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NUTRITIONAL REQUIREMENTS OF THE FUERTE AVOCADO: A SUMMARY OF 21 YEARS OF RESEARCH IN SOUTH AFRICA

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ABSTRACT

The purpose of this paper is to summarize the research done on nutritional requirements of Fuerte avocado over the past two decades in South Africa.

The most significant finding of this research was the establishment of a suitable leaf for the purpose of analysis and thus fertilizer advisory purposes (see Fig. 1). The proposed leaf sample had a constant concentration range for nutritional elements for at least two months, was sensitive to changes in fertilizer applications and showed a close relationship with yield volume of the following season. Analysis norms (Table 1) were established in long-term fertilizer trials. It was also shown that soil acidity plays a major limiting role in avocado production and that the most suitable method to determine the lime requirement was the determination of extractable Al status of the soil, rather than the pH. The objective should be to reduce the Al concentration to less than 20 $mg.kg^{-1}$ soil for optimal growth and production.

The postharvest fruit disorders grey pulp, pulp spot and vascular browning were shown to be closely related to the Ca, Mg and K status of the soil, especially the subsoil (300-600 mm depth). The ratio of these elements (Ca + Mg/K) was more important than their actual values. By maintaining a ratio of less than 5 (on $mg.kg^{-1}$ basis), vascular browning and pulp spot will be minimized, while grey pulp development will be enhanced.

INTRODUCTION

The avocado industry in South Africa is undergoing rapid growth with an export crop at present of 8 million cartons, expecting to reach the 20 million mark by the year 2000. Avocados are also the most expensive fruit crop on the South African market with an average price of more than $580 per ton during the 1993/94 period.

Research on the nutritional requirements of avocados has been done in South Africa since the early seventies. Koen and Smart (1973) showed the beneficial effect of optimal soil pH for seedlings in the nursery. This report will summarize the work done on lime requirement of avocados in field trials, the identification of a suitable leaf for leaf analysis purposes, and the establishment of optimal leaf analysis norms for fertilizer advisory purposes. Furthermore, the extensive research that was done on the relationship between mineral nutrition and postharvest fruit disorders of Fuerte avocados will be discussed.

METHODS OF INVESTIGATION

The following field trials and surveys were done:

- To obtain a suitable leaf sample for fertilizer advisory purposes (Koen and Du Plessis, 1991 and 1992).

This experiment was done on selected uniform, healthy Fuerte trees on Edranol seedling rootstocks. Three samples were chosen from marked spring flush branches. The samples were:

A - as recommended by Embleton et al (1958)
B - from a non-fruiting branch-showing no new flush (see Fig. 1)
C - the youngest leaf at the tip of a branch with new growth.

Samples were taken monthly from September until harvest in July and were evaluated in terms of their suitability as leaf sample on the following criteria (Langenegger and Du Plessis, 1977).

- the concentration of the elements in the sample should be fairly constant over a relatively long period of time (6 to 8 weeks).
- the concentration of elements in the sample should be sensitive to changes in fertilizer applications and
- the change in concentration of the elements in the sample should be reflected by a change in yield and fruit quality.

- To establish leaf analysis norms (Koen and Du Plessis, 1992; Koen, 1991)

For this purpose three separate N, P and K fertilizer experiments were conducted over a period of 5 years. Each trial consisted of 8 levels of the specific element with 3 trees per plot and 3 replicates. Leaf samples were taken according to the previously established time of sampling and position of leaf and analyzed for macro- and micro-elements. The relationship between foliar concentrations and yield for the particular season under investigation as well as the following season was determined. The optimal concentration ranges were subsequently determined for each element (N, P and K) for consecutive seasons and from these data norms were established. The average micro-element concentrations in the leaves was calculated for all seasons and related to changes in N-, P- and K-concentrations in the leaves.

- Lime requirement (Du Plessis and Koen, 1987)

A field experiment was conducted on mature trees over a period of 6 years. The soil was clayey (34-38 % clay) with a pH (H_2O) varying from 4,6 in the subsoil (300- 600 mm depth) to 4,8 in the topsoil (0-300 mm). Four sources of calcium (dolomitic lime, calcium silicate, calcium hydroxide and gypsum) were applied on the surface at 3 levels each and compared with a control of no treatment. Treatments were applied for 4 consecutive seasons, whereafter the residual effects on yield, leaf-, soil- and fruit composition were determined for a further two seasons.

