POSTHARVEST FUNGICIDE TREATMENTS AND THEIR EFFECT ON LONG-TERM STORAGE OF AVOCADOS FROM THREE GROWING REGIONS IN NEW ZEALAND

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ABSTRACT

The effect of two postharvest treatments, Pristine® and Sportak®, on length of storage life of avocados harvested from the three major avocado growing regions (Far North, Whangarei and Bay of Plenty) in New Zealand was evaluated. Fruit were coolstored at 5.5°C, and assessed for rots and disorders after 28, 42 and 56 days. Fruit treated with Pristine® was better quality than fruit treated with Sportak®. Fruit from Whangarei and Te Puke could not be stored for longer than 28 days because of the prevalence of chilling injury, and Far North fruit because of high rot incidence that was not controlled adequately by postharvest fungicides. Despite a statistically significant reduction of rots in fruit stored for 42 and 56 days, most of these fruit were still not acceptable for sale or consumption either because of high rot incidence, or because of chilling injury. In order to improve the storage life of avocados, the factors inducing and preventing chilling injury need to be determined. Ripening fruit at 15°C may further improve storage life.

Keywords: boscalid/pyraclostrobin, prochloraz, body rots, stem-end rots, diffuse flesh discolouration, bruising, chilling injury.

INTRODUCTION

New Zealand is producing increasing volumes of avocados. Most avocados are currently exported to the closest market, Australia, but fruit will need to be sent to more distant markets in the future. Longer periods of storage will be required to reach these markets. Fruit are usually commercially stored at 4 to 5.5°C to delay ripening, and development of rots, until the fruit reach their markets. Outturn monitoring of fruit in the USA during the 2000/01 and 2001/02 seasons showed that after 34 days there was a sharp increase in the number of fruit with rots (Dixon, 2001). Stem-end rots have been shown to infect New Zealand avocados at harvest (Hartill and Everett, 2002) and then to grow down the stem during coolstorage, taking 32-37 days to reach the flesh (Everett and Pak, 2002). In those trials, and others (Pak, 2001; Dixon *et al.*, 2003a), rots were the most important factor limiting storage of avocados. New fungicides and biological agents have been recently developed that may be more effective than the industry standard, which is Sportak®, for postharvest application. To improve storage life, several biological and chemical alternatives to Sportak® were evaluated as postharvest treatments during the first two years of this project (Everett and Timudo-Torrevilla, 2006; Everett *et al.*, 2007b). In 2008-2009, the most effective postharvest treatment (boscalid/pyraclostrobin; Pristine®) from the previous work was used to treat fruit from the three different growing regions, with the aim of extending storage life.

METHODS

Avocado fruit were harvested from an orchard in the Far North (Burnage Road, Hohoura) on 3 December, from Whangarei (Watrous Downs, Maungatapere) on 10 December, and from the Bay of Plenty (Rangiuru Road, Te Puke) on 18 December 2008. A standard copper fungicide

Table 1. Fungicides and application rates tested as a postharvest dip application for control of avocado fruit rots.

Fungicide product product/100 L	Active ingredient	% a.i.	Rate
Sportak®	Prochloraz	45	55 ml
Pristine®	boscalid/ pyraclostrobin	25.2/ 12.8	60 g

programme was applied by the growers. Phosphorous acid was applied as a trunk spray application in early 2008 to the trees in the Far North for controlling Phytophthora root rot. At each harvest, 300 fruit per treatment were immersed in 40 L of Pristine®, Sportak® or water, with agitation. Chemical treatments were applied at the rates shown in Table 1 for 2 minutes. On the same day, the fruit were air-dried on newspaper, and then 20 fruit were placed into trays, with 15 trays per treatment. There was an untreated control. The next day these fruit were transported to Plant & Food Research, Mt Albert Research Centre, and placed in the coolstore at 5.5°C within 24 hours of harvest. There were 3600 fruit in total.

