Optimal Fungicide Management of Purple Spot of Asparagus and Impact on Yield

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ABSTRACT

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Purple spot disease of asparagus, caused by the fungus *Stemphylium vesicarium*, results in lesions on spears and ferns and defoliation of ferns. In two newly established commercial asparagus fields (cvs. Jersey Giant and Jersey Knight), chlorothalonil or mancozeb was applied every 7, 10, or 14 days or according to Tom-Cast with a threshold of 15 disease severity values, and not applied to the control. Tom-Cast prompted four sprays, resulting in a 60% reduction in the number of fungicide applications when compared with the 7-day-interval treatment. When disease pressure was severe, lesions on ferns were significantly less for both cultivars when fungicides were applied according to Tom-Cast or every 7 days compared with spray intervals of 10 or 14 days. Applying fungicides according to Tom-Cast or every 7 days resulted in an increased Jersey Giant fern stand compared with applying fungicides every 10 or 14 days. Unsprayed control plots yielded 77 to 83% (depending on cultivar) of those plots treated according to Tom-Cast using chlorothalonil. Significantly higher yields of Jersey Knight were obtained for chlorothalonil versus mancozeb. When mancozeb was used, Jersey Knight yield was significantly increased with a 7-day versus Tom-Cast application regime. Using chlorothalonil in a Tom-Cast program provided a benefit per hectare (BPH) of \$1,005.24 (Jersey Knight) to \$2,057.69 (Jersey Giant). In comparison, using mancozeb in a Tom-Cast program provided a BPH of -\$484.27 (Jersey Knight) to \$1,030.55 (Jersey Giant) over a 2-year period.

Additional keywords: disease forecaster

Purple spot on asparagus spears and ferns is caused by the fungus *Stemphylium vesicarium* (Wallr.) E. Simmons (teleomorph *Pleospora herbarum*) and has become a significant problem for asparagus production in Michigan. *S. vesicarium* also affects asparagus in California (6), Washington (9,10), and New Zealand (5). Purplish lesions can occur on harvested spears and during epidemic years may occur on 60 to 90% of the spears (8). Purple spot lesions may also develop on the asparagus ferns, affecting the main stem, secondary branches, and cladophylls, and may result in premature defoliation. Although *S. vesicarium* has been known to infect asparagus spears for several years (12), only recently has it been considered a major defoliator of asparagus fern in Michigan. The emergence of this disease may be due to the adoption of a no-till cultural system whereby the dried fern from the previous growing season is chopped in April and left on the soil surface. This residue persists through the harvest season (mid-June) and is visible through the fern growth pe-

riod (late June to September). The teleomorph of *S. vesicarium* is considered to be the primary overwintering structure and was found by Evans and Stephens (4) in Michigan on the surface of asparagus debris.

Ethylenebisdithiocarbamate (EBDC) fungicides are registered for use on asparagus fern to control foliar fungal diseases. Since some processors refuse to buy asparagus spears if EBDC fungicides have been used on fern the previous growing season, Michigan has obtained a yearly Section 18 Specific Exemption Supplemental Labeling for State Emergency since 1990 for the use of chlorothalonil to control purple spot on asparagus fern. Growers apply fungicide after the last spears are harvested using calendar-based fungicide spray schedules. Due to the sporadic nature of disease occurrence, fungicide cost, and lack of control with some fungicide spray programs, it was desirable to explore the possibility of applying fungicides according to a disease forecaster.

A disease forecasting system (FAST), originally developed to help time fungicide sprays for *Alternaria solani* on tomato (13), has been used successfully to time fungicides sprays for controlling *S. vesicarium* on pear (14). FAST utilizes hours of leaf wetness and the average temperature during wetness periods, mean air temperature, hours of relative humidity greater than 90%, and total rainfall (13). When

used to manage *S. vesicarium* on pear, FAST resulted in disease control comparable to the 7-day application schedule with a reduction in fungicide sprays of 28 to 38% (14). Tom-Cast, a disease forecasting system derived from FAST (15), appeared promising in a preliminary field trial to determine its applicability in managing purple spot disease on asparagus (M. K. Hausbeck, unpublished data).

The objective of this research was to assess the impact of purple spot on asparagus yield and to develop a viable and economical management program using fungicides applied according to conventional schedules or according to Tom-Cast.

