South African Avocado Growers' Association Yearbook 1987. 10:143-146
Proceedings of the First World Avocado Congress

Some factors affecting post-harvest quality in avocado fruit

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SYNOPSIS
The effect of pre- and post-harvest stress on the quality of avocado fruit was investigated. Preharvest water stress caused increased post-harvest browning potential and also interacted adversely with restricted ventilation. Decreasing fruit moisture loss during storage significantly decreased the incidence of pathological and physiological disorders. An indication was found that abscisic acid played a role in physiological disorders.

INTRODUCTION

The South African avocado industry is based primarily on export. Post-harvest quality is therefore important, particularly as sea shipment requires low temperature storage for approximately 30 days.

The quality of South African fruit on European markets is variable. Some estimates (Bezuidenhout, 1983) indicated that more than 20 per cent of fruit had internal physiological disorders. While chilling injury (Eaks, 1976) and fruit suffocation during shipment (Van Lelyveld & Bower, 1984) are known to be contributing factors, Bezuidenhout & Kuschke (1982) noted that unknown pre-harvest conditions play a significant role in the post-harvest fruit quality.

The aim of the work was to elucidate the role of pre- and post-harvest stress factors in the determination of potential for physiological disorders, as measured by polyphenol oxidase (PPO) activity (Kahn, 1975). Abscisic acid (ABA), known to promote senescence (Leopold & Kriedemann, 1975), is also stress linked (Walton, 1980). A possible connection between ABA and PPO was thus investigated.

MATERIALS AND METHODS

Different levels of long-term pre-harvest stress were induced by varying irrigation regimes. Five single tree plots were used as data trees for each irrigation regime. While the same total quantity of water was applied, frequency differed, the timing being based on soil moisture tension at 300 mm depth. The irrigation regimes consisted of replacement of soil moisture to field capacity when tensions reached 35 kPa (frequent irrigation); 55 kPa (moderate irrigation) and 80 kPa (infrequent irrigation).

Experiment 1

Effect of irrigation on PPO activity Four fruits per data tree were picked from each irrigation regime during April 1984, and packed in export-type cartons. Half were stored at 5,5°C for 30 days before being allowed to ripen at 21 °C, while the other half were ripened immediately. When eating soft, as according to the firmometer of Swarts (1981), fruits were peeled, the seeds removed and the distal halves pulped and frozen until PPO analysis could be done. This procedure was repeated in July.

Experiment 2

Effect of irrigation and restricted ventilation on PPO activity

During May 1985, the interaction between irrigation regime and restricted ventilation in storage was studied. Ten fruits each from the 55 kPa and 80 kPa treatments were picked and packed as previously described. After storage for 30 days at 5,5°C, half the fruits from both treatments were enclosed in a glass tank and sealed for 48 h, at a temperature of 21 °C, before being allowed to ripen in normal atmosphere. Control fruits were ripened in normal atmosphere. Fruits were analysed as in Experiment 1.

Experiment 3

Effect of post-harvest moisture loss on fruit quality

To ascertain the effect of post-harvest moisture stress on fruit quality, fruits were waxed and packed as for export by a commercial packhouse. Two adjacent identical cold rooms were packed with a standard shipping pallet of cartons, randomly allocated. Ten cartons were selected from each, and fruits massed before and after storage at 5,5°C for 30 days. A humidifier was placed in one cold room to decrease the fruit-atmosphere moisture gradient, thereby decreasing fruit moisture loss. After the storage period, fruits were ripened at 21 °C, and 20 cartons containing 14 fruits each were evaluated for pathological and internal physiological disorders, while five fruits from each treatment were analysed for PPO activity.

At the same time when fruits for Experiment 1 were harvested, a further 10 fruits per treatment were harvested for analysis for abscisic acid content when 50% soft (according to the firmometer test of Swarts (1981)). Fruits from Experiment 1 were used for soft fruit ABA analysis.

Analysis of PPO activity was done in accordance with the method of Van Lelyveld & Bower (1984). Extraction of ABA was done as described by Cutting, Bower & Wolstenholme (1986) and the assay conducted according to the method of Cutting, Hofman, Lishman & Wolstenholme (1985).

RESULTS

Experiment 1

In the case of unstored fruit from the first harvest date, irrigation resulted in significant ($P<0,01$) differences in soluble PPO activity due to pre-harvest irrigation. The 55 kPa treatment resulted in lowest activity, followed by 35 kPa ($P < 0,01$) and the 80 kPa higher still ($P < 0,05$). Stored fruit showed the same pattern, except that all treatments had significantly increased levels of soluble PPO activity ($P<0,01$) as compared with unstored fruit. This is shown in Figure 1.

