DIAGNOSIS AND RECOMMENDATION INTEGRATED SYSTEM (DRIS) NORMS FOR AVOCADO PRODUCTION IN SOUTH AFRICA

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ABSTRACT
Diagnosis Recommendation Integrated System (DRIS) was used to determine correlations between avocado yield and soil and leaf nutrient content in the Tzaneen, Nelspruit, and Levubu areas. DRIS mainly uses the "nutritional balancing" concept (relationship among nutrients) in the detection of nutritional deficiencies or excesses in the plant. This report gives feedback on the data analysed for all the areas above. Segmented quantile regression, with both the 0.9 and 0.1 quantiles, was applied to the soil and leaf nutrient data, with crop yield as the determined variable. The graphs in the data provide a data envelope, within which 80% of the data points were located, indicating the minimum (0.1 quantile) and maximum (0.9 quantile) yields obtainable with different nutrient values. Correlations were established for yield related to soil pH, P, K, Ca, Mg, and Na respectively; as well as correlations between yields and leaf nutrient levels. Results are better than 2022, due to more data used. Some working correlations were established, which should be further investigated.

UITTREKSEL
Die "Diagnosis Recommendation Integrated System" (DRIS) is gebruik om korrelasies tussen avokado-opbrengs en grond- en blaarvoedingselement-inhoud in die Tzaneen-, Nelspruit- en Levubu-gebied te bepaal. DRIS gebruik hoofsaaklik die konsep van "voedingsbalans" (verhouding tussen voedingselemente) in die opsporing van voedingstekorte of -oormaat in die plant. Hierdie verslag gee terugvoering oor die data wat vir al die genoemde gebiede ontleed is. Gesegmenteerde kwantielregressie, met beide die 0.9 en 0.1 kwantiele, is toegepas op die data van grond- en blaarvoedingselemente, met opbrengs as bepaalde veranderlike. Die grafieke in die data verskaf 'n data-omhulsel, waarbinne 80% van die datapunte geleë was, wat die minimum (0.1 kwantiel) en maksimum (0.9 kwantiel) opbrengste aandui, en verkry kan word met verskillende voedingselementwaardes. Korrelasies is vasgestel vir opbrengs in verwantskap met grond pH, P, K, Ca, Mg en Na onderskeidelik; asook korrelasies tussen opbrengs en blaarvoedingselementvlakke. Resultate is beter as in 2022, as gevolg van meer data wat gebruik is. Sommige werkskorrelasies is vasgestel en moet verder ondersoek word.

INTRODUCTION

Nutrition and fertilisation are important factors in determining avocado yield and quality. There are several methods for plant nutritional status diagnosis. Among them, two are relevant and named as Sufficiency Range Approach (SRA) and Diagnosis and Recommendation Integrated System (DRIS). DRIS is an interpretation for analyses and was first developed by Beaufils (1973) to overcome these problems in nutrient diagnosis. DRIS enables the evaluation of the nutritional balance of a plant, ranking nutrient levels in relative order, from the most deficient to the most excessive. This method uses dual relation between a pair of nutrients instead of the use of critical level (CL) or sufficiency ranges (SR). These methods for interpretation of chemical analyses are performed from the comparison of nutrient concentrations characterized by the independence of nutrients. According to Baldock and Schulte (1996), the advantages of DRIS are that the nutrients are ordered from most deficient to the most excessive, and identify where the yield is limited by nutritional status.

However, the disadvantage of this methodology is that one nutrient's concentration can have a severe influence on the other's DRIS index. If there is severe deficiency in a nutrient, it will be considered when addressing those ratios. The DRIS index is nothing else than the average of the deviations of relationships containing a nutrient in relation to their optimal values. Each relationship between nutrients in the population of high productivity is a DRIS norm and has their respective mean and standard deviation.