MATERIALS AND METHODS

Evaluation of Tom-Cast and calendar-based programs using chlorothalonil and mancozeb in a newly established asparagus field. Two-year-old crowns of Jersey Giant and Jersey Knight were established in Benona sand in a plot contained within a 16.1-ha commercial asparagus field in Oceana County, Michigan, in 1995. The cultivars were spaced 0.4 km apart. Crowns were spaced 22.9 cm apart within the rows with 1.5-m spacing between rows. The experimental design for each cultivar was a randomized complete block with four 92.9-m blocks containing nine treatments randomly assigned within each block. Each treatment was contained within 7.6-m row sections in the blocks with two unsprayed buffer rows between the single treatment rows and 3.1-m unsprayed buffers between treatments within the rows. The fungicides chlorothalonil (Bravo Weather Stik at 1.7 kg a.i./ha, Zeneca Ag Products, Wilmington, DE) and mancozeb (Penncozeb 75DF at 1.7 kg a.i./ha, Elf Atochem, Philadelphia, PA) were applied with a CO₂ backpack sprayer operated at 40 psi through three D345 hollow-cone nozzles spaced 45.8 cm apart and calibrated to deliver 373.0 liters/ha.

Calendar-based sprays were initiated following the last harvest when the plants produced secondary branching and the cladophylls were beginning to emerge (3 July 1996, 30 June 1997). The first Tom-Cast spray was applied with the accumulation of 15 disease severity values (DSVs) following fern emergence. Subsequent sprays were applied after the accumulation of 15 DSVs since the last fungicide application. The Tom-Cast program uses the duration of leaf wetness and the average air temperature during the wetness period for

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each 24-h period (11:00 A.M. to 11:00 A.M.) to determine a DSV of 0 to 4, corresponding to an environment unfavorable to highly favorable for early blight (causal agent *A. solani*) development (15). Mancozeb or chlorothalonil treatments were applied at 7-day intervals (1996, 10 sprays; 1997, 8 sprays), 10-day intervals (1996, 7 sprays; 1997, 6 sprays), 14-day intervals (1996, 5 sprays; 1997, 4 sprays), or applied according to Tom-Cast with a threshold of 15 DSVs (1996, 4 sprays; 1997, 4 sprays).

Hourly averages of leaf wetness and temperature data were collected with a digital recorder (OmniData DP223; OmniData International, Inc., Logan, UT). The digital recorder was located approximately 400 m from the Jersey Knight experimental plot and approximately 565 m from the Jersey Giant experimental plot. Two leaf wetness sensors per site were coated with colored paint and placed approximately 61 cm above the ground, below the fern canopy, at a 45° angle facing north.

Yield and assessment of disease on spears in a newly established asparagus field. Spears were hand-harvested 13 times in 1997 (23 May to 21 June) and 21 times in 1998 (4 May to 15 June). Yield was measured by weight, and disease was assessed using the following ranking: 1 = no symptoms; 2 = 1 to 20 lesions on each spear; 3 = 21 to 50 lesions on each spear; 4 = 51 to 90 lesions on each spear; 5 = more

than 90 lesions on each spear. A disease severity index (DSI) was calculated for each harvest by modifying the formula of Sherwood and Hagadorn (16): $DSI = \Sigma(\text{disease class} \times \text{no. of spears in that class}) / 100 / (\text{total no. of spears} \times 5)$.

The overall effect of the different treatments was examined by combining spear yields from 1997 and 1998. Yield data were analyzed using an analysis of a randomized complete block design. The treatments were subsequently compared using the following orthogonal contrasts: (i) untreated control compared with any treatment receiving a spray; (ii) chlorothalonil contrasted with mancozeb; (iii) Tom-Cast contrasted with the 7-day schedule; (iv) Tom-Cast and 7-day schedules compared with the 10- and 14-day schedules; (v) 10-day schedule contrasted with the 14-day schedule; (vi) difference between Tom-Cast and 7-day schedules compared between chlorothalonil and mancozeb (fungicides); (vii) difference between Tom-Cast and 7-day schedule, and 10- and 14-day schedules contrasted between fungicides; and (viii) difference between 10- and 14-day schedules contrasted between fungicides. Contrasts (ii) through (v) examine the main effects of spraying schedules, irrespective of fungicides. Contrasts (vi) through (viii) examine the interaction between spraying schedule and fungicide. These contrasts were used for means separation

since contrasts provide for a complete and independent explanation for the differences in means between treatments and include all of the information in the data set (17). Treatment effects on disease severity were tested for 1997 and 1998 using an analysis of variance of a randomized complete block design with DSI as the dependent variable.

