Relationship between Leaf Nutrient Concentrations and Cropping or Fruit Quality in Mango

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ABSTRACT

Multiple regression analysis was applied to leaf, yield and fruit analysis data obtained from each of 10 tree groups, each comprising 18 trees of a particular cultivar. The cultivars Zill, Tommy Atkins, Sensation, Heidi, and Kent were included. Leaf nutrient concentrations were collectively stipulated as independent variables, and yield and quality related attributes were individually stipulated as dependent variables. Leaf nutrient concentrations were often found to be of importance in the determination of yield and fruit quality attributes. In certain instances, fruit disease incidence and leaf nutrient concentrations were correlated. However, although many statistically significant and meaningful relationships were found, relationship consistency was not apparent. It is concluded that nutrient balances or quantitative associations between mineral nutrients are of real importance in the consideration of tree nutrient status. This has the implication that many quantitative associations may be conductive to the development of fruit of good quality.

INTRODUCTION

The quality of South African mangoes on European markets is generally poor. During the 1995 export season,

exported were considered to be of acceptable quality. Fruit generally show poor ground skin colour development, they often possess internal disorders characterized by mesocarp breakdown, mesocarp browning, and cavity formation (Oosthuyse, 1993a), they frequently develop the diseases anthracnose, stem-end rot and soft brown rot, and they generally show some form of skin blemish (darkened lenticels, scratches and dark marks). Many of the problems occurring have a bearing on tree nutrient status. These include poor ground skin colouration and internal physiological disorder development (Smith, 1989; Oosthuyse, 1993b; McKenzie, 1994, 1995a, 1995b). Certain results have indicated that the incidence of lenticel damage and predisposition to disease development, chilling injury and latex burn have a bearing on tree nutrition (unpublished data).

A question which often arises is: How can recommendations to particular growers be made to rectify their specific problems or to generally enhance the quality of their fruit? The premise may be made that nutrient levels relative to one another are important, and that many quantitative associations may be conductive to the development of fruit of good quality. It follows that where an association is not ideal, specific nutrient adjustments will be required to improve the situation.

It is noteworthy that "good quality" as perceived by a particular target market should be of consideration. This has the implication of differing expectations and nutritional criteria between target markets. In general, the European Market requires attractively coloured large fruits (counts 8 to 12) which are free of disease, skin blemishes and internal abnormalities. Taste, as such, appears to be of lesser significance.

To determine shortfalls or required nutrient adjustments, the need for a high level of sophistication appears to exist. The approach of endeavouring to establish a direct empirical method of determining required adjustments to tree nutrient levels might be considered best.

In the present study, a multivariate analysis technique (multiple regression) was used to ascertain the relationships existing between leaf nutrient concentrations and various fruit quality and yield related attributes.

MATERIALS AND METHODS

Eighteen adjacent mango trees were selected in each of five cultivar blocks (Zill, Tommy Atkins, Sensation, Kent, Heidi) at Mariepskop Estate (Merensky Holdings), and at Bavaria Fruit Estate. These estates fall in the same region, and are in the vicinity of Hoedspruit.

In early November 1996, once fruit drop had ceased, the fruits on each tree were counted. In mid-November 1996, a leaf sample was taken from each tree for nutrient analysis. Four fruit bearing terminal shoots were selected per tree, one within each tree quadrant, and four leaves taken from each of them. The leaves were analyzed for N, P, K, Ca, Mg, Cu, Fe, Mn, and Zn by Outspan or Central Agricultural Laboratories. At harvest (fruits hard-mature), eight to 20 randomly selected fruits were removed from each tree. They were placed in a laboratory held at 20°C (± 1°C) within 12 hours of harvesting, and were evaluated once they became ripe.

The degree of softening of each fruit was monitored daily with a densimeter (Heinrich Bareiss, Oberdischingen, Germany). Each fruit was evaluated for quality when it was firm-ripe (densimeter reading of less than 60 and greater than 40 from a non-diseased portion of the fruit). The time

taken for the firm-ripe stage to be attained was taken to indicate shelf-life. Quality evaluation was performed as follows:

Ground skin colour of each fruit was rated. A rating of "0" was given when signs of skin colouration were absent, a rating of "1" if a transition to a lighter green was apparent, a rating of "2" if regions of the skin had become yellow but the total area which was yellow was less than the total area which was green, a rating of "3" if regions of the skin had become yellow and the total area which was yellow exceeded the total area which was green, or a rating of "4" if the skin was completely yellow. The skin area covered with red-blush was not considered.

Disease manifestation in each fruit was rated according its severeness. A rating of "0" was given if a fruit was disease free, a rating of "1" if symptoms were present but were localized to a small portion of the fruit's surface, a rating of "2" if approximately 1/3 of the fruit's surface showed symptoms, a rating of "3" if 2/3 of the fruit's surface was affected, or a rating of "4" if the entire fruit's surface was visibly diseased. The diseases occurring were also identified.

Blotch (green patchiness of skin) and lenticel damage were 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.