- Nutritional factors involved in physiological postharvest disorders of fruit (Koen, Du Plessis and Hobbs, 1989; Koen, Du Plessis and Terblanche, 1990; Du Plessis and Koen 1992)

This investigation was started as a survey of 48 commercial orchards over a period of two seasons. Leaf- and soil samples were taken from each orchard, and analysed for the concentration of macro-elements. Fruit samples were also taken and cold stored for 31 days at 5,5 ºC and thereafter for a further 3 days at 21 ºC. The soft fruits were cut open and the fruit flesh investigated for the occurrence of pulp spot, grey pulp and vascular browning. The extent of each disorder was calculated as a percentage of infected fruit. Fresh fruit samples were also dried at 60 ºC and analysed as for the leaf samples.

A similar investigation was carried out on fruit obtained from three fertilizer trials. Each trial consisted of 8 levels of either N, P or K with 3 trees per plot and 3 replicates. Leaf- and soil-samples were taken and analysed as before. In both investigations the relationship between the chemical composition of leaves, fruit and soil, and the observed occurrence of physiological disorders were computed by means of polynomial regressions.

RESULTS

Leaf sample

Leaf age - sample B showed a very stable concentration range for N, P and K from 6 to 8 months of age, whereas samples A and C varied considerably during this period. For a leaf sample to be suitable for fertilizer advisory purposes and to be used commercially, the concentration of elements should be constant for at least 4 weeks, but preferably longer. Samples A and C were consequently rejected while sample B was used to test the response to applied fertilizers as well as value for predicting crop size.

Response to changes in fertilizer applications - This investigation was carried out on sample B using leaves from the three fertilizer experiments. Highly significant differences were found in foliar concentrations of N, P and K with increased application rates of these elements and accordingly justified the selection of sample B.

Element concentrations and yield - Highly significant relationships were found between leaf N concentration for a particular season and yield of that season. In most cases this relationship was improved by using leaf N data of the current season to predict the yield for the following season. These relationships were curvilinear in most cases.

Leaf P content of any given season was only significantly related to the yield of the next season. R^2 values of between 26 and 62 % were obtained.

The relationship between leaf-K concentration and yield was not significant, despite the fact that K-applications increased the K-concentrations in the leaves dramatically (eg. from 1,07 to 1,62 %). No constant effect on yield was obtained with increasing levels of K-application although the soil exhibited an exchangeable level of only 60 mg $K.kg^{-1}$ dry soil.

Micro-elements : The average leaf analysis data over the 4 seasons for the N experiment showed a negative effect of increasing leaf-N concentrations on B and Cu concentration while a positive effect was observed on Mn and Fe. Furthermore, in the K experiment, increased leaf-K decreased B and increased Zn and Mn concentration while increased leaf-P values had no effect on the uptake of any micro-element.

Optimal leaf analysis norms

Following from data obtained from the aforementioned relationships Koen and Du Plessis (1992) and Koen (1991) derived leaf concentrations for the various nutrients as indicated in Table 1.

Lime requirements

Yields were significantly increased on these acid clayey soils by applying moderate levels of dolomitic lime W5 ton/ha for 4 consecutive seasons, total 19 ton/ha). These effects were observed for at least two seasons after the final application. However, both too low or too high levels of lime depressed yields. Calcium silicate and gypsum fared reasonably well with moderate levels of application, whereas calcium hydroxide at the two lowest levels gave better results than the high level for all seasons.

The effect of these materials even at high levels for 4 consecutive seasons was relatively small on the topsoil pH and even less on the subsoil. The Al- concentration was, however, significantly reduced in both top- and subsoil by dolomitic lime, calcium silicate and calcium hydroxide. It was also shown that increased Al-concentrations in the soil had a drastic negative effect on yield.

Nutritional factors involved in physiological postharvest fruit disorders

In a survey covering 48 orchards over a two year period in the most important avocado producing areas of South Africa, the occurrence of pulp spot was relatively high (averaging 30 % in certain orchards), whilst the occurrence of grey pulp and vascular browning averaged not more than 20 %. According to results, the Ca and Mg status of the top- and subsoil as well as their concentrations relative to K were significantly correlated with the occurrence of pulp spot and to a lesser extent, that of vascular browning. Results indicate that the least incidence of pulp spot and vascular browning occurred in orchards with a soil Ca + Mg/K ratio of < 5 (in mg/kg terms). In the case of grey pulp, however, an increase in the Ca + Mg/K ratio was observed to decrease the incidence of this disorder.

