Evaluation of TOM-CAST in Timing Fungicide Sprays for Management of *Alternaria* Blight on American Ginseng

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ABSTRACT

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Alternaria panax incites blighting of the foliage, peduncles, and drupes of cultivated American ginseng (*Panax quinquefolium*). A disease forecaster (TOM-CAST), originally developed to predict leaf blight caused by *A. solani* on tomato, was evaluated for management of *A. panax* in commercial ginseng gardens. For 3 years, fungicide sprays initiated by TOM-CAST (using 10 and 15 disease severity value thresholds) were compared with sprays applied at 7- and 10-day intervals. Three fungicide programs were evaluated: (i) chlorothalonil alone, (ii) chlorothalonil alternated with pyraclostrobin, and (iii) copper hydroxide alternated with pyraclostrobin. As many as 10 fewer fungicide applications were made when using TOM-CAST or the 10-day programs. Although select TOM-CAST treatment programs were comparable with the 7-day schedule in limiting foliar disease, only the 7-day applications adequately protected drupe and seed yield. Both *A. panax* and *A. alternata* were recovered from drupe tissues and seed coats. Only *A. alternata* was recovered from endosperm halves. Ginseng seed yield and quality is an important consideration when assessing fungicide programs.

Additional keywords: integrated pest management, reduced-risk fungicides

American ginseng (*Panax quinquefolium*) is a perennial herb grown primarily for the medicinal properties of its root (24). Currently, more than 95% of the cultivated commercial ginseng in the United States is grown in Wisconsin (1), totaling \$50 to \$75 million annually (11). Ginseng is grown on a raised plant bed under a natural tree or artificial black woven polypropylene canopy (24). The shade required by the crop and the dense plant spacing create a microclimate with limited air movement, increased temperatures, and extended leaf wetness periods that are favorable for foliar pathogens.

The most common foliar disease of ginseng is *Alternaria* blight, caused by *Alternaria panax* Whetzel (22). This disease is a yearly problem for ginseng growers in Wisconsin (22) and Michigan (11). *Alternaria* blight also occurs in other ginseng-growing regions, including Alberta, Canada (7,8), West Virginia (28), North Carolina (9), Oregon, and Washington (25). Typical foliar symptoms include necrotic lesions with dark-brown margins and yellow-green halos (22). Brown lesions often develop on the stem just above the soil line

and cause girdling (5). Infected drupes may develop a water-soaked appearance followed by the development of brown mycelium and pathogen sporulation. Infection of the root by *A. panax* is rare (22); however, root weight can be reduced when blighting of the leaves and stem causes premature defoliation.

A. panax can survive as conidia or mycelia in infected plant residue, on straw mulch, or in and on seed (16). In the spring, overwintered conidia may spread to and infect emerging healthy plants via rain splashing or air currents. Under favorable conditions, blight development and conidial production can occur in 5 to 7 days (30). Optimum conidial production occurs with temperatures ranging from 18 to 25°C (5,30). Leaf wetness parameters for *A. panax* are unknown. However, researchers have shown that conidia can germinate on leaf tissue within 1 to 2 h when incubated at 25°C and 70% relative humidity (26).

Cultural strategies to manage *Alternaria* blight include increasing plant spacing to enhance air circulation, removing infected foliage, and replacing mulch in the affected area (9). However, these strategies are not practical and would not preclude the reintroduction of inoculum via air currents. Previous researchers have investigated the use of biocontrols as alternatives to traditional fungicides. *Burkholderia cepacia* AMMD (*Pseudomonas cepacia* strain AMMD) was found to effectively inhibit *Alternaria* leaf and stem blight under growth-chamber conditions. However,

the biocontrol agent did not adequately reduce disease under field conditions due to poor survival on leaf surfaces (14,21).