The immediate browning potential, as shown by soluble PPO activity later in the harvest season (July), is shown in Figure 2.

Unstored fruits (Figure 2) showed the same trends as earlier in the season, with the 55 kPa treatment lowest, followed by the 35 kPa ($P<0,05$) and the 80 kPa considerably higher than the 55 kPa ($P<0,01$). After storage, differences were less marked, with only the 55 kPa and 80 kPa treatments differing significantly ($P<0,01$). The actual browning of late-harvested fruit was considerably higher than those harvested early, the PPO activity increasing in specific activity from approximately 0,8 to 4 for the 55 kPa treatment, and 1,2 to 5,6 for the 80 kPa. Further storage did not increase the browning potential, unlike fruit from the earlier harvest date.

Experiment 2

Fruit from the moderate (55 kPa) irrigation did not show a significant increase in browning potential (specific PPO activity) with a 48 h period of restricted ventilation (Figure 3), whereas fruit with a history of stress (80 kPa) did ($P<0,01$). The latter group also showed visual symptoms of internal disorders.

Experiment 3

The incidence of pathological and physiological disorders as influenced by fruit moisture loss during storage, is shown in Table 1. Fruit from the 'dry' cold room lost more moisture than fruit from the humidified room - mean of 2,2 g per fruit - which was a significant difference ($P<0,01$).

By decreasing moisture stress on fruit during storage, a better overall fruit quality was achieved ($P<0,01$). In addition, both pathological and physiological disorders showed lower incidence. Of the internal disorders, vascular blackening and pulp spot had the highest incidence. External cold damage however, showed no difference.

Stressed fruit had a higher immediate browning potential ($P < 0,01$), as shown by the specific activity of soluble PPO. Total PPO activity (indicating total potential browning) showed a similar trend, although this was not significant due to high variation in the dry treatment.

Abscisic acid analysis

In the pre-harvest stress experiment (Experiment 1) the ABA content in 50% soft fruit showed a significant correlation ($P<0,01$) with soluble PPO activity in fully-soft fruit ($r=0,88$). A decrease in ABA content (implying utilisation) also occurred during the latter half of the ripening period. The decrease (utilisation) was least (and nonsignificant) for the 55 kPa and greatest for the 80 kPa treatment, with significance at $P < 0,01$. The 35 kPa treatment was intermediate ($P < 0,05$). These results are summarised in Table 3.

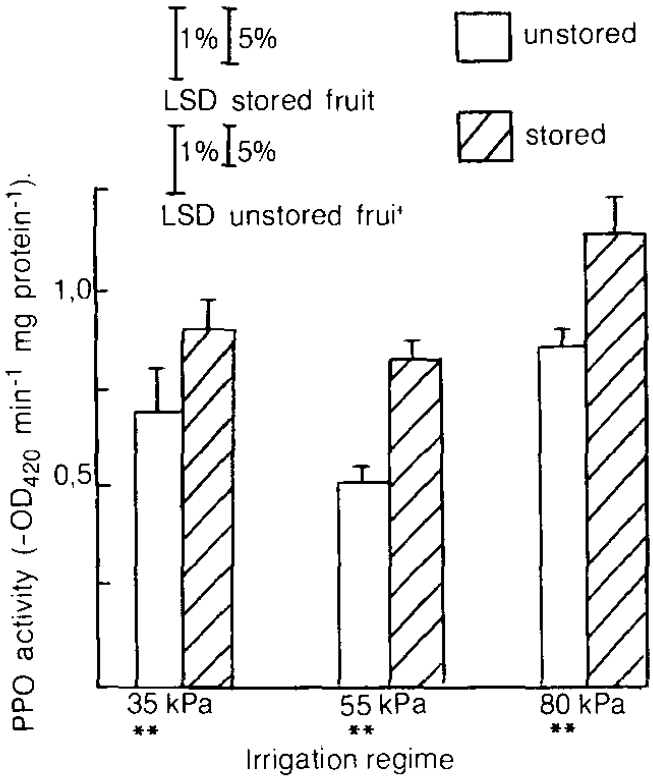

Fig 1 Influence of irrigation regime on soluble PPO activity in stored and unstored Fuerte avocado fruit for April harvest. Significance at $P = 0,01$ is indicated by **. Bars indicate SE of means, ten samples per mean.

