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Field evaluation of systemic inducing resistance chemicals at different growth stages for the control of apple (*Venturia inaequalis*) and pear (*Venturia pirina*) scab

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ABSTRACT

Two field trials were conducted using established apple (*Malus* cv. Golden Delicious) and pear (*Pyrus communis* 'Williams' Bon Chrétien') to assess the efficacy of three commercially available systemic inducing resistance (SIR) products, Messenger (a.i. Harpin protein), Phoenix (a.i. Potassium phosphite) and Rigel (a.i. Salicylic acid derivative) applied at four different growth stages of tree development (bud break, green cluster, 90% petal fall, early fruitlet) against the foliar pathogens *Venturia inaequalis* and *Venturia pirina* which cause apple and pear scab respectively. A conventional synthetic fungicide (penconazole) used within the UK for apple and pear scab control was included for comparison. Little efficacy as scab protectants was demonstrated when each SIR product and penconazole was applied at only two growth stages (bud break, green cluster). However when the above compounds were applied at three or more growth stages efficacy as scab protectants was confirmed. The synthetic fungicide penconazole provided greatest protection against apple and pear scab in both the 2006 and 2007 field trials. There was little difference in the magnitude of scab protection conferred by each SIR agent. Results suggest application of at least three sprays during bud break to early fruitlet formation with an appropriate SIR agent may provide a useful addition to existing methods of apple and pear scab management under field conditions.

1. Introduction

During the growing season ornamental and fruiting apple (*Malus* spp.) and pear (*Pyrus* spp.) are highly susceptible to attack by the foliar pathogens *Venturia inaequalis* and *Venturia pirina*, causes of apple and pear scab respectively (Hibbard et al., 1996; Sabri et al., 1997; Villalta et al., 2004). As suppliers, vendors and growers of apples and pears generally adopt a zero tolerance policy towards scab, any scab infection reduces the quality and marketable fruit yield (Percival and Boyle, 2005). Consequently, the economics of fruit and ornamental tree production require frequent application of synthetic fungicides throughout the growing season. Increased pathogen insensitivity to synthetic fungicides coupled with public demands to reduce pesticide use, stimulated by greater awareness of environmental and health issues has placed more emphasis on alternative pathogen control strategies (Agostini et al., 2003; Gozzo, 2003; Percival and Haynes, 2008; Schnabel and Parisi, 1997; Schneider et al., 1997; Stanis and Jones, 1985).

Constitutive and inducible based defence responses help to protect trees against insect and pathogen attack (Krokene et al., 2008). Inducible resistance mechanisms such as systemic induced resistance (SIR) can be acquired by exposing a plant to natural and/or synthetic compounds such as inorganic potassium and phosphate salts, compost water extracts, low molecular weight proteins, oxalate, and unsaturated fatty acids (Bécot et al., 2000; Fobert and Després, 2005; Friedrich et al., 1996; Hammerschmidt, 2003; Percival, 2001; Sticher et al., 1997). Products that induce resistance may be useful in the management of apple and pear scab where it is difficult to control these pathogens with protectant fungicides on rapidly expanding leaves and fruit. SIR products such as Messenger (harpin protein) Bion (BTH), Phoenix (potassium phosphite), Rigel (salicyclic acid analog) and Oryzemate® (Probenazole) are registered for commercial use in the horticultural industry although their availability differs among countries (Percival and Haynes, 2008). Several studies indicated that these SIR compounds are useful in the management of fungal pathogens (Christiansen et al., 1999; Kessmann et al., 1994) with the level of pathogen suppression, on occasion, comparable with synthetic fungicides. Consequently, induced resistance could provide systemic protection against pathogen attack to substitute for, or

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supplement control by conventional synthetic fungicides (Agostini et al., 2003; Van Loon et al., 2002). The majority of studies concerned with the efficacy of SIR agents on pathogen suppression has been conducted under controlled laboratory and glasshouse conditions that do not reflect field environments (Agostini et al., 2003; Kessmann et al., 1994; Percival, 2001).

Objectives of this study were to investigate the efficacy of three commercially available SIR agents on controlling apple (*V. inaequalis*) and pear scab (*V. pirnia*) under field conditions and identify key spraying times based on growth stages of tree development (bud break, green cluster, 90% petal fall, early fruitlet).

2. Materials and methods

2.1. Field trials

The apple trial site consisted of a 0.75 ha block of apple (*Malus* cv. Golden Delicious) interspersed with individual trees of *Malus* Red Delicious and Gala as pollinators. The pear trial site consisted of a 0.90 ha block of *Pyrus communis* 'Williams' Bon Chrétien' interspersed with individual trees of *P. communis* Beth and Concorde. Golden Delicious and 'Williams' Bon Chrétien' were chosen for the experiments because they are very susceptible to apple and pear scab infection respectively. Planting distances were based on 2×2 m spacing. The trees were planted in 2003 and trained under the central-leader system to an average height of $2.5 \text{ m} \pm 0.25$ m with mean trunk diameters of $12 \text{ cm} \pm 1.4$ cm at 45 cm above the soil level. The trial sites were located at the University of Reading Shinfield Experimental Site, University of Reading, Berkshire (51°43′ N, −1°08′ W).

