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Relationship between Mineral Nutrition and Postharvest Fruit Disorders of 'Fuerte' Avocados

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***Abstract.* The purpose of this investigation was to determine if plant nutrition was in any way related to the development of post-harvest fruit disorders in avocado such as gray pulp, pulp spot and vascular browning. Fruit from three existing fertilizer experiments were cold stored at 5.5C for 31 days, ripened at 21C for 3 days and then evaluated for these disorders. The incidence of these disorders was related to soil, leaf and fruit nutrient analysis by means of polynomial regressions. This investigation was conducted for 3 consecutive seasons.**

Results showed that mainly K, Ca and Mg were involved in the development of post harvest fruit disorders. The Ca + Mg/K ratio in the subsoil (25 to 50 cm depth) should be higher than 6.4 to reduce gray pulp, whereas a high K-status (low Ca + Mg/K ratio) in the soil and plant will minimize the development of both vascular browning and pulp spot. It is, therefore, impossible to completely eliminate all three disorders since K should be low in the one instance and high in the other.

Physiological postharvest fruit disorders are causing serious problems in the marketing of South African fruit on local as well as overseas markets. On a visit to the Rungis market in Paris, Bezuidenhout (1983) reported that 6.7% of the South African fruit sampled on the market, showed pulp spot symptoms, 19.9% gray pulp and 29.0% vascular browning.

Several investigations have been undertaken to identify the cause of these disorders. Ginsberg (1985) speculated on the role of calcium and concluded that increased uptake of calcium might alleviate the problem. The possible role of calcium and water stress on these disorders was investigated extensively by Bower (1984, 1985, 1988), Bower and Cutting (1987,1988) and Bower and Van Lelyveld (1986), which led them to speculate that a pre-harvest water stress especially during the first three months after fruit set, will increase the postharvest browning potential of the fruit. Vorster and Bezuidenhout (1988) showed that fruit without pulp spot symptoms had a higher Ca and Zn concentration than fruit with pulp spot, but concluded that these results were only preliminary.

In another investigation, Hofman and Husband (1987) concluded that polyphenol oxidase, abscisic acid and gibberellins showed no consistent relationship to the development of pulp spot and gray pulp.

The first positive indication of factors involved in the development of gray pulp, pulp spot and vascular browning was given by Koen *et al.* (1990). They showed that Ca, Mg and K were involved in the development of these disorders and concluded that insufficient soil K rather than excessive Ca and Mg were responsible for the development of pulp spot and vascular browning. Gray pulp on the other hand was enhanced by excessive K levels in the leaves and fruit or insufficient Ca and Mg levels.

The purpose of this investigation was, therefore, to verify the preliminary results of Koen *et al.* (1990) by using data available from fertilizer experiments.

Materials and Methods

Three existing fertilizer trials (investigating N, P and K, respectively) with 'Fuerte' trees on Duke 7 rootstocks at the Friedenheim Experimental Farm near Nelspruit were used for this investigation. Each trial consisted of 8 levels of either N or P or K with 3 trees per plot and 3 replicates. The trees were 10-yrs-old at the start of this investigation.

Leaf and soil samples were taken during March (Keen and du Plessis, 1991), and the soil was sampled at two depths (0-25 and 25-50 cm). The fruit were harvested during April. One carton of fruit was taken from each plot for cold storage and one for analytical purposes. The fruit for cold storage was stored for 31 days at 5.5C and thereafter for a further 3 days at 21C. As soon as the fruit were soft they were cut open and rated for the occurrence of pulp spot, gray pulp and vascular browning. The extent of each disorder was expressed as the percentage of affected fruit per sample. From the fruit sampled for analysis purposes, separate samples were taken from the proximal, middle and distal parts, dried at 60C, ground and analyzed. In all cases the relationship between the chemical composition of the leaves, fruit and soil and the physiological disorders were computed by means of polynomial regressions.

Results and Discussion

This investigation covers the three most important postharvest fruit disorders in avocado namely gray pulp, pulp spot and vascular browning, as defined by Swarts (1984). Gray pulp was the most common disorder during the three seasons of this investigation, with 5 to 60 % of the fruit developing this disorder after cold storage. Vascular browning occurred in two of the three seasons whereas pulp spot was only found in the 1989 season (35 % of all the fruit was affected).