Currently, the reduced-risk strobilurin fungicides azoxystrobin and pyraclostrobin are used in alternation with either chlorothalonil or mancozeb (11). Chlorothalonil and mancozeb have been available to Wisconsin and Michigan ginseng growers through yearly Section 18 Emergency Exemption labels. Iprodione is also registered for the control of *Alternaria* blight on ginseng and can be effective. However, following control failure in 1987, an iprodione-resistant *Alternaria* population was identified in Wisconsin (27) and use of this product declined.

Managing *Alternaria* blight is a priority of the ginseng industry in Michigan and Wisconsin (11). When *Alternaria* blight is not controlled, complete defoliation of ginseng can occur (12,31). Using a forecasting system to assess disease potential associated with environmental conditions may reduce the number of fungicide applications needed per season (3,4), lessen the chances for pathogens to develop fungicide resistance, and reduce grower costs. Disease-forecasting systems use weather variables (32) in conjunction with information about the biology and epidemiology of the pathogen to predict when conditions favor infection or disease development (15). TOM-CAST (developed for tomato disease forecasting) is a disease forecasting system that calculates daily disease severity values (DSVs) based on cumulative hours of leaf wetness and temperature. When the predetermined DSV threshold is reached, a fungicide is applied and the DSV is reset to zero (23). TOM-CAST has been successfully implemented to manage early blight on tomato (6,23), purple spot on asparagus (18), and foliar blights on carrot (3), and studies have shown it to be useful on crops such as parsley (19) and celery (2).

Growers have expressed interest in identifying the environmental conditions that favor blight development and testing the TOM-CAST forecasting system as a tool to assist in timing fungicide applications (10). The objective of this study was to compare the TOM-CAST disease-forecasting system with a calendar-based spray schedule using various fungicide programs for *Alternaria* blight control. The impact of these treatment programs on seed yield and health was also of interest.

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MATERIALS AND METHODS

TOM-CAST plot establishment. Field studies were conducted in a 3-year-old (2005) or 4-year-old (2006 and 2007) commercial ginseng garden located in Marathon County, WI. Each research site was 1.6 ha in area and consisted of a silt loam soil. Ginseng gardens were established from seed planted into 1.5-m-wide raised beds that were 22 to 30 cm high. After seeding, beds were covered with 15 cm of straw mulch. Each year, woven polyethylene or polypropylene cloth panels providing 80% shade were suspended via 2- to 3-m posts over the plant beds to mimic woodlot conditions. Weeds were hand pulled.

Treatment plots consisted of 1.5 by 3 m raised beds, with 0.60-m buffers on each end. Treatments were replicated four times in a randomized complete block design. Fungicides were applied with a CO₂ backpack boom sprayer equipped with four 8006 nozzles spaced 45.7 cm apart, operating at 275.8 kPa, and delivering 467.7 liter/ha.

Weather monitoring and DSV calculation. Hourly measurements of air temperature and relative humidity were recorded using a WatchDog data recorder (series 450; Spectrum Technologies, Inc., Plainfield, IL). An unpainted WatchDog leaf wetness sensor (Spectrum Technologies, Inc.) was placed at a 45° angle facing north within the upper 25% of the ginseng canopy. Data were downloaded weekly to a laptop computer using a computer program (Specware 6.01 and 7.01; Spectrum Technologies, Inc.). The program was set to record temperatures between 0 and 100°C and to detect leaf wetness whenever moisture was present on the grid. Rainfall was measured hourly using a tipping-bucket rain collector (series 3554WD, Spectrum Technologies, Inc.).

For the TOM-CAST treatments, the hours of leaf wetness and the average air temperature during the periods of leaf wetness were used to determine a daily DSV ranging from 0 to 4, corresponding to environmental conditions unfavorable to highly favorable for disease development, respectively (23). To accurately reflect the duration of a morning dew period, a 24-h monitoring period of 1100 h to 1100 h was used. Daily DSVs were accumulated until a threshold of 10 or 15 was reached, thus prompting a fungicide spray. After each fungicide application, the DSV was reset to zero for both of the TOM-CAST treatment programs.

