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to diagnose tree nutritional status from leaf analysis and production data

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Opsomming

Blaarvoedingstofkonsentrasies en opbrengsdata van verskeie produsente uit die belangrikste Suid-Afrikaanse sitrusproduksiestreke is ingesamel om die gebruik van DRIS as 'n benadering waardeur bome se voedingstatus gediagnoseer kan word te ondersoek. DRIS-norme het goed vergelyk met die algemeen aanvaarde

bedryfsnorme. Dit blyk egter dat, ongeag kultivar, die kalsiumnorme vir die Oos-Kaap hoër moet wees as die gevestigde norme, terwyl fosfor- en kaliumnorme vir dieselfde streek effens laer moet wees. Hierdie studie het ook bevestig dat DRIS-indekse baie nuttig kan wees om spesifieke voedingsbeperkings uit te wys, en om bemestingseffektiwiteit te kwantifiseer, veral op plaasvlak.

Summary

Leaf nutrient concentrations and yield data of various growers from major citrus producing regions in SA were collected and used to do a preliminary investigation into the use of Diagnoses and Recommendation Integrated System (DRIS) to diagnose citrus tree nutrient status. DRIS norms compared well to industry norms. It was found that calcium norms for the Eastern Cape should be higher than the established norms, irrespective of cultivar, while the norms for phosphorus and potassium in the same region should be slightly lower. This study has also shown that DRIS indices can be very useful to pinpoint specific nutrient limitations, and to validate fertiliser responses, specifically on farm level.

Introduction

Citrus mineral nutrition is widely recognised as a major contributor to fruit yield and quality, and leaf nutrient content of fruit bearing terminal shoots is considered a reliable indicator for tree nutritional status (Raath, 2021). However, tree nutritional status is affected by a variety of factors like time and type of fertiliser application, climate and soil physiochemical properties. Leaf nutrient content can assist to make

fertiliser recommendations, but soil chemical properties and nutrient status, as well as tree vigour, should also be considered. Furthermore, it must be borne in mind that yield and fruit quality are not exclusively affected by mineral nutrition - all management and pest control practices affect fruit yield. For this reason, it is important to develop cultivar and region-specific norms, even up to a farm level, to assist with designing fertiliser programs (Menino, 2012; Hernandez et al., 2014).

Interpretation of leaf mineral nutrient concentrations by comparing it to a set of reference norms is often regarded as too simplistic an approach due to the variety of factors that potentially dictate leaf nutrient concentration. In the past, the DRIS was proposed as a better approach to interpret or utilise leaf analysis results for Valencia oranges in SA (Woods and De Villiers, 1992). It is based on these principles:

- i. ratios of nutrient concentrations are often better indicators of a deficiency than individual leaf nutrient concentrations

- ii. some ratios are more important than others
- iii. maximal yields are only obtained when ratios are near the ideal (Jones, 1981).

The proposed benefits of DRIS diagnoses are that they reflect nutrient balances, identify the order in which nutrients limit yield, and that they can be used at any phenological stage (Srivastava and Singh, 2008). A DRIS index can be calculated for each nutrient, based on important nutrient ratios/expressions (e.g. for N as N/P, N/K, N/Ca and N/Mg, etc.). The formula is designed to allow the optimum DRIS index to be zero, while negative indices indicate deficiency. The generated DRIS indices, irrespective of sign, can also be totalled for each sample to determine the level at which nutrition is limiting, i.e. the smaller the value the higher demand exists for that specific nutrient.

In this project the potential value of using DRIS generated norms for citrus grown in the major South African production regions, i.e. Limpopo, Eastern Cape and Western Cape, was investigated and also compared to the currently accepted generic nutrient

Table 1. Important nutrient ratios, calculated using DRIS, as determined for Citrusdal Valencia. Significant F-values are shown with variance ratios that differ significantly at p < 0.05. These ratios were used for all DRIS index calculations.

EXPRESSION	MEAN – High yielding sub-group	MEAN – Low yielding sub-group	F-value
N/P	23.059	20.574	7.053
N/K	2.328	2.171	3.087
N/Ca	0.800	0.765	2.469
N/Mg	8.335	7.087	9.259
P/Ca	0.036	0.107	50.271
P/Mg	0.318	0.039	200.459
K/Ca	0.388	0.404	3.640
K/Mg	4.062	3.604	4.448
Ca/N	1.313	1.406	5.509
Ca/P	29.607	28.915	4.114
Ca/K	3.050	3.144	4.022
Ca/Mg	10.680	9.658	6.141
Mg/P	3.096	3.146	5.513

leaf norms for fruit bearing terminals.

Data used: Annual (2015 to 2021) leaf nutrient analysis and production data from orchards in full production (i.e. older than five years or production that exceeds 30 tonnes/ha) was obtained from producers in each major region. The leaves were sampled according to standard industry protocol, namely from fruiting terminals in March/April. Leaf mineral analysis was done according to standard protocol followed by the various commercial laboratories – accuracy of results of the laboratories is ensured through the AgriLASA inter-laboratory proficiency scheme.

Generation of DRIS indices: For each macro nutrient, a DRIS index was created using the method proposed by Jones (1981) and validated by Woods and De Villiers (1992); Srivastava and Singh, 2008; Hernandez et al., 2014) - each data set was split into a high/ideal and low/poor sub-group on account of the mean yield (tonnes/ha) for each production region and cultivar. For each sub-group, each nutrient was then expressed in relation to the other nutrients – DRIS indices (data not shown) was then calculated using these ratios and the method described by Jones (1981). The variance ratio for each relation between the high and low yielding sub-group was used to identify a significant ratio/expression. Furthermore, DRIS indices equal to and greater than zero for the high yielding sub-group were then used to determine optimum leaf nutrient concentrations, the mean of these concentrations ($\pm$ the standard deviation) was used to establish the optimum range for each nutrient.

