Effect of placing paper sleeves over ‘Fuerte’ or ‘Ryan’ avocados prior to harvest on disease incidence, fruit appeal and physiological disorder incidence at harvest or after extended cold-storage

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ABSTRACT

Placing durable paper sleeves placed over developing avocado fruits to cover them was considered as an alternative measure to control disease in avocado. Commercially, benomyl and copper are sprayed on trees to prevent or limit pre-harvest pathogen infections from occurring in the fruits. Infections give rise to Circospora spot prior to harvest, and stem-end rot and anthracnose during post-harvest ripening. Pathogen spore movement is considered to occur from tree to fruit in rainwater. Wind and insects may also transfer spores onto the fruits. Sporulation is favoured during wet, warm conditions. Developing ‘Ryan’ or ‘Fuerte’ fruits were covered with sleeves in late October or early November 2006, prior to the commencement of rain, or later during November 2006, once rainfall had occurred. Comparison was made with untreated fruits or fruits sprayed regularly with copper. The effect of one spray application of copper prior to sleeving in late October was also considered. Fruit evaluation with regard to solar injury, lenticel damage, fruit marking, or physiological disorder incidence was also made.

The season was dry, and hence, disease incidence was low. Evaluation was made at harvest, when solar injury, skin blemish, and Circospora spot were assessed, and after 28 days of cold-storage when anthracnose and physiological disorders were assessed. Circospora spot, anthracnose, stem-end rot, lenticel damage and skin marking did not occur in ‘Ryan’. Stem-end rot and lenticel damage did not occur in ‘Fuerte’. Sleeving was effective in preventing solar injury in both ‘Ryan’ and ‘Fuerte’. In ‘Fuerte’, early sleeving reduced Circospora spot or anthracnose to low levels, and was as effective in this regard as regular copper spraying. A positive relationship between degree of infection and sleeving date was apparent. In ‘Fuerte’, sleeving increased skin marking (blemish) slightly. This was visibly due to the activity of insects, mainly small cockroaches, which were noted to have sought refuge under the sleeves. In both ‘Ryan’ and ‘Fuerte’, grey-pulp or vascular browning occurred with low frequency, and bore no apparent relationship with treatment. The results were taken to strongly indicate that early sleeving, prior the onset of rain, is a viable alternative to disease control in avocado. Further research is required to evaluate sleeving in the other important varieties, and during a wet season.

INTRODUCTION

Avocados are susceptible to pathogen infection prior to harvest. *Pseudocercospora purpurea* causes raised, black, shiny spots prior to harvest, which are frequently associated with cracking and corking of the lenticles (Circospora spot) (Deighton, 1976; Darvas, 1982). Anthracnose (*Colletotrichum gloeosporioides*) and stem-end rot (*Dothiorella* spp., *Lasiodiplodia theobromae*, *Thyronecria pseudotrichia*, *Colletotrichum gloeosporioides*, and *Phomopsis perseae*, and *Fusarium descemcellulare*) are significant diseases, causing lesions after harvest when ripening commences (Darvas and Kotze, 1979a,b; Prusky, *et al*., 1990; Coates, *et al*., 1993a). Pathogen spores originate from regions of the tree canopy (dead leaves, dead twigs, dead branches, and possibly infected, living leaves) reaching the fruits via water flow, insect movement and wind (Peterson, 1978; Fitzell, 1987; Pegg and Coates, 1993; Coates, *et al*., 1993a; Pohronezny, *et al*., 1994). In the case of stem-end rot, infection may also occur endophytically through the pedicle (Johnson, *et al*, 1992; Johnson and Kotze, 1994). Pre-harvest sprays of benomyl and copperoxychloride effectively control these diseases (Darvas and Kotze, 1987; Lonsdale and Kotze, 1989; Lonsdale, 1991; Lonsdale, 1992; Duvenhage, 1994; Pegg, *et al*., 2002). In exporting avocado fruits to the EU, the fruits remain in transit storage for 21 to 28 days, and are generally shipped at 3 to $7^{o}C$. Following wet seasons, fruit loss due to Circospora spot and anthracnose is particularly significant, despite rigorous pre-harvest spraying (general obs.). Sporulation of *Colletotrichum gloeosporioides* and *Pseudocercospora purpurea* is favoured by wet, warm, and humid conditions (Peterson, 1978; Coates, *et al*., 1993a;

Pohronezny, *et al*., 1994).