<u>Gray pulp.</u> Table 1 shows the relationships obtained between soil composition and occurrence of gray pulp after cold storage over a period of three seasons. Only significant relationships are shown. The subsoil composition of especially K, Ca and Mg shows very consistent results over this 3 year period. Increased K concentration

increased the incidence of gray pulp very strongly (Fig. 1) as indicated by the high regression coefficients (r = 0.92, 0.93 and 0.60 for the three seasons, respectively). Both Ca and Mg showed negative relationships with the occurrence of gray pulp, which means that an increase in soil Ca or Mg decreased the development of gray pulp in the fruit. The ratio between Ca, Mg and K in the soil is also of significance. Gray pulp decreased with an increase in the ratio of Ca + Mg/K (Fig. 2). This ratio varied between 1.5 and 8.2 over the three seasons and should be higher than 6.4 to reduce the incidence of gray pulp to less than 20%. The optimal Ca + Mg/K ratio in soils for subtropical crops is 4 to 5 (Koen *et al.* 1990).

Table 2 shows the significant relationships obtained between fruit analysis and gray pulp for the 1989 and 1990 seasons. For 1989 only the P, Ca and Mg concentration in the middle part of the fruit were related to the development of gray pulp after cold storage. In all three cases the response was negative such that an increase in P, Ca or Mg concentration in the fruit reduced the development of gray pulp. The same effect was obtained in the 1990 season with the only difference being that Ca and Mg had a linear (1st order) negative effect on gray pulp. The same 1st order negative effect was also obtained with Mg in the proximal part of the fruit. For the 1989 season, an increase in K concentration of the fruit increased the percentage of fruit with gray pulp, but this effect was not observed in the following season. These data are in accordance with the soil analysis data shown in Table 1. From the data shown in Tables 1 and 2, it can be concluded that a subsoil analysis could be a more reliable indicator of the possible development of gray pulp in a particular orchard than either fruit, leaf or topsoil analysis.

<u>Vascular browning.</u> Since the incidence of fruit with vascular browning was very low for the 1988 season, only data for 1989 and 1990 are presented (Table 3). Leaf analyses show a negative relationship of K with vascular browning in both seasons but subsoil K and leaf N only for 1989. From these results it is suggested that a K level in the subsoil above 98 mg K/kg and in the leaves above 1.4 % K, is likely to reduce the incidence of vascular browning. These results were supported by the fact that a decrease in the Ca/K and Ca + Mg/K ratios in the soil also reduced vascular browning (Fig. 3). This was in agreement with the findings of Koen *et al.* (1990) who stated that the Ca + Mg/K ratio in the subsoil should be lower than 5 to minimize the incidence of vascular browning. Fruit analyses (Table 4) show a highly significant relationship between increased fruit N and the development of vascular browning for the 1989 season only. Mg was the only element showing a consistently positive relationship with vascular browning in both seasons. This was in agreement with the negative trend observed for the K/Mg in the leaves and development of vascular browning. Therefore, an increase in K should reduce the Mg status of the plant (leaf K versus leaf Mg; r =-0.62 and -0.78 for 1989 and 1990 respectively) and the fruit (leaf K versus fruit Mg; r = -0.62).

<u>Pulp spot.</u> The incidence of fruit with this disorder was relatively low in the fertilizer experiments used for this investigation. Only for the 1989 season was pulp spot present and some relationships obtained with certain elements in the fruit (Table 2). Potassium in the proximal part of the fruit showed a highly significant relationship with pulp spot. The lowest occurrence of pulp spot was associated with a K concentration of between

1.45 and 1.65 % K. Both higher and lower K values increased the incidence of pulp spot, but especially lower values. In the distal part of the fruit, K showed a linear negative effect on pulp spot. No relationship was observed for the middle part as far as K was concerned. The Ca concentration in the middle part, however, showed a first order positive relationship with pulp spot, implying that higher Ca concentrations in the fruit will favor pulp spot development. In an extensive survey of avocado orchards Koen *et al.* (1990) also found a significant relationship between fruit K concentration and pulp spot. They concluded that the K concentration in the proximal half of the fruit should be higher than 1.5 % K, which is in good agreement with the 1.45 to 1.65 % K found in this investigation.