In field trials with the macronutrients, the incidence of grey pulp showed a significant increase with an increase in subsoil-K values from 60 to 240 mg K/kg soil. Conversely, an increase in Ca + Mg/K ratio of the subsoil decreased the incidence of grey pulp. Increase in Mg and K status of the fruit showed consistently positive and negative relationships with the incidence of vascular browning, respectively. It was also shown that an increase in leaf-K reduced the Mg-status of both leaves and fruit. Furthermore, an increase in subsoil Ca + Mg/K ratio increased the percentage of fruit which developed vascular browning. Therefore, by increasing soil-K the occurrence of vascular browning will be reduced. In contrast the occurrence of pulp spot, which was observed in one season only, was reduced by relatively high and low concentrations of K and Ca respectively.

DISCUSSION

Leaf analysis

It was shown that the leaf sample initially recommended by Embleton and Jones (1964) was not suitable for fertilizer advisory purposes. The sample (Fig. 1) suggested by Koen and Du Plessis (1991) was far superior especially as far as N and P were concerned. In both cases the concentration of these elements were significantly correlated to the quantity of fertilizers applied as well as the expected yield for the following season. Only in the case of K was no relationship found with yield, although a close correlation occurred between applied K and leaf K. This would suggest that the lowest level of K (0,9 %) was optimal. This level was obtained with an exchangeable soil K level of only 60 mg $K.kg^{-1}$ soil, suggesting that K deficiencies will not be a common occurrence in avocado production. Although no micro-element applications were made, it was possible to calculate optimal levels for Cu, Zn, Mn and B which can be used as tentative norms for these elements (Table 1).

Soil analysis

The importance of soil acidity in inhibiting the growth and production of avocado trees was clearly shown by Du Plessis and Koen (1987). What was especially noteworthy, was the detrimental effect of high levels of extractable Al on avocado production and the fact that soil pH changes were small despite continual high application rates of liming material. It can therefore be concluded that lime requirements of a particular soil should be based on extractable Al concentrations rather than pH. An Al concentration of less than 20 $mg.kg^{-1}$ in the topsoil (0- 300 mm) at least, can be recommended for avocados.

Furthermore, it was shown by Du Plessis and Koen (1992) that the Ca, Mg and K content of the soil, and the subsoil in particular, were important parameters as far as postharvest fruit disorders were concerned. The ratio of these elements (Ca + Mg/K) was more significant than the absolute values. It can be concluded that by keeping the Ca + Mg/K ratio in the soil (expressed as mg.kg-1) in the optimal range of 4 to 5, the incidence of vascular browning and pulp spot will be reduced, but that grey pulp can develop to a certain extent. Since pulp spot was shown to be reduced by increasing the K concentration in the fruit, additional applications from a nutritional perspective (0,9% + leaf K), may reduce the incidence of pulp spot and even of vascular browning. On the other hand, however, an increase in soil K will increase the occurrence of grey pulp.

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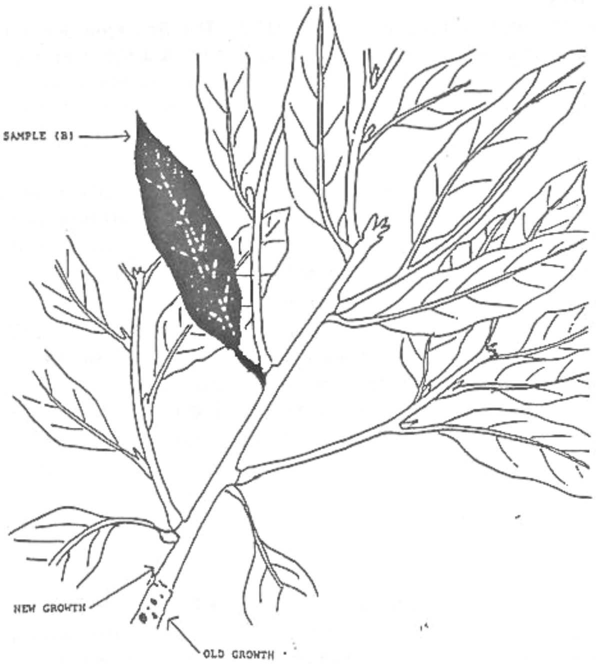

Fig. 1 Position B indicates the leaf to be sampled from non-fruiting branches which are not showing signs of new flush.

Table 1 Proposed optimal leaf analysis norms for Fuerte

Element	Optimal range
N	2,0 - 2,3 %
P	0,17 % +
K	± 0,9 %
B	24 - 36 $mg.kg^{-1}$
Zn	26 - 29 $mg.kg^{-1}$
Cu	6,5 - 9 $mg.kg^{-1}$
Mn	160 - 190 $mg.kg^{-1}$