Assessment of disease on ferns in a newly established asparagus field. On 13 September 1996 and 15 September 1997, four ferns were harvested randomly from every plot in each treatment within each cultivar, and the total number of purple spot lesions was counted. Treatment effects on lesion numbers from 1996 and 1997 were tested using an analysis of variance of a randomized complete block design. Treatments were subsequently compared using the orthogonal contrasts described previously. The data in the 1996 analysis of treatment effects on lesion number were not normally distributed and were transformed to normality as: $Y = \sqrt{(\text{lesion number} + 1)}$. The 1997 data also were not normally distributed and were normalized as: $Y = \log(\text{lesion number} + 1)$.

Impact of treatments on fern stand in a newly established asparagus field. In July 1998, the number of ferns within each treatment was counted and placed into one of the following three categories based on stem diameter measured 9 cm from the

Table 1. Number of purple spot lesions and summary of contrast results comparing treatments on Jersey Knight and Jersey Giant fern from newly established fields when not treated or treated with chlorothalonil or mancozeb according to a calendar schedule or according to the Tom-Cast disease predictor during 1996 and 1997

Treatment/spray interval (days)	Average number of purple spot lesions/fern					
	Number of applications		Jersey Knight		Jersey Giant	
	1996	1997	1996	1997	1996	1997
Untreated	...	...	4,573	15,643	3,631	15,254
Mancozeb ² /7 day	10	8	685	778	142	486
Mancozeb/10 day	7	6	572	2,989	203	3,356
Mancozeb/14 day	5	4	517	6,807	549	2,213
Mancozeb/Tom-Cast	4	4	537	1,232	1,375	2,279
Chlorothalonil ² /7 day	10	8	102	401	56	166
Chlorothalonil/10 day	7	6	426	1,191	472	535
Chlorothalonil/14 day	5	4	323	3,882	312	1,993
Chlorothalonil/Tom-Cast	4	4	218	605	248	718
			1996		1997	
<i>Jersey Knight contrast</i>			<i>F value</i>	<i>P value</i>	<i>F value</i>	<i>P value</i>
Untreated vs. all treatments			63.70	0.0001*	67.30	0.0001*
Chlorothalonil vs. mancozeb			3.80	0.0642	19.60	0.0002*
Tom-Cast vs. 7 day			0.20	0.6351	1.30	0.2600
Tom-Cast/7 vs. 10/14 day			0.40	0.5122	69.20	0.0001*
10 vs. 14 day			0.03	0.8650	9.00	0.0062*
Fungicide*(Tom-Cast vs. 7 day) interaction			0.20	0.7042	0.01	0.9179
Fungicide*(Tom-Cast/7 vs. 10/14 day) interaction			0.97	0.3343	0.01	0.9130
Fungicide*(10 vs. 14 day) interaction			0.02	0.8947	0.01	0.9380
<i>Jersey Giant contrast</i>						
Untreated vs. all treatments			302.60	0.0001*	120.60	0.0001*
Chlorothalonil vs. mancozeb			3.80	0.0653	43.80	0.0001*
Tom-Cast vs. 7 day			10.50	0.0036*	43.70	0.0001*
Tom-Cast/7 vs. 10/14 day			0.03	0.8701	20.30	0.0001*
10 vs. 14 day			0.20	0.6622	0.50	0.4863
Fungicide*(Tom-Cast vs. 7 day) interaction			2.60	0.1177	0.06	0.8084
Fungicide*(Tom-Cast/7 vs. 10/14 day) interaction			2.10	0.1643	0.60	0.4546
Fungicide*(10 vs. 14 day) interaction			1.40	0.2457	2.60	0.1192

² Applied at a rate of 1.7 kg a.i./ha.

base: small (<7.9 mm), medium (7.9 mm), and large (>7.9 mm). These categories were based on harvest standards set for minimum spear diameter of 7.9 mm.

Economic benefit of fungicide programs in a newly established asparagus field. Benefit assessments were determined for a processing crop value of \$1.36/kg. The yield from the unsprayed plot was subtracted from the yield obtained from treated plots to determine the crop value of the management programs. The total cost (TCOST) of each fungicide program was calculated by multiplying the number of applications during 1996 and 1997 by cost (\$12.60/ha per application of mancozeb and \$32.38/ha per application of chlorothalonil). The fungicide benefit per hectare (BPH) of the crop was determined by subtracting TCOST from the crop value for 1997 and 1998. The return per fungicide dollar (RPF) was calculated by dividing the BPH by the season-long fungicide cost (TCOST) to identify programs using fungicide dollars most efficiently.

