Systemic resistance inducers applied postharvest for potential control of anthracnose (*Colletotrichum gloeosporoides*)

Bosse, RJ, Bower, JP and Bertling, I

[1]*Horticultural Science, School of Agricultural Sciences and Agribusiness, University of KwaZulu-Natal - Pietermaritzburg, P/Bag X01, Scottsville 3209, South Africa*
Email: 206500143@ukzn.ac.za

Abstract

Avocado exports from South Africa require extended low temperature shipping which may enhance postharvest disease incidence such as anthracnose (*Colletotrichum gloeosporoides*). The fungus appears a s a latent infection and may cause considerable economic losses. Antifungal compounds, naturally present in the fruit, are able to control the outbreak of anthracnose decline during fruit ripening. The use of systemic resistance inducers, such as silicon, may enhance the presence of antifungal compounds. Therefore, fruit were treated postharvest with potassium silicate (1000 ppm a.i.), immediately ripened or stored for 28 days at either 5.5ºC or 2ºC before ripening at room temperature. Exocarp was sampled for analysis of antifungal compounds and phenylalanine ammonium-lyase (PAL). During ripening, the fruit condition was also evaluated. Potassium silicate decreased anthracnose development in stored fruit; PAL activity was also influenced by potassium silicate application. It is suggested that sufficient stimulation of antifungal activity occurred to consider the treatment for postharvest disease control.

Key words: anthracnose, potassium silicate, postharvest, avocado disease

Inductors sistemicos de resistenicia aplicados depues de la cosecha para el potencial control de la antracnosis (*Colletotrichum gloeosporioides*)

Bosse, RJ, Bower, JP y Bertling, I

Horticultural Science, School of Agricultural Sciences and Agribusiness, University of KwaZulu-Natal, P/Bag X01, Scottsville, 3209, Pietermaritzburg, South Africa
Email: 206500143@ukzn.ac.za

La exportación de avocados desde Sudáfrica requiere de largos periodos de transporte a baja temperatura. Esto puede incrementar la incidencia de enfermedades posteriores a la cosecha. La Antracnosis (*Colletotrichum gloeosporioides*) como una infección latente puede causar perdidas considerables. Los compuestos fungicidas presentes en la fruta declinan a medida que la maduración progresa. El objetivo de este estudio es el de usar inductores sistémicos para aumentar los compuestos fungicidas y en consecuencia disminuir enfermedades posteriores a la cosecha, disminuyendo la necesitad de usar otras medidas como el rociado con cobre. Los frutos fueron tratados posteriormente a la cosecha con silicato de potasio (1000 ppm i.a.). Frutos fueron madurados inmediatamente o almacenados por 28 días a 2 o 5.5º C antes de madurar. Muestras del epicarpio fueron tomadas durante la maduración y la condición de la fruta fue también evaluada. Los epicarpios fueron analizados por la presencia de compuestos fungicidas y actividad de la fenil-alanina amonioliasa (PAL). Tratamientos posteriores a la cosecha demostraron una disminución en el desarrollo de Antracnosis en los frutos almacenados. Los compuesto también influenciaron la actividad PAL. Es sugerido que suficiente actividad antifúngica ha ocurrido para considerar este tratamiento para el control de enfermedades posteriores a la cosecha.

Introduction

Avocados are transported over long distances in order to reach their final destination. During this time the fruit is prone to attack by several pathogenic fungi. This attack may be increased by lack of fungicide application or by placing the fruit under incorrect storage temperatures. Postharvest diseases, among them anthracnose (*Colletotrichum gloeosporoides*) is one of the most important; losses of up to 80% can result when avocados are infected with this disease (Kotze, 1987).

Anthracnose infects fruit at immature stages and remains dormant until avocado fruit ripen. The disease originates from latent infections with *Colletotrichum gloeosporoides*. Latency has been shown to be due to the presence of antifungal activity in the fruit peel; disease activity results from a decrease in antifungal activity due to a decrease in the antifungal compound concentration (Prusky, Keen & Eaks, 1983). Phenylalanine ammonium-lyase activity has been found to increase the resistance of avocado fruit to anthracnose. Phenolic compounds reduce the ability of infection of plant tissue by micro-organisms; the total amount of phenolics has been shown to decrease as avocado fruit mature (Cutting, Wolstenholme & Hardy, 1992).

As contact fungicides copper containing formulations need to be used frequently to achieve adequate coverage to maintain disease control. This is especially important during the stages of early fruit development, when the surface area is expanding rapidly; therefore, resulting in increased cost of disease control.
Many chemicals currently used to reduce the decay of fruit are deemed environmentally hazardous, as well as leave undesirable residues on the fruit, new techniques need to be implemented in order to control to be able to control anthracnose (Eckert & Brown, 1986).

