

Maximum maturation stage: Factors affecting the post-storage quality of fruits taken from a Fuerte and Hass orchard

SA Oosthuyse¹ and D Donkin²

¹Hort Research SA, PO Box 3849, Tzaneen 0850

²SAAGA, PO Box 866, Tzaneen 0850

E-mail: hortres@pixie.co.za

ABSTRACT

The aim of the present study was to determine a diagnostic model incorporating measurable factors, such as fruit moisture content, tree vegetativeness and crop load, to ascertain the stage of maturation beyond which post-arrival quality will not be adequate. Trees were selected such that between-tree variability in degree of vegetativeness and crop load existed. Fruits were harvested from each tree every second week over a period of 10 weeks (5 harvest dates). After cold-storage and subsequent ripening, a full quality analysis was performed. Fruit samples were also assessed for nutrient status. Vegetative vigour, fruit weight, fruit number and moisture content were considered as measurable factors that can be used to predict GQP (good quality percentage) after extended cold-storage. Fruit weight, number and moisture content were significant predictors of GQP. However, their accountability of GQP variation was less than 30%. Fruit nutrient levels were often found to be strongly associated with the yield and quality criteria that were assessed. It was concluded that standardization and optimization of tree nutritional status will markedly enhance fruit quality after extended cold-storage, and greatly enhance GQP predictability using measurable factors.

INTRODUCTION

A number of factors are known or are considered to affect the post-storage quality of avocados. A clear association between the transit-storage temperature and stage of fruit maturation at harvest, assessed in terms of oil or moisture content, has been found (Milne *et al.*, 1993). Tree vegetativeness, stage of maturation, crop load, fruit nutrition status, tree nutrition status, rainfall or irrigation amount and distribution during the fruit growth and development period, and soil nutrition status, are considered or have been found to affect post-storage quality (Arpaia, 1989; Cutting and Bower, 1989; 1990; Koen *et al.*, 1989a, 1989b; Koen and Du Plessis 1989; Witney *et al.*, 1990a; 1990b; Koen and Du Plessis, 1991; Koen, 1992; Bezuidenhout, 1993; Donkin *et al.*, 1994; Kaiser *et al.*, 1995). It is evident that there is a multi-factor influence. Factor interaction may also exist, e.g., the effect of soil water status on the ability of trees to assimilate boron. This may in turn reflect fruit boron nutrition status, and influence post-storage quality.

The "multi-factored" situation might be considered to require a multivariate approach and, hence, the use of multivariate data analysis techniques for meaningful progress. A univariate approach should not be seen to fit the situation, since it cannot serve as a basis for the provision of meaningful insight. Calcium application, for example, has been found to effect a reduction in the incidence of physiological disorders (Penter & Stassen, 1999). However, this response will invariably be found to be inconsistent, since nutritionally-reliant manifestations are dependent on the balance between all of the essential nutrients (Oosthuyse, 1997). A consideration of nutrient status in terms of deficiency or excess imbalances at the outset should serve as the basis for remedial nutritional measures aimed at reducing the incidence of physiological disorders.

The fundamental aim of the present study was to determine a prediction model incorporating measurable factors, such as fruit moisture content, tree vegetativeness and crop load, to ascertain the

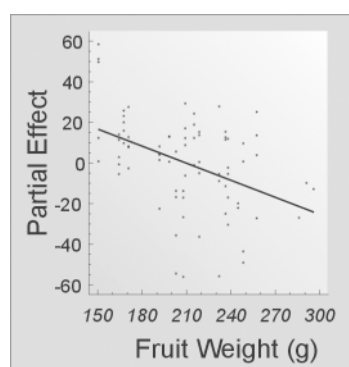


Figure 1 GQP in relation to fruit weight (tree averages) in Hass.

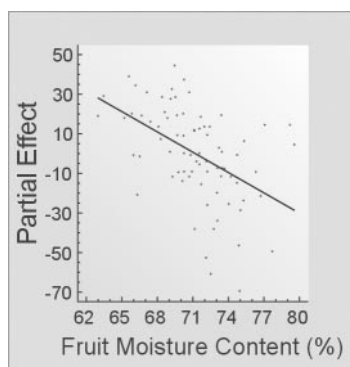


Figure 2 GQP in relation to fruit moisture content (tree averages) in Hass.