To assess internal quality of each fruit, each was first cut through twice; `longitudinally' along the flattened margins of the seed. In each fruit, juice from the `cheeks' thus obtained was evaluated by measuring its pH (Mettler Toledo 120 pH meter) and total soluble solids content (TSS) (Euromex RF 0232 hand-held refractometer), and by assessing its taste.

Taste was rated. A rating of "1" was given if taste was deemed appealing, a rating of "0" if taste was deemed satisfactory but not appealing, or a rating of "-1" if taste was deemed unsatisfactory.

Physiological disorder manifestation in each fruit was rated as was disease manifestation, except that the degree to which the mesocarp as opposed to the exocarp (skin) was affected, was taken into account. The disorders occurring were also identified.

Extent of pulp colouration was assessed with the "Zill" colour chart (obtainable from the South African Mango Growers' Assocation).

The data were subjected to multiple regression analysis. The quality and yield attributes were stipulated individually a dependent variables, and the leaf nutrient concentrations were collectively stipulated as independent variables.

RESULTS

The model fitting results for Tommy Atkins at Bavaria Fruit Estate are shown in Table 1. Leaf N, Mn and Zn concentrations were indicated to be of importance in the determination of number of fruit retained (R^2= 74% = the degree to which the regression model accounted for the variation in fruit retention found). Trees with higher N, higher Mn and lower Zn concentrations in their leaves retained lesser numbers of fruit. This may be seen to indicate that the simultaneous "de-application" of N and Mn and application of Zn will generally enhance fruit retention in the specific trees used.

The analysis indicates the absence of a relationship between leaf nutrient concentrations and fruit size (average fruit weight) in the specific trees used.

Leaf N, P and Mn concentrations were indicated to be of importance in the determination of tree yield (R^2= 86%). Trees with higher N, higher Mn and lower P concentrations in their leaves showed reduced yields. The analysis might thus be seen to indicate that the simultaneous "de-application" of N and Mn and the application of P will generally enhance tree yield in the specific trees used.

Leaf nutrient concentrations and shelf-life, lenticel damage incidence, ground skin colouration, total soluble solids content (TSS), pH, taste, pulp colour, or general physiological disorder incidence were apparently unrelated.

Blotch incidence was positively related to leaf N concentration (R^2= 43%). Internal breakdown incidence ("soft nose" or "jelly seed") was positively related to leaf Mg concentration (R^2 = 28%). Spongy tissue incidence was positively related to leaf Zn concentration (R^2 = 28%) Cavity incidence was positively related to leaf P concentration (R^2= 42%).

The foregoing results may be taken to indicate that a reduction in N, Mg and Zn leaf concentrations will be generally beneficial.

The model fitting results for Tommy Atkins at Mariepskop Estate are shown in Table 2. Leaf N, P, K and Mg concentrations were indicated to be of importance in the determination of number of fruit retained (R^2= 74%). Trees having leaves containing higher N, higher Mg, lower K and lower P retained greater numbers of fruits. The analysis may therefore be seen to indicate that the simultaneous "de-application" of P and K and application of N and Mg will generally enhance fruit retention in the specific trees used.

Mg and Zn leaf concentrations and fruit size (average fruit weight) were negatively related (R^2 = 49%), indicating that the "de-application" of Mg and Zn will generally result in an increase in fruit size in the specific trees used. Tree yield was positively related to leaf Mg concentration (R^2 = 33%), indicating that the application of Mg will generally enhance tree yield.

Lenticel damage or physiological disorder incidence and leaf P concentration were negatively correlated (R^2 = 23 and 25%, respectively). TSS was negatively correlated to leaf Zn concentration (R^2 = 26%), and pH was positively correlated to leaf K concentration (R^2 = 33%). Jelly seed incidence was negatively correlated to leaf Mg concentration (R^2 = 30%). The incidence of spongy tissue was negatively correlated to leaf Mg concentration and positively correlated to leaf Zn concentration (R^2 = 26%).

Shelf-life, ground skin colouration, blotch, taste, pulp colouration or cavity incidence did not appear to bear any relation to leaf nutrient concentrations.

Figs. 1, 2, 3 and 4 show the ranges of nutrients concentrations found in the leaves of the Tommy Atkins trees at Bavaria Fruit Estate and at Mariepskop Estate.

Tables 3 to 12 show the model fitting results for the remaining tree groups. The procedure followed in documenting the results for Tommy Atkins can be similarly adopted in documenting the results for each of the remaining tree groups. It is noteworthy that each situation (the analysis results of each group of trees) is unique and requires independent consideration. In many instances, the associations found were weak, but in certain instances they were very strong. In Kent at Bavaria Fruit Estate, for example, 97% of the variation in physiological disorder incidence was accounted for by the regression model comprising coefficients for K, Ca, Cu, Fe and Mn leaf concentrations. In some instances, leaf nutrient concentrations correlated with the incidence of bacterial black spot or soft brown rot. These results suggest differences in susceptibility to disease in relation to tree nutrient status.

The results expressly indicate that leaf nutrient concentrations are of great significance in the determination of yield and fruit quality attributes in mango.