Circospora spot, caused by *Pseudocercospora purpurea* (Deighton, 1976), infection mainly occurs as a result of conidia formation, spread and germination. Conidia are present throughout the season, particularly when conditions are humid. Most inoculum is considered to come from infected leaves (Pohronezny, *et al*., 1994). Sporulation is prolific during warm, rainy weather. Conidia are easily spread by wind, insects, and splashing rain or irrigation water, initiating new infections (Pegg and Coates, 1993). Infections taking place early in the season when the fruits are small (one to three quarters of their full size) result in the highest disease incidence and severity at harvest.

Anthracnose is also spread by conidia. Conidia of *Colletotrichum gloeosporioides* are produced in large numbers on dead leaves and twigs entangled in the tree canopy (Fitzell, 1987). During rainy weather they are washed down through the canopy of the tree and onto the fruits, fruit infection mainly occurring during extended periods of warm showery weather. Fruits are susceptible to conidia infection at all stages from fruit set until harvest (Peterson, 1978; Coates, *et al*., 1993a).

Protective, durable, paper sleeves, placed over the fruits prior to the onset of rain and attached firmly at the stem-end, may be effective in preventing spores from coming into contact with the fruits (**Figure 1**). Pre-harvest disease infection might in this way be prevented, rendering sleeving a viable alternative to the use of chemicals. If prevention occurs, it would be expected that earlier (pre-rain event) as opposed to later (post-rain event) sleeving will be more effective in preventing disease infection, due to the enhanced time of protection resulting from early sleeving and the absence of water flow over fruits sleeved prior to the onset of rain.

In the current study, the effect of sleeving avocados as a non-chemical measure to control Circospora spot, stem-end rot, and anthracnose was primarily evaluated. The date of sleeving relative to the occurrence of the first rains of the season, as well as the effect on visual appeal, solar injury, and physiological disorders, were also considered. Fruit evaluations were made at harvest and after 28 days of cold-storage at 6°C. Comparison was made with non-sleeved fruits and fruits sprayed regularly in the field with copper.

MATERIALS AND METHODS

In each of two bearing orchard blocks, a 'Fuerte' block and a 'Ryan' block, 70 trees were selected. The following procedures were carried out on the trees in each block:

In each tree, twenty fruits, well distributed in and on the canopy, were labelled. The following treatments were carried out on the labelled fruits in each of ten trees.

a) No treatment was applied to the fruits (Control).
b) The fruits were covered with sleeves on October 30, 2006.
c) The fruits were covered with sleeves on November 6, 2006.
d) The fruits were covered with sleeves on November 13, 2006.
e) The fruits were covered with sleeves on November 20, 2006.
f) The fruits were covered with sleeves on October 30, 2006, shortly after they were spray covered with copperoxychloride / Wenfinex oil.
g) The fruits were sprayed every three weeks with copperoxychloride / Wenfinex oil, commencing on Oct. 30, 2006.

Conditions became humid and wet during early November, 2006. Rain had not commenced by October 30, the first date of sleeving. Appreciable rain occurred on Nov. 4 and 5 (25 to 30 mm on each of the days, recorded by a rain gauge), and again on Nov. 18, when more than 100 mm was recorded. Appreciable rain occurred again in late December (Dec. 28 to 31), and in April, 2007. Conditions during January and February were dry.

Copperoxychloride / Wenfinex oil application in every instance was made with a knap sack sprayer. Copperoxychloide was applied at the rate of 300 g per 100 l, with Wenfinex oil at the rate of 300 ml per 100 l.

The fruits were harvested on May 08 ('Fuerte') and August 13 ('Ryan'), 2007, and immediately placed in a laboratory maintained at 20°C (±0.5°C). At this stage, the extent of solar injury, Circospora spot, or blemish was estimated in each fruit. Solar injury was rated. A rating of "0" was given if signs of injury were absent, a rating of "1" if injury was present but localized to a small area, a rating of "2" if approximately 1/3 of the fruit was affected, a rating of "3" if 1/3 of the fruit was affected, and a rating of "4" if the entire fruit was affected. Circospora spot or skin-blemish coverage was estimated in terms of a percentage. The percentages assigned were 0, 25, 50, 75 or 100. Evaluation continued until 14 May ('Fuerte') or Aug. 17 ('Ryan'), after the start of cold-storage.