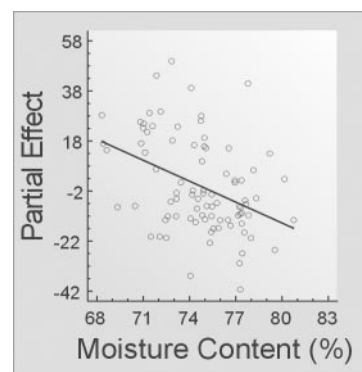
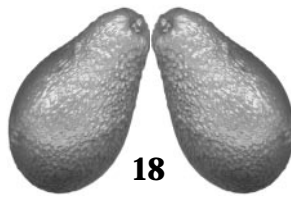


Figure 3 GQP in relation to fruit moisture content (tree averages) in Fuerte.



stage of maturation beyond which post-arrival quality will not be adequate. Implicit is the assumption that a negative relationship exists between stage of harvest maturation and good quality percentage (GQP) after extended cold-storage; deterioration

resulting from an increase in the incidence of disease and physiological disorders.

The study presented the opportunity to explore relationships, and to test assumptions concerning relationships.

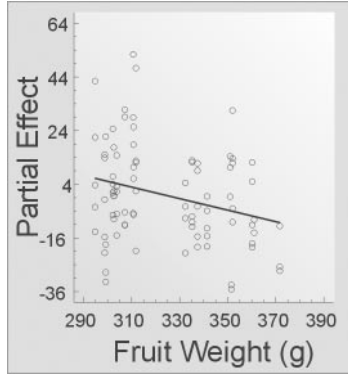


Figure 4 GQP in relation to fruit weight (tree averages) in Fuerte.

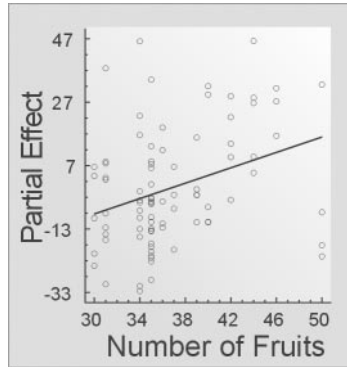


Figure 5 GQP in relation to number of fruits (tree averages) in Fuerte.

MATERIALS AND METHODS

A fully-grown Fuerte orchard and a similar Hass orchard, both on the outskirts of Mooketsi (Bertie van Zyl), were used (Duke 7 rootstock). Canopy size maintenance pruning is adopted. The trees, as a consequence, generally show vigorous shoot growth.

Twenty trees were selected in each orchard during April, 2001. Selection was such that between-tree variability in degree of vegetativeness and crop load was visually evident. The trees selected were evenly distributed in each orchard block.

In each tree, 30 bearing units were selected and labelled to assess degree of vegetativeness and fruitfulness. Each unit comprised the fruits set on an inflorescence, and the associated new shoots arising from and immediately proximal to the inflorescence after flowering. Selection was done to ensure a good distribution of units in the canopy, and without due care for the extent of fruit-set or degree of vegetativeness. The number of fruits on each unit was counted, and unit vegetativeness was quantified by removing and weighing the new shoots. The latter was carried out on project termination. New shoot development did not occur during the harvesting periods (see below). The tree averages for each criterion were used in the analyses.

32 fruits, chosen at random, were harvested from each tree every second week over a period

Table 1 Model fitting results for Hass. GQP bore a significant relationship with the measurable attributes, fruit weight and moisture content (analysis of tree averages).