Conclusions

Fruit from three independent N, P, and K fertilizer trials were used for this investigation. The occurrence of gray pulp symptoms in these fruit varied between 5 and 60% for the three seasons under investigation. Vascular browning was absent during the 1988 season but in 1989 and 1990 up to 45% and 60%, respectively, of the fruit developed symptoms after cold storage. Pulp spot was only present in the 1989 season, when 35% of the fruit developed this disorder. It was shown that a subsoil analysis (especially the Ca + Mg/K ratio) should be more reliable in predicting the possible occurrence of gray pulp than either fruit, leaf or topsoil analysis. In this case the ratio of Ca + Mg/K should be higher than 6.4 to reduce the occurrence of this disorder to a minimum.

In the case of vascular browning, a higher leaf and soil K, lower Ca + Mg/K ratio and lower Mg in the fruit reduced the percentage of fruit developing this disorder after cold storage. It was shown that a higher leaf K level reduced the leaf Mg and thus the fruit Mg, which in turn reduced the incidence of vascular browning. Therefore by increasing the K status of the soil, the Ca + Mg/K ratio decreased, K uptake increased, whereby Mg levels in the fruit were reduced and the development of vascular browning minimized.

Pulp spot was a factor in the 1989 season only. Fruit analysis show a relationship between K and Ca and the development of this disorder. Fruit K concentration should be relatively high (1.45 to 1.65 %) and Ca relatively low to reduce the incidence of pulp spot.

From this investigation it can be concluded that K, Ca and Mg were involved in the development of postharvest fruit disorders. The ratio between these elements in the soil (Ca + Mg/K ratio) should be higher than 6.4 to reduce gray pulp, whereas a low ratio (or high K-status in the soil and plant) will minimize the development of both vascular browning and pulp spot. Therefore, by keeping the Ca + Mg/K ratio in the soil in the optimal range of 4 to 5, gray pulp will always be present to a certain extent, but pulp spot and vascular browning will be minimized.

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Table 1. Relationship[z] (r) between the chemical composition of the soil (top- and subsoil) and percentage gray pulp development in fruit after cold storage.

	1988			1989			1990		
Element	r	Order 1st, 2nd, or 3rd	Optimal (mg/kg)	r	Order 1st, 2nd, or 3rd	Optimal (mg/kg)	r	Order 1st, 2nd, or 3rd	Optimal (mg/kg)
Topsoil									
K	0.68	2nd	50-80	0.85	1st	<58			
Ca				0.79	2nd	>400			
Mg				-0.58	1st	>125			
Ca/K				0.77	2nd	>5.8			
Mg/K				-0.77	1st	>1.9			
Ca + Mg/K				-0.75	1st	>7.7			
Subsoil									
K	0.92	1st	< 45	0.93	1st	< 80	0.60	2nd	115-135
Ca				-0.64	1st	> 500	0.56	2nd	> 470
Mg	0.71	2nd	70-80				0.63	2nd	80-95
Ca/K				-0.62	1st	> 6.0	-0.46	1st	> 6.4
Mg/K				-0.72	1st	> 1.4	0.74	3rd	> 0.8
Ca + Mg/K	-0.72	1st	> 6.4	-0.68	1st	> 6.4	-0.49	1st	> 6.4
LSD									
P<0.05	0.40			0.40			0.40		
P<0.01	0.52			0.52			0.52		

[z] (-) denotes a negative effect on the disorder ; 1st, 2nd, 3rd denotes the order of the relationship e.g. 1st order, second order etc. (Only highly significant relationships, $P \leq 0.01$, are shown).

Table 2. Relationship[z] (R^2 x 100) between the chemical composition of different parts of the fruit and gray pulp and pulp spot development in the fruit after cold storage (1989 and 1990).

Location of Element	Gray pulp 1989	Gray pulp 1990	Pulp spot 1989
Proximal part			
P			
K	43 (2nd)		70 (2nd)
Mg		(-) 69 (1st)	
Middle part			
P	78 (2nd)	51 (3rd)	
Ca	42 (3rd)	(-) 53 (1st)	42 (1st)
Mg	40 (3rd)	(-) 50 (1st)	
Distal part			
K			(-) 30 (1st)

[z] (-) denotes a negative effect on the disorder ; 1st, 2nd, 3rd denotes the order of the relationship e.g. 1st order, second order etc. (Only highly significant relationships, $P \leq 0.01$ are shown).

Table 3. Relationship (r) between the chemical composition of soil and leaves and percentage vascular browning in fruit after cold storage.