DISCUSSION AND CONCLUSION

Mango trees have been found to respond to applications of mineral nutrients, and correlations between leaf nutrient concentrations and yield or fruit quality attributes have, in certain instances, been found. Nutrients applications have also been associated with increases in disease susceptibility.

Malhi *et al.* (1988), in working with Langra mango trees, applied N at 100, 200 or 300 g, P_2O_5 at 43.7 or 87.4 g and K_2O at 83 or 166 g per year per tree over a period of 12 years. In the case of the P and K rates, yields were greater at the lower than at the higher rates. There were no significant effects of the treatments on final tree girth, canopy volume or fruit quality.

Baghel *et al.* (1989) found that combined foliar application of 6% urea and 150 ppm NAA to Sunderja mango trees was most effective in increasing percentage pulp TSS, reducing sugar and non-reducing sugar content, and in decreasing percentage pulp acidity. This treatment was also found to gave rise to greatest fruit weight, length, and diameter (Baghel *et al.*, 1987).

Kohli and Reddy (1989) noted that leaf N, P, K, Ca, Mg, S, Fe, Mn, Zn and Cu content did not correlate well with growth or cropping of Alphonso grafted on a number of different rootstocks.

Kumar *et al.* (1989) sprayed 30-year-old Dashehari mango trees with 1% $ZnSO_4$, applied either once or twice. Fruits from the sprayed trees showed less weight loss and spoilage, higher sugar content and lower acidity on ripening. Fruit vitamin C content was unaffected by the sprays. Fruit vitamin A content was increased slightly by the sprays. Single application was generally less effective than double application.

Rajput and Singh (1989) sprayed 15-year-old Dashehari mango trees twice before flowering during two successive years with combinations of urea (0, 3 or 6%) and gibberellic acid (0, 15 or 30 ppm). Urea alone increased vegetative growth, inflorescence length, number of secondary inflorescence branches formed, duration of flowering, number of flowers per inflorescence, fruit retention and fruit quality. Flower sex ratio (staminate/hermaphrodite) was reduced by urea, however.

Smith (1989), in carrying out a NPK trial using six-year-old Sensation mango trees, found that highest yield was associated with leaf N concentrations of between 1.17 and 1.40% and leaf K concentrations of between 0.84 and 1.03%. Higher leaf K concentrations were associated with reduced yields. In a similar trial at Hoedspruit where 15-year-old Sensation trees were used, optimum leaf N and leaf K concentrations were derived to be 1.62 to 1.78% and 0.64 to 0.84%, respectively. Leaf samples taken in November were found to give most reliable results. High leaf N concentrations depressed ground skin colouration. However, flavour, spoilage incidence, and the incidence of certain physiological disorders were not associated with high leaf N concentrations.

Syamal and Mishra (1989) applied two levels of N (0.5 or 1.0 kg), P (1.0 or 2.0 kg P_2O_5) and K (0.5 or 1.0 kg K_2O) ($N_1P_1K_1$ or $N_2P_2K_2$) to 17-year-old Langra mango trees. $N_2P_2K_2$ application resulted in greatest shoot growth, leaf number, and inflorescence number, fruit set, fruit retention, fruit size, TSS, ascorbic acid content and sugar content. This treatment also resulted in lowest total fruit acidity and shortest flowering duration.

Sharma *et al.* (1990) sprayed 10-year-old Langra mango trees with urea (0, 2 or 4%), KNO_3 (0, 1.5 or 3%) and/or NAA (0 or 40 ppm). Of the single applications, application of 4% urea, 3% KNO_3 or 40 ppm NAA resulted in greatest numbers of fruit being retained, highest fruit TSS, non-reducing sugars, total sugars and ascorbic acid content, and lowest fruit acidity. Of the combined applications, application of 4% urea and 3% KNO_3 resulted in highest fruit retention, highest fruit content of non-reducing sugars and ascorbic acid, and lowest fruit acidity. Highest TSS, reducing sugars, and total sugars were obtained following application of 4% urea and 40 ppm NAA.

Singh and Khan (1990) applied N, P, K, Cu, Zn and B via the soil and/or foliarly to 28-year-old Dashehari mango trees. Soil combined with foliar application was most effective in increasing yield. Individual fruit weight increased and fruit number decreased with increasing trace element application. Fruit quality was enhanced by increased trace element application.

Coetzer *et al.* (1991) investigated the effect of spraying five-year-old Tommy Atkins mango trees with B (3000 ppm) whilst they were flowering. Yield and fruit quality were enhanced.

Suriyapananont and Subhadrabandhu (1992) noted that fruit acidity and TSS varied in relation to tree fertilization.

Dhillon and Malhi (1993) observed that fruit yield or fruit quality in Langra mango were not significantly correlated with leaf concentrations of N, P or K. It was however noted that the mineral content of fruiting shoots was lower than that of vegetative shoots.

