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Trunk injection: An alternative technique for pesticide delivery in apples

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ABSTRACT

Field studies, laboratory bioassays, and residue profile analysis were used to determine the seasonal effectiveness of trunk injected pesticides against key apple disease and insect pests. Insecticides formulated for trunk injection, imidacloprid (Ima-jet™), rynaxypyr (XCL-r8™), and emamectin benzoate (TREE-age™) were injected into semi-dwarf Empire apple trees *Malus domestica* (Borkhausen) and evaluated for a wide range of insect pests. The fungicide compounds, propiconazole (Alamo®), phosphites (Phospho-jet), and penthiopyrad (Fontelis™), were injected into semi-dwarf MacIntosh (RedMax) apple trees *M.domestica* (Borkhausen) for control of apple scab fungus, *Venturia inaequalis* (Cooke). After the original single injection, imidacloprid was highly effective in controlling piercing and sucking pests such as the potato leafhopper, *Empoasca fabae* (Harris), and aphids (*Aphididae*), and emamectin benzoate was highly effective in controlling the oblique banded leaf roller, *Choristoneura rosaceana* (Harris), and potato leafhopper, *E. fabae* (Harris), and rynaxypyr was highly effective in controlling Oriental fruit moth, *Grapholita molesta* (Busck), and leafrollers all for two growing seasons. The residue profiles for insecticides showed that vascular delivery was predominantly to foliage, with fruit residues far below the EPA maximum residue limits (MRLs), and low to no residues detected in apple flower parts. Phosphites provided significant levels of apple scab control over two seasons for the single injection after the foliage recovered from the phytotoxicity damage in the first season. Propiconazole and penthiopyrad showed limited effectiveness for the control of apple scab. The residue profiles for fungicides showed phosphites to be delivered primarily to foliage, but inconsistent foliar residue levels for the other two compounds suggests possible incompatibilities may be responsible for poor product performance. These incompatibilities may include molecular or chemical properties. For example, on the molecular level such as the molecular size too large to fit through vascular tissue and chemical properties such as the viscosity of the compound resulting in poor translocation or pH.

1. Introduction

Meeting the high food quality standards of domestic and global markets often requires the judicious use of crop protection materials, including pesticides (Wise and Whalon, 2009). Advances in crop protection chemistry in the last several decades have improved farmers' ability to grow specialty crops, such as apples, while enhancing margins of food safety for the consumer.

Even though there has been significant evolution of the crop protection materials (i.e.; reduced-risk pesticides) available for pest management (USEPA, 1997), the spray equipment used by apple farmers has remained comparatively unchanged (McCartney and Obermiller, 2008). Scientists, like Pimentel and Levitan (1986), estimate that with conventional sprayers as little as 0.1% or less of

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the pesticide contacts the target pest. Other studies show that airblast sprayers are a relatively inefficient means of delivering pesticides to their target, with only 29–56% of the applied spray solution being deposited on the tree crown, and the remaining product drifting to ground or other off-target end points (Reichard et al., 1979; Steiner, 1969; Zhu et al., 2006). Some technical advancements have come to the conventional ground sprayer, such as adding towers or nozzle sensors (Landers and Farooq, 2005; Landers, 2002, 2004), but the fundamental elements for delivering materials to the tree crown have remained the same.

Pimentel and Levitan (1986) state that in most cases growers apply more pesticide than needed to account for the pesticide that does not reach the target crop. This off-target contamination may be lethal to many beneficial organisms such as pollinators, natural enemies, and decomposers (Devine and Furlong, 2007). Zhu et al. (2006) found that many nurseries and orchards are located in or close to the urban and suburban areas, making pesticide contamination of air, surrounding vegetation, and soil a threat to local residents. Thus the resulting impact of the inefficient application of pesticides on humans, beneficial insects, and the environment is a growing concern worldwide (Pimentel and Levitan, 1986).

Trunk injection is an alternative to conventional airblast sprayers for delivering crop protection materials to tree fruit crops. Trunk injection of insecticides, including imidacloprid and emamectin benzoate, has become the preferred method for controlling Emerald ash borer in urban landscapes because of minimized risks to the public and non-target organisms (McCullough et al., 2005, Mota-Sanchez et al., 2008). Until now, research on the potential for using trunk injection in apple pest management has been limited primarily to disease control.

Trunk injection of the fungicide imazalil in apple trees showed different levels of translocation and distribution after different times of injection (Clifford et al., 1987). Post-harvest injection resulted in extensive movement of fungicide up and down the trunk and into branches, while injection before bud break stage showed limited movement in the trunk and in the branches only at the end of the season. In another apple study however, injections in May provided a significant degree of apple scab protection in the next two seasons for seven fungicides (Percival and Boyle, 2005).