After 28, 42 and 56 days, five trays from each treatment from each orchard (400 fruit x three orchards) were removed and placed at 20°C for ripening. Ripening fruit were tested for firmness by gentle hand squeezing each day after placement at 20°C. When judged ripe by gentle hand squeezing, fruit were cut into quarters and peeled. Fruit were assessed for internal rots using the methods described in the NZ Avocado Industry Council Assessment Manual (Dixon, 2003).

Statistical analysis

Results were analysed using the General Linear Model (analysis of variance) or regression functions of MINITAB® (version 15.0), and means were separated using Dunnett's test (α=0.05). The results presented are the mean severity values, which are expressed as percentages.

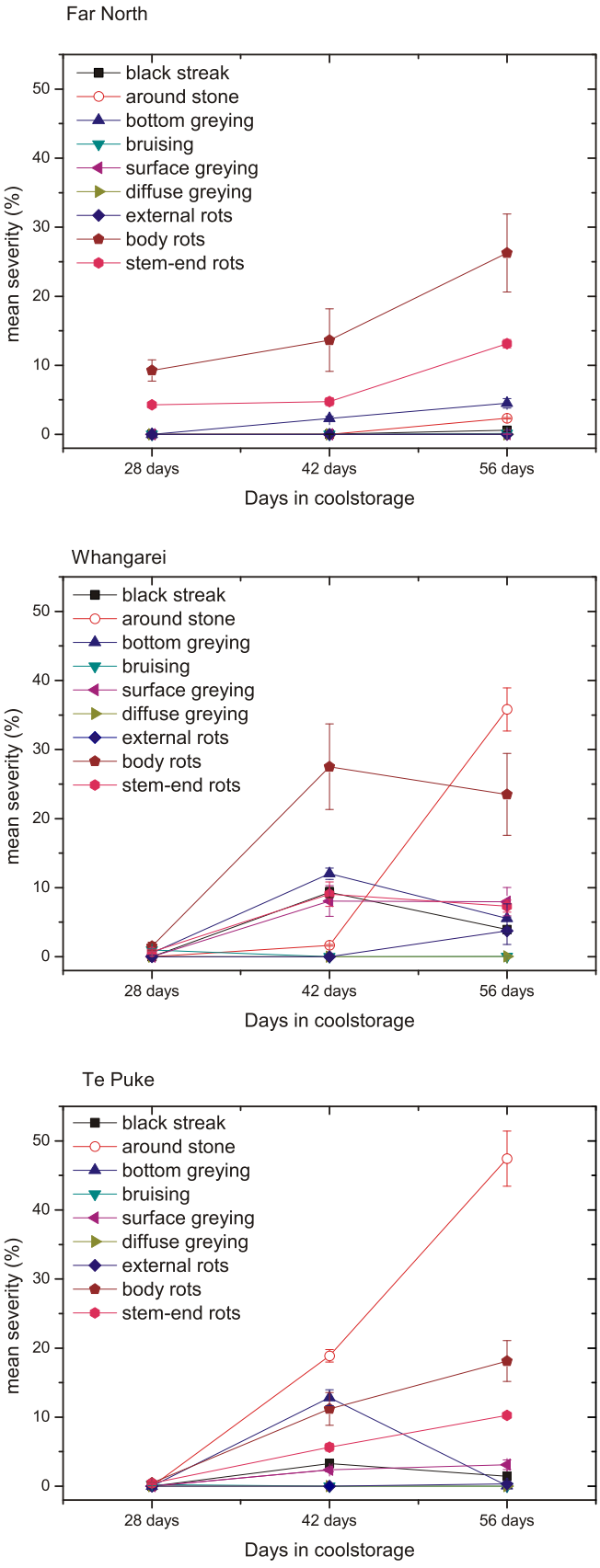

Figure 1. The increase in avocado rots and disorders following increasing the length of time in the coolstore at 5.5°C. Values are means ± standard errors for all treatments.

RESULTS

When fruit were coolstored for 28 days followed by ripening at 20°C, there was no statistically significant reduction in body rots or stem-end rots following postharvest applications of Pristine® or Sportak® (Table 2). After 42 days and 56 days of coolstorage, Pristine® and Sportak® provided significant reduction of body rots in fruit from the Far North. Pristine® provided significant reduction of body rots and stem-end rots in fruit from Whangarei after 42 days of coolstorage, and both Pristine® and Sportak® reduced body rots in fruit from Whangarei after 56 days of coolstorage. Pristine® provided significant reduction of body rots in fruit from Te Puke after 56 days of coolstorage.

