Development of a more effective postharvest treatment for the control of postharvest diseases of avocado fruit

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ABSTRACT

Results from previous work indicated that 200 ppm prochloraz + 50 mM *HCl* and 200 ppm prochloraz + 50 mM citric acid are as effective as 810 ppm prochloraz in terms of anthracnose and stem-end rot control on both 'Fuerte' and 'Hass' and that these treatments leave less prochloraz residues on fruit compared to 810 ppm prochloraz. The trials were repeated on both 'Fuerte' and 'Hass' using prochloraz EC and prochloraz SC formulations. The treatments were applied as either a 30 s dip treatment or as a spray-on treatment on different sets of fruit. After treatment, fruit samples were taken for prochloraz residue analysis and others were stored for 28 days at 5.5°C before being ripened and evaluated for postharvest disease incidence. There was no difference between the prochloraz EC and prochloraz SC formulations in terms of anthracnose and stem-end rot control on 'Fuerte' and 'Hass'. In terms of prochloraz residues, prochloraz EC resulted in slightly higher residues on the fruit, compared to prochloraz SC. The method of application (dip *vs*. spray-on) also did not differ in the control of postharvest diseases achieved. Based on the results from the work done from 2009 to 2011, 200 ppm prochloraz + 50 mM citric acid (acidified prochloraz) was evaluated semi-commercially in 2012 on waxed and un-waxed fruit to confirm the results. The results indicated that prochloraz 810 ppm and acidified 200 ppm prochloraz were better than the untreated control in terms of anthracnose and stem-end rot. However, white visible residues were observed on acidified 200 ppm prochloraz treated fruit that were waxed. White visible residues were more apparent on 'Hass' than on 'Fuerte'. Acidified prochloraz treatment of both 'Fuerte' and 'Hass' resulted in residue levels below 1 ppm. Based on the work done, acidified prochloraz is as effective as 810 ppm prochloraz for the control of postharvest diseases on both 'Fuerte' and 'Hass'.

INTRODUCTION

One of the most important problems facing the South African avocado industry is postharvest diseases (Darvas, 1985). The fungi causing these diseases include *Colletotrichum gloeosporioides* (anthracnose; ANT) and various species in the Botryosphaeriaceae (stem-end rot; SER) (Darvas, 1977; Darvas & Kotze, 1979). They occur as latent infections in the fruit and are therefore rather difficult to control with fungicides (Le Roux *et al*., 1985). In South Africa, anthracnose and stem-end rot as postharvest diseases are major limiting factors in the production and export of avocados (Le Roux *et al*., 1985). Currently these diseases are controlled by a combination of preharvest fungicide applications and a postharvest prochloraz dip in the pack house (Darvas, 1984). Despite the use of large amounts of fungicide, quality control results from the 2008 avocado season indicated that a substantial percentage of fruit were still lost due to ANT, SER or other body rots occurring on export fruit. This could indicate that the postharvest application of prochloraz currently being used is not optimally effective.

Research has shown that during ripening, the pH of avocado fruit increases from pH 5.2 to pH 6.0 (Yakoby *et al*., 2000). It was furthermore found that under these pH values *pelB*, one of the virulence genes of *C. gloeosporioides*, was expressed more actively and that the pathogen enhances this process by excreting ammonia in the infected host tissue (Prusky *et al*., 2001; Yakoby *et al*., 2000; 2001). This change in the ambient pH of the host tissue at the infection site is therefore regarded as the cause for the activation of the latent *C. gloeosporioides* infections to cause necrotic lesions in the fruit (Prusky & Yakoby, 2003).

This characteristic of the pathogen was used in Israel to develop a more effective postharvest treatment of mango fruit. It was found that by adding 50 mM hydrochloric acid (*HCl*) to the prochloraz solution in the pack house, the postharvest decay caused by *C. gloeosporioides* was controlled significantly better (Prusky *et al*., 2006). This effect of the acidified prochloraz is due to the pH (1) directly affecting the germination of the pathogen conidia (Pelser & Eckert, 1977); (2) influencing the virulence of the pathogen (Prusky *et al*., 2004); and (3) affecting the toxicity of the fungicides used (Smilanick *et al*., 2005). Prusky *et al*. (2006) showed that by adding hydrochloric acid to the prochloraz solution, the solubility of the prochloraz is increased significantly. This means that in an acidified prochloraz solution, a significantly lower concentration of prochloraz can be used while the disease control obtained by this solution is significantly better or the same.

