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Post-plant strategies for management of black root rot-related decline of perennial strawberry fields

Timothy D. Miles[a,*], Benjamin W. Glass[b,1], Roger W. Sysak[b], Annemiek C. Schilder[b]

[a] School of Natural Sciences, California State University Monterey Bay, Seaside, CA, USA
[b] Department of Plant, Soil and Microbial Sciences, Michigan State University, East Lansing, MI, USA

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ABSTRACT

Perennial strawberries affected with black root rot generally decline in runner production, yield, and overall plant vigor over time. Several plant pathogens have been implicated in black root rot, including plant-parasitic nematodes, *Pythium* and *Rhizoctonia* spp. Pre-plant treatments such as a 3- to 5-year crop rotation or chemical fumigation are the main means of disease management. During 2007 and 2008, five post-plant treatments were evaluated for mitigation of strawberry black root rot in a naturally declining site in Ottawa County in Michigan. Fungicides and nutritional amendments were applied as drenches or foliar sprays. Most treatments increased runner establishment, yield, and overall plant vigor, particularly azoxystrobin and azoxystrobin + potassium phosphite. Root necrosis and incidence of root infection by binucleate *Rhizoctonia* spp. were reduced. Results were more apparent and significant in 2008 than in 2007, indicating cumulative effects over the 2 years of the trial. During 2008 and 2009, a large-scale demonstration trial was conducted with these treatments in a strawberry field with a history of black root rot in Leelanau County, MI. Improvements in bed fill and average plant weight and reductions in root necrosis and *Rhizoctonia* isolations were noted. This research represents the first post-plant chemical management strategy capable of slowing or even reversing the decline due to black root rot in established strawberry fields.

1. Introduction

In Michigan, strawberries are typically produced in perennial, matted-row plantings (Hancock, 1999). Black root rot (BRR) is a disease complex that plagues older strawberry fields and occasionally new plantings. Multiple organisms and abiotic factors have been implicated in the cause of the disease. However, *Rhizoctonia fragariae* Husain & McKeen, specifically the binucleate anastomosis groups A, K, G and I, *Pythium* spp., and the root lesion nematode *Pratylenchus penetrans* (Cobb) Filipjev and Schuurmans Stekhoven are generally considered the primary agents acting in concert to cause the symptoms (D'Ercole et al., 1988; Martin, 2000; Sharon et al., 2007; Wilhelm, 1987; Wing et al., 1994). *Rhizoctonia* isolates from strawberry roots in Michigan have generally been binucleate and considered to be *R. fragariae* (Glass, 2008), although most studies (Botha et al., 2003; Sharon et al., 2007) prefer to use the term "binucleate *Rhizoctonia* species" (BNR) due to unresolved taxonomy. BNR species have been associated with root rot problems in several crops outside of strawberries, including potatoes, sugar beets and turfgrass (Miles et al., 2013; Martin and Lucas, 1984).

Strawberry plants with black root rot are less vigorous and produce fewer runners than healthy plants. Many of the main roots are black and few feeder roots are present (Wilhelm, 1987). Under dry conditions, affected plants wilt and die, resulting in bare patches in the field. Yields are diminished to the point where the planting becomes economically unsustainable. The disease can spread via infected nursery stock, movement of infested soil, or infected plant debris (Hildebrand, 1934; Strong and Strong, 1927; Wilhelm, 1987). Black root rot may significantly shorten the productive life of perennial strawberry plantings, with only 2 to 3 harvest years in some cases. In contrast, some perennial strawberry fields have been kept in production for up to 10 years (D. Gibbs, personal communication).

A common chemical treatment for prevention of black root rot is pre-plant soil fumigation, which is effective against all pathogens involved in the complex. However, because of the phase-out of methyl bromide, an effective soil fumigant used for decades, strawberry growers are looking for alternative methods of managing this disease (Batchelor, 1998; Rosskopf et al., 2005). Some chemicals, such as 1,3-dichloropropene (Telone, Dow AgroSciences, Indianapolis, Indiana, USA), chloropicrin, and metam sodium (Vapam, Amvac Chemical Corporation, Los Angeles, CA, USA) have shown success as alternative

* Corresponding author.
E-mail address: tmiles@csumb.edu (T.D. Miles).
[1] Current address: Zeeland Farm Services, Inc., Zeeland, MI, USA.

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Table 1
Active ingredients, trade names, manufacturers, application methods, rates, and schedules used to treat black root rot-affected strawberry plants in a small plot trial (cv. Jewel) in Ottawa County, in 2007 and 2008 and in an on-farm demonstration trial (cvs. Northeaster and Earliglow) in Leelanau County, Michigan, USA in 2008 and 2009.

Active Ingredient	Trade Name and Manufacturer	Application Method	Product Rate/ha	Application Schedule[a,b]
Small plot trial[a]				
2007				
Azoxystrobin	Abound, Syngenta Crop Protection, Greensboro, NC, USA	Drench	0.73 L	1, 5, 9
Potassium phosphite	ProPhyt, Helena Chemical Company, Collierville, TN, USA	Spray	2.34 L	1, 2, 3, 4, 5, 6, 7, 8, 9
Calcium, cobalt and zinc carbonates and microbial enzymes	Symbex 4x, Agro-K Corporation, Minneapolis, MN, USA	Drench	4.68 L	1, 5, 9
Calcium and copper phosphites	Sysstem-Cal, Agro-K, Corporation Minneapolis, MN, USA	Spray	7.02 L	1, 2, 3, 4, 5, 6, 7, 8, 9
2008				
Azoxystrobin	As above	Drench	0.73 L	1, 5
Potassium phosphite	As above	Spray	2.34 L	1, 2, 3, 4
Calcium, cobalt and zinc carbonates and microbial enzymes	As above	Drench	4.68 L	1, 5
Calcium and copper phosphites	As above.	Spray	7.02 L	1, 2, 3, 4
Demonstration trial[b]				
2008				
Azoxystrobin	As above	Chemigation	0.88 L	1, 2, 3
Sodium, potassium and ammonium phosphites	Phostrol, Nufarm Americas Inc., Burr Ridge, IL, USA	Spray	4.68 L	1, 2, 3
2009				
Azoxystrobin	As above	Chemigation	0.88 L	1, 2, 3
Sodium, potassium and ammonium phosphites	Phostrol, Nufarm Americas Inc., Burr Ridge, IL, USA	Spray	4.68 L	1, 2, 3