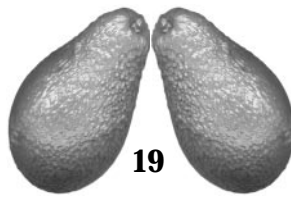
HASS: Model fitting results for Good Quality Percentage (GQP)				
Independent variable	coefficient	std. error	t-value	sig.level
CONSTANT	371.315069	58.813009	6.3135	0.0000
Fruit weight	-0.2803	0.07188	-3.8996	0.0002
Moisture Content	-3.421949	0.740365	-4.6220	0.0000
R-SQ = 0.28				

Table 2 Model fitting results for Fuerte. GQP bore a significant relationship with the measurable attributes, fruit moisture content, weight and number (analysis of tree averages).

FEURTE: Model fitting results for Good Quality Percentage (GQP)				
Independent variable	coefficient	std. error	t-value	sig.level
CONSTANT	234.861978	52.354223	4.4860	0.0000
Moisture content	-2.787772	0.727334	-3.8329	0.0002
Fruit weight	-0.214785	0.081557	-2.6336	0.0101
Number of fruit	1.212428	0.394785	3.0711	0.0029
R-SQ = 0.25				

Table 3 Fruit weight as it relates to fruit number and degree of vegetativeness in Hass (bearing unit associations).

HASS: Model fitting results: Fruit weight vs fruit number and vegetativeness				
Independent variable	coefficient	std. error	t-value	sig.level
CONSTANT	319.677796	16.053391	19.9134	0.0000
Fruit number	-4.332344	0.491596	-8.8128	0.0000
Vegetativeness	6.236732	1.179107	5.2894	0.0000
R-SQ. = 0.45				



19

of 10 weeks (5 harvest dates). In Fuerte, harvesting commenced on April 13, 2001, and in Hass, harvesting commenced on June 21, 2001.

The fruit samples taken from each tree on each harvest date were treated as follows:

The fruits were individually weighed. 12 fruits were randomly chosen for moisture and oil content assessment (6 fruits were used for each assessment). Moisture content was assessed by determining the fresh and dry weight of a segment of mesocarp tissue cut from each fruit. The pulp tissue was dried in an incubator maintained at 70°C. Oil content was determined by Burpak (Kiepersol).

After washing (1% BiProx solution) and waxing (avocado polyethylene wax, Dormas), the remaining fruits were placed in cold-storage at 5.5 (± 0.5) °C for 28 days. They were then placed in

a well ventilated laboratory maintained at 20 (± 1)°C to continue ripening. In each fruit, the degree of softening was monitored daily with a densimeter (Heinrich Bareiss, Oberdischingen, Germany). When the ripe-stage was attained (Fuerte: densimeter reading < 48; Hass: densimeter reading < 64), the fruit were evaluated for black-cold, lenticel damage incidence, anthracnose, stem-end rot, *Dothiorella* spot, vascular browning, grey-pulp, and pulp-spot (symptom definitions according to SAAGA manual). Shelf-life was taken as the number of days required after cold-storage for the ripe-stage to be attained.

Disease (except for *Dothiorella* spot) and physiological disorder manifestation (except for black-cold) in each fruit was rated according to severeness. A rating of 0 was given if a fruit was symptom free, a rating of 1 if symptoms were present but were localised to a small portion of the fruit, a rating of 2 if approximately 1/3 of the fruit showed symptoms, a rating of 3 if 2/3 of the fruit was affected, or a rating of 4 if the entire fruit was visibly affected.

Table 4 Fruit weight as it relates to fruit number and degree of vegetativeness in Fuerte (bearing unit associations).

FUERTE: Model fitting results: Fruit weight vs fruit number and vegetativeness				
Independent variable	coefficient	std. error	t-value	sig.level
CONSTANT	343.816907	15.862214	21.6752	0.0000
Vetegativenes	2.110262	0.386196	5.4642	0.0000
Fruit number	-1.374818	0.459423	-2.9925	0.0035
R-SQ. = 0.24				

Lenticel damage, *Dothiorella* spot or black-cold was rated by approximating the percentage of the skin surface over which symptoms could be seen. The percentages designated were either 0, 25, 50, 75 or 100.