Fungicide programs and application schedules. Fungicide programs included chlorothalonil (Bravo Weather Stik 6SC, 0.68 kg of active ingredient [a.i.]/ha; Syngenta Crop Protection, Inc., Greensboro, NC), chlorothalonil (0.68 kg a.i./ha) alternated with pyraclostrobin (Cabrio 20EG, 0.07 kg a.i./ha; BASF Ag Products Research Triangle Park, NC), and copper hydroxide (Kocide 2000 54DF, 0.73 kg a.i./ha; DuPont Crop Protection, Wilmington, DE) alternated with pyraclostrobin (0.07 kg a.i./ha). Fungicide programs were initiated on 26 May 2005, 26 May 2006, and 5 June 2007. Subsequent applications were scheduled according to a calendar-based interval of every 7 or 10 days or according to the TOM-CAST disease forecaster using 10 or 15 DSVs. Fungicide programs were terminated on 9 September 2005, 13 September 2006, and 30 August 2007.

Disease assessment. Disease was assessed by counting the number of *A. panax*-infected plants in a 3-m section of the bed on 31 August and 14 September 2005; 20 July, 3, 16, and 24 August 2006; and weekly from 3 July to 4 September

2007. Data were subjected to analysis of variance (ANOVA) and a Student-Newman-Keuls significant difference test ($P = 0.05$) was used to compare treatment efficacy (Statistical Analysis Software [SAS] 9.1.3; SAS Institute, Inc., Cary, NC) (20). The area under the disease progress curve (AUDPC) was calculated according to the methods of Shaner and Finney (29) to express the yearly cumulative numbers of infected plants throughout the seasons. The cumulative AUDPC values for each fungicide program and application interval were subjected to ANOVA and a Student-Newman-Keuls significant difference test ($P = 0.05$; SAS 9.1.3) was used to compare treatment efficacy. Treatments were also assessed for phytotoxicity.

At the completion of the 2007 TOM-CAST trial, drupes within the treatment and control plots were harvested. After recording the fresh weights for each plot, 20 drupes per replicate of each treatment and control were selected for fungal assessment. The remaining drupes were placed in 3.8-liter plastic zip bags and stored at 37°C for 2 weeks. Selected drupes were soaked in a 70% ethanol solution for 1 min and allowed to air dry in a sterile laminar flow hood. Portions of drupe tissue were aseptically excised and embedded in water agar (16 g agar/liter) plates (100 by 15 mm) amended with ampicillin (2 ml/liter) and incubated at 25°C under fluorescent lighting.

Seed of the respective drupe samples were also soaked in a 70% ethanol solution for 1 min and allowed to air dry in a sterile laminar flow hood. Following transverse sectioning, seed coat and endosperm halves were embedded in water agar and incubated as described for drupe tissues. After 48 h, all cultures were examined microscopically (×200) for identification

Table 1. Effect of fungicide programs and application schedules on the number of infected plants and the area under disease progress curve (AUDPC) values for management of *Alternaria panax* on ginseng during the 2005 to 2007 growing seasons^w