For the establishment of DRIS norms, the population will be divided into high yields and low yields with a cut-off value. This will be done with the population of high yields established from yields that were greater than the average yield of the areas plus their standard deviation (m + s). Walworth and Sumner (1987) alleged that the reference limit to separate two sub-populations should be arbitrarily chosen, because each sub-population ought to present a normal distribution. A Chi-square test is used to assess the distribution.

The DRIS norms consist of average and standard deviations of dual ratios between nutrients (e.g., N/P, P/N, N/K, K/N, etc.). The database size might not be directly related to standard quality. Walworth *et al.* (1988) identified that, when they used 10 data observations to establish the DRIS norms, the results obtained were more accurate than the use of a large dataset of observations. What is more important is to improve the efficacy of DRIS norms by ensuring the quality of the data, because it is not acceptable to use sick plants for the data bank. DRIS norms are calculated in two steps: first, the functions for each nutrient pair ratio, and second, the sum of functions involving each nutrient (Fig. 1).

The DRIS approach has been used to create nutrient norms for a range of crops including peaches (Awasthi *et al.*, 2000), yams (Dagbenonbakin *et al.*, 2012), soybeans (Castamann *et al.*, 2012), and sugarcane (Reis & Monnerat, 2003), amongst others. In South Africa, the DRIS approach has been adapted to determine soil properties susceptibility to soil erosion (Van Zijl *et al.*, 2014) and surface crusting (Mills *et al.*, 2006). Soil information for the entire South Africa is available as the land type survey, at a scale of 1:250 000 (Land Type Survey Staff, 1972-2006). The land type survey identifies and groups relatively homogeneous areas where the soil distribution patterns are similar. The land types are delineated by geology, climate, and vegetation. Therefore, a land type does not consist of one soil type or soil characteristic, but rather similar soil characteristics and distribution. The distribution of the soils in a land type are described by the Terrain Morphological Unit (TMU), which indicates where in the landscape the soils are found. Land types have been disaggregated into soil associations (Van Zijl *et al.*, 2013; Van Tol *et al.*, 2016; Botha, 2016) using digital soil mapping (DSM) methods (Van Zijl, 2019).

Schulze *et al.* (2007) mapped the current climate of South Africa at a 1.8 km resolution. This information is representative of climate patterns, as climate changes over regional scales. This dataset has been used in DSM projects (e.g. Van Tol *et al.*, 2018).

The objective of this project is to determine fertiliser norms for avocados using the DRIS principles; and then compare these norms to the currently used norms in the industry.

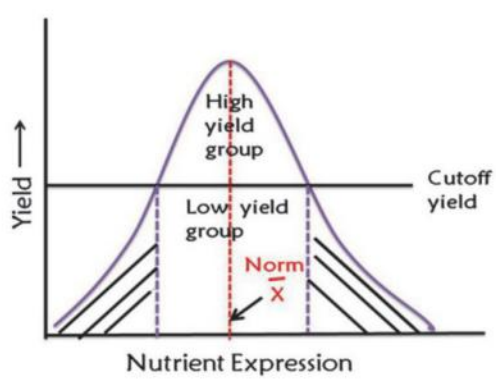

Figure 1: Schematic representation of the DRIS norms (from Walworth & Sumner, 1987).

MATERIALS AND METHODS

Data were gathered for 'Hass' avocado orchards in Tzaneen, Levubu and Nelspruit areas. Data included soil analyses, leaf analyses, and yield data, together with year of harvest, tree age, cultivar planted, and GPS coordinates of the farm. In total, there were 855 data points which included all or parts of the mentioned variables. Data points were assessed and obvious outliers as well as 0 yields, were eliminated. As avocado yields are heavily dependent on tree age, box and whisker plots were created for yields per tree age, which indicated that tree age did not influence yields, as all trees were 7 years and older. In total, 780 data points were analysed. Some significant results are reported but much is still lacking, as a result of not enough data collected.