A number of physiological symptoms were expressed in fruit that were coolstored for longer than 28 days (Figure 1). 'Bottom greying' and bruising were the first of the physiological disorders that expressed in fruit after 28 days storage. The bottom greying symptom consisted of a grey or brown discolouration of the flesh that began at the bottom of the fruit (Figure 2). Bruising was a discolouration of the flesh that began from the inside of the fruit closest to the stone. There was often a line of healthy flesh between the bruising symptom and the outside of the fruit (Figure 3). After 42 days storage, other physiological symptoms became apparent. The around-stone symptom was similar to bottom greying except that there was a visible amount of green tissue between the skin and the browning or greying (Figure 4) indicating that the symptom originated from inside the fruit (around-stone). Where there was no green tissue between the symptom and the skin of the fruit the symptom was described as bottom greying. Surface greying was a symptom that was restricted to the flesh immediately under the skin, and a darkening of the skin. The flesh was difficult to separate from the skin (Figure 5). Black streak consisted of a browning or greying of the flesh surrounding and including the vascular tissue of the avocado resulting in stringy brown tissue that could be removed from the rest of the flesh.

Up to 28 days, bottom greying and bruising were observed but they were less frequent than rots (Figure 1). In fruit from the Far North, rots remained the most common storage disorder even after 56 days of coolstorage. However, the around-stone symptom (Figure 1) was more common than rots after 56 days of coolstorage in fruit from Whangarei and Te Puke. This symptom was difficult to

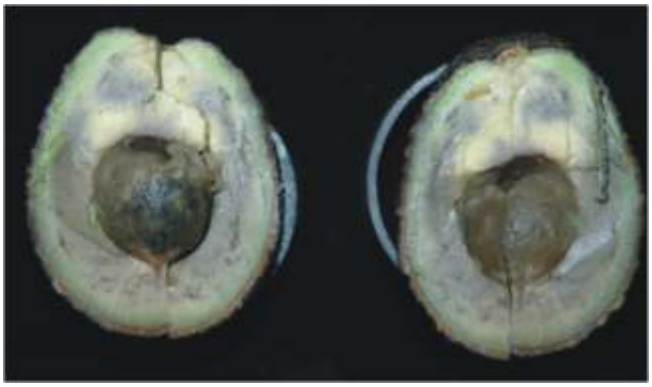

Figure 2. Avocado rot symptoms that expressed after fruit were stored at 5.5^{0}C for 28 days then ripened at 20^{0}C. These symptoms were described as 'bottom greying'.

Figure 3. Avocado rot symptoms that expressed after fruit were stored at 5.5^{0}C for 28 days then ripened at 20^{0}C. These symptoms were described as 'bruising'.

Table 2. Effect of fungicides and storage time on rot severity (percent coverage) in avocado fruit stored for various lengths of time. Values are mean severity standard errors.