Outcomes: Only expressions which differed significantly between high and low yielding sub-groups, based on variance ratio, were used in final calculation of DRIS indices (Table 1 is an example of this, as calculated for Valencia oranges in the Western Cape – Citrusdal). From Table 1, for

instance, it was found that phosphorous (P) and potassium (K) leaf concentration were most significantly influenced by calcium (Ca) and magnesium (Mg) levels in Valencia trees in Citrusdal. Variance ratios for nitrogen (N) and Ca with other macro-nutrients all differed significantly. Therefore, all N and Ca expressions were deemed as significant in affecting N and Ca leaf concentrations. From **Table 1** means for each expression from the high-yielding population can then be used to determine DRIS indices for Valencia grown in Citrusdal, but ideally these means can be determined for a specific farm.

Table 2. Comparison of the accepted industry norms for citrus leaf nutrient concentration to the proposed optimal macro-nutrient ranges generated from DRIS indices, using foliar analysis and production data from for three major production regions in SA.

Cultivar	Origin of norm	Region	N	P	K	Ca	Mg
			Proposed optimal nutrient concentration (%)				
Valencia	Industry norms*	Hot regions	2.3-2.6	0.12-0.15	0.9-1.5	3.5-6.0	0.35-0.50
		Other regions	2.1-2.3				
	Calculated optimal norms using DRIS	Western Cape - Citrusdal (n = 289)	2.5-2.9	0.11-0.17	1.3-1.9	3.2-4.3	0.31-0.54
		Eastern Cape – Sunday's River Valley (n = 202)	2.4-2.8	0.13-0.20	1.0-1.6	4.4-5.6	0.46-0.61
		Limpopo - Letsitele (n =64)	2.4-2.7	0.12-0.18	1.0-1.5	4.1-5.4	0.34-0.54
Navel	Industry norms*	All regions	2.4-2.6	0.12-0.15	0.7-1.1	3.5-6.0	0.35-0.50
	Calculated optimal norms using DRIS	Western Cape - Citrusdal (n = 315)	2.4-2.9	0.11-0.17	1.1-1.8	2.4-3.9	0.26-0.42
		Eastern Cape – Sunday's River Valley (n = 183)	2.5-2.9	0.13-0.21	1.3-1.8	4.5-5.6	0.42-0.56
Mandarin	Industry norms*	All regions	2.3-2.5	0.12-0.15	0.9-1.5	3.5-6.0	0.35-0.50
	Calculated optimal norms using DRIS	Western Cape - Citrusdal (n = 229)	2.2-2.9	0.12-0.16	1.0-1.9	2.7-3.7	0.36-0.58
		Eastern Cape Sunday's River Valley (n = 78)	2.4-2.9	0.12-0.18	0.8-1.0	4.8-5.9	0.49-0.58
Clementine	Industry norms*	All regions	2.2-2.4	0.12-0.15	0.9-1.6	3.5-6.0	0.35-0.50
	Calculated optimal norms using DRIS	Western Cape Citrusdal (n = 192)	2.1-2.7	0.11-0.18	1.6-2.3	2.4-3.8	0.37-0.56
Lemon	Industry norms*	All regions	2.3-2.6	0.12-0.15	0.8-1.2	3.5-6.0	0.35-0.50
	Calculated optimal norms using DRIS	Eastern Cape Sunday's River Valley (n = 278)	1.9-2.4	0.12-0.16	0.9-1.4	5.7-7.0	0.35-0.53

*As per Raath (2021) n=amount of data points used (i.e., leaf samples from individual orchards)

Norms generated using DRIS: From all the DRIS indices generated for each region and variety, (data not shown) optimal nutrient ranges could be determined. With a few exceptions, these DRIS ranges corresponded well with norms provided in the CRI handbook for fertilisation of citrus (Raath, 2021) – see **Table 2**. The DRIS generated norms were found to be very comparable to the established norms. However, the following differences might be worth noting:

- The DRIS generated P norms were slightly higher for Valencias and navels grown in the Eastern Cape
- The DRIS generated K norms were slightly higher for most cultivars and the range

was narrower in most cases – a notable exception is for mandarins in the Eastern Cape, where the DRIS generated norms are distinctly lower

- Lower Ca norms were obtained through DRIS for the Western Cape than the established norms, but higher Ca norms were established for the Eastern Cape
- The DRIS generated Mg norm lower limits were slightly higher for Eastern Cape cultivars, except for lemons.

Conclusion: This study emphasised the value of using DRIS indices to identify nutrients that are limiting tree performance, and also to evaluate possible responses to fertiliser applications. Leaf nutrient norms

that were generated using DRIS indices compared well to most of the established norms – where differences occurred, they are worth taking note of. They will be tested as more data is collected and through further data analysis. The use of DRIS can also be very useful to create nutrient norms on farm level, where less variability in management practices and climatic conditions occur, or where it is possible to note differences in orchard performance. The research team at CRI will continue to refine significant relationships/ratios using DRIS, and to further improve the leaf nutrient reference norms for the citrus industry.

Acknowledgements

The authors would like to thank and acknowledge growers from all the mentioned production regions for supplying us with leaf and production data, and their overall assistance.

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