Goede (1993) treated flood-irrigated, four-year-old Tommy Atkins mango trees growing in a gravel soil with inorganic fertilizer or enriched organic fertilizer (composted poultry droppings amended with inorganic fertilizers), either in a single dose after harvest, or in split doses -

2/3 applied after harvest and 1/3 applied after fruit set. The inorganic fertilizer comprised calcium ammonium nitrate (LAN), superphosphate and potassium chloride. The N, P and K content of the organic fertilizer was equal to that of the inorganic fertilizer. Split application of organic fertilizer resulted in greatest yield. Moreover, application of organic fertilizer reduced internal and external fruit coloration, reduced pH, enhanced TSS, enhanced flavour and increased fruit size.

Oosthuyse (1993) obtained Sensation mangoes of similar maturity from five different growers. On ripening, ground skin colouration was greatest in the fruits obtained from growers who applied lesser amounts of N to their trees. The incidence of internal breakdown was least in these fruits.

Singh *et al.* (1993) sprayed twelve-year-old Dashehari mango trees with $Ca(NO_3)_2$ (1 or 2% Ca_2^+) or $CaCl_2$ (0.6 or 1.2% Ca_2^+) 20 and 10 days before harvest. The Ca treatments delayed ripening and improved fruit quality during storage.

Bhuyan (1994), in working with Carabao mango trees, applied NPK fertilizer (14:14:14) at 0, 2 or 4 kg per tree at full-bloom, and subsequently irrigated the trees at fortnightly intervals. Certain trees were not irrigated. Number of inflorescences produced was increased as a result of fertilization. Bud emergence was more delayed in the fertilized trees. Fertilization and irrigation resulted in the production of longer and wider inflorescences, greater fruit set per inflorescence, higher fruit retention per inflorescence at harvest and higher tree yield. The highest yield was obtained following application of 2 kg of fertilizer per tree and fortnightly irrigation. Fertilizer application and irrigation decreased fruit size, lengthened the fruit ripening period, and increased percentage fruit weight loss during ripening. Moreover, pH and TSS were increased, and titratable acidity and fruit dry mass were reduced at ripening.

Abd El Al *et al.* (1994) applied three rates of K fertilizer (0, 500 or 1000 g per tree per year) to Hindi Be Sinnara mango trees growing in a clay-loam soil by either soil or foliar application. Neither K rate nor application method had a significant effect on vegetative growth characteristics, inflorescence length, peduncle diameter, number of hermaphrodite flowers formed per inflorescence, or fruit or seed weight. Fruit number per tree, fruits per inflorescence and fruit TSS increased with K application rate. K application rate or method of application had no apparent effect on the leaf N or P concentration. Leaf K concentration increased with K application rate irrespective of whether K was applied foliarly or to the soil.

McKenzie (1994), in performing a survey relating grower nutritional practices to the quality of fruit produced, found that orchards fertilized heavily with N tended to produce greener fruits. Orchards which were deprived of N tended to produce yellower fruits.

Ghosh *et al.* (1995) sprayed Himsagar mango trees with trace element formulations during the period of inflorescence development and when the fruits were the size of marbles. Application increased yield and juice TSS. Total sugars and acidity were not affected by the sprays.

McKenzie (1995a) selected 60 Sensation mango trees and 20 Kent mango trees on seven different farms, and related tree yield or fruit quality to leaf nutrient concentrations. High leaf N was associated with poor ground skin colouration and enhanced "jelly seed" incidence. Low Ca and K leaf concentrations were not associated with diminished quality. Yield was not depressed in trees whose leaves generally had low nutrient concentrations.

McKenzie (1995b) attempted to raise leaf concentrations of certain nutrients by foliar spraying. Three postharvest sprays on newly hardened flush and three pre-harvest (fruit and foliage) sprays on mature foliage were tested. Two concentrations of potassium nitrate, potassium sulfate, calcium nitrate (all at 1 or 2%) or Wuxal Suspension Calcium R (at 0.3 or 0.6%) were applied. The Ca sprays did not increase Ca in the leaves nor did they affect fruit quality. The $Ca(NO_3)_2$ sprays elevated N in the leaves and increased mesocarp breakdown. Some measurable uptake of K occurred after six sprays of potassium nitrate or potassium sulphate. Ca and K leaf concentration and fruit quality bore no apparent relationship. Increased leaf N was associated with reduced ground skin colouration and increased "jelly seed" incidence at ripening.

Ray *et al.* (1993) presented evidence indicating that pre-harvest application of calcium compounds (stated to be a common practice for increasing the storage life and maintaining the quality of fruits) predisposes mango fruits to *Diplodia* stem-end rot (caused by *D. natalensis* [*Botryodiplodia theobromae*]). In a storage experiment conducted under artificial epiphytotic conditions, both calcium nitrate and calcium chloride, at 2500 or 5000 ppm, significantly increased the incidence of disease when applied to Bombay Green mango. Disease incidence increased with increasing rate of application.

