significant yield responses were ob-

tained to N and K, but not P treatments (Pan, 1957). Beginning with the control treatment (0N-0P-0K), both approaches diagnose K and N as being limiting, and, when these nutrients are applied, yield generally increases until treatment 1N-0P-2K is reached, at which point the critical value approach indicates that N, P, and K are adequate, but the DRIS approach diagnoses N to be most limiting. Application of N in treatment 2N-

0P-2K results in a further yield increase, indicating that the diagnosis by DRIS was correct. Thus, the DRIS approach was able to make diagnoses that resulted in the treatment with the highest yield in the experiment being reached, whereas the critical value approach was less successful. When a different starting point was chosen, such as treatment 0N-1P-0K, a similar result is obtained, with the DRIS approach being superior to that of the

Fig. 1. Relationship between nutrient balance index and fruit yield of pineapple using data from Pan (1957).

Table 4. DRIS diagnosis of the nutritional requirements of pineapple treated with N and K using the data of Eligio (1978).

Treatment (g/plant)		Concn (%)			DRIS indices			Order of requirements	Fruit wt (kg) ^a
N	K	N	P	K	N	P	K		
0	0	0.77	0.35	2.92	-36	32	4	N>K>P	1.04
0	10	0.51	0.26	2.82	-56	32	23	N>K>P	1.01
0	20	0.72	0.30	3.55	-42	23	20	N>K>P	1.51
10	0	0.96	0.11	2.75	5	-20	15	P>N>K	1.82
10	10	0.89	0.13	3.32	-8	-15	22	P>N>K	2.01
10	20	0.91	0.15	3.25	-9	-9	18	P=N>K	1.66
20	0	1.00	0.12	2.67	5	-16	11	P>N>K	1.54
20	10	1.00	0.11	2.75	7	-21	14	P>N>K	1.77
20	20	1.07	0.10	3.33	9	-33	24	P>N>K	1.72

^aMean separations presented by Eligio (1978) are not given because the statistical treatment was inappropriate.

critical value. When treatment 0N-2P-0K was selected as a starting point, both systems had equal accuracy. If an inappropriate treatment (one that is not limiting) were applied, one would expect little or no increase in yield, as shown when the process starts with either treatments 1N-0P-1K or 2N-0P-2K. Application of P in these cases either increases the requirement for K or results in no change or a decrease in yield. In all cases, as the limiting nutrients are supplied, the nutrient balance index (NBI), being the sum of the DRIS indices irrespective of sign, progressively decreases to a low value, thus indicating that nutrition is coming into balance (Beaufils, 1973). When an inappropriate treatment is applied the reverse is true. As has been shown previously (Sumner, 1977b), a strong inverse relationship should exist between yield and NBI (Fig. 1). This relationship clearly illustrates the importance of nutrient balance in determining the yield of a crop.

A summary of such diagnostic comparisons using two sets of DRIS norms (current study and those of Langenegger and Smith, 1978) and the norms derived by taking the appropriate ratios of the critical values is presented in Table 3 for all the data represented by Pan (1957). In the case of both forms of expressing yield (fruit or plant

weight), the DRIS norms obtained in the current study had superior precision over the others. The fact that the norms derived from critical levels proved to be as effective as those derived from the data base points to the importance of assessing nutrient balance when making diagnoses. By calculating the ratios of the critical values, balance is automatically built into the diagnosis, which the critical value approach is unable to do.

Comparison of the diagnostic precision of the two systems using the data of Eligio (1978) showed that they were equally effective, but, because of the limited nature of his data set, it was impossible to test whether a response to P would have been obtained (Table 4).

The DRIS norms derived in the current study have proven to be better diagnostic parameters than were the critical values for assessing the most-limiting nutrient among N, P, and K for pineapples and are therefore offered as preliminary norms suitable for further testing. However, before the DRIS approach can be applied more effectively to pineapple, it will be necessary to derive norms for the other essential elements.