On May 10 and August 15, 2007, the fruits removed from each tree were placed into each of two 4 kg avocado cartons, and then into a cold-room maintained at 6°C (±0.5°C). Carton packing in the cold-storage room was carried out in orchard randomisation sequence to retain an effect of "blocking" (experiment layout). After 28 days, the cold-room temperature was increased to 20°C. At this stage, the degree of anthracnose, grey pulp and vascular browning was estimated in each fruit once softening had commenced (densimeter reading <60). Fruit firmness was assessed with a densimeter (Heinrich Bareiss, Obischingen, Germany). The number of anthracnose lesions was counted, after which the fruit being evaluated was cut through from the stem-end downwards. After cutting, the extent to which each of the physiological disorders (grey pulp and vascular browning) affected the pulp was estimated. Estimation was carried-out as was solar injury.

Lenticel damage, stem-end rot, or pulp spot did not occur.

There were 10 treatment replicates of 7 treatments, each comprising 20 fruits, in a Randomized Complete Blocks design. The tree or double-carton averages were subjected to Analysis of Variance. Mean separation was based on the 5% LSD criterion.

Figure 1 shows sleeved 'Ryan' fruits prior to harvest. **Figure 2** shows the method of sleeve attachment. Attachment was carried out with thin paper-coated wires. **Figure 3** shows a fruit having been sprayed with copperoxychloride using Wenfinex oil as a wetter-sticker. A 'Ryan' fruit within a sleeve is shown in **Figure 4**, and an exposed 'Fuerte' fruit in **Figure 5**.

Figure 1. 'Ryan' fruits prior to harvest.

Figure 2. Sleeve attachment. The sleeves were attached with thin paper-coated wires.

RESULTS

'Fuerte'

The sleeves were entirely effective in preventing solar injury to the fruits when applied prior to Nov. 20, 2006 (**Figures 6** and **7**). Solar injury was noted as necrotic or yellowed areas on the fruit neck or shoulders. A small proportion of fruits sleeved on Nov. 20 showed signs of injury (<2%), this resulting from sun exposure prior to sleeving. Injury occurred in the un-sleeved fruits. Only fruits ex-

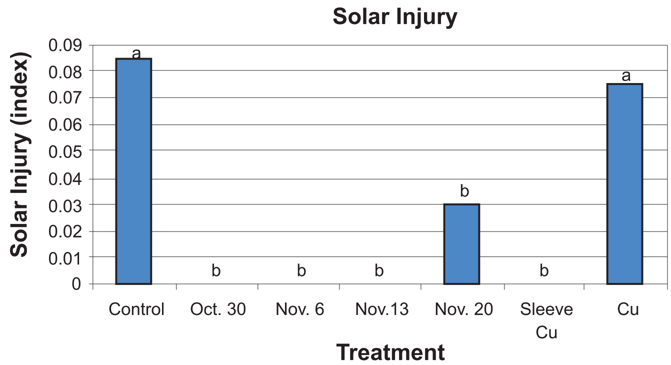

Figure 6. Average severity of solar injury in relation to treatment (P_{treat} <0.001). Bars headed by different letters differ significantly according to the 5% LSD criterion.

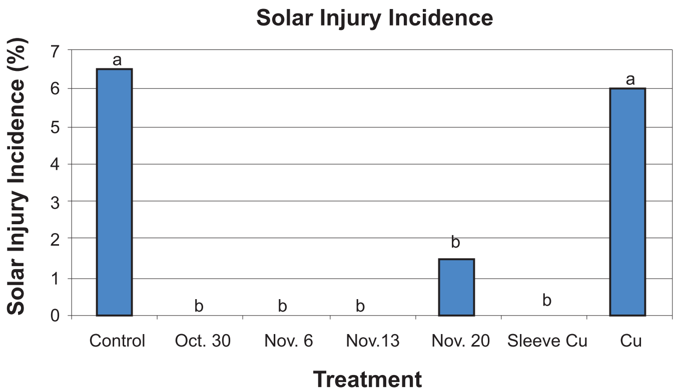

Figure 7. Incidence of solar injury in relation to treatment (P_{treat} <0.001). Bars headed by different letters differ significantly according to the 5% LSD criterion.

Figure 3. 'Fuerte' fruit sprayed with copperoxychloride (Demildex, at 300 g per 100 l), using Wenfinex oil (300 ml per 100 l water) as a wetter-sticker.

Figure 4. 'Fuerte' avocado enclosed by the sleeves used.

Figure 5. Exposed 'Fuerte' avocado.

