Follow-up study on the effect that iron supplements have on the post-harvest chilling injury disorder of avocado fruit

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ABSTRACT

This paper deals with recent research aimed at reducing chilling injury in South African export avocado fruit. Our previous research has shown that fruit with higher iron contents may be less susceptible to post-harvest chilling injury. During the 2008 season, two trials were performed. In the first trial, 60 grams DDPA, split into 6 monthly dosages of 10 grams each, were applied by fertigation to a 'Pinkerton' orchard in the Schagen area. In the second trial, 90 grams of DDPA (Fe chelate) was applied as a topdressing to a 'Hass' orchard in the Kiepersol area. The results indicated that, although the mean chilling injury scores of the treatment were always lower than that of the control, the difference was only statistically significant on certain dates and at specific storage temperatures. However, in both cultivars, neither the flesh nor the skin iron content was increased by the additional iron treatments. Interestingly, the iron applications reduced the nitrogen content of the fruit at both experimental sites. Feedback from the industry suggests that chilling injury was low during the 2008 season. In the present study, a remarkable increase in fruit iron content was observed during January. Our final deduction is that, while Fe would appear to play a role in chilling injury, its uptake is primarily dependent on climatic and edaphic conditions.

INTRODUCTION

Previous surveys and trials have indicated that the susceptibility of avocado fruit to post-harvest chilling injury may be associated with fruit iron content (Magwaza *et al.*, 2008). To substantiate these results, a further two trials were performed during the 2008 season.

MATERIALS AND METHODS

The first trial was conducted in a 'Pinkerton' orchard on the farm of Dr. Anton Hough (block A5 and A6). In this experiment, 60 grams of DDPA per tree was split into 6 monthly dosages of 10 grams each from September 2007 to February 2008.

The second trial was laid out in a 'Hass' orchard (H13-2) on Mr. JJ Prinsloo's farm in the Kiepersol area. The trial consisted of two treatments, namely the Fe treatment and an untreated control. During September 2007, 90 grams of DDPA (Fe chelate) was applied as topdressing to the treatment trees. Each treatment was replicated 5 times and each replicate consisted of 7 trees of which the 5 middle trees served as data trees.

Fruit sampling for mineral analysis took place on a monthly basis from December 2007 to September 2008. Sampling for storage purposes in both trials was done on a two weekly basis from May to September 2008. In the 'Pinkerton' trial, 67 fruit per replicate were sampled of which 60 were assigned to three post-harvest storage temperatures (2, 4 and 6°C) and 7 used for maturity and mineral analysis. In the 'Hass' trial, a total of 15 fruit per replicate were harvested on each date of which 5 fruit were used for maturity and mineral content analysis and 10 were stored at phytosanitary temperatures (2°C for 28 days).

RESULTS AND DISCUSSION

The storage results of the 'Pinkerton' trial at Schagen indicated that chilling injury was high at the beginning of the season and tended to gradually decrease as the season progressed and the fruit matured (**Figure 1**). Of the three storage temperatures, fruit stored at 2°C had the highest chilling injury scores followed by the 4°C treatment. Fruit stored at 6°C consistently had the lowest incidence of chilling injury. The chilling injury scores of fruit from trees that received additional iron were consistently lower than that of the control fruit, although the difference was only statistically significant on one date and two temperature settings.

The skin iron content is shown in **Figure 2** and that of the flesh in **Figure 3**. No differences were observed between the two treatments. The iron content of the skin was around 30 ppm at beginning of the sampling period while that of the flesh was around 50 ppm. During January, a remarkable increase in iron content was recorded. The skin iron content increased to 250 ppm while that of the flesh increased to 180 ppm. The levels then decreased to between 30 and 40 ppm for the rest of the season. A possible explanation for this pheno-

menon is offered later in this article.