Evaluation of Tom-Cast DSV thresholds using chlorothalonil in a mature asparagus field. Twelve-year-old asparagus cv. Viking KB3 established in Benona sand in a plot contained within a 16.1-ha commercial asparagus field in Oceana County, Michigan, was used during the 1996 and 1997 study. Crowns were spaced 30.5 cm apart within rows with 1.5-m spacing between rows. The experimental design was a randomized incomplete block with eight blocks containing two treatment plots randomly assigned within each block and separated by an unsprayed buffer plot of the same size as the treatment plots. Blocks 6.1 m long were separated by an unsprayed buffer row. Treatments consisted of single rows that were untreated, or treated with chlorothalonil (Bravo at 1.7

kg a.i./ha) at 7-day intervals or according to Tom-Cast with a threshold of 12 or 15 DSVs. Each block was staggered 3.8 m from the previous block. Fungicide applications were made as previously described. Calendar-based sprays were initiated when the plants produced secondary branches and the cladophylls were beginning to emerge (17 July 1996, 30 June 1997). Hourly averages of leaf wetness and temperature data were collected as previously described, with the leaf wetness and temperature sensors located in a buffer row and placed approximately 61 cm above the ground.

Assessment of disease on ferns in a mature asparagus field. Four ferns were selected randomly from each treatment plot and were harvested on 10 September 1996 and 8 September 1997. The total number of purple spot lesions was counted on each fern for each treatment. Treatment effects on fern were tested using an analysis of variance of a randomized incomplete block design. Treatments were subsequently compared using the following contrasts: (i) untreated control compared with any treatment receiving a spray; (ii) Tom-Cast compared with the 7-day schedule; and (iii) Tom-Cast 12 DSVs compared with Tom-Cast 15 DSVs.

RESULTS

Assessment of purple spot on ferns in a newly established asparagus field. In 1996, the number of purple spot lesions ranged from 4,573 to 3,631 per untreated fern for Jersey Knight and Jersey Giant, respectively (Table 1). Disease pressure in 1997 was severe, with 15,643 lesions per unsprayed Jersey Knight fern and 15,254 lesions per unsprayed Jersey Giant fern. Using Tom-Cast eliminated a minimum of six and three sprays in 1996, and four and

two sprays in 1997, compared with a weekly or 10-day application regime, respectively (Table 1). In 1997, the 14-day application regime and Tom-Cast required the same number of sprays, whereas one spray was eliminated in 1996 when Tom-Cast was used versus the 14-day program. The efficacy of the treatment programs differed significantly, so orthogonal contrasts were utilized as a multiple comparison test. All fungicide treatments effectively limited the number of purple spot lesions on Jersey Giant and Jersey Knight ferns compared with the untreated controls in each year (Table 1). Chlorothalonil was more effective than mancozeb in limiting purple spot lesions on Jersey Giant and Jersey Knight ferns when disease was severe in 1997. In 1997, the 7-day application regime and Tom-Cast significantly limited disease on Jersey Giant and Jersey Knight ferns versus the 10- and 14-day application regimes. The 10-day application regime significantly limited disease on Jersey Knight ferns versus the 14-day application regime in 1997 (Table 1). In both years of the study, the 7-day application regime was significantly better in limiting disease on Jersey Giant ferns versus Tom-Cast (Table 1).

Yield and purple spot severity on spears in a newly established asparagus field. Spear yields were combined for 1997 and 1998 to allow accumulation of differences that may not be significant in any one year (Table 2). Treatments of Jersey Knight differed significantly, so orthogonal contrasts were utilized as a multiple comparison test (Table 2). The combined 1997 and 1998 Jersey Knight yield was significantly higher when asparagus ferns were protected yearly from purple spot using chlorothalonil rather than mancozeb (Table 2). When mancozeb was used, the 7-day application schedule resulted in a significantly higher yield than the Tom-Cast regime. Incidence and severity of purple spot on spears were not significantly influenced by treatment in either year for either cultivar but were affected by harvest date (data not shown).