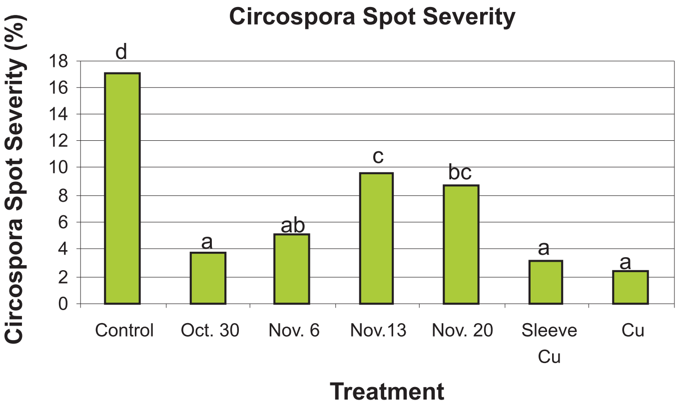

Figure 8. Average severity of Circospora spot in relation to treatment (P_{treat} <0.001). Bars headed by different letters differ significantly according to the 5% LSD criterion.

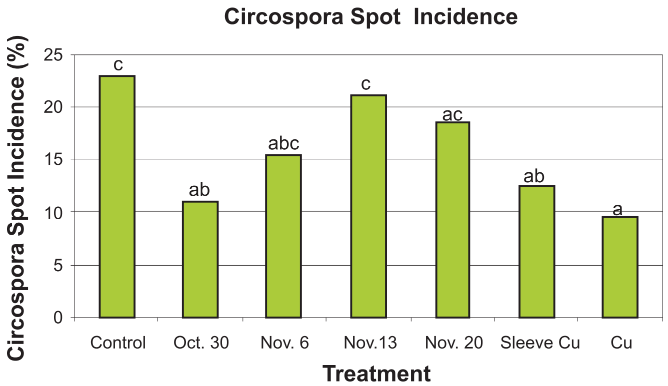

Figure 9. Incidence of Circospora spot in relation to treatment (P_{treat} <0.01). Bars headed by different letters differ significantly according to the 5% LSD criterion.

Figure 10. Insects of various types found refuge under the sleeves. They were often seen residing at the stem-end of the fruits. A small cockroach species were generally observed.

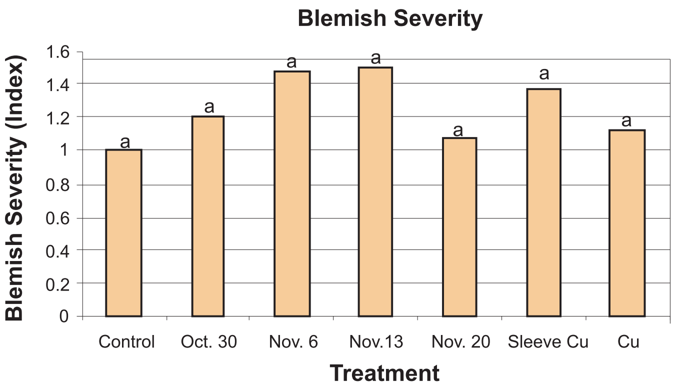

Figure 11. Average blemish marking severity in relation to treatment (P_{treat} <0.89). Bars headed by different letters differ significantly according to the 5% LSD criterion.

posed to direct sunlight were affected. Copper coating had no apparent effect in increasing or reducing solar injury.

Average severity or incidence of Circospora spot is shown in **Figures 8** and **9**. Early sleeving (Oct. 30 or Nov. 6) or copper spraying was effective in reducing the severity and incidence of Circospora spot. A positive relationship between incidence or severity and sleeving date was apparent. In comparing regular copper spraying or early sleeving with copper spraying just prior to sleeving, differences were not apparent. The incidence of Circospora spot in the fruits sleeved on Nov. 13 or 20 was similar to that in the untreated fruits.

Figures 11 and **12** show average skin marking severity or marking incidence in relation to treatment. Insects of various types took refuge under the sleeves, and some caused fruit marking (**Figure 10**). Marking often resembled that of wind damage. In most instances, a small cockroach species was observed on the sleeved fruits.

Due to the activity of insects on sleeved fruits, blemish marking was slightly elevated in the sleeved fruits. Marking in non-sleeved fruits was that typically resulting from skin abrasion due to wind. Copper coating prior to sleeving did not appear to deter insect occupation.

In two fruits, an uncommon lenticel reaction occurred.