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Nitrogen and Phosphorus Preconditioning of Small-plug Seedlings Influence Processing Tomato Productivity

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Abstract. Seedlings of processing tomato 'H 2653' (*Lycopersicon esculentum* Mill.) were cultured in 288-cell (< 6 cm³ volume) plug trays in a soilless growing medium. Pretransplant fertilization with nutrient solutions containing 10 or 20 mM N and 2 or 5 mM P for 10 days altered the total ammoniacal-N and P, and the soluble NO₃-N and PO₄-P concentrations in the shoot tissue at transplanting. Post-transplanting shoot and root growth were more rapid in late May plantings than in earlier plantings. The 20-mM N and 2-mM P pretransplant treatment caused the most rapid shoot growth following early season plantings in the field. Rapid seedling establishment after transplanting was generally not a good indicator of potential fruit yield. The 5-mM P pretransplant treatment produced higher marketable fruit yields in early plantings but not in later. Culture of seedlings under a low fertilization regime (5.4 mM N, 1.0 mM P, and 1.6 mM K) before pretransplant treatment produced as high or higher fruit yields than did seedlings from a higher regimen. Withholding fertilizer temporarily before transplanting resulted in a depletion in tissue N and P concentrations, slow post-transplanting shoot growth, and lower yields.

Vegetable seedlings cultured for transplanting in small-size plug cells require careful management (Dufault and Waters, 1985; Weston, 1988) due to the volume limitations of the cell (< 6 cm³) and the high seedling

densities within the tray (≈ 28 plants/100 cm²). Essential nutrient elements within the cell plug are frequently insufficient to sustain plant growth for an extended period. A proposed fertilization scheme (Widders, 1989) for culture of tomato seedlings involves application of moderately low-concentration nutrient solutions (e.g., 4.3 mM N, 0.8 mM P, and 1.3 mM K) throughout the first 3 to 5 weeks of growth, followed by treatment with high concentrations of N and P for 5 to 10 days before transplanting. This fertilization strategy has two distinct advantages for small

plug-cell seedling culture: 1) Vegetative growth of seedlings can be controlled by limiting initial supply of nutrients, thus reducing the potential for root binding or excessive stem elongation; 2) N and P content within the seedling tissue can be enhanced before transplanting, which is important for rapid plant establishment and nutrient uptake from the soil thereafter (Widders, 1989).

The objective of this study was to determine the influence of pretransplant fertilization with N and P of small plug-cell cultured processing tomato seedlings on field establishment and ultimate fruit yield. The effects of field environmental conditions, as determined by time of planting, on seedling response to the pretransplant treatments were also evaluated.

Field experiments were conducted at the Agriculture Canada Research Station at Harrow, Ont., during Summer 1986 and 1987 and at the Michigan State Univ. Horticulture Research Center, East Lansing, during 1987. The soil at Harrow was a Fox sandy loam (Brunisolic gray brown Luvisol Typic Hapludalf) with a pH of 6.4. Nitrogen (80 kg·ha⁻¹) was applied as ammonium nitrate to the field before planting. At East Lansing, the soil was a Spinks sandy loam (Psammic sandy, mixed, mesic, Hapludalfs) with a pH of 6.3 and a cation exchange capacity of 4. The soil was preplant fertilized with (kg·ha⁻¹) 80N-160P-160K.

In all three experiments, seeds of 'H 2653' (H.J. Heinz Co.) processing tomato were sown in 288-cell plug trays (TLC Polyform, Plymouth, Minn.) containing ASB medium (ASB Greenworld, Waterloo, Ont.), a peat-based variation of the Cornell mix. Individual cells were tapered with a volume of < 6 cm³ (2 × 2 × 2 cm length, width, depth). The seedlings were cultured in a greenhouse with no supplemental lighting.

At Harrow, seeds were sown on 1 and 16 Apr. 1986 and 24 Mar. and 16 Apr. 1987. Seedlings were fertilized three times weekly with soluble fertilizer (20N-8.6P-16.6K) at 0.3 g·liter⁻¹ (4.3N-0.8P-1.3K; mM). When the seedlings were 4 to 5 weeks old, ≈ 12 cm high, four pretransplant fertilization

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