Treatments ^z	No. of applications			No. of infected plants ^x			AUDPC infected plants ^y		
	2005	2006	2007	2005	2006	2007	2005	2006	2007
Nontreated	0	0	0	60.3 b	133.5 b	183.8 c	36.0 b	55.8 b	21.3 e
7-day schedule	16	16	12						
Chlorothalonil	...	...	...	0.0 a	7.8 a	33.0 a	0.0 a	1.7 a	2.1 ab
Chlorothalonil/pyraclostrobin	...	...	...	0.0 a	1.8 a	11.5 a	0.0 a	0.4 a	1.1 a
Copper hydroxide/pyraclostrobin	...	...	...	0.0 a	0.8 a	19.8 a	0.0 a	0.2 a	1.6 a
10-day schedule	10	12	8						
Chlorothalonil	...	...	...	0.0 a	9.0 a	134.3 ab	0.0 a	2.3 a	8.8 abcd
Chlorothalonil/pyraclostrobin	...	...	...	0.0 a	2.3 a	120.0 ab	0.0 a	0.5 a	6.7 abc
Copper hydroxide/pyraclostrobin	...	...	...	0.5 a	7.0 a	191.5 c	0.6 a	2.0 a	9.9 bcd
TOM-CAST 10 DSV schedule	10	7	4						
Chlorothalonil	...	...	...	0.0 a	42.3 a	170.5 c	0.0 a	11.5 a	13.7 cd
Chlorothalonil/pyraclostrobin	...	...	...	0.0 a	6.5 a	42.5 a	0.0 a	1.6 a	4.1 ab
Copper hydroxide/pyraclostrobin	...	...	...	0.0 a	10.5 a	79.3 ab	0.0 a	2.8 a	7.0 abc
TOM-CAST 15 DSV schedule	6	5	3						
Chlorothalonil	...	...	...	0.0 a	26.5 a	175.0 c	0.0 a	9.2 a	13.6 cd
Chlorothalonil/pyraclostrobin	...	...	...	0.0 a	21.0 a	80.3 ab	0.0 a	5.1 a	6.4 abc
Copper hydroxide/pyraclostrobin	...	...	...	0.0 a	38.5 a	184.8 c	0.0 a	10.5 a	15.4 d

^w Column means followed by the same letter are not significantly different (Student-Newman-Keuls, $P = 0.05$).

^x Mean number of *A. panax*-infected plants per 3 m of treated garden section on the final rating date.

^y Mean AUPDC values per 3 m of treated garden section on the final rating date.

^z Chlorothalonil was applied at 0.68 kg a.i./ha, pyraclostrobin at 0.07 kg a.i./ha, and copper hydroxide at 0.73 kg a.i./ha. DSV = disease severity value.

of fungi. *Alternaria* spp. were identified as *A. alternata* according to Lagopodi and Thanassouloupoulos (17) (average conidium, 30.4 by 11.1 μm) or as *A. panax* according to Brammall (5) (average conidium, 150 to 160 by 12 to 20 μm). The percentage of *Alternaria* spp. isolated from both drupe and seed tissues were subjected to ANOVA and a Student-Newman-Keuls significant difference test as previously described.

Following cold storage, the remaining drupes were macerated by hand and the seeds removed. Seeds were soaked for 5 min in a 10% bleach solution, triple rinsed with distilled water, and allowed to air dry before weighing. Seed and drupe weights were also statistically analyzed.

RESULTS

Evaluation of fungicide programs and spray schedules with TOM-CAST. The 7-day schedule resulted in 16 sprays in 2005 and 2006 and 12 sprays in 2007. The 10-day schedule resulted in 10 (2005), 12 (2006), and 8 (2007) applications. The TOM-CAST 10 DSV schedule prompted 10, 7, and 4 applications and the 15 DSV schedule prompted 6, 5, and 3 fungicide applications in 2005 (89 total DSVs), 2006 (83 total DSVs), and 2007 (57 total DSVs), respectively.

In each year of the study, *Alternaria* blight resulted in premature defoliation and death of nontreated plants. In 2005 and 2006, all fungicide programs were similar and limited foliar blight compared with the nontreated control (Table 1; Fig. 1). Similar results were seen for 2005 and 2006 AUDPC data (Table 1). In 2007, disease pressure was greater. The 7-day schedule, regardless of fungicide program, significantly limited numbers of infected plants compared with the nontreated control (Fig. 1; Table 1). Across all years tested, the following treatment programs were similar to the 7-day treatments in numbers of plants infected: chlorothalonil applied every 10 days, chlorothalonil/pyraclostrobin applied every 10-days and according to TOM-CAST 10 DSV and 15 DSV schedules, and copper hydroxide/pyraclostrobin applied according to TOM-CAST 10 DSV (Table 1). However, according to the AUDPC data, only chlorothalonil/pyraclostrobin applied every 10 days or according to TOM-CAST 10 and 15 DSV schedules and copper hydroxide/pyraclostrobin applied according to TOM-CAST 10 DSV provided consistent season-long protection similar to the 7-day schedules (Table 1). Phytotoxicity was not observed with any of the treatments.