[a] Small plot trial: application dates in 2007: 1 = 23 May, 2 = 6 June, 3 = 20 June, 4 = 5 July, 5 = 18 July, 6 = 2 August, 7 = 15 August, 8 = 29 August, and 9 = 8 September. Application dates in 2008: 1 = 19 April, 2 = 6 May, 3 = 21 May, 4 = 4 June and 5 = 9 June.
[b] Demonstration trial: application dates in 2008: 1 = 31 May, 2 = 19 June, and 3 = 10 September. Application dates in 2009: 1 = 17 June, 2 = 8 July, and 3 = 26 August.

fumigants (Batchelor, 1998). However, due to the cost, increased regulation and negative environmental effects of chemical soil fumigants (Batchelor, 1998; Rosskopf et al., 2005), there is renewed interest in management alternatives, such as using crop rotation, cover crops, improved drainage, and biological soil disinfestation methods (Ajwa et al., 2003; Martin and Bull, 2002; Martin and Hancock, 1983; Perry and Ramsdell, 1994; Shennan et al., 2014; Wilhelm, 1987). If a field has a history of BRR, the recommendation is frequently made to use a 3- to 5-year rotation out of strawberries or to find a new location for the strawberries (Funt et al., 1997; Perry and Ramsdell, 1994). However, land constraints and limitations on the location of pick-your-own fields may be reasons why strawberries cannot be grown in a different area on a given farm. In general, it is assumed that not much can be done to manage black root rot once the disease shows up in a planting. The goal of this research project was to challenge this assumption and evaluate post-plant treatments for their ability to slow or reverse plant decline in black root rot-affected strawberry fields.

Several products are labeled for use specifically against pathogenic organisms that are part of or related to those involved in the black root rot complex. The fungicide azoxystrobin (Abound, Syngenta Crop Protection, Greensboro, North Carolina, USA) is labeled as a drench in strawberries to control root rot caused by *Rhizoctonia*. Azoxystrobin is a member of the quinone outside inhibitor (QoI) class of fungicides which have broad-spectrum activity against many fungal and oomycete species (Anke, 1995). Phosphite fungicides such as potassium phosphite (ProPhyt, Helena, Collierville, Tennessee, USA) and mono- and dibasic sodium, potassium, and ammonium phosphites (Phostrol, Nufarm Americas Inc., Burr Ridge, IL, USA) are highly systemic products similar to fosetyl-Al (Aliette, Bayer Crop Science, Research Triangle Park, North Carolina, USA). They can be applied foliarly or as a pre-plant dip to strawberry roots and crowns. Since they are effective against Phytophthora diseases in strawberries, they may also have the potential to control *Pythium* spp. Potassium phosphite applied foliarly to 'Honeoye' strawberries from bloom to harvest gave excellent control of *Phytophthora cactorum* (Rebollar-Alviter et al., 2005). Furthermore, a potassium phosphite dip treatment of 'Sweet Charlie' strawberry transplants followed by a foliar application increased the percentage of healthy plants after 24 days compared to untreated plants in a North Carolina study aimed at controlling *P. cactorum* (Louws et al., 2004). Additionally, a pre-plant dip of strawberry transplants with azoxystrobin + potassium phosphite also improved plant growth and establishment in a field with a history of black root rot in Michigan (Glass, 2008).

In addition to fungicides, it is conceivable that nutritional amendments can improve root growth and overall health of declining plants. While a product containing calcium and copper phosphites (Sysstem-Cal, Agro-K Corporation, Minneapolis, Minnesota, USA) is marketed as a foliar fertilizer, it also may have disease control activity due to its phosphite content. In addition, a fermentation product containing microbial enzymes, calcium carbonate, cobalt carbonate, and zinc carbonate (Symbex 4x, Agro K, Minneapolis, Minnesota, USA) has been claimed to boost soil microbial populations and root growth. This product is also labeled for organic production.

To develop recommendations for increasing the longevity and profitability of perennial strawberry plantings, we investigated the effectiveness of post-plant fungicide and fertilizer treatments in reversing black root rot-related decline.

2. Materials and methods

2.1. Post-plant treatment efficacy trial

A commercial strawberry field (cv. Jewel) with typical black root rot symptoms in Hudsonville (Ottawa County), Michigan, USA, was selected for the trial. The soil type was a Granby loamy sand-lake plain soil with the top 28 cm consisting of loamy sand. The field had been established in 2005 with transplants purchased from a commercial nursery in Michigan and was showing severe decline symptoms. Preliminary tests indicated that the site had high levels of needle nematodes [*Longidorus elongatus* (de Man) Thorne & Swanger] as well as several fungal root pathogens (*Rhizoctonia, Cylindrocarpon* and *Fusarium* spp.). The trial was established on 23 May 2007 in a randomized complete block design with four replications per treatment. Each treatment plot consisted of three 3.05-m rows, spaced 1.07 m apart. All