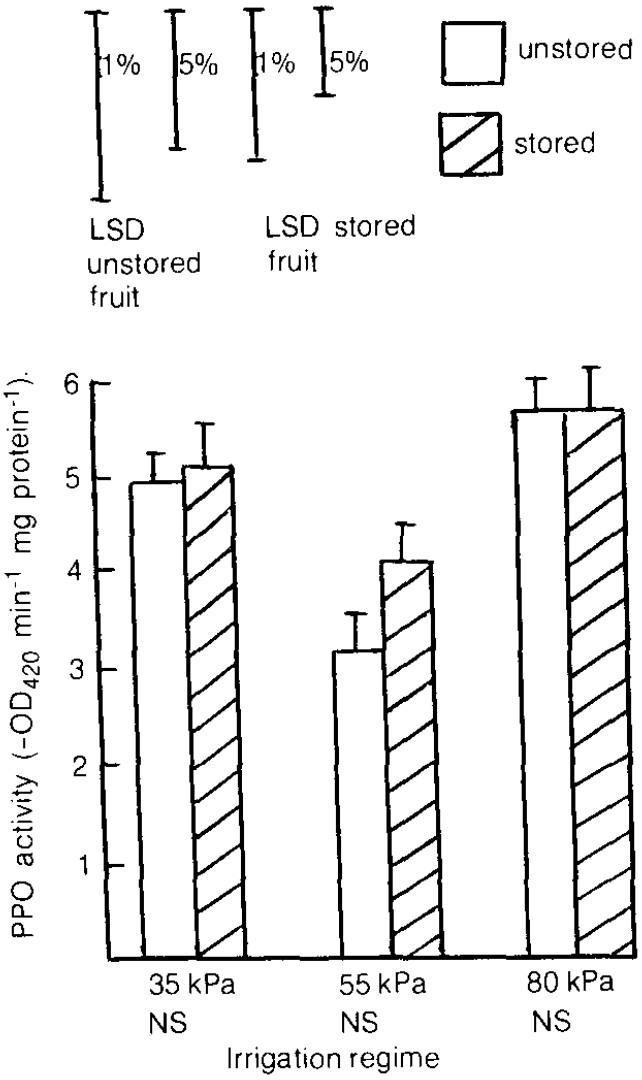

Fig 2 Influence of irrigation regime on soluble PPO activity in stored and unstored Fuerte avocado fruit for July harvest. Bars indicate SE of means, ten samples per mean.

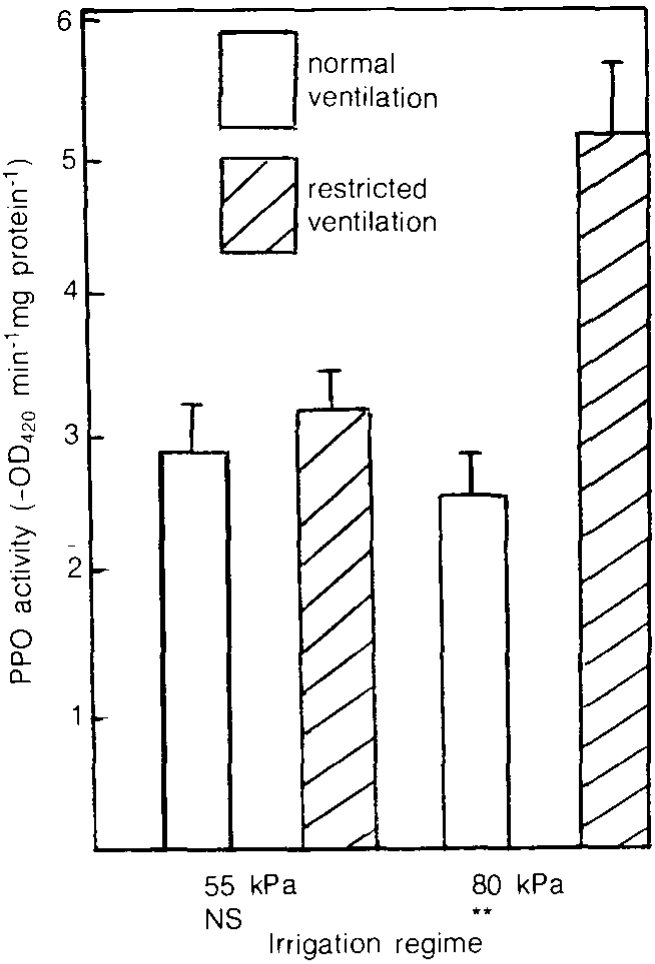

Fig 3 Effect of irrigation regime on container ventilation on soluble PPO activity. Significance at $P = 0,01$ is indicated by **. Bars indicate SE of means, five samples per mean.