Silicon applications might become an alternative to currently used fungicides, as Silicon has also been seen to reduce the effects of mildew on barley (Rodriguez, Benhamou, Datnoff, Jones and Bélanger, 2003). Silicon has been seen to be used in sugarcane fields in South Africa where it was able to reduce the effect of the sugarcane stalk borer, *Eldana saccharina* (Meyer and Keeping, 2005). Depositions of Si into epidermal cells may form an effective mechanical barrier against fungal penetration. Plants harden physically as a result of Si accumulation resulting in additional protection, preventing fungi from entering plant cells (Kim, Kim, Park & Choi, 2002). However, Si might also have other means of reducing disease spread, as application of Si compounds has been found to increase the antioxidant concentration in avocado (Tesfay, Bertling & Bower, 2011).

Potassium silicate was therefore applied in order to determine whether such practice could increase the concentration of antifungal compounds and / or the enzyme PAL to be able to increase the concentration of phenolic compounds present at later ripening stages in order to decrease disease incidence.

Induced systemic resistance is a phenomenon describing an antagonist inducing systemic resistance in the host plant. The antagonist therefore causes changes in the plant's physiology that are only expressed later on when the host plant is under stress due to attack by the pathogen (Whipps, Lewis and Cook, 1988). Silicon can also act in the host tissue whereby it alters the signals that are sent between the host and the pathogen. This results in the plant defence mechanism being activated, much faster and more extensively, as demonstrated in cucumber plants (*Cucumis sativus*) (Samuels, Glass, Ebret & Menzies, 1991; Marschner, 1995).

The objective of the research was to better understand the physiology of systemic resistance inducers, and to enhance antifungal compounds and thus potentially decrease disease incidence while minimising the need for other measures such as copper sprays.

Material and Methods

Fruit were obtained from Wartburg and Howick, KwaZulu-Natal, South Africa. Fruit were either stored at 5.5^{o}C or 2^{o}C for 28 days, the ripened at room temperature or were ripened immediately without prior storage.

Results

In fruit stored at room temperature potassium silicate seemed to have a greater effect than in fruit subjected to cold storage (Figure 1a-c); the total phenolic concentration in Si-treated fruit was highest at the intermediate softness stage (Figure 1a).

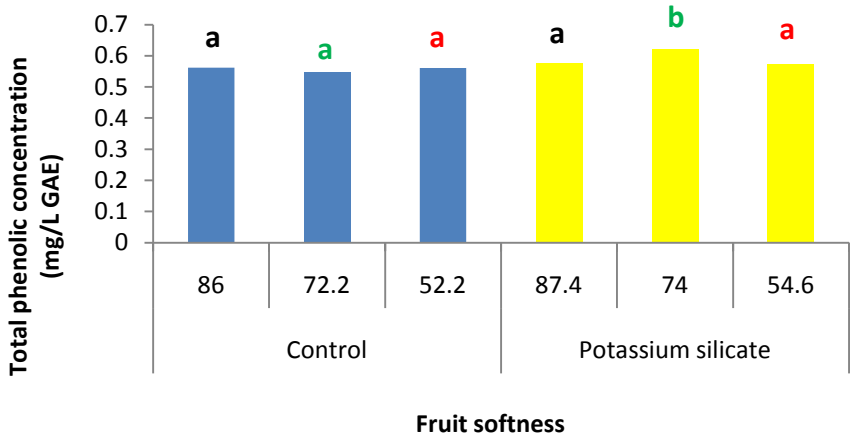

Figure 1a.

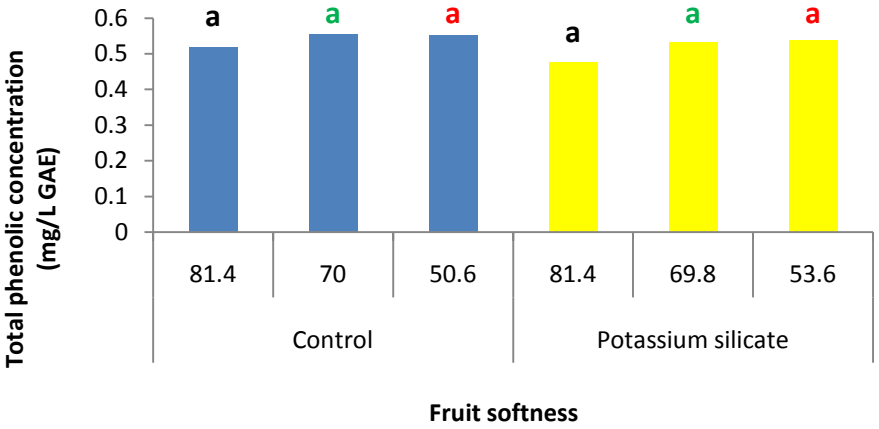

Figure 1b.