It might be deduced from the foregoing that research has not shown clear and consistent effects of nutrient applications to mango trees. Furthermore, correlations with leaf nutrient concentrations are inconsistent. It might be generalized that N fertilization or a high concentration of leaf N is conducive to increased tree yield, and poor ground skin colouration, increased mesocarp breakdown, increased sugar content and reduced acidity of fruits. This generalization is not supported by the present study. The notion that a single measure will be effective in all situations to correct a specific problem is also not supported. An example here is the general application of calcium chelates where fruit disorders characterized by mesocarp breakdown are encountered.

The present study supports the view that nutrient balances or quantitative associations between nutrients are of real importance. The effectiveness of remedial nutritional practices, indicated by the method of analysis performed here, requires testing. The technique demands that both a leaf and a fruit sample be taken for analysis. Clarity concerning the definition of a good quality fruit is also required (fruits which appeal to a specific target market).

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Table 1 *Model fitting coefficients and their significance levels [H_0(coefficient) = 0] for Tommy Atkins at Bavaria.*

	Fruit No		Avg Weight		Tree Yield		Shelf Life		Lenticel Damage	
	Coeff.	Sig. level	Coeff.	Sig. level	Coeff.	Sig. level	Coeff.	Sig. level	Coeff.	Sig. level
N %	-45.2	0.000			-26.9	0.000				
P %					+60.9	0.032				
K %										
Ca %										
Mg %										
Cu ppm										
Fe ppm										
Mn ppm	-0.01	0.009			-0.004	0.054				
Zn ppm	+0.78	0.066								
R^2 %	74		0		86		0		0	

	Ground Colour		Blotch		TSS		pH		Taste	
	Coeff.	Sig. level	Coeff.	Sig. level	Coeff.	Sig. level	Coeff.	Sig. level	Coeff.	Sig. level
N %			+0.63	0.004						
P %										
K %										
Ca %										
Mg %										
Cu ppm										
Fe ppm										
Mn ppm										
Zn ppm										
R^2 %	0		43		0		0		0	

	Pulp Colour		% with Phys. Disorders		% with Int. Breakdown		% with SpongyTissue		% with Cavity	
	Coeff.	Sig. level	Coeff.	Sig. level	Coeff.	Sig. level	Coeff.	Sig. level	Coeff.	Sig. level
N %										
P %									+136	0.005
K %										
Ca %										
Mg %					+158	0.030				
Cu ppm										
Fe ppm										
Mn ppm										
Zn ppm							+0.96	0.029		
R^2 %	0		0		28		28		42	

Table 2 *Model fitting coefficients and their significance levels [H_0(coefficient) = 0] for Tommy Atkins at Mariepskop.*

	Fruit No		Avg Weight		Tree Yield		Shelf Life		Lenticel Damage	
	Coeff.	Sig. level	Coeff.	Sig. level	Coeff.	Sig. level	Coeff.	Sig. level	Coeff.	Sig. level
N %	+82.4	0.003								
P %	-244.8	0.035							-119	0.045
K %	-86.3	0.061								
Ca %										
Mg %	+349	0.000	-510	0.003	+81.8	0.012				
Cu ppm										
Fe ppm										
Mn ppm										
Zn ppm			-1.21	0.020						
R^2 %	74		49		33		0		23	

	Ground Colour		Blotch		TSS		pH		Taste	
	Coeff.	Sig. level	Coeff.	Sig. level	Coeff.	Sig. level	Coeff.	Sig. level	Coeff.	Sig. level
N %										
P %										
K %							+0.73	0.025		
Ca %										
Mg %										
Cu ppm										
Fe ppm			+0.002	0.042						
Mn ppm										
Zn ppm					-0.02	0.031				
R^2 %	0		23		26		33		0	

	Pulp Colour		% with Phys. Disorders		% with Jelly Seed		% with SpongyTissue		% with Cavity	
	Coeff.	Sig. level	Coeff.	Sig. level	Coeff.	Sig.l evel	Coeff.	Sig.l evel	Coeff.	Sig. level
N %										
P %			-237	0.036						
K %										
Ca %										
Mg %					-101	0.019	-63.9	0.030		
Cu ppm										
Fe ppm										
Mn ppm										
Zn ppm										
R^2 %	0		25		30		26		0	

Table 3 *Model fitting coefficients and their significance levels [H_0(coefficient) = 0] for Sensation at Bavaria Fruit Estate.*

	Fruit No		Avg Weight		Tree Yield		Shelf Life		Lenticel Damage		Ground Colour		Blotch	
	Coeff.	Sig. Level	Coeff.	Sig. Level	Coeff.	Sig. Level	Coeff.	Sig. Level	Coeff.	Sig. Level	Coeff.	Sig. Level	Coeff.	Sig. Level
N %														
P %			-725	0.023										
K %							-16.3	0.009					+1.14	0.04
Ca %														
Mg %									+257	0.020				
Cu ppm							-0.03	0.023	-0.42	0.001			-0.003	0.021
Fe ppm														
Mn ppm														
Zn ppm														
R^2 %	0		28		0		49		55		0		46	