To develop a protocol for the use of acidified prochloraz on avocado fruit for the control of postharvest diseases, a study was initiated in 2009. Results from the first season indicated that applying acidified prochloraz postharvest treatments as a dip application resulted in more fruit free from ANT and SER, compared to spray-on application, while applying 50 mM *HCl* combined with 200 ppm prochloraz was just as effective in controlling postharvest diseases compared to the commercially used 810 ppm prochloraz dip (Mavuso & Van Niekerk, 2010). As follow-on to the trials of 2009, additional objectives were set in the 2010 season. These were (1) to compare the efficacy of acidified prochloraz EC formulation to acidified prochloraz SC formulation; and (2) to determine if other acids could be used in the acidification of prochloraz. The results indicated that there was no difference between the prochloraz EC and prochloraz SC formulations in terms of anthracnose and stem-end rot control on 'Fuerte' and 'Hass'. In terms of prochloraz residues, prochloraz EC resulted in slightly higher residues on the fruit compared to prochloraz SC (Mavuso & Van Niekerk, 2011). It must, however, be remembered that the SC formulation is the only one registered under Act 36 of 1947 for use as a dip treatment on avocado fruit. The disease pressure was very low, which resulted in no significant difference between the treatments and the trial was repeated in 2011 using unsprayed fruit.

In 2011 trials were repeated on unsprayed 'Fuerte' and 'Hass' fruit. The results indicated that 200 ppm prochloraz + 50 mM *HCl* and 200 ppm prochloraz + 50 mM citric acid are as effective as 810 ppm prochloraz in terms of anthracnose and stem-end rot control on both 'Fuerte' and 'Hass' and leave less prochloraz residue on fruit compared to 810 ppm prochloraz. Based on the results from the work done from 2009 to 2011, 200 ppm prochloraz + 50 mM citric acid was evaluated semi-commercially in 2012 to confirm the results (Mavuso & Van Niekerk, 2012).

MATERIALS AND METHODS

Specific objectives for the 2012 season

1. To determine the efficacy of prochloraz combined with citric acid and prochloraz alone concentrations for the control of postharvest diseases on 'Hass' and 'Fuerte' fruit in semi-commercial trials.
2. To do prochloraz residues analysis on fruit from the different treatments to determine compliance with MRL's.

In order to address the objectives above, fruit from cultivars 'Fuerte' and 'Hass' were subjected to the following treatments: (1) Water treated fruit (control); (2) 810 ppm prochloraz; and (3) 200 ppm prochloraz + 50 mM citric acid. The treatments were applied as a dip using the prochloraz SC formulation. The trial was done on a commercial pack line. Each treatment was evaluated for two days. Fruit samples were taken three times a day (in the morning, during the day and in the afternoon) and were sent for prochloraz residue analysis. Other fruit samples (100 fruit per treatment) were stored for 28 days at 5.5°C before being ripened and evaluated for postharvest

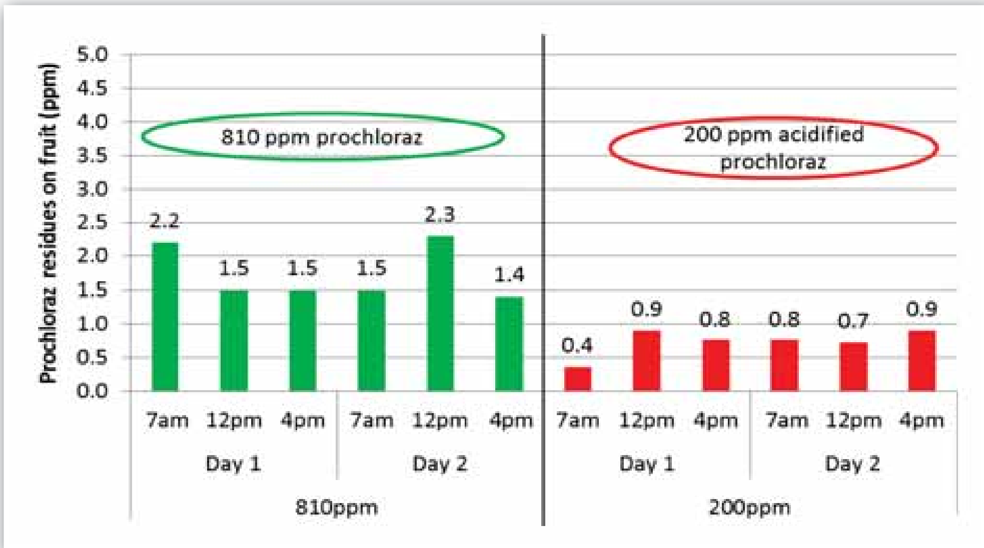

Figure 1. Prochloraz residues analysis results of 'Fuerte' fruit subjected to different prochloraz treatments taken at different times.

disease incidence. The trial was done on early and late season fruit. Early in the season the trial was done on waxed fruit, due to the appearance of white visible residues on the waxed fruit. On the late season fruit it was done on both waxed and un-waxed fruit. Chemical cost per treatment was calculated. Results were statistically analysed using STATISTICA (StatSoft, Inc., Tulsa, USA).

