Report on the incidence of diseases (anthracnose, stem-end rot) and physiological disorders in 'Hass' avocados from Tzaneen region

Continuation of the project: *'Investigating the pre-harvest factors associated with the postharvest quality of 'Hass' avocados exported to the UK'*

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ABSTRACT

It is well-known that the postharvest quality of avocado fruit is influenced by several pre-harvest factors, including nutrition, maturity level and subsequent storage conditions. It is argued that the quality of avocado fruit is defined by its biochemical composition. This project started in 2017, as no recent thorough study, including biochemical analysis of fruit from different cultivation practices and maturity levels (early-, mid- and late season fruit), had been conducted. This project aimed to investigate the differences in the fruit biochemical composition to enable differentiation between "good" and "poor" quality avocado fruit destined for export. The level of nitrogen being used in the orchard has previously been identified among the factors that could affect the quality of the fruit; thus orchards selected for our trials included those with high, low and what is considered to be "optimum" nitrogen levels. In agreement with the data from 2017, mannoheptulose content showed decreasing trend from early- to late season and was found to correlate with a number of days to ripen. The main fatty acid identified in avocado fruit was oleic acid (18:1). As the season progressed, its content increased in the fruit from all the orchards, however, we have also noticed that oleic acid content was higher when high level of nitrogen was used. There were some differences between the years. For example, the late season fruit from orchards with high level of nitrogen had high incidence of grey pulp (36-62%) in 2017, while this specific issue was not often found in 2018 fruit, even though there is still an indication that grey pulp is associated with increasing level of nitrogen. It is worth noting that high level of nitrogen led to increased incidence of vascular browning. The findings also suggest that there is a link between the nitrogen level and disease incidence, i.e. early season fruit from low nitrogen level orchards had higher incidence of diseases, especially stem-end rot, which could be associated with these fruit being too immature, i.e. harvested too early – the role of nitrogen in fruit development. The phenolic acids content increased with ripening and decreased as the season progressed. The relationship between the fruit quality and specific phenolic acids is yet to be established.

INTRODUCTION

This report follows the year-one report (Glowacz *et al.*, 2018) with some of the findings from this project (February 2017 – September 2018). The South African Avocado Industry (SAAI) is mainly export orientated with more than half of the avocado production being exported, predominantly to the European markets (Potelwa & Ntombela, 2015). As previously highlighted (Nelson, 2010), the industry faces competition from other southern hemisphere countries such as Peru and Chile. Furthermore, due to long distance shipping and low storage temperatures required for the South African avocado fruit to reach overseas markets, avocados are at high risk of developing various physiological disorders (Nelson, 2010) – often determined by pre-harvest factors, including

irrigation, nutrition and growing location due to climate conditions, season (early, mid and late). The quality of the fruit varies among the years and may also be affected by postharvest handling of the produce at their destination.

The fruit quality is often related to the changes in the biochemical composition. Although it is widely accepted that the oil content (Ozdemir & Topuz, 2004) and total phenolic concentration (Cutting *et al.*, 1992) in avocado fruit increase with maturity, there is no clear indication of the behaviour of individual fatty acids and phenolic acids and how they relate to visual quality of the fruit as the harvesting season progresses. Ozdemir and Topuz (2004) found a significant increase in oleic acid and a decrease in the remaining fatty acids in 'Fuerte' avocado as the maturity level advanced. Similarly, Teng *et al.* (2015) observed an increase in oleic acid in late season fruit. On the other hand, changes in the phenolic compounds were not clear (Golukcu & Ozdemir, 2010), as an increase in epicatechin content from the first to the second harvest was reported, with a decrease from the second to the third harvest.

The postharvest quality of the fruit is often affected by nutrition, e.g. calcium and nitrogen level. High nitrogen application can lead to high N/Ca ratio, which has been associated with an increase in certain internal disorders in apples (Ferguson & Watkins, 1989) and pears (Curtis *et al.*, 1990). High nitrogen application has been reported to induce cytokinin activation that may alter the production of ethylene and abscisic acid (Hernández *et al.*, 2016), thus interfering with fruit development, ripening and senescence.

The overall objectives of this project are: i) to determine the incidence of mesocarp disorders and incidence of diseases in ripe early-, mid- and late season 'Hass' avocado fruit from Tzaneen region, South Africa; ii) to conduct biochemical analyses - C7 sugar, fatty acids and phenolic compounds (from harvest, through cold storage at commercially used temperatures for export up to the point when the fruit is ripe and ready to eat); iii) to subsequently establish a possible relationship between the incidence of diseases and mesocarp disorders and biochemical composition of the fruit. This needs to be done in order to meet high consumer expectations, and to ensure that South Africa remains among the preferred avocado suppliers for the European market.