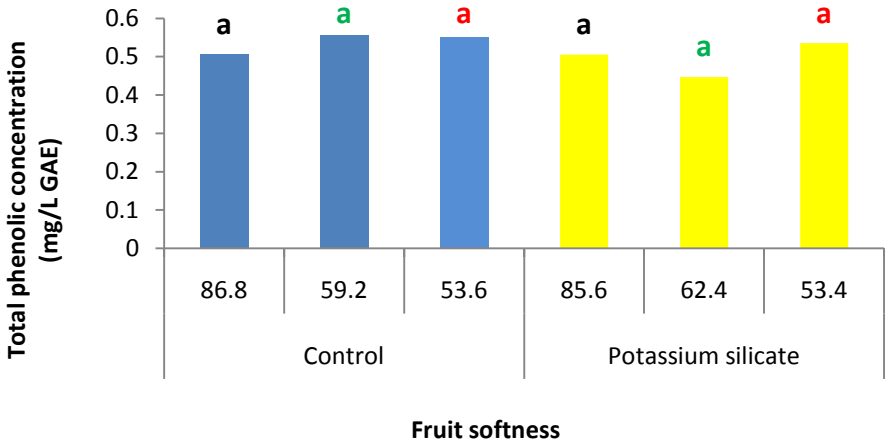

Figure 1c. Total phenolic concentration at specific fruit softness of 'Fuerte' avocados stored at room temperature (a), 5.5°C (b) and 2°C (c). Letters above columns indicate significant differences with different letters indicating significant differences.

Postharvest application of Si significantly altered PAL activity resulting in a stimulation of activity by the KSil application (Figure 2a). After removal from 5.5ºC storage fruit showed fruit had similar PAL activity while in those stored at 2ºC Si significantly increased PAL activity. During softening PAL activity increased in fruit stored at 2ºC remaining high throughout the softening period.

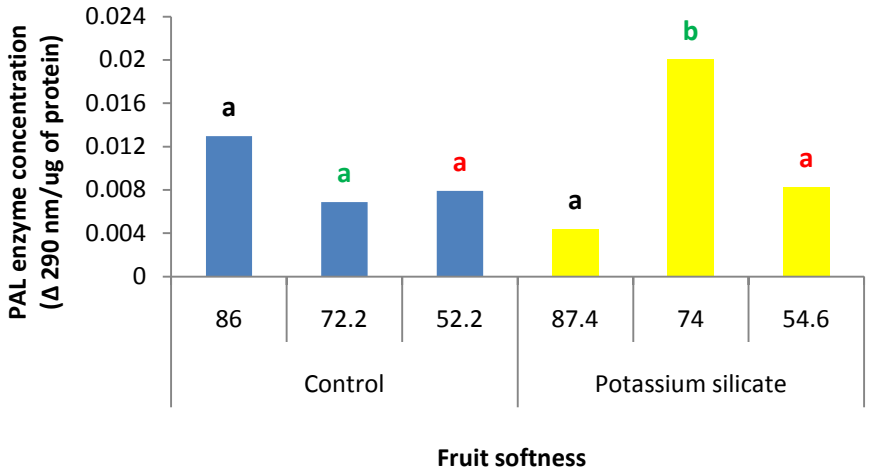

Figure 2a.

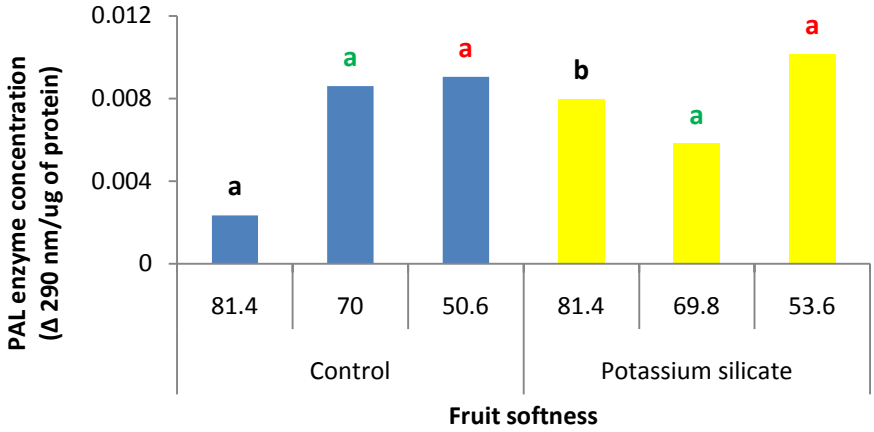

Figure 2b.