Impact of treatments on fern stand in a newly established asparagus field. The total number of ferns and the number of large ferns in 1998 differed significantly among treatments, so orthogonal contrasts were utilized as a multiple comparison test. When Jersey Giant plots were left unsprayed, there were significantly fewer ferns overall and fewer large ferns compared with the treated plots (Table 3). Chlorothalonil treatment produced more ferns and more large ferns than mancozeb treatment. Although applying fungicides every 7 days or according to Tom-Cast resulted in more ferns than applying fungicides every 10 or 14 days, the number of large ferns was not affected. The total number of Jersey Knight ferns per plot and the number of large ferns per

Table 2. Average weight (g) of spears combined for 1997 and 1998 in a newly established Jersey Knight and Jersey Giant field and summary of contrast results comparing treatments for Jersey Knight when the previous season's fern was not treated or treated with chlorothalonil or mancozeb according to a calendar schedule or according to the Tom-Cast disease predictor

Treatment/spray interval (days)	Spear weight (g)/harvest/6.1 m	
	Jersey Knight	Jersey Giant
Untreated	4,428.6	5,107.1
Mancozeb ² /7 day	5,509.9	6,282.7
Mancozeb/10 day	4,544.5	5,920.4
Mancozeb/14 day	5,046.3	6,194.9
Mancozeb/Tom-Cast	4,191.8	5,861.3
Chlorothalonil ² /7 day	5,015.1	6,961.9
Chlorothalonil/10 day	5,815.8	6,456.1
Chlorothalonil/14 day	5,179.4	6,846.3
Chlorothalonil/Tom-Cast	5,352.2	6,643.2
<i>Jersey Knight contrast</i>	<i>F value</i>	<i>P value</i>
Untreated vs. all treatments	3.95	0.0583
Chlorothalonil vs. mancozeb	5.58	0.0266*
Tom-Cast vs. 7-day	2.51	0.1265
Tom-Cast/7 vs. 10/14 day	0.35	0.5607
10 vs. 14 day	0.05	0.8300
Fungicide*(Tom-Cast vs. 7 day) interaction	7.14	0.0134*
Fungicide*(Tom-Cast/7 vs. 10/14 day) interaction	0.71	0.4075
Fungicide*(10 vs. 14 day) interaction	3.37	0.0787

² Applied at 1.7 kg a.i./ha.

plot did not differ significantly among the treatments.

Economic benefit of management programs. Jersey Giant responded especially well to purple spot control with an overall larger BPH (\$963.24 to \$2,344.82) than that seen with Jersey Knight (−\$484.27 to \$1,562.03) (Table 4). Although mancozeb applied to Jersey Giant ferns offered the greatest RPFDP in this study, the largest BPH was achieved using chlorothalonil-based treatment regimes (Table 4). When Jersey Giant ferns were treated with chlorothalonil, the BPH ranged from \$1,601.63 to \$2,344.82, whereas mancozeb treatment yielded a \$963.24 to \$1,589.55 BPH.

When Jersey Knight ferns were treated, chlorothalonil use resulted in a BPH that was overall higher (\$214.32 to \$1,562.03) than that observed when mancozeb was used (−\$484.27 to \$1,360.81) (Table 4). Applying mancozeb to Jersey Knight ferns according to Tom-Cast resulted in a negative BPH (−\$484.27) and RPFDP (−\$4.80), whereas using chlorothalonil resulted in a BPH of \$1,005.24 and the highest RPFDP (\$3.88) among the chlorothalonil spray regimes.

Disease assessment on ferns in a mature asparagus field. All treatments effectively limited purple spot disease to <100 lesions per fern compared with the controls, which had 388 (1996) or 2,358 (1997) lesions per fern (Table 5). Using Tom-Cast eliminated a minimum of five sprays (DSVs = 12) or six sprays (DSVs = 15) compared with the 7-day application regime. There were significant differences among the treatments, so orthogonal contrasts were utilized as a multiple comparison test. In both years, any treatments that received fungicide sprays had significantly

fewer lesions than the untreated control (Table 5). In 1996, Tom-Cast treatments provided significantly less disease control than the 7-day spray schedule, although the Tom-Cast 12 and 15 DSVs treatments did not differ significantly from each other.

DISCUSSION

Since purple spot severity can vary widely among years, growers have been reluctant to apply fungicides to asparagus fern on a preventive basis, especially in light of overall increasing production costs. With the emergence of purple spot as a yearly threat to fern health, it has become necessary to understand the potential impact of this disease on yield and to develop a viable and economical management program.