MATERIALS AND METHODS

The methodology used in this work has been exactly the same as described in the previous report (Glowacz *et al.*, 2018).

RESULTS AND DISCUSSION

Similar to the previous observations (Glowacz *et al.*, 2018) and in agreement with other researchers, fruit ripened faster with progressing season (Fig. 1). The percentage of avocado fruit with anthracnose is shown in Figure 2. In 2017, anthracnose incidence appeared to be higher in the early season fruit compared

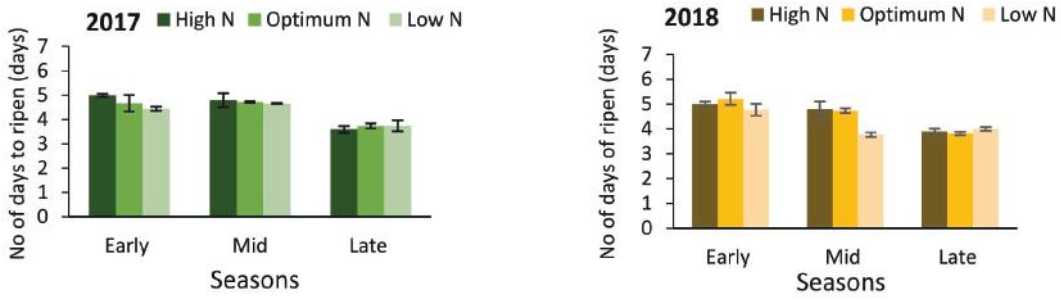


Figure 1. Number of days to ripen the 'Hass' avocado fruit from high, optimum and low nitrogen level orchards during the early-, mid- and late season.

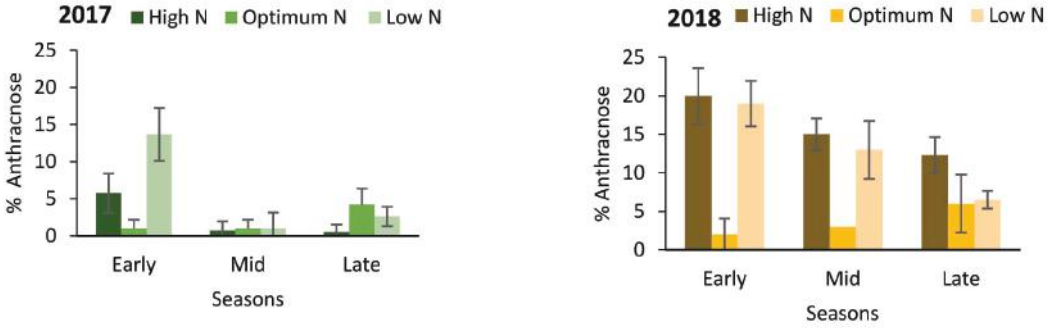


Figure 2. Anthracnose incidence in 'Hass' avocado from high, optimum and low nitrogen level orchards during the early-, mid- and late season.

with those harvested during the other seasons. Even though this trend was still observed in 2018, the difference between seasons was less obvious. Interestingly, in both years the orchards with "optimum" nitrogen levels had a lower incidence of anthracnose. Anthracnose has previously been found to be enhanced by the application of high level of nitrogen in mango orchards (Nguyen *et al*., 2004). Finding further supported by Bally *et al*. (2009) who also observed that the application of nitrogen at the intermediate stage of flowering and fruit development significantly increased the severity of anthracnose in mango.

It is also worth noting that incidence of anthracnose often depended on the orchards (hence the high standard error). This suggests that the occurrence of anthracnose could be related to other pre-harvest factors (orchard management), such as the timing of the nitrogen application (Bally *et al*., 2009), fungicide sprays and postharvest stress, such as water loss during storage (Bower and Cutting, 1988).

The percentage of fruit with stem-end rot is presented in Figure 3. There was also no clear trend for the seasons and nitrogen levels during both years, however there was an indication that in years with the high incidence of stem-end rot, the orchards with low nitrogen level exhibited the highest incidence, especially in the early-season fruit. The stem-end rot pathogen is present in the living and dead plant parts and the inoculum is produced mainly in high humidity conditions (Dreistadt, 2008). Twizeyimana *et al.* (2013) reported that early-season fruit are more prone to stem-end rot due to a high level of humidity during harvest. This would fit with an idea that level of rainfall could affect the disease incidence, i.e. dryer year 2016 (2 rainy months) resulted in lower disease incidence in 2017, while rainy 2017 (4 rainy months) led to higher incidence of disease the following year.