	TSS		pH		Taste		Pulp Colour		% with Phys. Disorders		% with Internal Breakdown	
	Coeff.	Sig. level	Coeff.	Sig. level	Coeff.	Sig. level	Coeff.	Sig. level	Coeff.	Sig. level	Coeff.	Sig. level
N %												
P %							+0.68	0.028				
K %	+8.09	0.050							+95.8	0.045		
Ca %												
Mg %			-1.65	0.045	+5.41	0.020						
Cu ppm												
Fe ppm												
Mn ppm												
Zn ppm												
R^2 %	22		23		29		27		23		0	

	% with Spongy Tissue		% with Cavity		% with Internal Browning		% with Soft Brown Rot		% with Bacterial Black Spot		Scald	
	Coeff.	Sig. level	Coeff.	Sig. level	Coeff.	Sig. level	Coeff.	Sig. level	Coeff.	Sig. level	Coeff.	Sig. level
N %												
P %												
K %									+222	0.004		
Ca %												
Mg %												
Cu ppm											-0.03	0.033
Fe ppm												
Mn ppm												
Zn ppm												
R^2 %	0		0		0		0		42		25	

Table 4 *Model fitting coefficients and their significance levels [H_0(coefficient) = 0] for Sensation at Mariepskop Estate.*

	Fruit No		Avg Weight		Tree Yield		Shelf Life		Lenticel Damage	
	Coeff.	Sig. level	Coeff.	Sig. level	Coeff.	Sig.level	Coeff.	Sig.level	Coeff.	Sig. level
N %										
P %										
K %	+319	0.008			+115	0.024				
Ca %	-84.7	0.001			-31.6	0.003				
Mg %							+22.50	0.005		
Cu ppm										
Fe ppm	+0.76	0.011								
Mn ppm	+0.23	0.028			+0.11	0.009				
Zn ppm	-0.80	0.061								
R^2 %	83		0		65		40		0	

	Ground Colour		Blotch		TSS		pH		Taste	
	Coeff.	Sig. level	Coeff.	Sig. level	Coeff.	Sig. level	Coeff.	Sig. level	Coeff.	Sig. level
N %	-1.09	0.017								
P %										
K %										
Ca %										
Mg %										
Cu ppm										
Fe ppm										
Mn ppm			-0.003	0.005					+0.002	0.006
Zn ppm			-0.009	0.033						
R^2 %	31		44		0		0		38	

	Pulp Colour		% with Phys. Disorders		% with Int. Breakdown		% with SpongyTissue		% with Cavity	
	Coeff.	Sig. level	Coeff.	Sig. level	Coeff.	Sig.l evel	Coeff.	Sig.l evel	Coeff.	Sig. level
N %										
P %										
K %										
Ca %										
Mg %										
Cu ppm										
Fe ppm										
Mn ppm										
Zn ppm										
R^2 %	0		0		0		0		0	

Table 5 *Model fitting coefficients and their significance levels [H0(coefficient) = 0] for Kent at Bavaria Fruit Estate.*

	Fruit No		Avg Weight		Tree Yield		Shelf Life		Lenticel Damage		Ground Colour	
	Coeff.	Sig. level	Coeff.	Sig. level	Coeff.	Sig. level	Coeff.	Sig. level	Coeff.	Sig. level	Coeff.	Sig. level
N %									-8.33	0.020		
P %												
K %												
Ca %	+15.5	0.009										
Mg %												
Cu ppm							-0.02	0.051				
Fe ppm											-0.003	0.045
Mn ppm					-0.01	0.003						
Zn ppm			-2.65	0.037			0.07	0.007				
R^2 %	35		36		60		74		47		37	

	TSS		pH		Taste		Pulp Colour		% with Phys. Disorders		% with Jelly Seed	
	Coeff.	Sig. level	Coeff.	Sig. level	Coeff.	Sig. level	Coeff.	Sig. level	Coeff.	Sig. level	Coeff.	Sig. level
N %	+4.34	0.002										
P %	-6.45	0.007										
K %									-64.1	0.038		
Ca %									-32.5	0.001		
Mg %												
Cu ppm									+0.20	0.025		
Fe ppm									-0.06	0.021		
Mn ppm	+0.002	0.056							-0.04	0.010		
Zn ppm			+0.004	0.043	+0.01	0.013						
R^2 %	81		38		51		0		97		0	

	% with SpongyTissue		% with Cavity		% with Soft Brown Rot		% with Bacterial Black Spot		% with Periferal Browning	
	Coeff.	Sig. level	Coeff.	Sig. level	Coeff.	Sig. level	Coeff.	Sig level	Coeff.	Sig. level
N %			+34.7	0.003						
P %										
K %			-61.1	0.012						
Ca %			-28.7	0.000	-31.9	0.008			-26.1	0.016
Mg %										
Cu ppm										
Fe ppm			-0.04	0.030					-0.09	0.016
Mn ppm	-0.04	0.002			-0.03	0.063				
Zn ppm							-0.81	0.014	-0.29	0.054
R^2 %	68		95		68		50		87	

Table 6 *Model fitting coefficients and their significance levels [H_0(coefficient) = 0] for Kent at Mariepskop Estate.*