The skin (**Figure 4**) and flesh (**Figure 5**) nitrogen contents of the fruit that received additional iron were significantly lower than that of the control fruit. This trend was consistent throughout the sampling period. The reduction in tree nitrogen content was so severe that trees that received additional iron turned yellow. To reduce nitrogen stress on these trees, extra nitrogen at a rate of 380 g LAN/tree was applied to the treatment trees at the end of March. Tree health was significantly improved after the nitrogen application, but the fruit nitrogen content was only slightly affected by this supplementary nitrogen. A number of interesting spin-offs were observed. For instance, the fruit calcium content

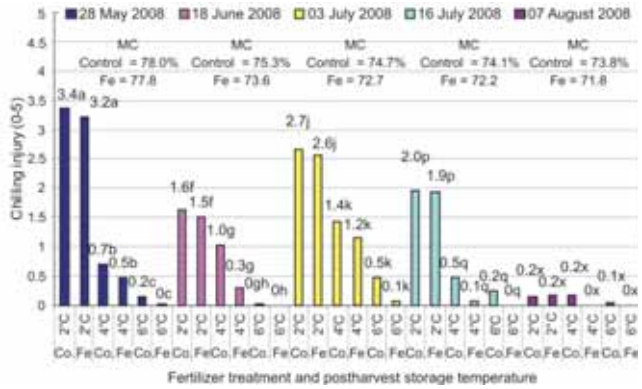

Figure 1. The effect of iron fertilizer treatments on the severity of the chilling injury disorder of 'Pinkerton' avocado fruit harvested at different dates and stored at different temperatures

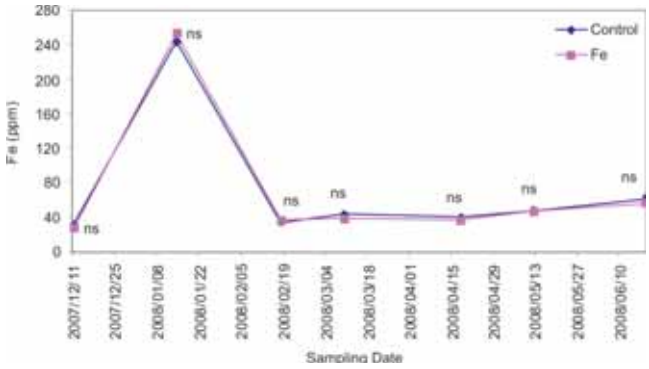

Figure 2. Mean skin iron content of 'Pinkerton' avocado fruit on different dates

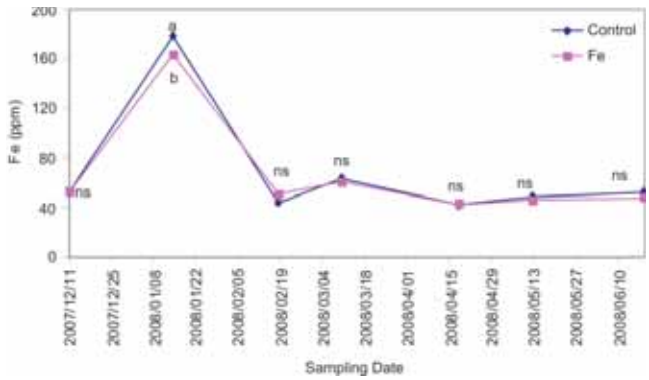

Figure 3. Mean flesh iron content of 'Pinkerton' avocado fruit on different dates

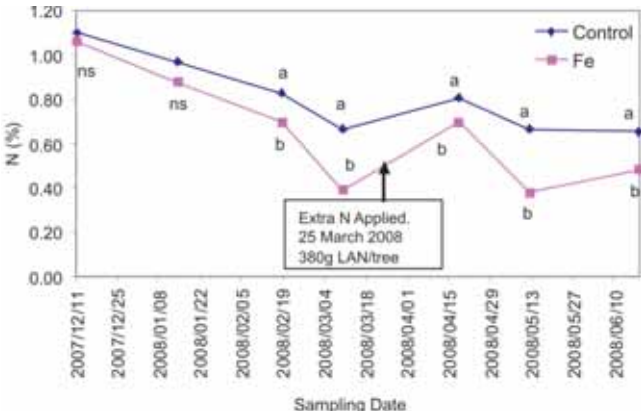

Figure 4. Mean skin nitrogen content of 'Pinkerton' avocado fruit on different dates