Regardless of the fungicide program, the fresh weights of the drupes were significantly higher for treatments sprayed every 7 days compared with all other treatments and the nontreated control (Table 2). The seed weight was significantly greater for the treatments applied every 7 days, re-

gardless of fungicide program, when compared with the nontreated control. The weight of the seed from plots treated with chlorothalonil/pyraclostrobin every 10 days or according to TOM-CAST 10 and 15 DSV schedules was similar to that resulting from the 7-day schedule (Table 2) but was not significantly different from the nontreated control. Similarly, copper hydroxide/pyraclostrobin applied every 10 days or according to TOM-CAST 10 DSV resulted in seed weight similar to the 7-day schedule but was not significantly different than the nontreated control.

After the drupe tissue was incubated for 48 h, *A. alternata* and *A. panax* were iso-

lated from all treatments (Table 3). Only copper hydroxide/pyraclostrobin applied to plants every 10 days significantly reduced the incidence of *A. panax* on drupes and seed coats compared with the nontreated control. *A. panax* was not detected on any of the seed endosperms, regardless of treatment (*data not shown*). *A. alternata* was commonly found on the drupe, seed coat, and endosperm tissue. Only a 7-day treatment of chlorothalonil alternated with pyraclostrobin significantly reduced the occurrence of *A. alternata* on the drupe and seed coat compared with the nontreated and all other treatments.

Fig. 1. Disease progress curves for *Alternaria panax* infection of 4-year-old ginseng plants not treated or treated with the fungicide chlorothalonil (0.68 kg a.i./ha), chlorothalonil (0.68 kg a.i./ha) alternated with pyraclostrobin (0.07 kg a.i./ha), or copper hydroxide (0.73 kg a.i./ha) alternated with pyraclostrobin (0.07 kg a.i./ha). Fungicide programs were scheduled during the 2006 growing season every **A**, 7 or **B**, 10 days; or according to the TOM-CAST disease forecaster using disease severity values (DSVs) of **C**, 10 or **D**, 15 DSV. Fungicide programs were scheduled during the 2007 growing season every **E**, 7 or **F**, 10 days; or according to the TOM-CAST disease forecaster using **G**, 10 or **H**, 15 DSV.

DISCUSSION

Alternaria leaf blight on ginseng is especially destructive, causing rapid defoliation and plant death when left nontreated. Without effective control measures, growers risk reduced root yields or losing entire plantings (5). Wisconsin and Michigan ginseng growers currently rely on fungicides to manage *Alternaria* blight during the relatively long growing season of May through September. Ginseng growers must apply fungicide sprays judiciously to protect the crop while complying with the labeled seasonal application limits.

Optimizing fungicide applications by using a disease forecaster with reduced-risk fungicides may offer an integrated pest management (IPM) strategy suitable for ginseng production. A conservative threshold (10 DSV) of TOM-CAST used with an alternating program of chlorothalonil and pyraclostrobin provided control equivalent to 7-day applications. Under moderate disease pressure, fungicides applied according to TOM-CAST 10 or 15 DSVs adequately protected the crop foliage. In 2007, DSVs did not accumulate quickly and fewer fungicide treatments

were prompted. Some of the TOM-CAST programs that included pyraclostrobin provided control similar to the 7-day programs. Initial inoculum levels in 2007 may have been higher than in 2005 and 2006, increasing disease pressure.