	Fruit No		Avg Weight		Tree Yield		Shelf Life		Lenticel Damage		Ground Colour		Blotch	
	Coeff.	Sig. level	Coeff.	Sig. level	Coeff.	Sig. level	Coeff.	Sig. level	Coeff.	Sig. level	Coeff.	Sig. level	Coeff.	Sig. level
N %														
P %													-1.00	0.040
K %														
Ca %	+38.4	0.000	-102	0.006	+14.2	0.001	+1.61	0.030						
Mg %											+4.10	0.056		
Cu ppm														
Fe ppm														
Mn ppm														
Zn ppm														
R^2 %	81		38		69		26		0		21		24	

	TSS		pH		Taste		Pulp Colour		% with Phys. Disorders		% with Internal Browning	
	Coeff.	Sig. level	Coeff.	Sig. level	Coeff.	Sig. level	Coeff.	Sig. level	Coeff.	Sig. level	Coeff.	Sig. level
N %							+0.23	0.001				
P %												
K %							-0.12	0.021				
Ca %					+0.52	0.005			-19.8	0.042		
Mg %												
Cu ppm												
Fe ppm												
Mn ppm												
Zn ppm												
R^2 %	0		0		39		58		23		0	

	% with Jelly Seed		% with SpongyTissue		% with Cavity		% with Soft Brown Rot		% with Bacterial Black Spot		% with Periferal Browning	
	Coeff.	Sig. level	Coeff.	Sig. level	Coeff.	Sig. level	Coeff.	Sig. level	Coeff.	Sig level	Coeff.	Sig. level
N %			+2.72	0.017								
P %											-70.6	0.011
K %												
Ca %	-19.24	0.051							-29.6	0.056		
Mg %							+257	0.014	+279	0.053		
Cu ppm			+0.02	0.002								
Fe ppm			+0.01	0.000								
Mn ppm			-0.007	0.000								
Zn ppm												
R^2 %	22		95		0		32		49		34	

Table 7 *Model fitting coefficients and their significance levels [H_0(coefficient) = 0] for Heidi at Bavaria Fruit Estate.*

	Fruit No		Avg Weight		Tree Yield		Shelf Life		TSS		Ground Colour	
	Coeff.	Sig. level	Coeff.	Sig. level	Coeff.	Sig. level	Coeff.	Sig. level	Coeff.	Sig. level	Coeff.	Sig. level
N %												
P %												
K %												
Ca %									+1.46	0.009		
Mg %												
Cu ppm												
Fe ppm												
Mn ppm												
Zn ppm												
R^2 %	0		0		0		0		36		0	

	pH		Taste		Pulp Colour		% with Soft Brown Rot		% with Phys. Disorders		% with Internal Breakdown	
	Coeff.	Sig. level	Coeff.	Sig. level	Coeff.	Sig. level	Coeff.	Sig. level	Coeff.	Sig. level	Coeff.	Sig. level
N %												
P %												
K %							+52.7	0.049				
Ca %												
Mg %												
Cu ppm	-0.007	0.014										
Fe ppm												
Mn ppm					-0.001	0.032						
Zn ppm			-0.03	0.004			+1.62	0.036				
R^2 %	32		41		26		43		0		0	

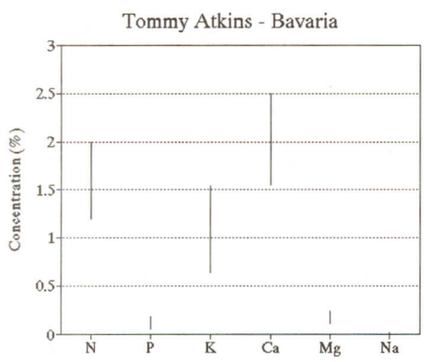

Fig. 1 *Range in concentration of N, P, K, Ca or Mg in the leaves sampled from the Tommy Atkins mango trees at Bavaria Fruit Estate.*

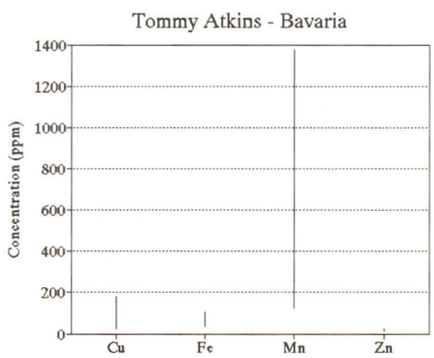

Fig. 2 *Range in concentration of Cu, Fe, Mn or Zn in the leaves sampled from the Tommy Atkins mango trees at Bavaria Fruit Estate.*

Table 8 *Model fitting coefficients and their significance levels [H_0(coefficient) = 0] for Heidi at Mariepskop Estate.*

