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Improving fruit quality and tree health of *Prunus persica* cv. 'Sandvliet' through combined mineral and salicylic acid foliar applications

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ABSTRACT

Foliar products that can address crop protection through systemic resistance and simultaneously also enhanced fruit quality will promote a reduction for the requirement of chemical applications in commercial orchards. Such products may include flavonoids and salicylic acid combined with mineral nutrients such as calcium, potassium, magnesium and boron which are widely linked to enhancing plant resistance to pathogens. In this study the efficacy of foliar formulations to improve fruit quality and enhance tree health of *Prunus persica* cv. 'Sandvliet' over two seasons were evaluated. Alexin™-containing foliar applications were effective in controlling *Xanthomonas* infection on both leaves and fruit of 'Sandvliet'. The efficiency was however related to the infection incidence which varied between organs and seasons. During the second season, all treatments reduced shoot length compared to the unsprayed control. K-Max™ and Alexin™ treatments confirmed the role of potassium (K) in disease resistance. Xanbac™ reduced the severity of *Xanthomonas* infections, but the efficacy varied between seasons. Applications of Alexin™, Cropbiolife™ and K-Max™ significantly increased fruit size to the control.

1. Introduction

A strong drive exists in the commercial fruit industries worldwide to reduce the application of herbicides and pesticides to both soils and crops in favour of safe biological crop protection products which can increase systemic resistance and enhanced product quality simultaneously (Urquhart, 1999). Flavonoids and salicylic acid (SA) are recognized compounds which enhance plant resistance as elicitors of systemic acquired resistance (SAR) (Malamy et al., 1990) by regulation of pathogen-related gene expression for antimicrobial enzyme and secondary metabolite production (Durner et al., 1997; Khan et al., 2002; McConchie et al., 2007; Agati et al., 2012). Flavonoids produce a physical barrier for pathogen infection through lignification of the cell wall and function as antioxidants by scavenging reactive oxygen species (ROS) which may result from stress or a pathogen attack within the plant (Agati et al., 2012). However, the effect of these compounds on fruit size and quality is not widely documented and understood. Tareen et al. (2012) showed that SA when applied post-harvest to peaches contributes towards the reduction of fruit weight loss, while maturity was retarded by delaying fruit softening and by decreasing of the associated juice pH. Additionally, antioxidant enzymes such as superoxide dismutase (SOD), catalase (CAT) and peroxidase (POD) activity was stimulated by the application of SA at 0.5–20 mmol L^{-1}. Similarly, the presence of SA increased total soluble solids (TSS), titratable acidity (TA), fruit colour and yield on strawberries (Karlidag et al., 2009). Calcium (Ca), magnesium (Mg), boron (B) and potassium (K) are typically included in foliar formulations to support general metabolic and physiological functions; increased root growth, water uptake and fruit size are all associated with K (Datnoff et al., 2007; Marschner, 2012), the stabilization of the cell wall integrity by Ca and B incorporation, whilst chlorophyll production is supported in the presence of Mg. Apart from their central role in primary metabolism, these elements have also been known to enhance mechanisms of plant defence (Datnoff et al., 2007). Matthee and Daines (1969) reported K to facilitate higher disease resistance as *Xanthomonas pruni* was reduced in peach foliage when exposed to K foliar applications. Similarly, the application of Ca resulted in a reduction of *Leucostoma persoonii* disease severity on peach twigs (Biggs et al., 1994). Magnesium, being structural to the chlorophyll molecule, plays a vital role in photosynthesis and subsequently a reduction in crop disease is promoted by sufficient levels of magnesium (Datnoff et al., 2007). As B forms stable esters with cell wall saccharides such as mannose and its derivatives, B application has been shown to effectively reduce pathogenic infections, including that of *Xanthomonas* in cauliflower (Kumar and Sharma, 1997).

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Xanthomonas is a bacterial disease which can be a serious threat in South African stone fruit producing areas (Du Plessis, 1988; Labuschagné, 1994), as it occurs sporadically under wet, wind-driven rainy conditions (Du Plessis, 1988), being most severe and common in areas with sandy soils, under humid and warm conditions (Battilani et al., 1999). Although no South African based statistical data regarding the incidence of this disease is available, it was confirmed (personal comm. Charl Stander, Franschhoek Marketing (Pty) Ltd) that, unless treated, especially susceptible plums like 'Angeleno' and 'Saphire' can drop up to 100% of their leaves due to *Xanthomonas* infection in certain climatic regions. This will result in high losses in yield.

The *Xanthomonas* pathogen causes small spots on fruit which further develops into sunken and dark brown, black lesions which ultimately results in cracks in the fruit, rendering it unmarketable. In addition with respect to the tree health, *Xanthomonas* causes lesions on the leaves which eventually lead to chlorosis and defoliation. Therefore, not only is there a direct loss of fruit production due to superficial damage, but defoliation early in the season leads to a reduction of fruit size and inevitably, fruit quality (Werner et al., 1986). Strategies combating this disease in South Africa has focused primarily on breeding for cultivar resistance such as in 'Songold', as continuous and increasing banning of antibiotics in crop production together with the phytotoxicity of many copper compound containing chemicals (Zaccardelli et al., 1992) has severely limited options for biological and chemical control. An approach where improved tree health through mineral application and required systemic resistance can be combined with improved genetics could provide the South African industry with a viable option for the safe and sustainable control of this important and potentially disastrous pathogen.