Average number of anthracnose lesions or anthracnose incidence are shown in **Figures 13** and **14**. Sleeving and

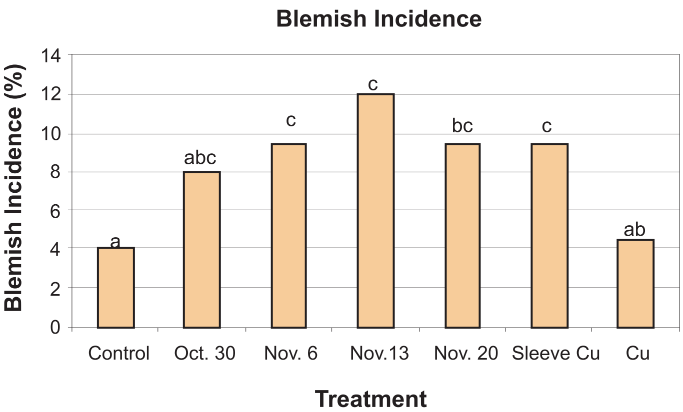

Figure 12. Blemish marking incidence in relation to treatment (P_{treat} <0.02). Bars headed by different letters differ significantly according to the 5% LSD criterion.

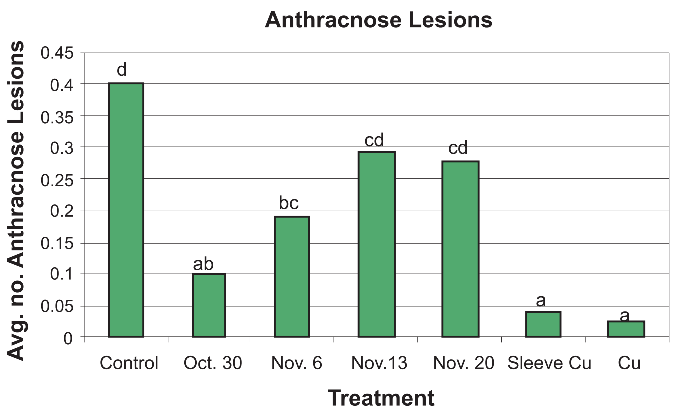

Figure 13. Average number of anthracnose lesions per fruit in relation to treatment (P_{treat} <0.001). Bars headed by different letters differ significantly according to the 5% LSD criterion.

copper application were effective in reducing the number of lesions and incidence of anthracnose. Lowest lesion counts and fruit-incidence occurred in the copper-sprayed fruits. Treatment differences relating to the date of sleeving were not clearly apparent. However, in the fruits sleeved on Nov. 13 or 20 the average number of lesions and fruit incidence appeared to be slightly elevated.

Figures 15 and **16** show the average severity or incidence of grey pulp in relation to treatment. Differences arising due to the treatments carried out were not apparent. The incidence of grey pulp was generally less than 10%.

Figures 17 and **18** show the average severity or incidence of vascular browning in relation to treatment. Differences in relation to treatment were not apparent. The incidence of vascular browning was generally less than 10%.

'Ryan'

Figure 21 shows a typical sleeved 'Ryan' fruit at harvest. At harvest, the fruits did not show signs of Circospora spot, lenticel damage, or skin marking. Less than 1% of the fruits exhibited blemish marks. There was not indication of an influence of treatment on blemish (data not shown). After cold-storage, anthracnose or stem-end rot did not occur.

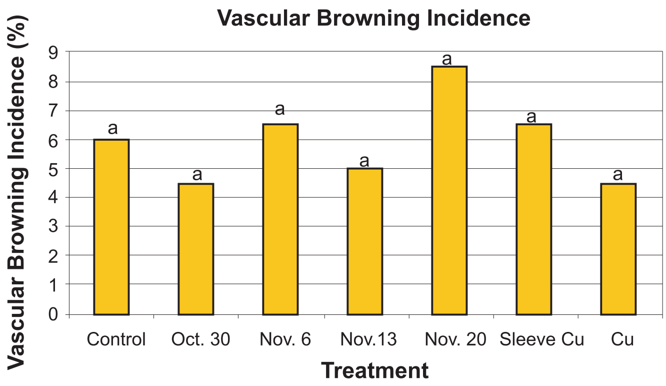

Figure 18. Incidence of vascular browning in relation to treatment (P_{treat} <0.68). Bars headed by different letters differ significantly according to the 5% LSD criterion.

Figure 21. Typical sleeved 'Ryan' fruit at harvest.

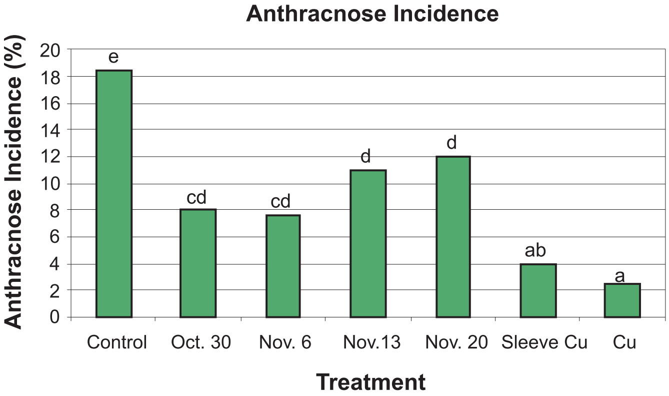

Figure 14. Incidence of anthracnose in relation to treatment (P_{treat} <0.001). Bars headed by different letters differ significantly according to the 5% LSD criterion.