Element	1989 r	1989 Relationship 1st, 2nd, or 3rd	1989 Optimal value[z]	1990 r	1990 Relationship 1st, 2nd, or 3rd	1990 Optimal value[z]
Subsoil						
K	-0.68	1st	> 98			
Ca/K	0.80	2nd	< 3.0			
Mg/K	0.77	2nd	< 3.6			
Ca + Mg/K						
Leaves						
N	0.72	1st	< 1.69	0.62	1st	< 1.60
K	-0.65	1st	> 1.58	0.82	3rd	> 1.40
K/Mg				0.77	3rd	> 2.84
Ca + Mg/K				0.82	3rd	< 1.00
LSD						
$P \leq 0.05$	0.51			0.40		
$P \leq 0.01$	0.64			0.52		

[z] Optimal values are reported as mg/kg for soil samples and % for leaf samples.

Table 4. Relationship[z] (R^2 x 100) between fruit composition and percentage of fruit developing vascular browning after cold storage (1989 and 1990 seasons).

Location of Element	Vascular browning 1989	1990
Proximal part		
N	(-) 68 (2nd)	
P		(+) 57 (1st)
Mg		(+) 60 (1st)
Middle part		
N	(-) 66 (2nd)	
P		(+) 58 (1st)
Mg		(+) 54 (1st)
Distal part		
K	(-) 57 (2nd)	
Mg	(-) 63 (2nd)	

[z] (-) denotes a negative effect on the disorder ; 1st, 2nd, 3rd denotes the order of the relationship e.g. 1st order, second order etc. (Only highly significant relationships, $P \leq 0.01$, are shown).

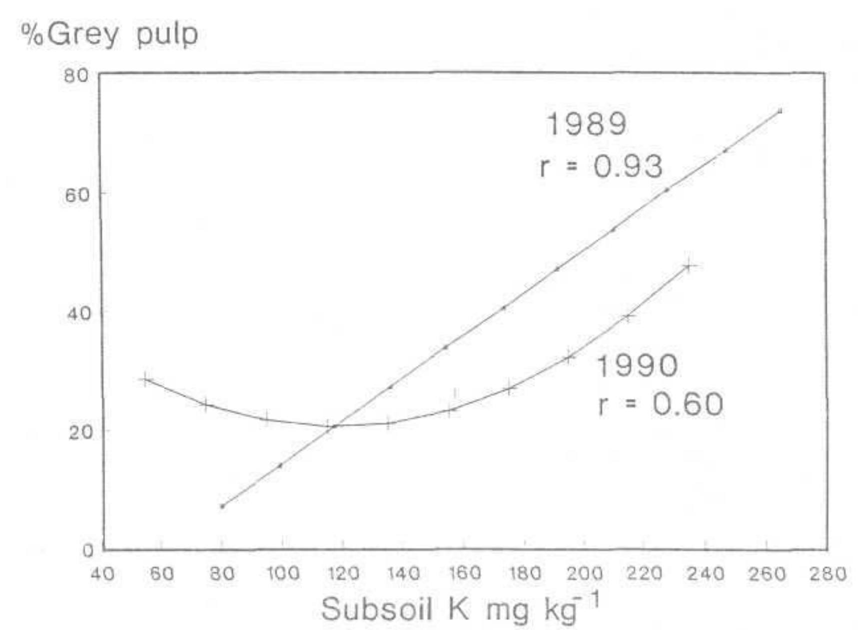

Fig. 1. Relationship between subsoil K (x) and incidence of gray pulp (y) in the fruit after cold storage for two seasons ($y = -21.637 + 0.360x$ for 1 989 and $y = 48.471 - 0.473x + 0.002x^2$ for 1990).