A 14- to 21-day interval is most commonly used for fungicide applications among growers, even though control is not always attained with this program. Spray intervals for weather-based systems such as Tom-Cast vary according to environ-

mental conditions; i.e., longer intervals will occur during periods that do not favor disease development. While the number of Tom-Cast-prompted sprays was comparable to the 14-day-interval treatment, disease control was significantly better with the Tom-Cast regime. In our study, when disease was severe, purple spot lesions on fern were significantly less for both cultivars when fungicides were applied according to Tom-Cast or every 7 days compared with spray intervals of 10 to 14 days. Applying fungicides every 7 days or according to Tom-Cast resulted in an increased Jersey Giant fern stand compared with applying fungicides every 10 or 14 days. Although weekly chlorothalonil sprays were more effective than Tom-Cast in limiting the number of leaf lesions on Jersey Giant fern, the current Section 18 chlorothalonil label allows a maximum of six applications, whereas 8 to 10 weekly applications are often necessary to keep the fern protected for the duration of the growing season. In contrast, Tom-Cast

Table 4. Benefit per hectare (BPH) and return per fungicide dollar (RPFDP) of foliar fungicide application schedules to control purple spot in asparagus used for processing in 1997 and 1998

Treatment/spray interval (days)	Jersey Knight		Jersey Giant	
	BPH ^x (\$)	RPFDP ^y (\$)	BPH (\$)	RPFDP (\$)
Mancozeb/7 day	1,360.81	6.00	1,589.55	7.01
Mancozeb/10 day	−17.57 ^z	−0.11	963.24	5.88
Mancozeb/14 day	796.63	7.02	1,535.35	13.54
Mancozeb/Tom-Cast	−484.27	−4.80	1,030.55	10.22
Chlorothalonil/7 day	214.32	0.37	2,334.80	4.01
Chlorothalonil/10 day	1,562.03	3.71	1,601.63	3.80
Chlorothalonil/14 day	821.40	2.82	2,344.82	8.05
Chlorothalonil/Tom-Cast	1,005.24	3.88	2,057.69	7.94

^x BPH = (crop value for 1997 + 1998) − TCOST; TCOST = (no. of fungicide applications during 1996 + 1997) (cost per application).

^y RPFDP = BPH/TCOST.

^z Negative values represent fungicide expenditure in addition to crop loss.

Table 3. Stand count and number of large ferns per 6.1-m row for Jersey Knight and Jersey Giant and summary of contrast results comparing treatments for Jersey Giant in 1998 when not treated or treated with chlorothalonil or mancozeb according to a calendar schedule or according to the Tom-Cast disease predictor during 1996 and 1997

Treatment/spray interval (days)	Total number of ferns		Number of large ferns ^y	
	Jersey Knight	Jersey Giant	Jersey Knight	Jersey Giant
Untreated	95.5	96.0	48.0	17.8
Mancozeb ^z /7 day	90.5	130.0	44.8	31.0
Mancozeb/10 day	88.0	117.5	49.5	24.8
Mancozeb/14 day	105.0	118.0	53.0	25.5
Mancozeb/Tom-Cast	97.0	121.8	41.2	22.8
Chlorothalonil ^z /7 day	97.0	133.0	51.3	32.2
Chlorothalonil/10 day	87.8	120.8	46.2	30.8
Chlorothalonil/14 day	95.0	135.8	53.0	32.8
Chlorothalonil/Tom-Cast	122.0	140.3	53.8	31.2
<i>Jersey Giant contrast</i>				
	F value	P value	F value	P value
Untreated vs. all treatments	36.4	0.0001*	20.2	0.0002*
Chlorothalonil vs. mancozeb	9.5	0.0050*	12.1	0.0019*
Tom-Cast vs. 7 day	0.0	0.9190	3.9	0.0592
Tom-Cast/7 vs. 10/14 day	5.8	0.0245*	0.3	0.6010
10 vs. 14 day	2.5	0.1241	0.4	0.5614
Fungicide*(Tom-Cast vs. 7 day) interaction	2.5	0.1241	2.4	0.1336
Fungicide*(Tom-Cast/7 vs. 10/14 day) interaction	0.0	0.9713	0.3	0.6010
Fungicide*(10 vs. 14 day) interaction	2.2	0.1490	0.1	0.7912

^y Stem diameter measured 9 cm from the base >7.9 mm.

^z Applied at a rate of 1.7 kg a.i./ha.

prompted four fungicide sprays during the course of our study, resulting in a reduction in the number of fungicide applications by as much as 60% compared with the 7-day-interval treatment.