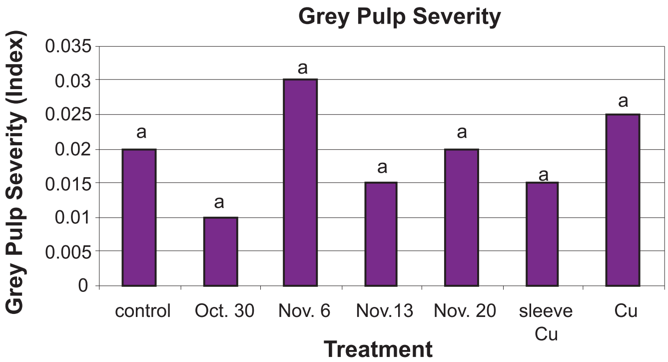

Figure 15. Average severity of grey pulp on relation to treatment (P_{treat} <0.54). Bars headed by different letters differ significantly according to the 5% LSD criterion.

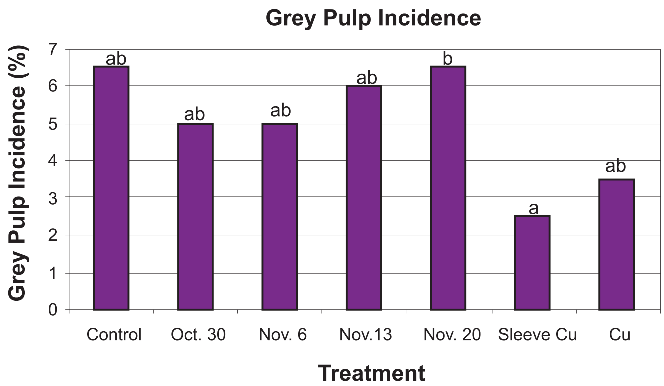

Figure 16. Incidence of grey pulp on relation to treatment (P_{treat} <0.29). Bars headed by different letters differ significantly according to the 5% LSD criterion.

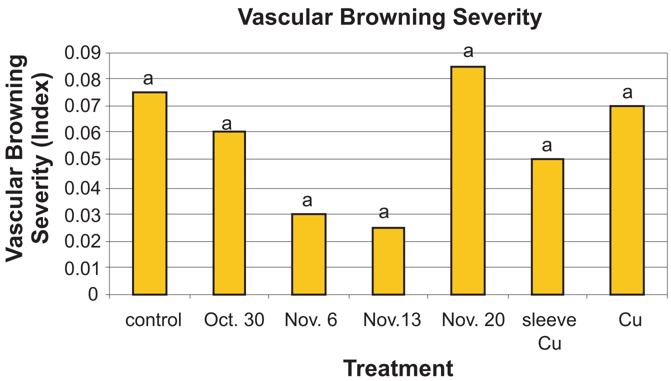

Figure 17. Average severity of vascular browning in relation to treatment (P_{treat} <0.80). Bars headed by different letters differ significantly according to the 5% LSD criterion.

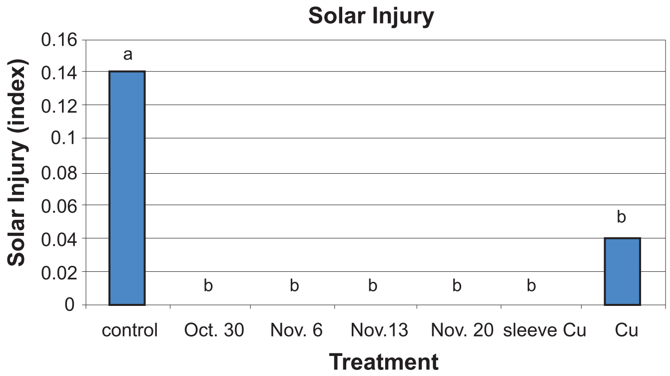

Figure 19. Severity of solar injury in relation to treatment (P_{treat} <0.001). Bars headed by different letters differ significantly according to the 5% LSD criterion.