		Region											
		Far North				Whangarei				Te Puke			
Storage time	Treatment	Body rot	*P*	Stem-end rot	*P*	Body rot	*P*	Stem-end rot	*P*	Body rot	P	Stem-end rot	P
28 days	Untreated	9.52±2.00		3.73±0.70		0.87±0.32		0.63±0.16		0.76±0.21		0.66±0.14	
	Water dipped	7.46±2.36	NS	3.87±1.16	NS	3.17±1.53	NS	0.97±0.32	NS	0.47±0.16	NS	0.39±0.25	NS
	Pristine®	6.58±1.00	NS	4.17±1.57	NS	1.46±0.94	NS	0.80±0.52	NS	0.31±0.18	NS	0.18±0.10	NS
	Sportak®	13.47±2.23	NS	5.34±0.59	NS	0.56±0.10	NS	0.44±0.11	NS	0.31±0.14	NS	0.51±0.29	NS
42 days	Untreated	24.50±2.73		4.52±0.45		35.19±2.23		8.61±0.64		9.44±2.81		4.86±1.20	
	Water dipped	17.67±2.52	NS	6.16±0.75	NS	31.05±2.10	NS	12.42±1.84	NS	15.75±2.92	NS	6.25±0.99	NS
	Pristine®	5.61±0.60	*	3.48±0.10	NS	9.13±1.35	*	4.27±0.43	*	5.34±1.13	NS	4.58±0.66	NS
	Sportak®	6.82±2.12	*	4.84±0.74	NS	34.67±1.96	NS	10.89±1.86	NS	14.29±2.24	NS	6.95±0.69	NS
56 days	Untreated	37.18±3.13		14.51±3.48		34.32±3.95		5.01±1.58		24.37±3.00		10.51±1.24	
	Water dipped	34.20±3.50	NS	12.75±1.85	NS	32.51±3.25	NS	9.20±2.46	NS	20.02±5.52	NS	10.54±0.48	NS
	Pristine®	13.47±2.10	*	11.72±1.49	NS	9.82±1.52	*	7.82±1.35	NS	10.19±1.14	*	9.39±0.80	NS
	Sportak®	20.17±2.99	*	13.54±1.49	NS	17.37±0.47	*	7.25±0.78	NS	17.92±3.57	NS	10.61±1.60	NS

*Values are significantly less than untreated controls according to Dunnett's one-tailed test ($P<0.05$), NS not significant.

distinguish from bottom greying and these two symptom types are probably the same disorder that were described as diffuse flesh discolouration elsewhere (White *et al.*, 2001, Dixon, 2003). The symptom described as surface greying was only expressed in fruit after 42 days of coolstorage and

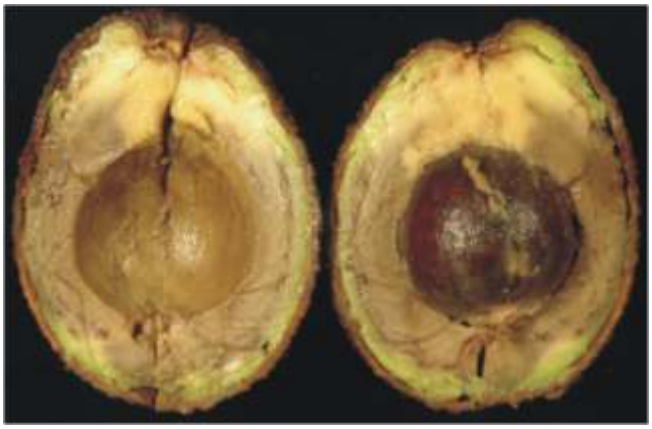

Figure 4. Symptoms expressed after avocados were stored for 56 days at 5.5^{0}C then ripened at 20^{0}C described as around-stone.

Figure 5. Symptoms expressed after avocados were stored for 56 days at 5.5^{0}C then ripened at 20^{0}C described as surface greying. The tissue affected by this disorder was firmly attached to the skin, resulting in difficulty of peeling (right), and it did not penetrate far into the flesh (left).