	Fruit No		Avg Weight		Tree Yield		Shelf Life		Scald		Ground Colour	
	Coeff.	Sig. level	Coeff.	Sig. level	Coeff.	Sig. level	Coeff.	Sig. level	Coeff.	Sig. level	Coeff.	Sig. level
N %												
P %			+984	0.052	+26.8	0.023						
K %												
Ca %												
Mg %	+154	0.000			+134	0.000						
Cu ppm					-0.46	0.010						
Fe ppm												
Mn ppm					+0.02	0.060						
Zn ppm	+0.10	0.016	+1.34	0.031	+0.58	0.003					-0.002	0.008
R^2 %	73		46		86		0		0		36	

	TSS		pH		Taste		Pulp Colour		% with Phys. Disorders		% with Internal Breakdown	
	Coeff.	Sig. level	Coeff.	Sig. level	Coeff.	Sig. level	Coeff.	Sig. level	Coeff.	Sig. level	Coeff.	Sig. level
N %									+84.4	0.039	+40.5	0.038
P %											+131	0.000
K %							+0.173	0.049				
Ca %												
Mg %					+2.20	0.005						
Cu ppm												
Fe ppm					-0.001	0.004			+0.03	0.062	+0.02	0.017
Mn ppm												
Zn ppm			-0.001	0.006			-0.001	0.056				
R^2 %	0		39		56		50		37		77	

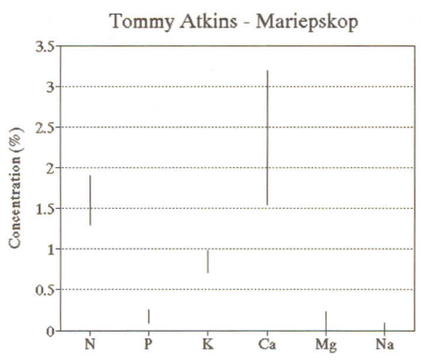

Fig. 3 *Range in concentration of N, P, K, Ca or Mg in the leaves sampled from the Tommy Atkins mango trees at Mariepskop Estate.*

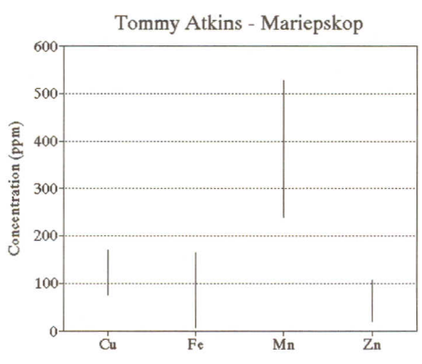

Fig. 4 *Range in concentration of Cu, Fe, Mn or Zn in the leaves sampled from the Tommy Atkins mango trees at Mariepskop Estate.*

Table 9 *Model fitting coefficients and their significance levels [H_0(coefficient) = 0] for Zill at Bavaria Fruit Estate.*

	Fruit No		Avg Weight		Tree Yield		Shelf Life		Scald		Ground Colour		TSS	
	Coeff.	Sig. level	Coeff.	Sig. level	Coeff.	Sig. level	Coeff.	Sig. level	Coeff.	Sig. level	Coeff.	Sig. level	Coeff.	Sig. level
N %														
P %													-14.8	0.010
K %														
Ca %													-1.02	0.063
Mg %														
Cu ppm														
Fe ppm							-0.001	0.004						
Mn ppm							+0.005	0.028						
Zn ppm														
R^2 %	0		0		0		46		0		0		41	

	Taste		Pulp Colour		Lenticel Damage		% with Soft Brown Rot		% with Phys. Disorders		% with Jelly Seed	
	Coeff.	Sig. level	Coeff.	Sig. level	Coeff.	Sig. level	Coeff.	Sig. level	Coeff.	Sig. level	Coeff.	Sig. level
N %			+0.140	0.016								
P %												
K %												
Ca %							+24.9	0.000				
Mg %							-133	0.019				
Cu ppm												
Fe ppm												
Mn ppm												
Zn ppm	-0.036	0.023	-0.005	0.001								
R^2 %	28		60		0		68		0		0	

Table10 *Model fitting coefficients and their significance levels [H_0(coefficient) = 0] for Zill at Mariepskop Estate.*

	Fruit No		Avg Weight		Tree Yield		Shelf Life		Ground Colour	
	Coeff.	Sig. level	Coeff.	Sig. level	Coeff.	Sig. level	Coeff.	Sig. level	Coeff.	Sig. level
N %							+7.92	0.015	-2.98	0.016
P %	-520	0.006			-160	0.005				
K %										
Ca %										
Mg %										
Cu ppm										
Fe ppm										
Mn ppm										
Zn ppm										
R^2 %	38		0		40		32		31	

	Scald		TSS		Taste		Pulp Colour		% with Jelly Seed	
	Coeff.	Sig. level	Coeff.	Sig. level	Coeff.	Sig. level	Coeff.	Sig. level	Coeff.	Sig. level
N %			-6.38	0.003	-1.47	0.013				
P %										
K %										
Ca %										
Mg %			-15.4	0.056			-1.61	0.018		
Cu ppm										
Fe ppm							0.001	0.014		
Mn ppm										
Zn ppm										
R^2 %	0		54		33		46		0	