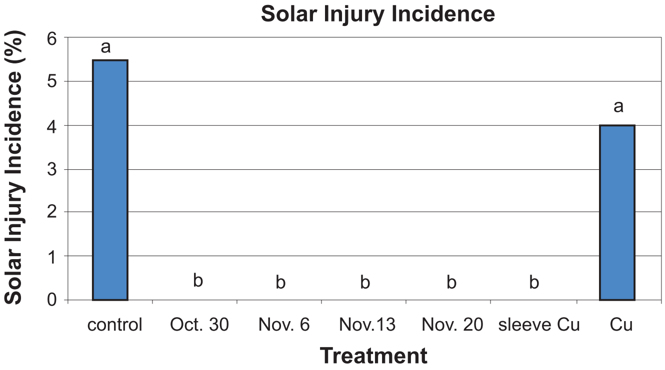

Figure 20. Incidence of solar injury in relation to treatment (P_{treat} <0.0001). Bars headed by different letters differ significantly according to the 5% LSD criterion.

Figures 19 and **20** show the average severity or incidence of solar injury in relation to treatment. Sleeving, irrespective of the date when carried out, prevented solar injury from occurring.

Figures 22 and **23** show the average severity or incidence of grey pulp in relation to treatment. Differences arising due to the treatments carried out were not apparent. The incidence of grey pulp was generally less than 5%.

Figures 24 and **25** show the average severity or incidence of vascular browning in relation to treatment. Differences in relation to treatment were not apparent. The incidence of vascular browning was generally less than 5%.

DISCUSSION AND CONCLUSION

The season was generally dry. This was probably the reason for the severity and incidence of diseases being low. 'Ryan' is a variety that is less prone to develop disease and physiological disorders, whereas 'Fuerte' is generally more susceptible to disease infection, mechanical injury, and lenticel damage, in the experience of the author. Moreover, 'Fuerte' is also more likely to develop physiological disorders during cold-storage. 'Fuerte' is stated to be particularly susceptible to anthracnose, stem-end rot and insect attack, and 'Ryan' to be susceptible to vascular browning and certain fruit diseases (Pegg, *et al*., 2002). Circospora spot, anthracnose, stem-end rot, lenticel damage, or skin markings did not occur in 'Ryan'. The incidence of physiological disorders was low in both 'Ryan' and 'Fuerte'. Previous studies evaluating sleeve or bag covering of de-

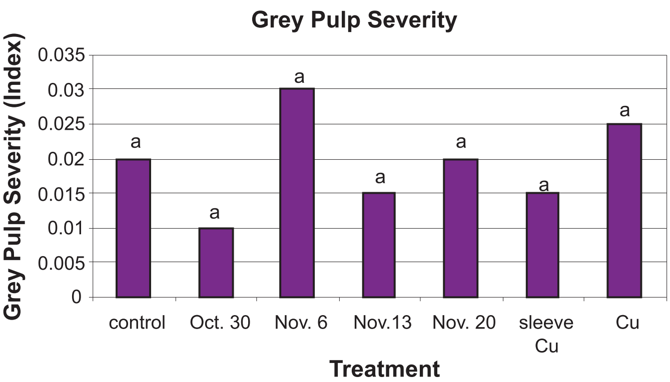

Figure 22. Average severity of grey pulp in relation to treatment (P_{treat} <0.61). Bars headed by different letters differ significantly according to the 5% LSD criterion.

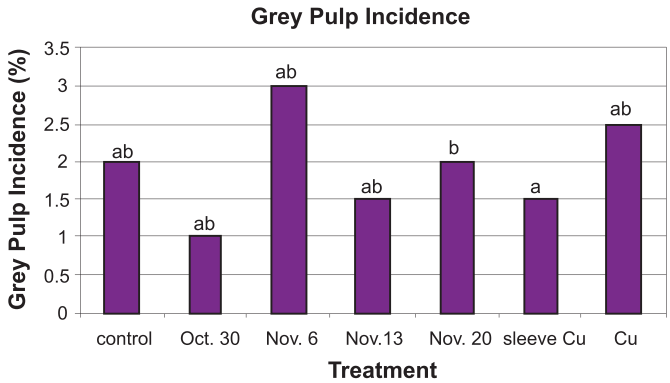

Figure 23. Incidence of grey pulp on relation to treatment (P_{treat} <0.61). Bars headed by different letters differ significantly according to the 5% LSD criterion.