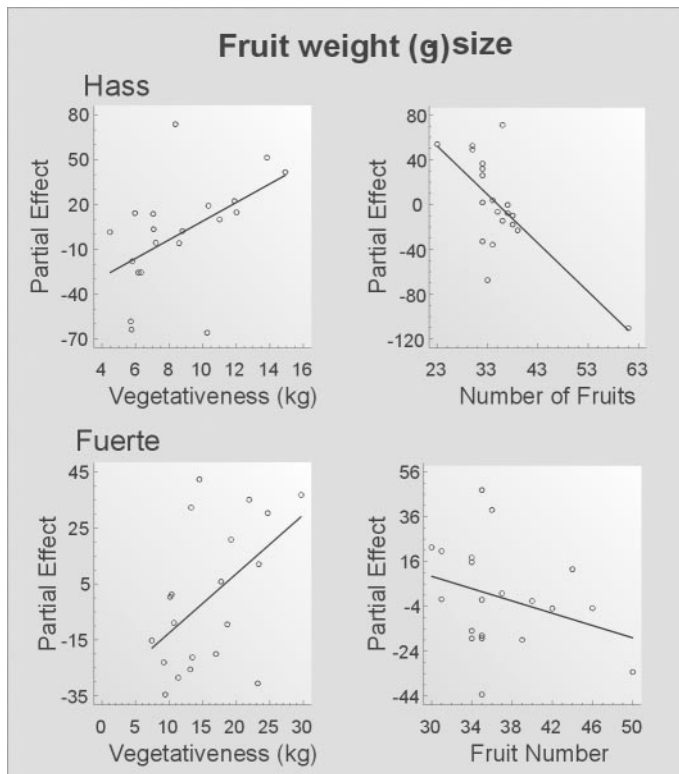


Figure 6 Component relationship between fruit weight and tree vegetativeness or number of fruits (tree averages) in Hass and Fuerte.

An additional sample of 10 fruits was harvested from each tree on the third sampling date, and sent to Central Agricultural Laboratories (Pelidaba, near Pretoria) for nutrient analysis (entire fruit analysis). The fruit concentrations of N, P, K, Ca, Mg, S, Fe, Mn, Cu, Zn, B, Mo and Na were thus obtained.

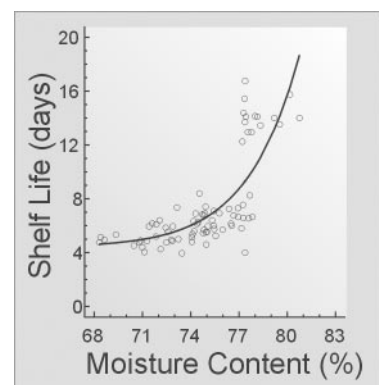


Figure 7 Relationship between fruit moisture content and shelf-life in Fuerte.

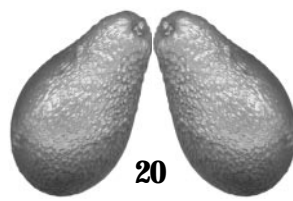


Table 5 Fruit mineral content associations with the criteria indicated in Hass. ‘+’ indicates a positive component effect, and ‘-’ indicates a negative component effect. N, P, K, Ca, Mg, and S were measured in terms of the % of dry weight, and Fe, Mn, Cu, Zn, B, Mo, and Na in terms of the number of mg/kg of dry weight.

Criterion	N	P	K	Ca	Mg	S	Fe	Mn	Cu	Zn	B	Mo	Na	R-Sqr (%)
Fruit number		+		+									-	91
Fruit weight (g)								-						33
Vegetativeness (kg)	+			+							+			78
Shelf-life (days)												+		22
Black-cold (%)										-				24
Lenticel damage (%)	-									-				53
<i>Dothiorella</i> spot (%)														0
Stem-end rot (%)				+		+	+	-		-				91
Anthracnose (%)	-			+										47
Grey-pulp (%)							-							24
Vascular browning (%)							-							28
Pulp-spot (%)	+													26

Table 6 Fruit mineral content associations with the criteria indicated in Fuerte. ‘+’ indicates a positive component effect, and ‘-’ indicates a negative component effect. N, P, K, Ca, Mg, and S were measured in terms of the % of dry weight, and Fe, Mn, Cu, Zn, B, Mo, and Na in terms of the number of mg/kg of dry weight.