RESULTS AND DISCUSSION

Based on the available data, the indications given in Table 1 could be inferred. However, these indications must be confirmed with more data. The current dataset is lacking in the following ways:

1. Not enough data. All the data points come from three major production areas and cannot be seen as representative of South Africa's avocado industry.
2. The data ranges where the graphs are applicable are quite narrow and need to be expanded to represent the conditions met in the South Africa avocado growing area.

Data were only sourced and analysed for 'Hass' avocado. However, all data include one major soil form, the Hutton soil form, which is representative for 'Hass' production in South Africa. The data in Table 1, identified with an asterisk (*), indicate significance, which should be further investigated. Results and data are presented and discussed in the graphs.

DATA INTERPRETATION

Soil Quantile Regressions: variables vs yield

Soil pH (*)**:** The orange dots represent where 90% of the soil pH data occur (Fig. 2). This is also where maximum yields of ± 30 ton/ha occur (current pH range for avocado is 5.8-6.8). In other words, Figure 2 indicates that the currently used pH-range under the stated circumstances is correct.

Soil P (Bray 1) (*)**:** Range is 30-60 mg/kg. Yields decline with high soil-P values. For low yields, P matters (Current norm: 30 mg/kg) (Fig. 3). Data indicate that the lower soil P norm of 30 mg/kg should be used as a fertilizer recommendation.

Soil K (*)**:** Maximum yield at 90% quantile - 33 ton/ha. Good bell-shape graph (Current norm: 70-250 mg/kg) (Fig. 4). Optimum yield at K-levels of 250 mg/kg, thereafter a decline in yield. K is also important at lower yields.

Soil Ca (*)**:** Graph shows minimal influence of Ca on yield. Ca very important for good yield, however, no drastic yield differences between 500-2000 mg/kg (Current norm: 350-1000 mg/kg) (Fig. 5). This means that lower Ca applications in the form of lime and gypsum may be efficient; meaning a cost-saving.

Soil Mg (*)**:** 90% yield at between 25-30 ton/ha yield. For low yields Mg matters. Indication that ≥ 230 mg/kg K, yields decline (Current norm: 100-200 mg/kg) (Fig. 6).

Soil Na: No final conclusion (Norm: < 30 mg/kg) (Fig. 7).

Leaf Quantile Regressions: variables vs yield

Leaf N (*)**:** Maximum yield at leaf N% of 2.5 for 'Hass' avocado. Decline > 2.5%. Good bell-shape (Current norm: 1.7-2.3) (Fig. 8). The results suggest that the leaf N norm for 'Hass' could be managed closer to between 2.3 to 2.5%.

Leaf P (*)**:** Yield decline when P > 0.15% (Current norm: 0.08-0.15%) (Fig. 9).

Leaf Ca (*)**:** Optimal yield at Ca = 1%. Yield decline

Table 1: Indications for the different measured properties

Property	Range	Maximum yield effect	Minimum yield effect
		Soil analyses	
pH (H_2O)	5-7	decreasing with lower and higher values (*)	None
P Bray 1	0-75	decreasing with increase in P	P (*)
P Ambic	0-45	none	None
K	0-400	decrease with increasing Ca (*)	Increase with increase in K (*)
Ca	0-2100	decrease with increasing K (*)	Decrease with increase in Ca (*)
Mg	0-375	none	Decrease with increase in Mg (*)
Na	0-90	increase with increase in Na (*)	None
		Leaf analyses	
N	1.6-3.2	increase with increasing N up to N = 2.6, then decrease (*)	Increase with increasing N (*)
P	0.075-0.21	decrease with increase in P (*)	None
K	0.6-1.2	none	None
Ca	0.5-1.5	decrease at lower and higher values. Optimal around 1 (*)	None
Mg	0.3-0.75	none	None
S	0.17-0.32	decrease when S > 0.28 (*)	None
Zn	16-75	increase up to Zn = 55, then decrease with increasing Zn (*)	None
B	20-90	none	None
Fe	70-210	none	None
Mn	80-670	none	Increase with increasing Mn (*)
Cu	0-350	none	None
Na	0-160	none	None
Mo	0-5	increase with increasing Mo (*)	None