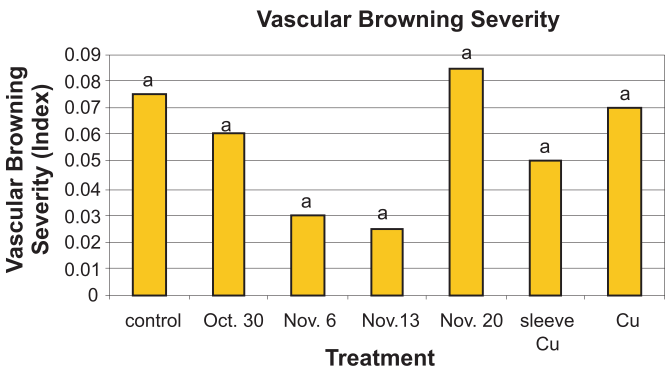

Figure 24. Average severity of vascular browning in relation to treatment (P_{treat} <0.49). Bars headed by different letters differ significantly according to the 5% LSD criterion.

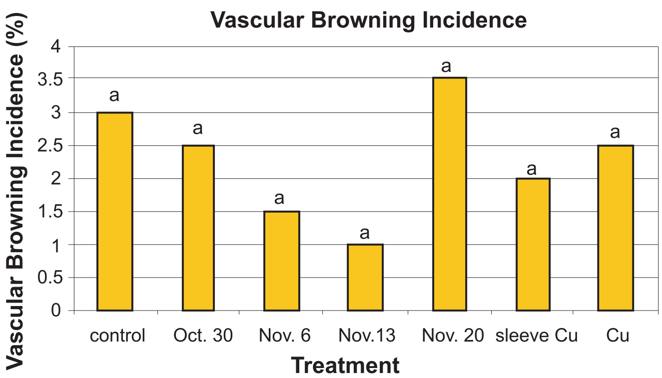

Figure 25. Incidence of vascular browning in relation to treatment (P_{treat} <0.66). Bars headed by different letters differ significantly according to the 5% LSD criterion.

veloping avocados to prevent disease or enhance eating quality, have not been carried out to the knowledge of the author. Post-harvest enclosure with polyethylene or paper bags to extend shelf-life has been considered (Nwufo, *et al*., 1994).

In both 'Ryan' and 'Fuerte', the sleeves were effective in preventing solar injury. This would be expected in view of the sleeves literally preventing the fruits from being exposed to direct solar radiation.

The severity and incidence of the physiological disorders occurring was low and bore no apparent relation to the treatments imposed. Rowell (1988) noted that grey pulp incidence was markedly increased by wax covering, as noted after 4 weeks of cold-storage at 5.5°C. Sleeve covering has no apparent effect on grey pulp. Vascular browning incidence has been associated with maturation stage, cold-storage duration, and nutrient balance (Koen, *et al*., 1989a,b; Cutting, *et al*., 1992; Zauberman and Décor, 1995). Sleeving might therefore not be expected to affect the severity or incidence of this disorder.

In the 'Fuerte' fruits, sleeving was effective in reducing the severity and incidence of the diseases occurring, namely, Circospora spot and anthracnose. A relationship indicating increased incidence with date of sleeving was apparent concerning Circospora spot, but less apparent with respect to anthracnose. The increase with sleeving date can be explained in terms of direct exposure rainfall of the fruits sleeved on Nov. 13 and 20, 2006, and the absence of such exposure of the fruits sleeved on Oct. 30 and Nov. 6, 2006. This result supports the contention that disease results from the transfer of rainwater containing conidia from canopy to fruit. Reduced exposure of the peel to direct air movement (wind) of the sleeved fruit may also be cited as a reason for the reduction in Circospora spot found.

Sleeving gave rise to an increase in skin marking due to certain insects finding refuge under the sleeves. Cockroach species were mainly observed on sleeved fruits. Marking probably arose due to insect feeding.

The abnormal lenticel reaction observed in response to sleeving, and occurring with very low frequency in 'Fuerte', is difficult to explain. The lenticels become enlarged, coalescing to an extent. The reason for the response probably related a subtle change in conditions under the sleeve. A build-up of air moisture content under the sleeve resulting from fruit transpiration may have been the cause.

It might be concluded that in both in 'Fuerte', early sleeving prior to the onset of rain is an effective measure to control Circospora spot and anthracnose. In 'Fuerte' and 'Ryan', early sleeving prevented solar injury. The negative effects of increased blemish marking or a change in lenticel character were not such that significant loss resulted. Sleeve impregnation with a pesticide prior to covering may limit insect activity under the sleeves. Conversion of the sleeves to closed bags would solve the problem associated with insect access. It may be concluded that further research to assess bagging as opposed to sleeving during a wetter season is justified. Moreover, research should be carried out on the other important cultivars grown.

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