Criterion	N	P	K	Ca	Mg	S	Fe	Mn	Cu	Zn	B	Mo	Na	R-Sqr (%)
Fruit number									-					21
Fruit weight (g)		+												53
Vegetativeness (kg)										+	-			46
Shelf-life (days)														0
Black-cold (%)					+							+		50
Lenticel damage (%)						+								48
<i>Dothiorella</i> spot (%)														0
Stem-end rot (%)														0
Anthracnose (%)														0
Grey-pulp (%)											+			34
Vascular browning (%)														0
Pulp-spot (%)												+		37

The batch averages (batches differentiated by harvest date and tree) were subjected to multiple regression analysis. Model adequacy was appraised on residual analysis and inspection.

RESULTS AND DISCUSSION

Modeling on measurable factors

The percentage of fruits per batch that were free of physiological disorders was determined (Good Quality Percentage or GQP). Fruit moisture or oil content, tree vegetativeness, tree fruitfulness, and fruit size were considered measurable factors that can be used by growers to estimate GQP. Fruit weight (fruit size), number, and moisture content (or oil content - data not shown) were highly significant predictors of GQP (Tables 1 and 2). However, their accountability of the GQP variation was less than 30%. Hence, GQP prediction using these factors is bound to be poor, since in excess of 70% of the variability in GQP resulted from other factors.

Fruit weight and moisture content bore a negative relationship with GQP, whereas crop-load or fruitfulness bore a positive relationship with GQP. The relationships in Hass are shown in Figs. 1 and 2, and the relationships in Fuerte are shown in Figs. 3, 4 and 5. It is noteworthy that co-linearity would be expected between fruit weight and crop load.

The most suitable model fitted for Hass was

$$GQP = 371.31 - 0.2803.frtwt - 3.4219.mois,$$

and that for Fuerte was

$$GQP = 234.86 - 2.787.mois - 0.2147.frtwt + 1.2124.frcnt,$$

where

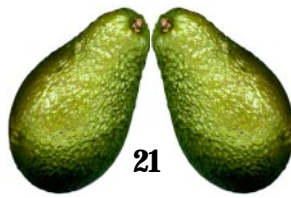
frtwt = average fruit weight,
 mois = average moisture content, and
 frcnt = average fruit number.

Fruit size vs fruit number and degree of vegetativeness

Tables 3 and 4 show the model fitting results for Hass and Fuerte respectively. In both varieties, the fitting of constants for fruit number and degree of vegetativeness resulted in a significant reduction in the variability in fruit weight. The tests to indicate constant non-equality with zero were highly significant. Fruit weight and number were negatively related, whereas degree of vegetativeness and fruit weight were positively related (Figure 6). These results suggest that vegetative growth stimulation following fruit set was associated with an increase in fruit drop after set, and a resulting increase in fruit size after harvest.

Shelf-life vs moisture content

In Fuerte, moisture content at harvest and shelf-life were strongly related (Figure 7). Here, the variation in moisture content with harvest date was pronounced relative to that in Hass, a marked increase in shelf-life being associated with moisture contents exceeding 77%. This



21

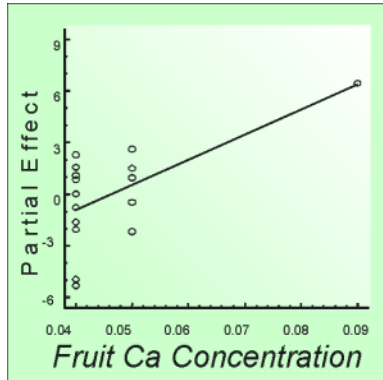


Figure 8 Stem-end rot relationship with fruit calcium content.