TABLE 1 Percentage incidence of avocado fruit disorders as influenced by fruit moisture loss during storage. Significance at P = 0,05 is indicated by * and P = 0,01 by ** calculated from frequency of disorder by X^2 test.

Fruit moisture loss	Percentage fruit with disorders			
	External cold damage	Anthracnose	Stem-end rot	Internal physiological disorders
High loss	0,69	22,0	3,81	31,2
Low loss	1,04	13,9	0,35	17,8
Significance	NS			

Results of fruit PPO activity analysis are shown in Table 2.

TABLE 2 Effect of post-harvest fruit moisture loss on soluble and total polyphenol oxidase activity ($\Delta OD_{420} min^{-1}$ mg $protein^{-1}$). Significance at P=0,01 is shown by ** SE of means, five samples per mean are shown in brackets.

Fruit moisture loss	Soluble PPO	Total PPO
High loss	3,24 (± 0,24)	6,21 (± 1,27)
Low loss	2,01 (± 0,18)	4,04 (± 0,49)
Significance	**	NS

TABLE 3 Free abscisic acid content (ng g fresh $mass^{-1}$) of fruit at 50 and 100% soft for three irrigation regimes. Significance is indicated by * for P=0,05 and ** for P=0,01. SE of means, five samples per mean are shown in brackets.

Treatment	ABA at 50% soft	ABA at 100% soft	Significance
35 kPa	140,9 (± 5,8)	65,0 (± 2,2)	**
55 kPa	109,2 (± 10,6)	82,5 (± 7,9)	NS
80 kPa	160,2 (± 4,1)	66,2 (± 4,6)	**
Significance		NS	
LSD (P = 0,05)	25,2		
LSD (P=0,01)	36,3		

DISCUSSION AND CONCLUSIONS

It is clear that pre-harvest stress can be a factor in the determination of postharvest fruit quality, The optimal long-term irrigation regime would appear to be a moderate one, allowing for some drying of soil, thus preventing long periods near field capacity. Avocado trees are known to be sensitive to such conditions (Curtis, 1949) which create oxygen shortage as well as promote *Phytophthora cinnamomi* root rot (Zentmyer, Paulus, Gustafson, Wallace & Burns, 1965). At the same time, soil moisture tension of 55 kPa was shown by Bower, Wolstenholme & De Jager (1978) not to cause stomatal closure under moderate environmental conditions, while a tension of approximately 70 kPa and more could, resulting in tree stress. The mechanism by which stress enhances browning potential of fruit is unknown, but is likely to be deep-seated and may involve membrane structure as the stress period was identified as the first three months after fruit set. Thereafter rainfall was sufficient to prevent stress until harvest. This early fruit developmental period corresponds with maximum fruit calcium concentration (Witney, Wolstenholme & Hofman, 1986) known to be important in membrane structure (Bangerth, 1979).

An apparent link between PPO activity, long-term pre-harvest stress and metabolism of the senescence hormone ABA has been noted. The manner in which enhanced levels of ABA at the climacteric (approximately 50% soft as shown by Cutting et al, 1986), are influenced by stress during early fruit development, and which may result in enhanced metabolism of the growth regulator with possibly increased PPO activity, is unknown, but is also speculated to be membrane-related. Further work is required to elucidate this mechanism, as a means of decreasing ABA metabolism could enhance fruit shelf life and decrease physiological disorders.

Post-harvest conditions were also shown to affect fruit quality, but the suffocation experiment (Experiment 2) showed that pre- and post-harvest stress factors could interact in the determination of final fruit quality. Increased moisture loss resulting in stress during storage, caused not only enhanced PPO activity and visual symptoms of disorders, but also increased prevalence of pathological disorders. The mechanism is not known, but the consequences for the avocado industry are clear.

Good potential avocado fruit quality can only be achieved by limiting preharvest stress, particularly water stress during the first three months after fruitset, and controlling post-harvest environmental conditions. Further research into the role of abscisic acid in fruit physiology is required.

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