The purpose of this study was thus to evaluate the efficacy of various commercial foliar formulations containing mineral nutrients and/or SA to improve fruit quality parameters such as fruit size, total soluble sugar, titratable acid and firmness, and to reduce the severity of *Xanthomonas* infections of *Prunus persica* cv. 'Sandvliet' leaves and fruit, by enhancing tree health.

2. Material and methods

2.1. Plant material

The trial was conducted over two seasons (2008/2009 and 2011/2012) on a commercial site in the Worcester area, Western Cape, South Africa (33° 34′, 19° 17′). 'Sandvliet' peach trees planted in 1990 on a Kakamas rootstock with a tree spacing of 5.0 m × 2.0 m were selected for the trial.

For each season, fruit was hand thinned at the end of September, according to a commercial standard of 100 fruit 100 mm^{-1} stem diameter. Harvesting commenced on 1 February and 16 January during the 2008/2009 and 2011/2012 seasons, respectively, to correspond with commercial harvesting times. Standard commercial orchard management continued throughout the experimental period, with the exception that any routine applications that could counter bacterial and fungal diseases or influence fruit size, were omitted.

2.2. Experimental design and treatments

A randomized complete block design was followed, where a single tree represented an experimental unit. Buffer trees were used within the row and between rows to reduce spray drift between treatments. During the first season, nine treatments replicated six times were applied at various intervals and concentrations (Table 1).

Foliar treatments were applied until the point of runoff between 8h00 and 11h00, using a Stihl mist blower (SR420, Germany), according to product specifications. All products were supplied by Nulandis (Boksburg, South Africa). Croplife™-150-14 [Code name used: product-rate (ml $100L^{-1}$) – application interval (days)] was first applied at the start of petal drop (1 August 2008). Alexin™-125-28, Alexin™-250-28, Alexin™-250-14, Alexin™-250-infection period and Alexiboost™-250-14 were first applied at 75% petal drop (19 August 2008). Infection period applications occur when climatic conditions prevailed that were considered conducive for *Xanthomonas* infections. The first application of Xanbac™-200-14 and Xanbac™-200-14 + Alexin™-250-14 was at fruit set (2 September 2008). The control received a foliar application of tap water only at corresponding dates to that of the Croplife™-50-28 treatment.

Alexin™ (Plaaskem Pty Ltd, Witfield, 1476, South Africa) is an organic foliar nutrient complex with active ingredients SA (31.5 g L^{-1}), Ca (33.3 g L^{-1}), Mg (10.6 g L^{-1}), B (3.0 g L^{-1}) and K (56.7 g L^{-1}). Croplife™ (Biorevolution, Paarl, South Africa) is an organic carbon complex with 5–10% phenolic flavonoid compounds as active ingredients. Xanbac™ (Plaaskem Pty Ltd, Lilianton, South Africa) is a broad spectrum fungicide and bactericide with dicholorophen at 19–21% as active ingredient. Alexiboost™ is a combination of Alexin™ and Maxiboost™ (Nulandis, Boksburg, South Africa; 14–18% mono ammonium phosphate, 3–4% ammonium sulphate, 12–15% mono sodium phosphate) which, in addition to Alexin™ is also understood to contain iron (Fe), zinc (Zn), copper (Cu), molybdenum (Mo), sulphur (S) as well as the plant growth regulators, cytokinin and auxin.

During the second season, the three most promising treatments observed in season 1 were re-applied (Alexin™-250-14, Xanbac™-200-14 and Croplife™-50-28) and compared to two additional treatments, using six replications (Table 1). Cropbiolife™ (Biorevolution, Paarl, South Africa), an improved formulation replaced Croplife™ as a treatment used during the first season. Cropbiolife™ was first applied at the start of petal drop (10 August 2011), while Alexin™ was first applied at 75% petal drop (29 August 2011). Xanbac™ and K-Max™ (Plaaskem Pty Ltd, Lilianton, South Africa), a liquid organic potassium complex at 115 g L^{-1} K and 139 g L^{-1} K_2O, were applied at fruit set (6 September 2011), whereas the control received tap water on dates that coincided with the Cropbiolife™ application times.

2.3. Sampling and data collection

For season 1, each experimental tree was inspected 7 days before commercial harvest for the presence of *Xanthomonas* infection symptoms on the leaves. Trees were scored on a rating scale of 0–10, where '0' indicated a healthy tree with no leaf loss and '10' referred to trees with total leaf drop due to *Xanthomonas* infection. Rating scores where then converted to percentage values. At harvest (1 February 2009), two branches (on the sun-and shade side of the tree respectively) were randomly selected and 25 fruit per shoot evaluated for incidences of *Xanthomonas* infection. Fruit infection rates were expressed as a percentage (%) of the number of infected fruit to the total number of fruit evaluated.

At harvest, a randomly selected sample of 15 fruit per tree was collected for the quantification of the following fruit quality parameters the following day: fruit weight (g), diameter (mm), height (mm), firmness (kg), peel colour (according to a grading system; (1) fruit with a greenish background, (2) dim yellowish coloured fruit, and (3) yellow ripe coloured fruit), as well as total soluble solids (TSS) and titratable acidity (TA). Fruit height was determined with a Mitutoyo Corporation calliper (CD-6, Japan), while fruit diameter (across the seam), weight and firmness (after a small piece of skin was removed from opposite sides of the fruit) were determined