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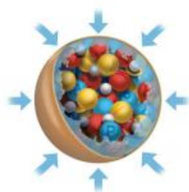

2 Following to application, soil moisture penetrates the polymer capsule and dissolves the nutrients

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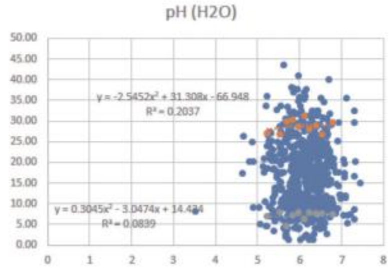

Figure 2: Soil pH vs yield.

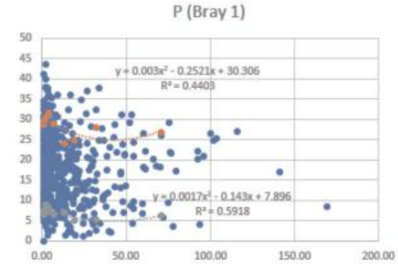

Figure 3: Soil P (Bray 1) vs yield.

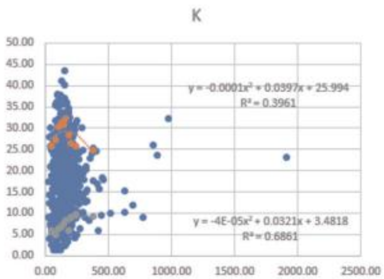

Figure 4: Soil K vs yield.

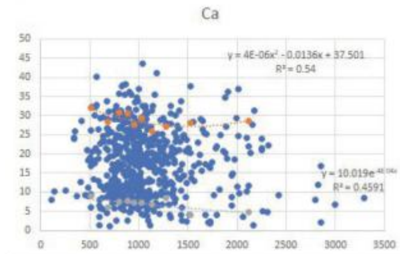

Figure 5: Soil Ca vs yield.

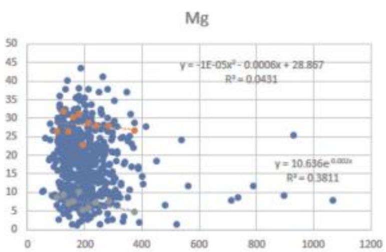

Figure 6: Soil Mg vs yield.

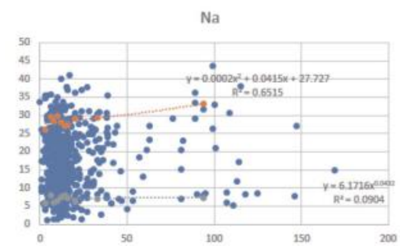

Figure 7: Soil Na vs yield.

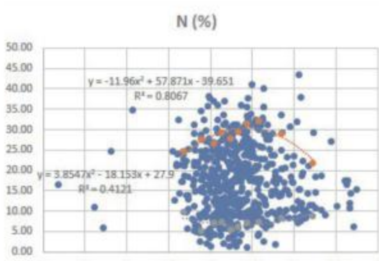

Figure 8: Leaf N vs yield.

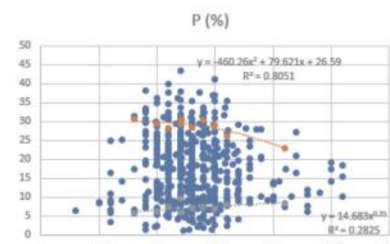

Figure 9: Leaf P vs yield.

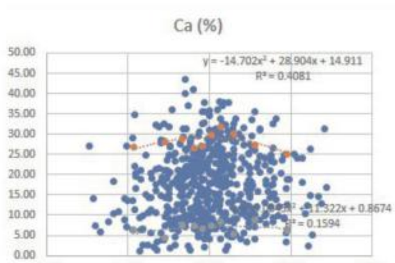

Figure 10: Leaf Ca vs yield.