Although TOM-CAST 15 DSV is a practical and economical alternative to calendar-based applications in asparagus (18), carrot (3), and tomato (6), high-value crops such as celery and ginseng pose unique challenges. Carrot plants can tolerate some *Alternaria* leaf blight and *Cercospora* leaf spot (caused by *A. dauci* and *Cercospora carotae*, respectively) as long as they can withstand the mechanical harvesting which pulls the roots from the ground (3). Also, these foliar pathogens do not typically defoliate the crop as rapidly as observed with *A. panax* on ginseng. Similarly, purple spot of asparagus (incited by *Stemphylium vesicarium*) causes premature browning and defoliation of the photosynthetic tissue but consecutive years of premature defoliation is required before yield is reduced (18). Carrot and asparagus are valued at \$3,424 and \$2,420/ha, respectively (2), whereas celery and ginseng root average \$20,431/ha (2) and \$13,930/ha (11), respectively. There is no tolerance for late blight on celery incited by *S. apiicola* because the marketable portion of the celery is affected and consumers demand unblemished product (2). Similarly, *A. panax* cannot be tolerated in a ginseng crop because of its ability to rapidly blight and defoliate the crop, negatively affecting root and seed yield.

Ginseng seed yield and quality is an important consideration when assessing fungicide programs. Current market prices for stratified seed are \$55/kg. With an average seed yield of 336.3 kg/ha, each hectare

Table 2. Effects of fungicide programs and application schedule in management of *Alternaria panax* on drupe and seed weight in 2007

Treatments ^z	Fresh weight (g) ^y	
	Drupe	Seed
Nontreated	25.7 b	11.1 b
7-day schedule		
Chlorothalonil	515.4 a	118.7 a
Chlorothalonil/pyraclostrobin	618.6 a	143.7 a
Copper hydroxide/pyraclostrobin	602.9 a	142.9 a
10-day schedule		
Chlorothalonil	67.1 b	21.1 b
Chlorothalonil/pyraclostrobin	177.1 b	53.9 ab
Copper hydroxide/pyraclostrobin	176.7 b	53.8 ab
TOM-CAST 10 DSV schedule		
Chlorothalonil	47.9 b	20.4 b
Chlorothalonil/pyraclostrobin	243.1 b	62.3 ab
Copper hydroxide/pyraclostrobin	188.6 b	54.9 ab
TOM-CAST 15 DSV schedule		
Chlorothalonil	44.2 b	16.4 b
Chlorothalonil/pyraclostrobin	272.2 b	75.6 ab
Copper hydroxide/pyraclostrobin	33.1 b	13.9 b

^y Column means followed by the same letter are not significantly different (Student-Newman-Keuls, $P = 0.05$).

^z Number of fungicide applications scheduled according to timing intervals of 7 days = 16 (2005 and 2006) and 12 (2007); 10 days = 10 (2005), 12 (2006), and 8 (2007); 10 disease severity value (DSV) = 10 (2005), 7 (2006), and 4 (2007); and 15 DSV = 6 (2005), 5 (2006), and 3 (2007). Chlorothalonil was applied at 0.68 kg a.i./ha, pyraclostrobin at 0.07 kg a.i./ha, and copper hydroxide at 0.73 kg a.i./ha.

Table 3. Effect of fungicide programs and application schedules on recovery of *Alternaria* spp. from drupe, seed coat, and endosperm tissues in 2007