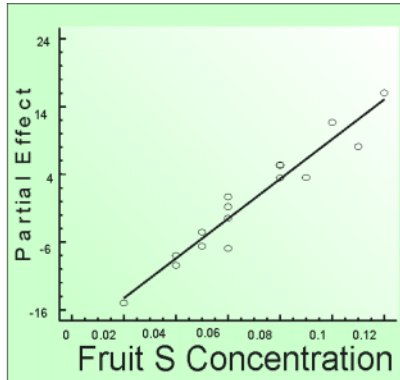


Figure 9 Stem-end rot relationship with fruit sulphur content.

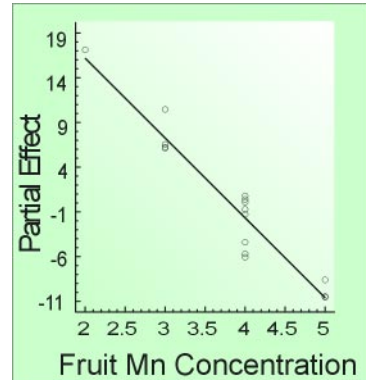


Figure 10 Stem-end rot relationship with fruit manganese content.

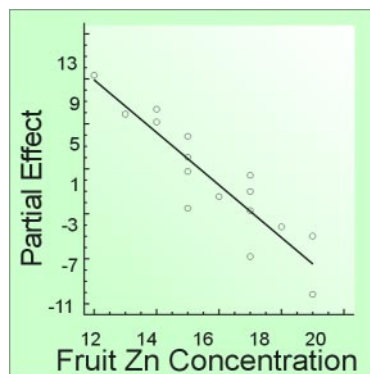


Figure 11 Stem-end rot relationship with fruit zinc content.

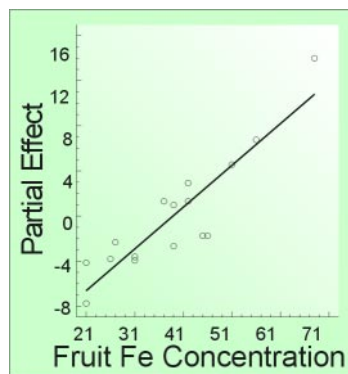


Figure 12 Stem-end rot relationship with fruit iron content.

serves to explain why a similar association was not found in Hass, where moisture content varied between 68 and 74%.

Relationships with fruit nutrient status at harvest

Tables 5 and 6 show the nature of relationships existing between the tree cropping or fruit quality criteria quantified, and the fruit concentrations of mineral nutrients analysed for. Also shown is the extent to which criterion variation is accounted for by the variation in nutrient concentrations (R^2). The data clearly indicate that fruit nutritional status can have a strong bearing on tree fruitfulness or vegetativeness, or on fruit disorder or disease incidence. In certain cases, the accountability was high. The examples here are fruit number or stem-end rot incidence in Hass, where the accountability exceeded 90%. The relationships existing between stem-end rot incidence and Ca, S, Mn, Zn, or Fe concentration in Hass are shown in Figure 8, 9, 10, 11, and 12. These relationships would suggest that that interpreted to be stem-end rot was a physiological disorder whose occurrence was associated with nutrient imbalances.

CONCLUSION

The value of a multivariate approach to gaining insight regarding critical relationships is clearly demonstrated by the present study. The results plainly show that fruit nutrition status is a major determinant of quality after extended cold-storage. The previous work of Cutting and Bower (1989), Koen (1992), Koen and Du Plessis (1991), Koen *et al.* (1989a, 1989b), and Witney *et al.* (1990a, 1990b) well supports this contention. Standardization and

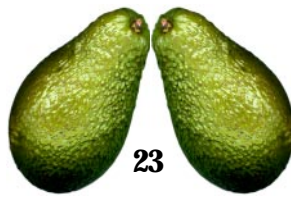
optimization in this regard will markedly enhance fruit quality after extended cold storage, and greatly enhance GQP predictability in using factors which can be measured. The nutrient balances minimizing disorder and disease incidence after extended cold-storage require determination. A practical reference such as a set of leaf norms for each of the important varieties grown locally will greatly facilitate the objective of maintaining ideal balances in carrying out nutritional practices.