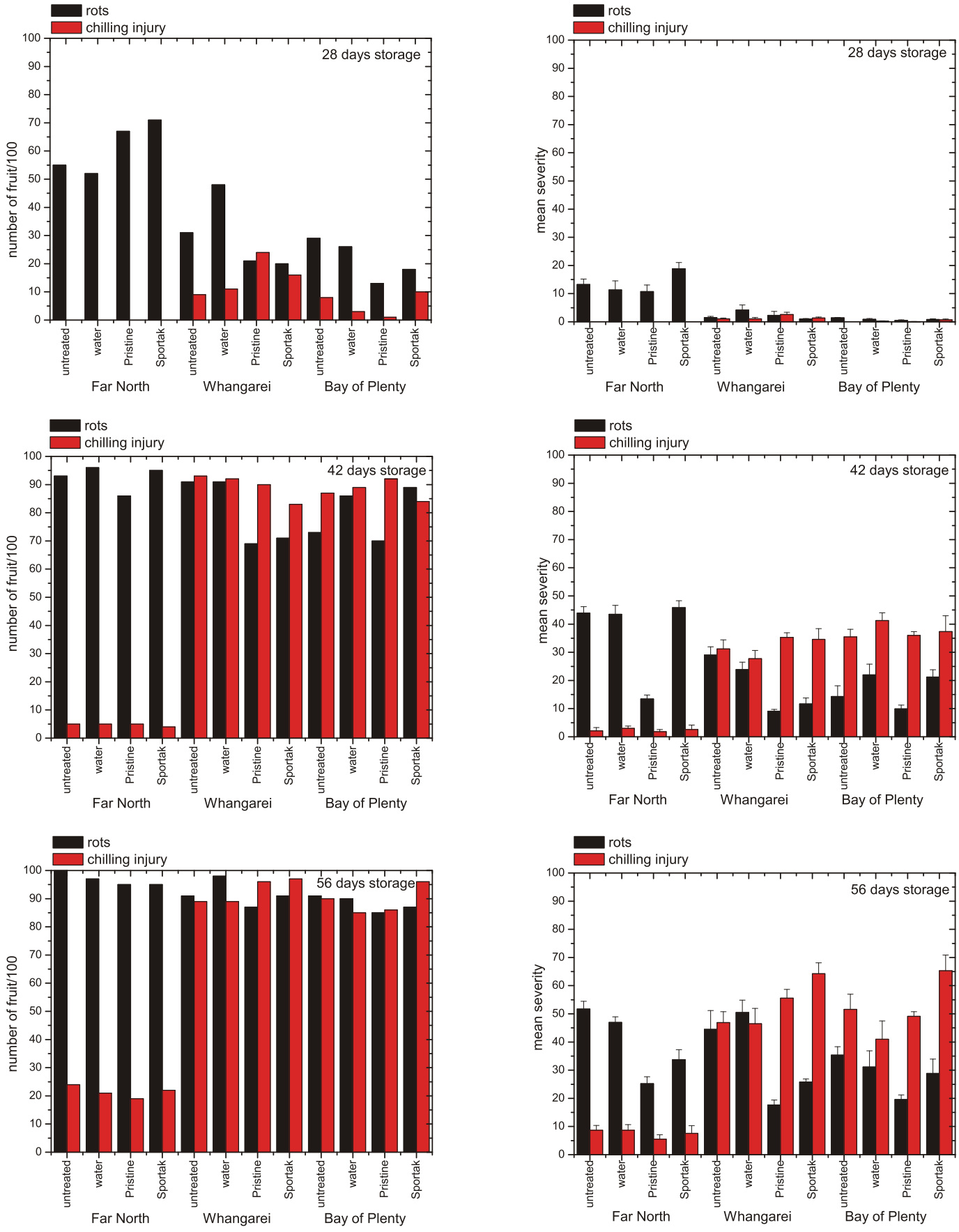

Figure 6. Number of avocado fruit and severity of rots and chilling injury following coolstorage at 5.5^{0}C for 28, 42 and 56 days and ripening at 20^{0}C.

has been described elsewhere as outer flesh blackening (White *et al.*, 2001).

Black streak and diffuse greying were less common (Figure 1) and are elsewhere described, respectively, as vascular browning and diffuse flesh discolouration (Dixon, 2003). The diffuse greying symptom is distinguishable from bottom greying or around-stone, but was present in only a few fruit. This symptom consisted of a greying symptom that was not associated with either the inside or the outside of the fruit

When rots and disorders were pooled into two categories, total rots and chilling injury, it was apparent that fruit from the Far North were markedly less affected by chilling injury than fruit from the other two regions (Figure 6). After 28 days of storage, fruit from all treatments from Whangarei and Te Puke were acceptable for sale and consumption, but about 70% of the fruit from the Far North was affected by rots covering about 10% of the surface area in Pristine® treated fruit.