The soil was a sandy loam containing 4–6% organic matter, pH of 6.2, available P, K, Mg, Na and Ca were 52.0, 659.1, 175.2, 49.4 and 2188 mg l^{-1} respectively. Weeds were controlled chemically using glyphosate (Roundup; Green-Tech, Sweethills Park, Nun Monkton, York, UK) throughout experiments. No watering or fertilisation was applied during the two year trial. Historically the apples suffered from apple and pear scab infection on an annual basis. Prior to the trial commencing in 2006 and 2007 trees were inspected in September 2005 and 2006 and only those trees with >50% of leaves affected with severe foliar discolouration, and subsequent scab infection were included in the trial. A minimal insecticide program based on the residual pyrethroid insecticide deltamethrin (Product name Bandu, Headland Agrochemicals Ltd, Saffron Walden, Essex, UK) was applied every three months during each growing season commencing in May 2006 to September 2007. All sprays were applied using a Tom Wanner Spray Rig sprayer at 40 ml deltamethrin (Bandu) per 100 l^{-1} of water. Trees were sprayed until runoff, generally 0.30 l^{-1} insecticide per tree. Average climatic conditions during the 2006 and 2007 growing season (April–September) were as follows: max temp 18.0 °C, 17.9 °C, min temp 8.8 °C, 8.7 °C, sunshine hours 596.6, 603.4, rainfall 158 mm, 221 mm respectively.

2.2. SIR and fungicide treatments

SIR and fungicide treatments were applied at four growth stages or combinations of stages identified as key spraying times for scab control under field conditions (Bevan and Knight, 2001), namely: bud break (March 11, 2006, March 17, 2007), green cluster (April 1, 2006, April 7, 2007), 90% petal fall (May 13, 2006, May 19, 2007), early fruitlet (June 1, 2006, June 8, 2007). Prior to SIR application trees were inspected and no visible symptoms of apple or pear scab were apparent. During SIR spray treatments polythene screens 2.5 m high were erected around each tree to prevent dispersal of sprays and possible cross-contact with other trees. The base of the tree was covered with a $0.5 \text{ m} \times 0.5$ m polythene mulch to prevent potential soil percolation. The treatments, 3 SIR inducing compounds, 1 fungicide × 4 spray times were applied in 5 randomized complete blocks plus a water control with a single tree as the experimental unit, giving a total of 85 observations per response variable. Foliar sprays of each SIR product and penconazole were applied until runoff using a hand-sprayer at manufacturers recommended rate:

Topas (a.i. penconazole): 1.5 ml l^{-1} of water (Syngenta Crop Protection UK Ltd, Whittlesford, Cambridge, UK).
Messenger (a.i. Harpin protein): 3.2 g l^{-1} of water (EDEN Bioscience Corporation, N. Bothell, Washington, USA).
Phoenix (a.i. Potassium phosphite): 10 ml l^{-1} of water (Orion Future Technology Ltd, Henwood House, Henwood, Ashford, Kent).
Rigel (a.i. Salicylic acid derivative): 3 ml l^{-1} of water (Orion Future Technology Ltd, Henwood House, Henwood, Ashford, Kent).

2.3. Leaf chlorophyll measurements

To keep the physiological age of the leaves comparable throughout the experiment, measurements of chlorophyll content (SPAD) were made only on fully expanded mature leaves. In all cases SPAD measurements were taken from six leaves (two from the top of the crown, two in the centre and two at the base) per tree. A Minolta chlorophyll meter SPAD-502 was used. Chlorophyll was measured at the mid point of the leaf next to the main leaf vein. Calibration was obtained by measurement of absorbance at 663 and 645 nm in a spectrophotometer (PU8800 Pye Unicam) after extraction with 80% v/v aqueous acetone (regr. eq. $= 5.58 + 0.053x$; r^2 adj $= 0.94$, $P = <0.001$) (Lichtenthaler and Wellburn, 1983).

2.4. Scab severity

Scab severity of leaves and fruit was assessed visually commencing each September. Leaf scab severity of each tree was rated using a visual indexing technique and ratings on the scale: 0 = No scab observed; 1 = less than 5% of leaves affected and no aesthetic impact; 2 = 5–20% of leaves affected with some yellowing but little or no defoliation; 3 = 21–50% of leaves affected, significant defoliation and/or leaf yellowing; 4 = 51–80% of leaves affected, severe foliar discolouration; 5 = 81–100% of leaves affected with 90–100% defoliation. Scab severity on fruit was calculated on the scale: 0 = no visible lesions; 1 = <10% fruit surface infected; 2 = 10–25% fruit surface infected; 3 = 25–50% fruit surface infected; 4 = >50% fruit surface infected. The individual ratings for each tree in each treatment were used as a measure of scab severity for statistical analysis. Leaf scab severity ratings used in this study were based on UK and Ireland market standards for fungicide evaluation of scab control (Butt et al., 1990; Swait and Butt, 1990). Fruit scab severity was based a scale used by Ilhan et al. (2006).

2.5. Fruit yield

Yield per tree was determined by weighing all fruit on each tree at harvest and dividing by the number of trees per treatment.

2.6. Statistical analysis

Mean pathogen severity values for all treatments were transformed using the Arcsin ($\sin^{-1}$) transformation. All data were analyzed using ANOVA and the differences between means were determined