ACKNOWLEDGEMENTS

Tommy van Zyl (Bertie van Zyl) is graciously thanked of allowing this research to be performed on ZZ2. Soekie Esbach is especially thanked for his assistance. Thanks are also due to Derek Donkin (SAAGA) for his inputs.

LITERATURE CITED

- ARPAIA, M.L. 1989. Avocado fruit quality as influenced by pre-harvest cultural practices. *California Avocado Society Yearbook* 73:49-52.
- BEZUIDENHOUT, J.J. 1993. Temperature regulation with export avocados during 1992. *South African Avocado Growers' Association Yearbook* 16:56-58.
- CUTTING, J.G.M. and BOWER, J.P. 1989. The active control of calcium allocation in avocado trees. Progress report. *South African Avocado Growers' Association Yearbook* 12:50-52.
- CUTTING, J.G.M. and BOWER, J.P. 1990. Spring vegetative flush removal: the effect on yield, size, fruit mineral composition and quality. *South African Avocado Growers' Association Yearbook* 13:33-34.
- DONKIN, D.J., MANS, T., CUTTING, J.G.M., and SLABBERT, M.J. 1994. Progress report: cold storage temperature regimes and tolerance of avocado fruit to cold storage. *South African Avocado Growers' Association Yearbook* 17:18-20.



- KAISER, C., BOSHOFF, M., MANS, C.C., DONKIN, D.J., and SLABBERT, M.J. 1995. Distal-end browning ("Bolverkleurig") of Fuerte fruit in the KwaZulu-Natal Midlands. *South African Avocado Growers' Association Yearbook* 18:99-101.
- KOEN, T and DU PLESSIS, S. 1989. Unique research. Fertilizing and physiological post-harvest disorders in avocados. *Information Bulletin*, Citrus and Subtropical Fruit Research Institute 204:1-2.
- KOEN, T.J. 1992. The effect of nitrogen, phosphorus and potassium on the trace element status of avocado trees (cv. Fuerte on Duke). *Inligtingsbulletin* Instituut vir Tropiese en Subtropiese Gewasse. 231:21-23.
- KOEN, T.J. and DU PLESSIS, S.F. 1991. Determination of the correct leaf sample and sampling time with Fuerte avocados for purposes of advice on manuring. *South African Avocado Growers' Association Yearbook* 14:19-21.
- KOEN, T.J., DU PLESSIS, S.F., and HOBBS, A. 1989a. The relationship between the chemical composition of the soil and that of the leaves of Fuerte avocado trees and physiological postharvest disorders. *South African Avocado Growers' Association Yearbook* 12:48-49.
- KOEN, T.J., HOBBS, A., and BEZUIDENHOUT, C. 1989b. Relationship between the chemical composition of the soil of Fuerte avocado trees and physiological post-harvest disorders. *Information Bulletin*, Citrus and Subtropical Fruit Research Institute 202:10.
- MILNE, D.L. 1993. Postharvest handling of avocado, mango, and lychee for export from South Africa. Postharvest handling of tropical fruits. *ACIAR Proceedings* 50:110, Chiang Mai, Thailand, 19-23 July 1993.
- OOSTHUYSE, S.A. 1997. Relationship between leaf nutrient concentrations and cropping or fruit quality in mango. *SA Mango Growers' Assoc. Yearbook* 17:1-15.
- PENTER, M.G., and STASSEN, E.J. 1999. Chemical manipulation as part of management programme for improved fruit yield and quality in avocado orchards. *South African Avocado Growers' Association Yearbook* 22:69-75.
- WITNEY, G.W., HOFMAN, E.J., and WOLSTENHOLME, B.N. 1990a. Mineral distribution in avocado trees with reference to calcium cycling and fruit quality. *Scientia Hort.* 44:279-291.
- WITNEY, G.W., HOFMAN, E.J., and Wolstenholme, B.N. 1990b. Effect of cultivar, tree vigour and fruit position on calcium accumulation in avocado fruits. *Scientia-Hort.* 44:269-278.