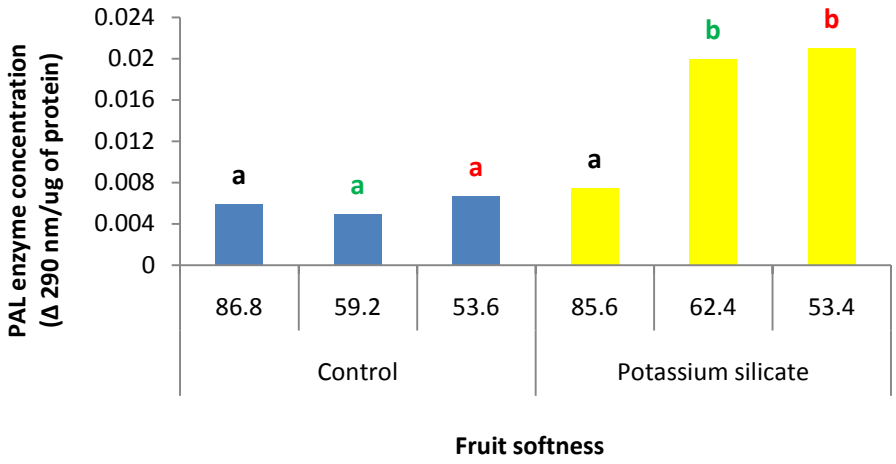

Figure 2c. Phenylalanine ammonia-lyase activity at specific fruit softness of 'Fuerte' avocados stored at room temperature (a), 5.5°C (b) and 2°C (c). Letters above columns indicate significant differences with different letters indicating significant differences.

Discussion

Fruit maturity affects the natural resistance of fruit tissue to fungal attacks (Prusky, 1996). Decreasing concentrations of antifungal dienes to sub-fungitoxic levels during fruit ripening result in the increased susceptibility to anthracnose (Domergue, Helms, Prusky & Browse, 2000).

Increased diene concentrations have been found to increase transcription of genes and the activity of epicatechin biosynthesis genes (Beno-Moualem and Prusky, 2000); in particular the enzymes 9-denaturase, 12- denaturase and elongase thus resulting in an increase and activation of the phenylpropanoid pathway. These genes and enzymes have been related to an increase in resistance of avocado to anthracnose (Yakoby, Beno, Kobiler & Prusky, 2002).
It is likely that PAL activity increases the level of epicatechin, implying that higher PAL activity will be related to higher levels of anti-fungal compounds. Therefore, by increasing PAL activity by the addition of potassium silicate in these experiments, the fruit's resistance to disease can be increased. This may be especially important as fruit softens. However, storage temperature appears to affect the process, with storage at 5.5°C seemingly negating the effects of potassium silicate. At lower temperature of storage (2°C) potassium silicate also enhanced activity. At this stage, the underlying biochemical processes are not clear and warrant further investigation.

Prusky, Kami, Kobiler, & Plumbley (1990) found that the diene concentrations in fruit peel decreases between the first and third day postharvest but initial levels were regained thereafter with regaining initial levels faster in more mature fruit. This could explain why, in some instances, control fruit phenolic concentrations and enzymatic activities appeared to decrease slightly and then increase again towards ripening. Where the opposite was seen for treated fruit, the treatment could be have had an effect on the antifungal diene concentrations.

Temperature also plays an important role in disease incidence. Fungal rots have been found to develop once ripening has begun due to the decrease in antifungal compounds (Prusky *et al*., 1983). The rate at which fruit ripens depends on the temperatures to which fruit are conditioned under. The higher the temperature, the faster fruit ripens and therefore fungal development increases (Hopkirk, White, Beever, & Forbes, 1994). Therefore, by reducing storage temperature and fruit ripening will be slowed down and rot development may be inhibited due to the presence of antifungal compounds.

Conclusions

The treatments had positive effects on phenolic compounds and enzymes of the phenolic pathway indicating that they could have positive effects decreasing disease incidence through altering anti-fungal compounds and prolonging diene concentrations in avocados. Temperature as well as Si treatment affected concentrations of enzymes and the phenolics pathway.

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