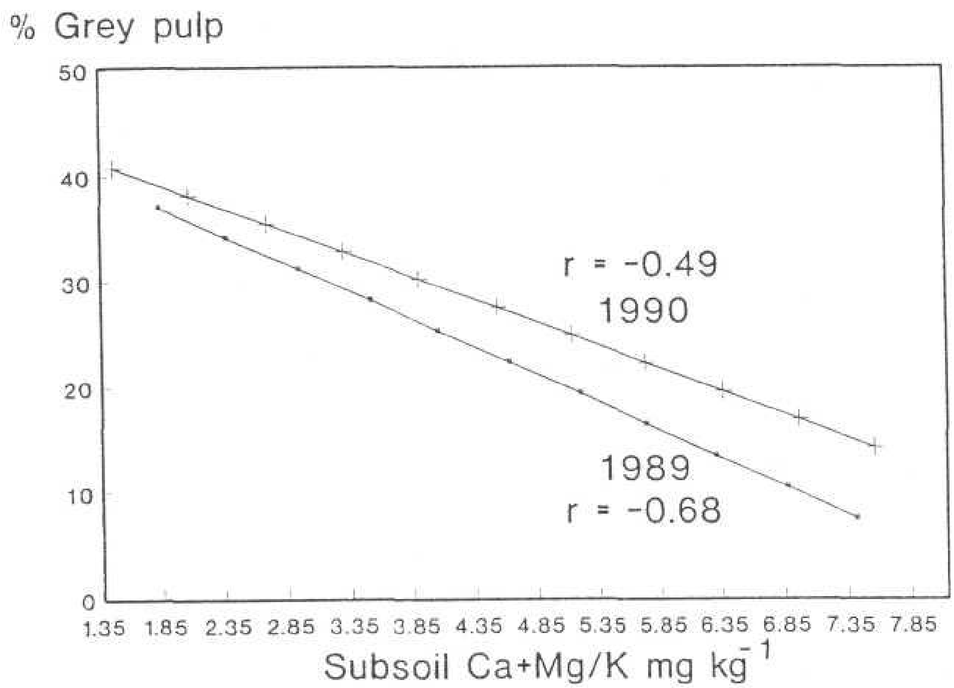

Fig. 2. Relationship between subsoil Ca + Mg/K (x) and gray pulp (y) for two seasons ($y = 46.712 - 5.280x$ for 1989 and $y = 47.143 - 4.347x$ for 1990).

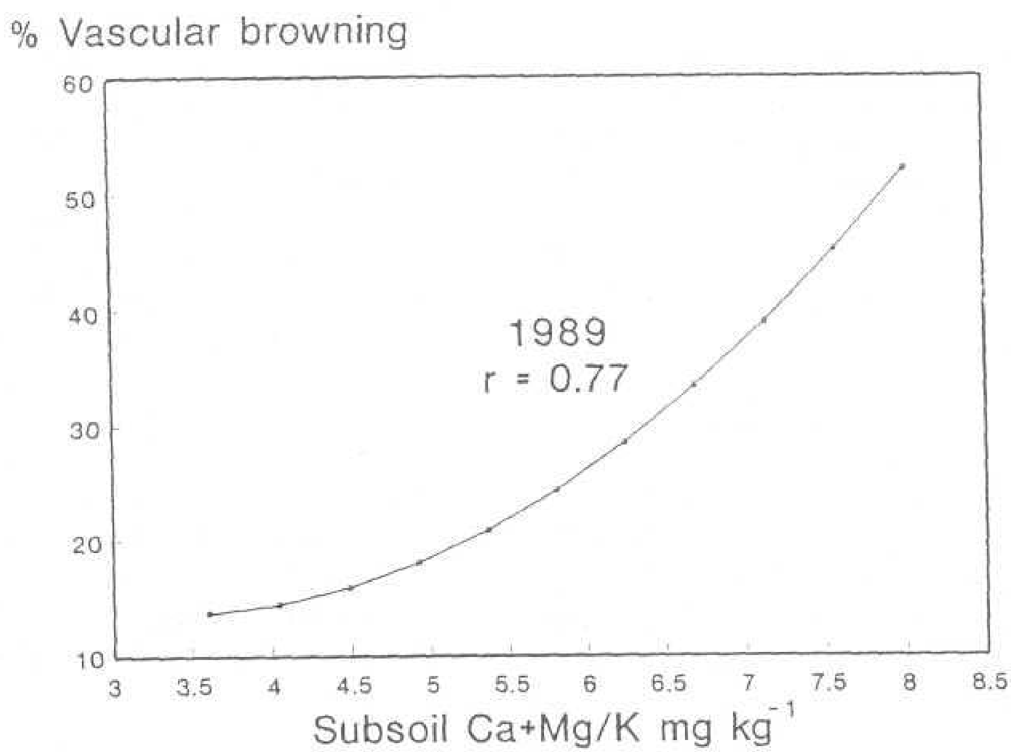

Fig. 3. Relationship between subsoil Ca + Mg/K (x) and incidence of vascular browning (y) after cold storage for the 1989 season ($y = 33.509 - 11.932x + 1.782x^2$).