RESULTS

For early season fruit, on 'Fuerte', 810 ppm prochloraz and 200 ppm prochloraz + 50 mM citric acid gave a significant better disease control in terms of anthracnose and SER compared to the untreated control treatment (Table 1). On 'Hass', there was no significant difference between the treatments. However, the untreated control treatment was less effective in terms of anthracnose and SER control (Table 2). There was no significant difference between early and late season fruit in terms of anthracnose and SER. In terms of outside appearance, waxed fruit treated with 200 ppm prochloraz + 50 mM citric acid were not shiny, but had visible white residues on the fruit surface with the residues being much more vis-

Table 1. Mean percentage of marketable 'Fuerte' fruit, based on postharvest disease symptoms, resulting from the various postharvest treatments.

Treatment #	Treatment	% Marketable fruit free from anthracnose	% Marketable fruit free from stem-end rot
1	Control	82a	79a
2	200 ppm prochloraz + 50 mM citric acid	98b	98b
3	810 ppm prochloraz	99b	97b

Table 2. Mean percentage of marketable 'Hass' fruit, based on postharvest disease symptoms, resulting from the various postharvest treatments.

Treatment #	Treatment	% Marketable fruit free from anthracnose	% Marketable fruit free from stem-end rot
1	Control	88a	88a
2	200 ppm prochloraz + 50 mM citric acid	93a	91a
3	810 ppm prochloraz	94a	93a

Table 3. Chemical cost and savings per treatment application.

	Cost of chemical*			Savings	
Water in prochloraz bath (L)	810 ppm prochloraz	810 ppm prochloraz + 0.2% HCL	200 ppm prochloraz + 50 mM citric acid	810 ppm prochloraz + 0.2% HCL	200 ppm prochloraz + 50 mM citric acid
100	R31	R43	R21	-R10	R10
3000	R918	R1 278	R633	-R288	R285
6000	R1 836	R2 556	R1 265	-R576	R571

* Cost calculations are based on January 2013 figures.

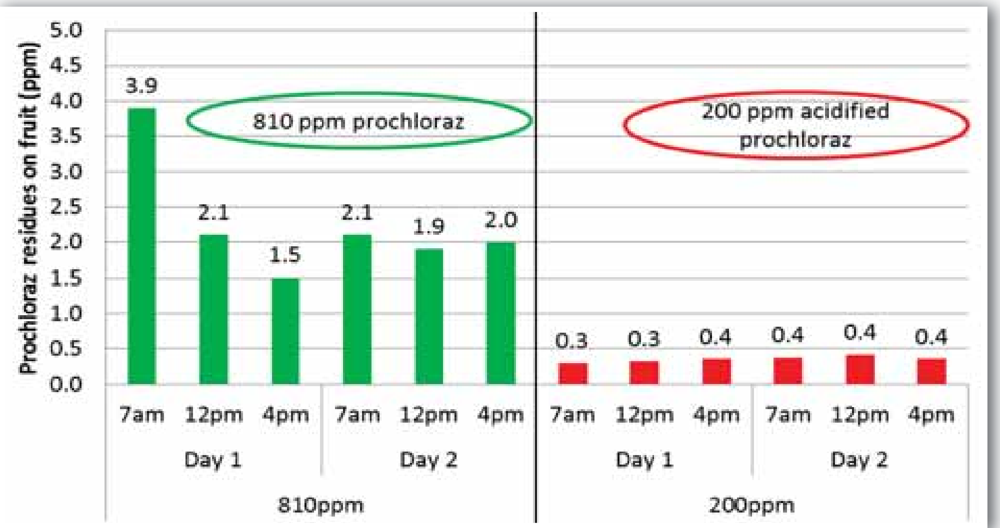

Figure 2. Prochloraz residues analysis results of 'Hass' fruit subjected to different prochloraz treatments taken at different times.

ible on 'Hass' fruit compared to 'Fuerte'.

With regards to prochloraz residues on treated fruit of both 'Fuerte' and 'Hass', all the treatments resulted in residue levels below the EU MRL level of 5.0 ppm and acidified 200 ppm prochloraz is even less than South African MRL of 2.0 ppm. However, the prochloraz residues were higher on 810 ppm prochloraz treated fruit compared to the 200 ppm prochloraz + 50 mM citric acid treated fruit (Figs. 1 and 2).

In terms of chemical cost, the results indicated that application of 200 ppm prochloraz + 50 mM citric acid is cheaper than 810 ppm prochloraz (Table 3).

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