Apple scab, the most serious fungal disease of apples in the Eastern U.S., caused by the fungus *V. inaequalis* (Cooke), can require as many as fifteen fungicide applications per season (Ellis et al., 1984). The inoculum develops in the spring in infected leaves from the previous season, and fruit infection results in scabby lesions that crack and deform fruit directly impacting apple quality. Even minimal foliar infections can result in defoliation of apple trees, leading to a reduction of fruit size, quality, yield, loss of winter-hardiness, or even death of young trees (MacHardy, 1996). Conventional tactics for controlling apple scab require timely preinfection application of fungicides to protect apple leaves and fruit (Sundin, 2009). If the primary scab infection can be completely controlled, significant savings can be made in limiting the otherwise season-long cover sprays (Jones and Sutton, 1996). Propiconazole, phosphites, and penthiopyrad are registered in the U.S. for use as foliar sprays in tree fruits for disease control (Wise et al., 2012).

Apples grown in the eastern U.S. are host of 10 or more different unwanted insects, some of which are direct and indirect pests. Reduced-risk insecticides, such as imidacloprid, emamectin benzoate, rynaxypyr are registered in the U.S. for use as foliar sprays in apples for various direct and indirect insect pests (Wise et al. 2012). Direct insect pests include the oblique banded leaf roller *C. rosaceana* (Harris) (OBLR), Oriental fruit moth *Grapholita molesta* (Busck) (OFM), codling moth *Cydia pomonella* (L.) (CM), plum curculio *Conotrachelus nenuphar* (Herbst) (PC), apple maggot *Rhagoletis pomonella* (Walsh) (AM), Japanese beetle *Popillia japonica* (Newman) (JB), rosy apple aphid *Dysaphis plantaginea* (Passerini) (RAA), while indirect pests include the spotted tentiform leaf miner *Phyllonorycter blancardella* (Fabr.) (STLM), green apple aphid *Aphis pomi* (Passerini) (GAA), and potato leafhopper *E. fabae* (Harris) (PLH). There are some direct pests that also feed on the foliage, which can be considered direct and indirect feeders such as the OBLR and OFM.

The purpose of this study was to test the effectiveness of the selected insecticides and fungicides delivered by trunk injection, for controlling the key disease and insect pests of Michigan apples.

2. Materials and methods

2.1. Injection procedure

Semi-dwarf apple trees *M. domestica* (Borkhausen) were chosen for trunk injection at MSU Trevor Nichols Research Center in Fennville, MI, USA (latitude 42.5951°: longitude −86.1561°) based on overall health and crown structure, to assure uniform compound delivery to the crown. There were five replicate trees per treatment used in a randomized complete block design (RCBD). To calculate the rate per tree pre-injection data were collected for each tree. This data included the trunk diameter one foot or 30.48 cm above the ground (DFH), calculating milliliters of compound per 2.54 cm of DFH, rate of compound in grams of active ingredient (g AI) per DFH inch, total volume for the injection solution per tree (all four injection ports combined), total volume of injection solution per injection port (total volume per tree divided by four), and the date of injection. These data were used for treatment preparation and rate calculation. The tree DFH was taken prior to injection by wrapping a forester's D-tape (Lufkin®, Sparks, MD) 30.48 cm above the ground for each repetition. The injection equipment included an Arborjet Quick-jet™ injector and no. four Arborplugs (Arborjet Inc., Woburn, MA), screwdriver-like plug tapper, hammer, cordless drill, and a 0.95 cm diameter wood drill bit. The injection system and drill bit were sanitized before each injection with Arborjet Cleanjet™ solution (Arborjet Inc. Woburn, MA). The drill bit was sterilized between each tree injection to prevent microbial contamination or infection. The Quick-jet™ was used according to the instruction manual provided by ArborJet. Injection ports were drilled radially into the apple trunk 5.08 cm deep, and 30.48 cm above the ground. The injection ports were strategically placed under main scaffold branches around the trunk approximately at cardinal direction (N, S, E, W) orientations. The injection ports were sealed using Arborplugs so that the outside rim of the plug was beneath the bark with cambium tissue. The compound was then injected at the desired rate in each plug through the one-way silicone valve in the Arborplug.

2.2. Insecticides injected

Treatment applications were injected at apple petal fall stage on 5 May 2010 and in separate trees on 30 May 2011, with each of three insecticides formulated for trunk injection: imidacloprid 5% (Ima-jet™, Arborjet Inc., Woburn, MA), emamectin benzoate 4% (TREE-age™ Arborjet Inc., Woburn, MA), and rynaxypyr 4% (XCL-r8™, Arborjet Inc., Woburn, MA). There are four insecticide treatments, including a non-injected control, which is considered treatment one. Injections were conducted on twenty 12.7–15.24 cm DFH semi-dwarf Empire apple trees *M. domestica* (Borkhausen). Predetermined low and high rates of each compound were injected at volumes depending on tree DFH. A low rate of 0.2 g Active Ingredient (AI) per 2.54 cm DFH and high rate of 0.4 g AI per 2.54 cm DFH were injected for all insecticides.