Although specific fungicide regimes significantly affected subsequent yield of Jersey Knight, Jersey Giant yield was not significantly affected by treatment regimes during the course of this study. Jersey Giant has a larger, denser canopy under Michigan growing conditions than Jersey Knight and may be more tolerant of defoliation caused by purple spot. There was, however, a decreased Jersey Giant fern stand and fewer large ferns at the conclusion of this study when plots were left untreated compared with the treated plots, indicating potential future yield differences.

Chlorothalonil appeared to provide more effective control of purple spot than mancozeb based on fern leaf lesions, yield, and fern stand. Under severe disease pressure, chlorothalonil significantly limited fern leaf lesions on both cultivars compared with mancozeb. Significantly higher yields of Jersey Knight were obtained when chlorothalonil was used versus mancozeb. Since Jersey Knight yield was significantly increased with a 7-day versus Tom-Cast application regime when using mancozeb, mancozeb is not currently recommended for use with Tom-Cast. Chlorothalonil treatment produced significantly more Jersey Giant ferns and more large ferns compared with mancozeb treatment. Economic analysis revealed that using chlorothalonil in a Tom-Cast program provided a BPH of \$1,005.24 (Jersey Knight) to \$2,057.69 (Jersey Giant). In comparison, using mancozeb in a Tom-Cast program provided a BPH of -\$484.27 (Jersey Knight) to \$1,030.55 (Jersey Giant). While RPFID often indicated a higher return when mancozeb was used compared with chlorothalonil, the BPH appeared to be a more accurate parameter in determining effective and profitable disease control strategies.

Unlike annual crops, where a disease epidemic one year will not necessarily

influence yields during subsequent years, diseases affecting asparagus fern have been shown to reduce subsequent yields if present in consecutive years. Yield is associated with fern vigor as defined by the number and diameter of stalks during the previous season (3). When left uncontrolled, foliar diseases cause premature browning and defoliation during the growing season, thereby limiting the photosynthetic capability of the fern and decreasing the availability of carbohydrate reserves for the crown. In a study conducted by Johnson and Lunden (11), total spear weight was decreased by 2 to 23% and the number of spears decreased from 5 to 25% after 1 year of rust disease on the fern. When the rust epidemic remained uncontrolled for two subsequent years, total spear weight was decreased from 11 to 54% and the number of spears decreased up to 46%. Similarly, the amount of *Cercospora* blight (*Cercospora asparagi*) on the fern was inversely correlated with yield the following spring (2). Conway et al. (2) determined that applications of mancozeb or chlorothalonil fungicides to ferns resulted in greater yield than other disease management strategies such as tillage and burning.

Purple spot on spears was affected by harvest date, with weather conditions likely being the most important component. The rupture of asci, discharge, and germination of ascospores of *P. herbarum* is dependent on water (1). When Hausbeck et al. (8) monitored atmospheric concentrations of *P. herbarum* in no-till commercial asparagus fields, peak concentrations of ascospores were usually associated with rainfall events. According to a study by Falloon et al. (7), disease severity on spears is positively correlated with rainfall events, and disease increases after heavy rainfall at temperatures between 0 and 20°C.

Although protecting the fern with fungicides did not appear to affect disease incidence and severity on spears the following year, experimental plots likely were exposed to fern residue from adjacent un-

treated buffer rows. Since there was one experimental treated row flanked by untreated buffer rows, when fern was chopped in the spring just prior to spear emergence, fern residue from both the untreated buffer rows and the treatment row were mixed and deposited between and within the rows, masking any potential benefit of fern disease management. Additional studies that include larger treatment blocks would ensure a better evaluation of the impact of fern disease management on subsequent purple spot disease on spears.

Results from this study indicate that the health of fern during summer and fall can affect subsequent yields and fern stands. Tom-Cast appears to be a promising alternative to calendar-based spraying in commercial asparagus fields and is currently being implemented in major asparagus producing regions within Michigan. Applying fungicides according to the disease predictor Tom-Cast has the potential to reduce significantly the number of sprays necessary to provide economic control of purple spot. Based on data from this study, growing asparagus in Michigan without an effective fungicide to protect against purple spot disease puts asparagus growers at a significant disadvantage. Unsprayed control plots yielded 77 to 83% of plots treated with chlorothalonil according to Tom-Cast. In the face of increasing production costs and increased foreign competition, effective purple spot management may provide a crucial profit margin to Michigan asparagus growers. Additional research is needed to investigate the long-term effects of purple spot of asparagus and treatment regimes on subsequent yield and fern stand.