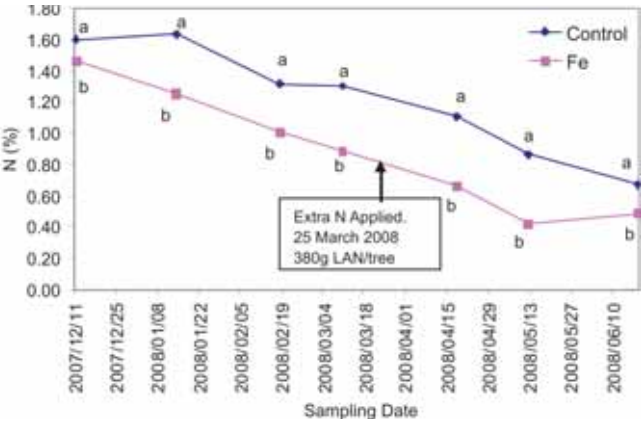

Figure 5. Mean flesh nitrogen content of 'Pinkerton' avocado fruit on different dates

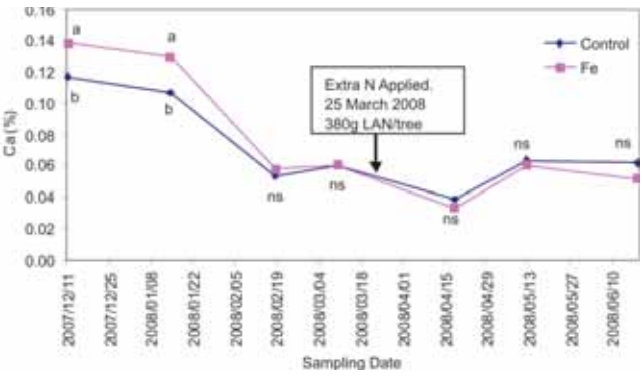

Figure 6. Mean flesh calcium content of 'Pinkerton' avocado fruit on different dates

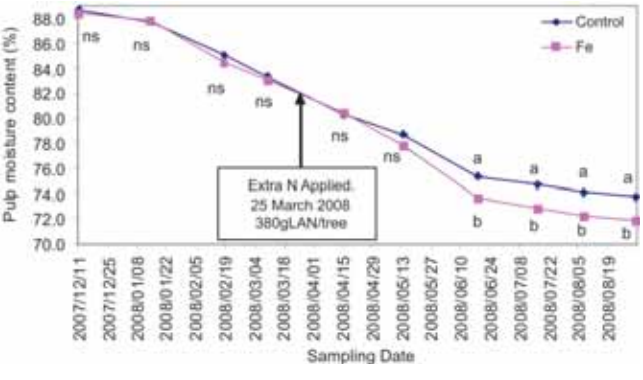

Figure 7. Mean maturity of 'Pinkerton' avocado fruit on different sampling dates

of the fruit that received the iron treatment was significantly higher than that of the control fruit during the first half of the sampling period (**Figure 6**). The fruit maturation rate was also affected by nitrogen application (**Figure 7**). There was no difference between the maturation rates of the control and the iron treatments until the additional 380 g of LAN per tree was applied in March. A month after the LAN application, the maturation rate of this treatment was significantly faster than that of the control. This confirmed that the late nitrogen application increased the rate of fruit maturation, as reported by Snijder *et al.* (2003).

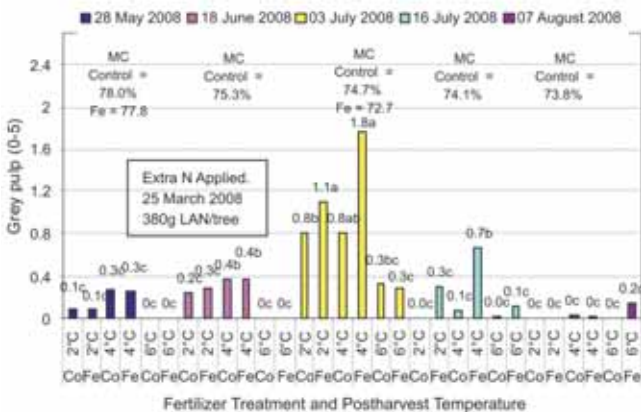

Figure 8. The effect of iron fertilizer treatments on the severity of mesocarp discoloration in 'Pinkerton' avocado fruit harvested on different dates and stored at different temperatures