Figure 4 illustrates the average percentage of grey pulp in early-, mid- and late season in 'Hass' avocado fruit from high, optimum and low nitrogen level orchards in the Tzaneen production area in 2017 and 2018. Grey pulp incidence was much lower in the orchards with low nitrogen level in 2017, whereas the impact of nitrogen level on grey pulp incidence was less evident in 2018, due to the frequency of this issue being lower. In both years, grey pulp was associated with late-season fruit. It has been suggested that high level nitrogen application may interfere with the ethylene and abscisic acid production/signaling (Hernández *et al*., 2016).

The pulp epicatechin content of early-, mid-, and late season 'Hass' avocado pulp in fruit originating from high, optimum and low nitrogen level orchards from different producers in the Tzaneen production area is presented in Figure 6. Overall, there was some variation in the data. The early season fruit from low nitrogen orchards had a higher concentration of epicatechin compared to those from the high

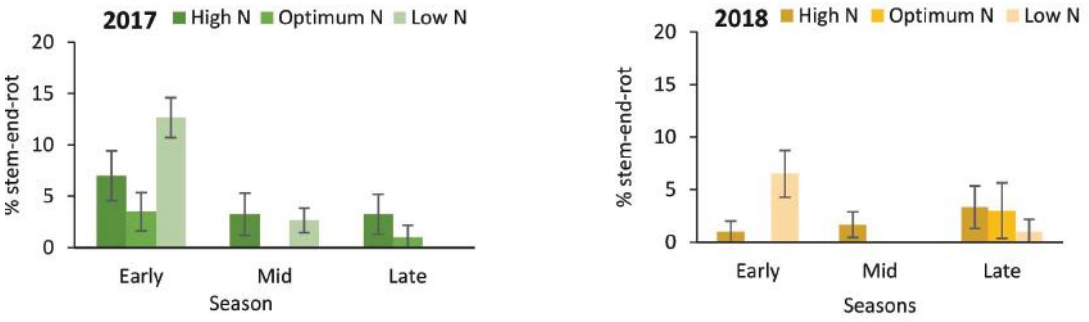


Figure 3. Stem-end rot incidence in 'Hass' avocado from high, optimum and low nitrogen level orchards during the early-, mid- and late season.