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LITERATURE CITED

1. Atanasoff, D. 1919. A novel method of ascospore discharge. *Mycologia* 11:125-128.
2. Conway, K. E., Motes, J. E., and Foor, C. J. 1990. Comparison of chemical and cultural controls for *Cercospora* blight on asparagus and correlations between disease levels and yield. *Phytopathology* 80:1103-1108.
3. Ellison, J. H., and Scheer, D. F. 1958. Yield related to brush vigor in asparagus. *Am. Soc. Hortic. Sci.* 73:339-344.
4. Evans T. A., and Stephens, C. T. 1984. First report in Michigan of the teleomorph of *Stemphylium vesicarium*, causal agent of purple spot of asparagus. *Plant Dis.* 68:1099.
5. Falloon, P. G. 1982. The need for asparagus breeding in New Zealand. *N.Z. J. Exp. Agric.* 10:101-109.

Table 5. Number of purple spot lesions and summary of contrast results comparing treatments on cv. Viking KB3 ferns from a mature commercial field when not treated or treated with chlorothalonil every 7 days or according to the Tom-Cast disease predictor during 1996 and 1997

Treatment/spray interval (days)	Number of applications		Average number of purple spot lesions/fern	
	1996	1997	1996	1997
Untreated	...	...	388	2,358
Chlorothalonil ^y /7 day	8	8	24	80
Chlorothalonil/Tom-Cast 12 DSVs ^z	3	3	85	72
Chlorothalonil/Tom-Cast 15 DSVs	2	2	93	59
	1996		1997	
Contrast	F value	P value	F value	P value
Untreated vs. all treatments	38.07	0.0001*	95.08	0.0001*
Tom-Cast vs. 7 day	21.00	0.0001*	0.15	0.7031
Tom-Cast 12 vs. 15 DSVs	3.30	0.0749	0.55	0.4627

^y Applied at a rate of 1.7 kg a.i./ha.

^z Tom-Cast 12 and 15 disease severity value (DSV).

6. Falloon, P. G., Falloon, L. M., and Grogan, R. G. 1984. Purple spot and *Stemphylium* leaf spot of asparagus. Calif. Agric. July-August.
7. Falloon, P. G., Falloon, L. M., and Grogan, R. G. 1987. Etiology and epidemiology of *Stemphylium* leaf spot and purple spot of asparagus in California. Phytopathology 77:407-413.
8. Hausbeck, M. K., Hartwell, J., and Byrne, J. M. 1999. Epidemiology of *Stemphylium* leaf spot and purple spot in no-till asparagus. Acta Hortic. 479:205-210.
9. Johnson, D. A., and Lunden, J. D. 1984. First report of purple spot (*Stemphylium vesicarium*) of asparagus in Washington. Plant Dis. 68:1099.
10. Johnson, D. A., and Lunden, J. D. 1986. Effects of wounding and wetting duration on infection of asparagus by *Stemphylium vesicarium*. Plant Dis. 70:419-420.
11. Johnson, D. A., and Lunden, J. D. 1992. Effect of rust on yield of susceptible and resistant asparagus cultivars. Plant Dis. 76:84-86.
12. Lacy, M. L. 1982. Purple spot: A new disease of young asparagus spears caused by *Stemphylium vesicarium*. Plant Dis. 66:1198-1200.
13. Madden, L., Pennypacker, S. P., and MacNab, A. A. 1978. FAST, a forecast system for *Alternaria solani* on tomato. Phytopathology 68:1354-1358.
14. Montesinos, E., and Vilardell, P. 1992. Evaluation of FAST as a forecasting system for scheduling fungicide sprays for control of *Stemphylium vesicarium* on pear. Plant Dis. 76:1221-1226.
15. Pitblado, R. E. 1992. The development and implementation of Tom-Cast. Ministry of Agriculture and Food, Ontario, Canada.
16. Sherwood, R. T., and Hagadorn, D. J. 1958. Determining common root rot potential of pea fields. Wisc. Agric. Exp. Stn. Bull. 531.
17. Steel, R. G. D., Torrie, J. H., and Dickey, D. A. 1997. Principles and Procedures of Statistics: A Biometrical Approach. 3rd ed. McGraw-Hill, New York.