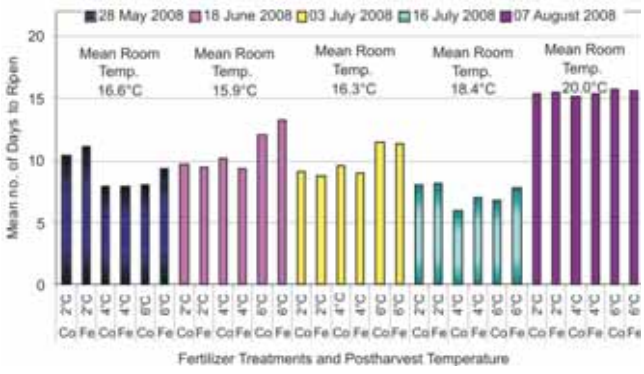

Figure 9. The effect of iron fertilizer treatments on the number of days to ripen 'Pinkerton' fruit harvested on different dates and stored at different temperatures

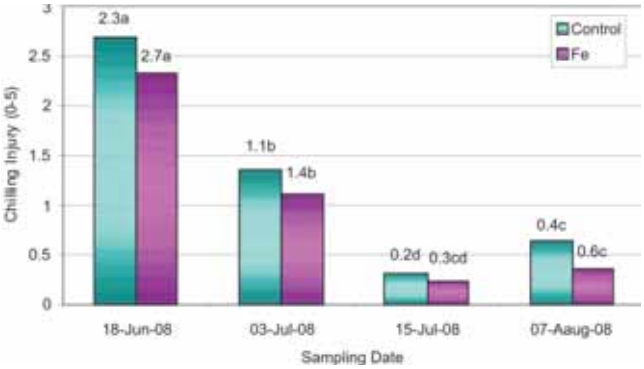

Figure 10. The effect of iron fertilizer treatments on the severity of chilling injury on 'Hass' fruit harvested on different dates

The results obtained for mesocarp discolouration (grey pulp) are shown in **Figure 8**. The results from the first two sampling dates show that the disorder only developed at 2°C and 4°C while nothing was recorded at 6°C. This changed on later sampling dates when fruit stored at 6°C also developed the disorder. However, the score of fruit stored at 6°C was still lower than those of the other storage temperatures. In general, these observations concur with previous observations that the disorder is low at the beginning of the season and increases with fruit maturity (Kruger *et al.*, 2000; 2001; 2004; Lemmer *et al.*, 2005; Snijder *et al.*, 2002; 2003). In both the 3 and 16 July samples (2 – 3 months after applying the additional N), the iron treatment fruit had higher grey pulp scores. It is very interesting to note that on the final sampling date, mesocarp discolouration was reduced to very low levels of not more than 0.2%. This observation ties up with the hereunder cited ripening results.

The ripening results are presented in **Figure 9**. The 'Pinkerton' cultivar is known to be stable at relatively high storage temperatures. The current results indicate that during the first storage trial, the fruit stored at 2°C took longer to ripen than fruit stored at higher temperatures. This trend changed unexpectedly on 18 June and 3 July, with fruit stored at 6°C taking at least 2 days longer to ripen than fruit at lower temperatures. It is interesting to note that Lemmer *et al.* (2009) reported that the respiration rate of avocado fruit increased when chilling injury lesions occur. The increase in respiration rate is presumably caused by ethylene production associated with chilling damage. It will therefore be interesting to establish whether this was also the case in the present study.

The fruit harvested on 16 July ripened the fastest at between 6 and 8 days. It is important to take into account that the avocados were ripened at room temperature. The mean daily temperatures for the ripening period are therefore also indicated on the graph. On the final sampling date (7 August) the fruit took nearly 16 days to ripen which was 6 – 10 days more than the other dates. The observation that certain late season consignments have ripening problems, is often reported on by industry members. It is interesting to note that, in the present study, very low levels of mesocarp discolouration coincided with slow ripening. Ethylene is not only involved in the initiation and coordination of ripening of avocado fruit (Seymour and Tucker, 1993) but has also been shown to induce or hasten the appearance of mesocarp discolouration (Pesis *et al.*, 2002). Seymour and Tucker (1993) reported that the onset of ethylene production and the fruit's receptiveness to ethylene is maturity dependant. The slowing down of the ripening rate and the recorded reduction in mesocarp discolouration in more mature fruit could therefore reflect on a reduction of not only the ability of the fruit to synthesize ethylene, but also its sensitivity to this hormone.

The chilling injury scores of the second trial conducted with 'Hass' are portrayed in **Figure 10**. As with 'Pinkerton', the chilling injury disorder was consistently

lower in fruit from trees that received the additional iron treatment but, in this case, the difference was not statistically significant. Again, chilling injury was higher at the beginning of the season and decreased as the fruit matured.