Treatments ^z	<i>Alternaria</i> spp. recovered ^y				
	<i>A. panax</i>		<i>A. alternata</i>		
	Drupe	Coat	Drupe	Coat	Endosperm
Nontreated	100.0 b	100.0 b	100.0 b	100.0 d	67.0 a
7-day schedule					
Chlorothalonil	60.0 ab	60.0 ab	18.0 b	17.5 bcd	11.0 ab
Chlorothalonil/pyraclostrobin	45.0 ab	45.0 ab	7.8 a	3.0 a	5.0 ab
Copper hydroxide/pyraclostrobin	55.0 ab	55.0 ab	14.0 b	10.0 bc	14.0 ab
10-day schedule					
Chlorothalonil	70.0 ab	70.0 ab	80.0 b	45.0 b	65.0 ab
Chlorothalonil/pyraclostrobin	75.0 ab	75.0 ab	70.0 b	87.5 bcd	50.0 ab
Copper hydroxide/pyraclostrobin	40.0 a	40.0 a	100.0 b	70.0 bcd	39.0 ab
TOM-CAST 10 DSV schedule					
Chlorothalonil	70.0 ab	70.0 ab	84.0 b	65.0 bcd	37.5 ab
Chlorothalonil/pyraclostrobin	97.5 b	97.5 b	100.0 b	100.0 d	85.0 b
Copper hydroxide/pyraclostrobin	52.5 ab	52.5 ab	100.0 b	100.0 d	67.5 ab
TOM-CAST 15 DSV schedule					
Chlorothalonil	100.0 b	100.0 b	100.0 b	94.0 cd	37.5 ab
Chlorothalonil/pyraclostrobin	100.0 b	100.0 b	100.0 b	84.0 bcd	41.3 ab
Copper hydroxide/pyraclostrobin	100.0 b	100.0 b	100.0 b	100.0 d	40.0 ab

^y Percentage of infected seeds per 3 m of treated garden section. Column means followed by the same letter are not significantly different (Student-Newman-Keuls, $P = 0.05$).

^z Number of fungicide applications scheduled according to timing intervals of 7 days = 16 (2005 and 2006) and 12 (2007); 10 days = 10 (2005), 12 (2006), and 8 (2007); 10 disease severity value (DSV) = 10 (2005), 7 (2006), and 4 (2007); and 15 DSV = 6 (2005), 5 (2006), and 3 (2007). Chlorothalonil was applied at 0.68 kg a.i./ha, pyraclostrobin at 0.07 kg a.i./ha, and copper hydroxide at 0.73 kg a.i./ha.

represents a value of \$18,537. Even when fungicide programs were adequate, seed yield and quality was not always acceptable. Sprays according to TOM-CAST 10 or 15 DSV or every 10 days resulted in reduced seed weights compared with spraying every 7 days. Future research will test a hybrid program whereby TOM-CAST 10 DSV with chlorothalonil and pyraclostrobin is used from plant emergence to flowering (mid- to late June), after which fungicides are applied every 7 days to protect developing seed from becoming infected by *A. panax* inoculum. As ginseng growers harvest their own seed for planting and to sell to other growers, therefore, the potential seed dissemination of *Alternaria* is an important component of overall disease management and must be addressed for an IPM program to be successful. In our studies, *A. panax* was prevalent on the ginseng drupe and seed coat. Although *A. panax* was not isolated from the endosperm in this study, previous seed samples from ginseng growers submitted for diagnosis have often yielded this pathogen from the endosperm tissue (13).

In addition to *A. panax*, *A. alternata* was recovered from ginseng seed. *A. alternata* is often encountered on other ginseng tissue, including stem and leaves submitted for diagnostic evaluation (S. N. Hill, unpublished data). The impact of *A. alternata* associated with seed tissues on viability and crop health is unknown.

Considering the chemical control measures needed to maintain commercial ginseng gardens, continued efforts to explore methods to reduce sprays without risking crop health are desirable. Alternating applications of fungicides with different modes of action is critical due to restrictions on numbers of applications or amounts of fungicides per season and to delay development of resistance in the pathogen. In our study, alternating chlorothalonil with pyraclostrobin provided protection of the foliage and seed. Because all fungicide programs tested in our project exceeded seasonal label allowances, growers must incorporate additional labeled fungicides (i.e., mancozeb or boscalid) into their management programs. Although these products were not included in this study, field studies have been conducted that tested these fungicides against *Alternaria* and indicated that mancozeb and boscalid would be helpful (12).

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