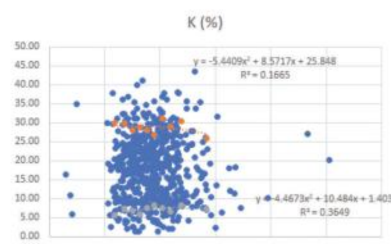

Figure 11: Leaf K vs yield.

when > 1% (Current norm: 1-2%) (Fig. 10). Results suggest that Ca leaf % should be managed at the lower level of the currently recommended norm at around 1%.

Leaf K (*)**:** MAXIMUM yield at K levels 1%. Yield decline when K > 1.25% (Norm: 0.75-1.15%) (Fig. 11).

Leaf Mg: No final conclusion (Current norm: 0.4-0.8%) (Fig. 12). Mg is important for growth at both lower and higher leaf levels.

Leaf S (*)**:** Very good bell-shape. Maximum yield at 0.22%. Yield decline when > 0.2% (Current norm: 0.2-0.6%) (Fig. 13). Preliminary results indicate that leaf S should be managed around the lower level of 0.2% of the currently recommended norm for 'Hass' avocado.

Leaf B: No final conclusion (Current norm: 40-80 mg/kg) (Fig. 14).

Leaf Na: Slight yield decline when leaf Na > 40 mg/kg (Fig. 15).

Leaf Al: Yield decline ≥ 4 mg/kg (Fig. 16). These results are consistent with the fact that too much Al may be toxic.

Leaf Cu: Good correlation and drastic yield decline when Cu > 50 mg/kg (Norm: 5-15 mg/kg) (Fig. 17). This very important result should be taken seriously, as we know that increased Cu levels are toxic, and also the fact that the avocado industry has in general much higher Copper levels in the soil and leaves.

Leaf Zn (*)**:** For leaf Zn, there is a poor correlation between yield and Zn concentration. No final conclusion (Current norm: 25-100 mg/kg) (Fig. 18).

Leaf Fe: Between the 90-160 mg/kg envelope, no effect of Fe at maximum yield of 30 ton/ha (Current norm: 50-150 mg/kg) (Fig. 19).

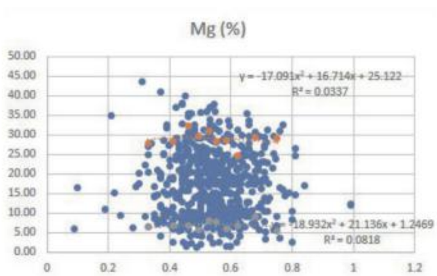

Figure 12: Leaf Mg vs yield.

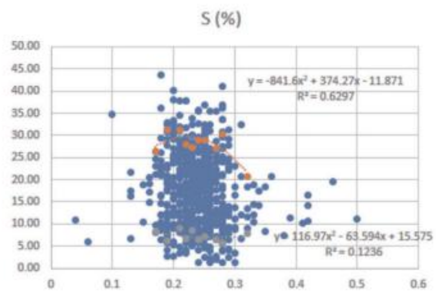

Figure 13: Leaf S vs yield.

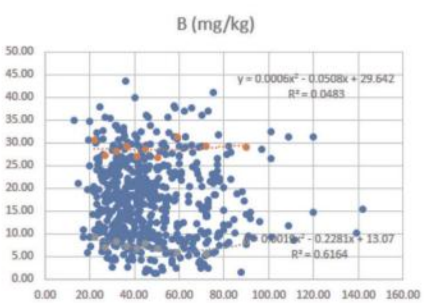

Figure 14: Leaf B vs yield.