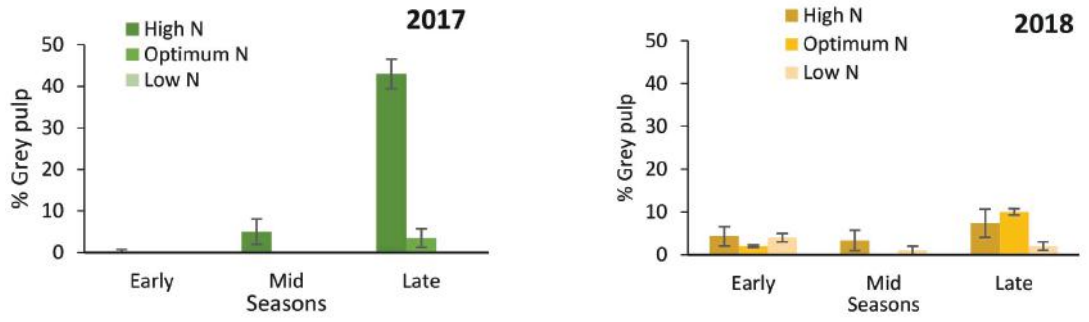
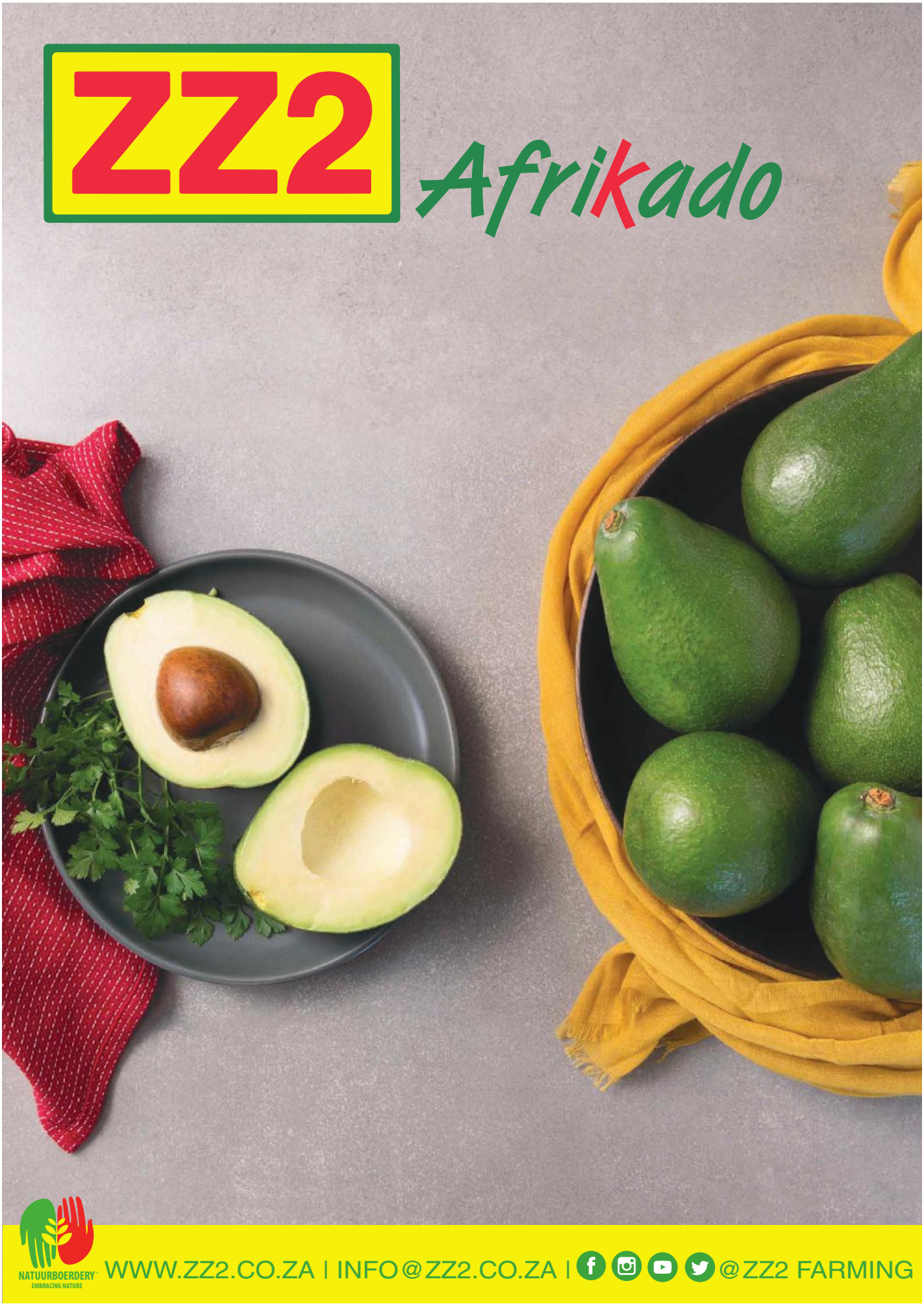


Figure 4. Grey pulp incidence in 'Hass' avocado pulp from high, optimum and low nitrogen level orchards during the early-, mid- and late season.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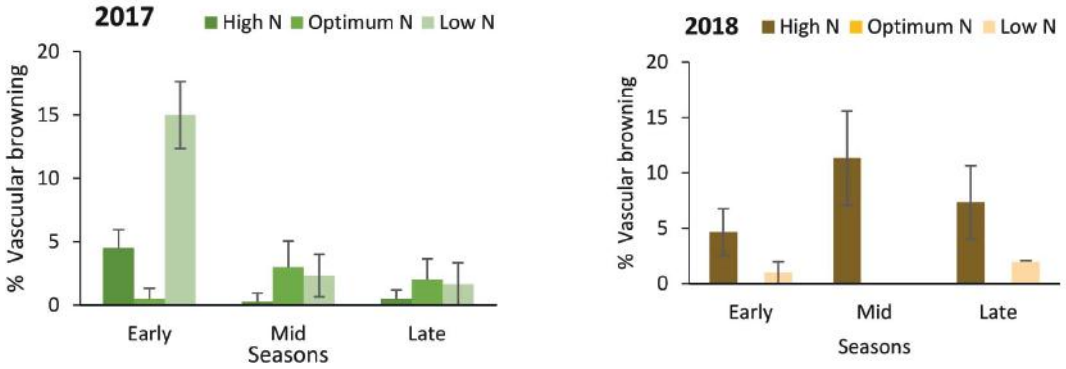

Figure 5. Vascular browning incidence in 'Hass' avocado pulp from high, optimum and low nitrogen level orchards during the early-, mid- and late season.