The skin iron content results presented in **Figure 11** are quite similar to those of 'Pinkerton'. During the early season, the iron content of the skin was relatively low at around 25 ppm. It then increased more than fourfold in January, followed by a reduction to original levels until the end of the sampling period. There were no statistically significant differences in iron content between fruit that received additional iron and the control fruit. As was the case in the 'Pinkerton' trial, the nitrogen content of fruit that received additional iron was significantly lower than that of the control fruit (**Figure 12**).

The similarity in the iron content patterns of the two cultivars is important, since it suggests that the uptake of this mineral is influenced by environmental factors. In previous trials (Magwaza *et al.*, 2008), the iron content of the pulp and skin of 'Fuerte' fruit remained between 30 – 40 ppm from November to July. A nitrogen application in December increased the iron content to around 60 ppm in February, where it remained until June. This treatment was found to develop significantly less chilling injury than the control (Magwaza *et al.*, 2008). During the present trials, the iron content of the pulp and skin showed large increases in January, followed by comparable decreases and stabilization for the rest of the season. The additional nitrogen application in March did not cause the iron content to increase for a second time. Although the chilling injury was consistently less in the iron treatment, it was mostly not statistically significant and the differences between the treatments and controls were nowhere near the levels reported by Magwaza *et al.* (2008).

The uptake and translocation of iron is a very complex issue. It is pH dependant and organic acids produced by the plant are excreted to the rizhophere to increase Fe availability and also to bind the mineral to improve solubility while being transported in the xylem (reviewed by Abadia *et al.*, 2002). We previously noticed similar transitory spikes in the fruit iron of other subtropical crops such as citrus (Kruger *et al.*, 2005; Kruger and Lemmer, 2006) and mangoes (Kruger *et al.*, 2003; Kruger and Fraser, 2004; Kruger and Lemmer, 2006) and hypothesize that they are caused by a preceding build up of organic acids in the plant, followed by a period during which the climate is suitable for the uptake and translocation of iron.

According to industry statistics, the incidence of chilling injury varies considerably from one year to the next. During 2008 it was particularly low. Taking all the above into account we conclude that iron uptake in correctly fertilized South African orchards is primarily influenced by climatic conditions. However, in contrast with elements such as nitrogen and calcium, it is not worthwhile attempting to modulate the fruit iron content to decrease post-harvest chilling injury. An effort will nevertheless be made to use avocado pulp and skin iron contents to predict the fruit's susceptibility to chilling injury on a seasonal basis.

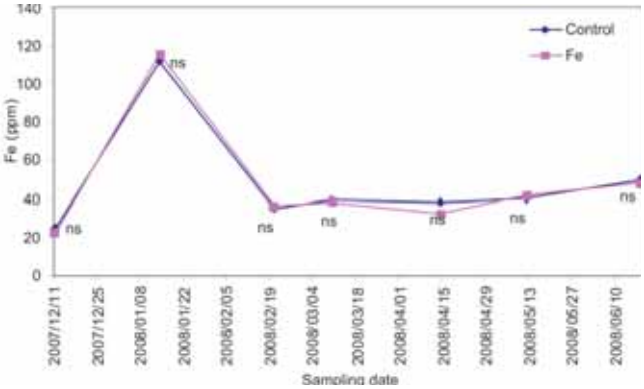

Figure 11. Mean skin iron content of 'Hass' avocado fruit sampled on different dates

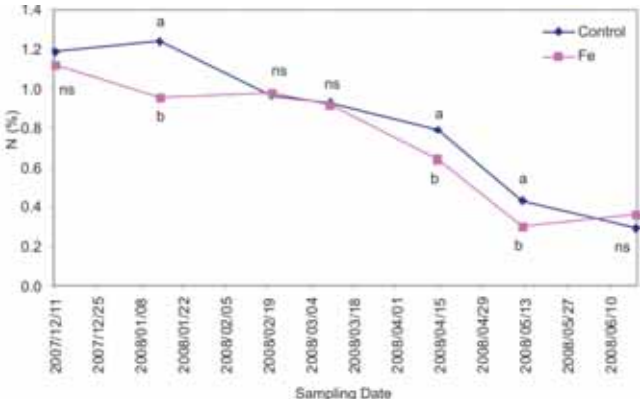

Figure 12. Mean skin nitrogen content of 'Hass' avocado fruit sampled on different dates

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