Rots in the best quality fruit after 28 days of storage (harvested from Te Puke and treated with Pristine®) increased from about 10% to about 70% of fruit affected after a further 14 days of storage. After 42 and 56 days storage very few of the fruit from any region were unaffected by rots, despite a statistically significant reduction in rots following treatment with the fungicides. After 42 days storage, rot severity was greater in fruit from all regions, and from all treatments.

Chilling injury was more prevalent and more severe than rots in fruit stored from Whangarei and Te Puke when stored for longer than 28 days. After 42 days storage, over 30% of the surface area of more than 80% of fruit from all treatments was affected. After 56 days, over 40% of the surface area of more than 85% of the fruit was affected by chilling injury.

DISCUSSION

Pristine® applied postharvest was as effective as Sportak®. After storage for 42 and 56 days, Pristine® reduced rots in more lines of fruit than did Sportak®. Although rots were statistically significantly reduced, there was a high incidence even in treated fruit after 42 days of storage, and at least 85% of fruit were affected by rots in all treatments after 56 days of storage. Thus postharvest fungicides were not effective treatments for extending the storage life of avocados. However, the amount of the fruit affected was relatively small at about 10% of the surface area after 42 days and about 20% after 56 days in Pristine® treated fruit from Whangarei and Te Puke. Ripening fruit at 15°C has been demonstrated to reduce storage rots by 60% (Everett, 2002) compared with ripening at 20°C. A further improvement of quality would be expected if fruit is ripened at this temperature. However, chilling injury was very common and the proportion of the fruit surface affected was greater than 40% in all the fruit from Whangarei and Te Puke after 56 days. This fruit would be unmarketable and storage temperatures need to be further optimised to reduce chilling injury before storage life could be extended.

Fruit affected by the proportion of rots found in fruit after 42 and 56 days storage is generally unacceptable for consumption, unless only a small proportion of the flesh is affected. After 42 days storage, rot severity was greater than the 5% threshold used by Dixon *et al.* (2003b) in fruit from all regions, and from all treatments. If 10% is considered acceptable, then fruit from Whangarei and Te Puke treated with Pristine® was able to be stored for up to 42 days before rots limited storage life, and fruit from the Far North was able to be stored for 28 days.

Physiological disorders were not seen in fruit in a previous study of 23 orchards harvested in January, but not coolstored before ripening (Everett *et al.*, 2007a). In 2008, these symptoms were first seen in fruit harvested in November

2007, and also in fruit harvested in March 2008. These symptoms were also present in fruit in these postharvest experiments harvested in December 2008. There was a marked increase in chilling injury after 30 days of storage for avocados harvested late in the season (Dixon *et al.*, 2003b). All these later fruit were coolstored for at least 28 days, followed by ripening at 20°C. Because these symptoms were not seen in fruit that had not been coolstored, this result is consistent with the conclusion by Dixon *et al*. (2003b) that they are caused by chilling injury. Diffuse flesh discolouration, bruising and bottom greying were probably not caused by rot fungi which could not be consistently isolated from these symptoms (data not shown). These symptom types were difficult to distinguish and there was probably some overlap. The surface greying symptom may have been caused by *Colletotrichum gloeosporioides* on the basis of isolations (data not shown). Surface greying affected only a few fruit compared with those symptoms which resembled each other, *i.e.* diffuse flesh discolouration, bottom greying and bruising. Further systematic study of the cause and differences between these symptom types is required to find control measures.

Long-term storage of fruit from Whangarei and Te Puke was detrimentally affected by the development of severe physiological disorders. These disorders were markedly fewer in fruit from the Far North. In those fruit rots were the most prevalent quality issue. The reason for this difference is not known. If the factor that is reducing chilling injury in these Far North fruit can be determined, then once rots are reduced by effective pre-harvest treatments, postharvest fungicides, and optimal ripening temperatures, long-term storage is feasible.

CONCLUSIONS

Postharvest application of fungicides was not able to extend the storage life of avocados. Fruit from Whangarei and Te Puke were severely affected by chilling injury symptoms if stored for longer than 28 days. Fruit from the Far North was markedly less affected by chilling injury. If the factors responsible for the low rate of chilling injury in the Far North fruit are determined, this could enable avocados to be stored for longer.

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