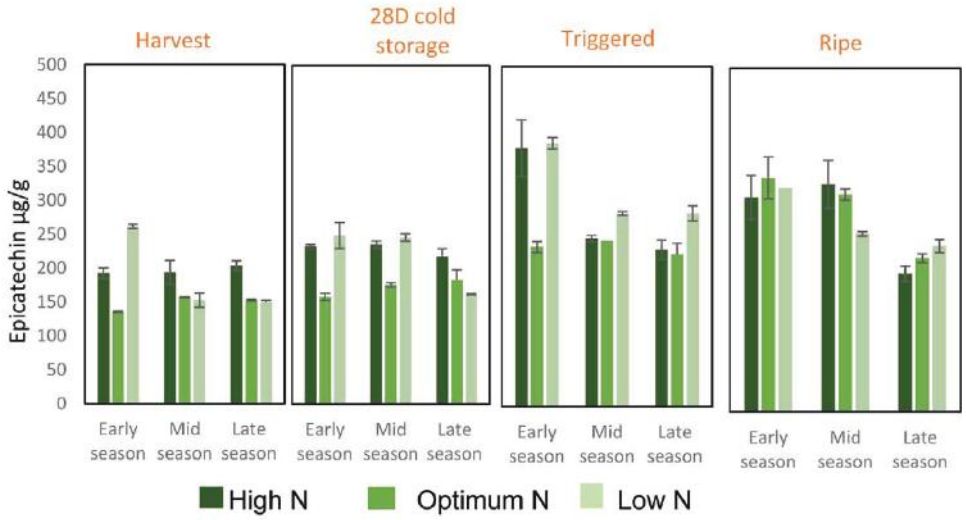

Figure 6. Epicatechin content of 'Hass' fruit pulp originating from high, optimum and low nitrogen level orchards during the early-, mid- and late season.

and optimum nitrogen orchards at harvest. In the mid- and late seasons, the fruit from the high nitrogen orchards displayed the highest epicatechin content compared to the fruit from the optimum and low nitrogen orchards at harvest. The data suggest that the epicatechin content increased with progressing ripening, however this could also be associated with the improved extractability as fruit ripens.

Postharvest browning of fruit occurs as a result of oxidation of quinones, which are produced by the conversion of monophenols by the enzyme polyphenol oxidase (Martinez and Whitaker, 1995). Phenolic acids are found in the cell vacuole and other special tissues. They are released only when the membrane integrity has been compromised. Polyphenol oxidase (PPO) is suggested to play a role in plant defence. The interaction between polyphenol oxidase and phenolic compounds produces antibacterial and antifungal compounds (hydroxyphenolics and quinones) which may polymerise to seal off infected tissues (Vaughn *et al.*, 1988). In other words, the primary role of the reaction between polyphenol oxidase and phenolic compounds is to repair tissue damage, however, the reaction by-products (quinones) are easily oxidised to brown melanin pigments (Bower and Cutting, 1988). Tissue browning reflects loss in membranes integrity but a strict correlation between the total level of phenolic compounds and the quality of the fruit does not always exist (Kołodziejczyk *et al.*, 2010). Thus, we will attempt to link changes in fruit quality with changes in the content of individual phenolic compounds.

CONCLUSION

The two-year investigation of pre-harvest factors (e.g. orchard location, nitrogen level and season) associated with the postharvest quality of 'Hass' avocados from Tzaneen region exported to the UK revealed that mannoheptulose content which showed a decreasing trend from early- to late season correlates well with a decreasing number of days to ripen as the season progresses. High nitrogen level orchards yielded fruit with higher values of this C7 sugar when compared to the fruit of the low nitrogen level orchards. During the ripening stages, the C7 sugar declined, regardless of the level of nitrogen in

the orchard. The content of oleic acid increased in the fruit as the season progressed. However, fruit from orchards with high nitrogen level had higher content of this fatty acid when compared to low nitrogen level orchards.

Even though high nitrogen level is often used to promote fruit growth and development, and also leads to fruit with higher level of mannoheptulose and oleic acid, it may have a negative impact, especially in the late season fruit – grey pulp, which could be related to higher "age of the fruit".

The content in epicatechin was quite variable and no clear trend was found, thus they could not be directly linked to the incidence of grey pulp and fruit quality. The relationship between other phenolic compounds and fruit quality is yet to be determined. Further data analysis will be conducted to establish a possible relationship between the biochemical composition of the fruit with the observed fruit quality.

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