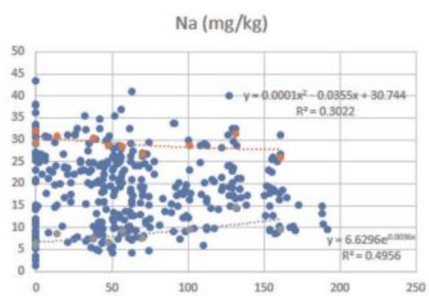

Figure 15: Leaf Na vs yield.

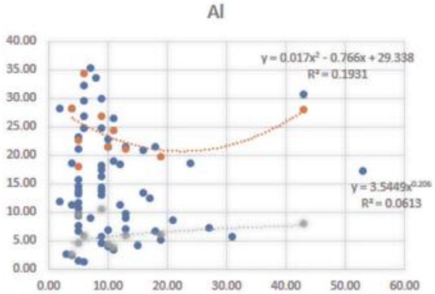

Figure 16: Leaf Al vs yield.

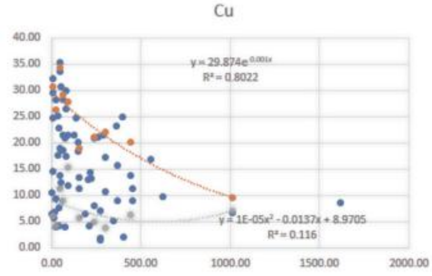

Figure 17: Leaf Cu vs yield.

Leaf Mn: No significant yield effect (Norm: 50-250 mg/kg) (Fig. 20).

Leaf Mo: No final conclusion (Fig. 21).

CONCLUSIONS

Interesting results from complete data sets for 'Hass' avocado on the Hutton soil form, for the Levubu, Tzaneen, and Nelspruit production areas. Current indications are that leaf data is a better indicator than soil data. However, more data (complete data sets) are needed to support these findings and draw significant final conclusions.

Acknowledgement
Our thanks to SAAGA and all participating farmers.

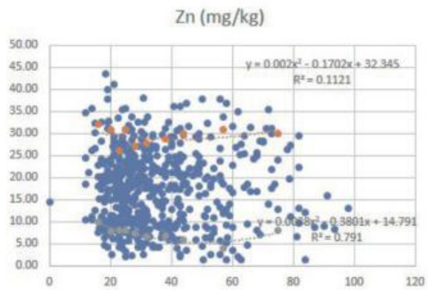

Figure 18: Leaf Zn vs yield.

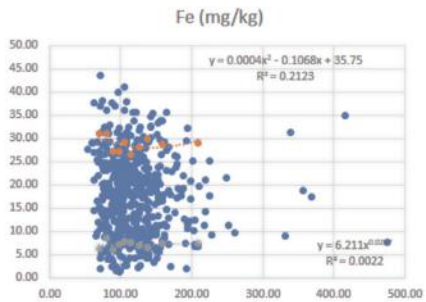

Figure 19: Leaf Fe vs yield.

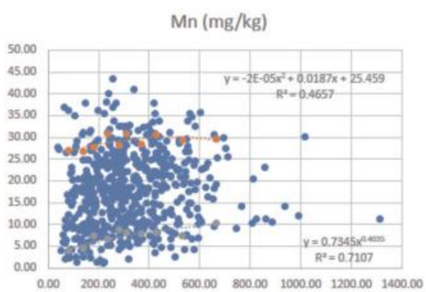

Figure 20: Leaf Mn vs yield.

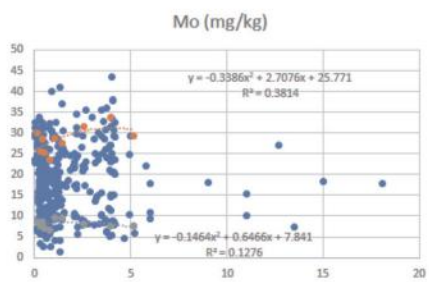

Figure 21: Leaf Mo vs yield.

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