Germinability of *Venturia inaequalis* Conidia Exposed to Sunlight

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ABSTRACT

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Detached conidia of *Venturia inaequalis* were exposed simultaneously outdoors to direct sunlight or in an adjacent ventilated enclosure in darkness for periods ranging from 0.5 to 16.5 h. In addition, conidia were either exposed or not exposed to UV light (254 nm) from 1 to 64 min in the laboratory. After exposure, conidia were placed on water agar in closed petri dishes and allowed 24 h to germinate. Germinability of conidia in the

laboratory was reduced up to 95% by doses of UV₂₅₄ of 8.1 to 10.8 kJ m⁻². Germinability of conidia in the field was reduced up to 95% by doses of UV-B of about 44 kJ m⁻². A significant percentage of conidia survived radiation doses equivalent to 12 h in full sunlight.

Additional keywords: apple scab, long-distance spore transport, solar irradiance, *Spilocaea pomi*, spore survival, spore transport, vapor pressure deficit.

Conidia of *Venturia inaequalis* (Cooke) G. Wint. (anamorph *Spilocaea pomi* Fr.) are attached strongly to their conidiophores and generally are not considered to be dispersed readily by wind. However, they have been found in the air in scabby orchards (9,15) and at heights of 610 m in the atmosphere (7). Questions about possible long-distance dispersal of apple scab by conidia have been raised (7,15). A key element to long-distance transport is the survival of detached spores in the atmosphere (1). The purpose of this study is to determine the survival of conidia exposed in the field, as measured by their ability to germinate after exposure to sunlight for various lengths of time.

MATERIALS AND METHODS

Experimental material. Conidia of *V. inaequalis* were obtained from scab lesions on diseased leaves from McIntosh apple trees in a small orchard that had not been sprayed with fungicides. Leaves with young, expanding lesions, selected based on their appearance (9), were used in the tests. *V. inaequalis* conidia were transferred to glass microscope-slide coverslips (22 × 22 × 0.15 mm) by lightly touching a coverslip to a lesion.

Coverslips were held by the edge and pressed lightly to lesions. Conidia-laden coverslips were placed (conidia-side up) on plastic window screening stretched on light-weight wooden frames (~15 cm²). The coverslips were secured with a small piece (~5 mm²) of transparent, double-stick tape between the screen and the underside of the coverslip. They were secured by pressing down on one point with the tip of a sterilized needle.

Exposure tests in the field. The exposures of conidia to sunlight were conducted on 23 days between 12 June and 3 September 1996. Conidia were placed in the test conditions within about 10 min of being collected from leaves. The length of exposure varied from 0.5 to 16.5 h. For each exposure period (total of 48), two sets of samples were used. The screens holding the coverslips in one set were oriented horizontally and were placed in full sunlight at a height of 1.4 m above the ground in a 0.4-ha field of mown grass. The screens in the second set were placed in a darkened enclosed

area within a larger ventilated enclosure. These screens were shielded from both direct and indirect sunlight and served as the no-sun (NS) controls. Coverslips were considered as experimental units, and there were three coverslips (three replicates) for each exposure. Exposure to sunlight for more than 8 h was achieved over a period of two consecutive days. After an 8-h exposure to sunlight, the screens were placed inside the enclosure next to the NS controls. The next morning (7:30 a.m.) the sunlight-exposed samples were removed from the enclosure and placed in sunlight as before. At the end of each exposure period, coverslips were collected and placed conidia-side down on water agar in petri plates and allowed to germinate.

At the start of each exposure series, conidia were collected on three coverslips, as described above, and these were placed immediately on water agar (within about 1 min) after collecting them from leaves. These samples served as nonexposed (pretest) controls and were considered controls for daily variation in germinability of the population. On days when conidia were harvested more than once, each collection had its own associated control.

The temperature of the coverslips that contained samples of conidia was estimated by continuously monitoring the temperature of two otherwise identical coverslips with small-gauge (0.127 mm) copper-constantan thermocouple wires fastened to the bottoms with a small drop of epoxy. The orientation and placement of these instrumented coverslips were the same as those that contained the conidia.

Exposure tests in the laboratory. Leaves with freshly sporulating scab lesions were collected in the orchard and transported to the laboratory in a humidifier. Conidia were transferred to coverslips from the leaves within 1 h of being collected in the field and were handled as described for the field tests. Conidia-laden coverslips were exposed in the laboratory at room temperature (22 to 25°C) to short-wavelength (254 nm) UV light from a 15-W germicidal lamp (G15T8, General Electric Co., Schnectady, NY) for 1, 2, 4, 8, 16, 32, and 64 min. The distance from the bulb to the conidia-laden coverslips was ~15 cm. UV irradiance at the level of the conidia was determined to be 4.9 ± 0.6 W m⁻² using a short-wavelength UV meter (Black-Ray, model J-225, UVP, Upland, CA). A duplicate set of samples was not exposed to UV light but was otherwise held under the same conditions in the dark. These samples were collected concurrently with those exposed to UV and served as the no-UV controls. There were three replicate cov-

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erslips at each exposure period for each condition (UV and no UV), and the entire experiment was repeated three times.

Assessment of germinability. At the end of each exposure, coverslips were collected and placed conidia-side down on 2% water agar medium contained in 9-cm plastic petri plates. The plates were incubated at room temperature (20 to 25°C) for 24 h to induce conidial germination, at which time germinability (8) was assessed. In preliminary tests, little change in the percentage of germinated conidia was noted after 16 h. Germinated and ungerminated conidia on each coverslip were counted in random fields at 100× with a light microscope. A total of 300 to 500 conidia were examined on each coverslip, with the higher number of conidia counted when germinability was low. A conidium was considered germinated if the length of the germ tube was greater than or equal to the length of the conidium (~20 μm). Percent germination was calculated as 100 × the number germinated/the total number of conidia examined.

Meteorological measurements. Air temperature, relative humidity (RH), and wind speed were monitored at the test sites using a data logger (model 21X, Campbell Scientific, Logan, UT). Air temperature and RH were measured with a probe (Campbell model 207) shielded from the sun and located at a height of 1.5 m.

TABLE 1. Nomenclature

Symbol	Explanation	Unit
A_0	Regression parameter (equation 1)	Dimensionless
α_0	Regression parameter (equation 1)	$\text{m}^2 \text{kJ}^{-1}$
$B_{0,1,2,\dots}$	Regression parameters (equations 2–6)	Dimensionless
$\beta_{0,1,2,\dots}$	Regression parameters (equations 2–6)	h^{-1} or $\text{m}^2 \text{MJ}^{-1}$
D_{solar}	Dose of total solar irradiance	MJ m^{-2}
D_{UV}	Dose of UV (290–385 nm) radiation in field tests	MJ m^{-2}
D_{UVB}	Dose of UV-B (280–320 nm) radiation in field tests	kJ m^{-2}
D_{254}	Dose of UV (254 nm) radiation in laboratory tests	kJ m^{-2}
G_0	Percent germination of conidia prior to exposure to sunlight	Dimensionless
G_{NS}	Percent germination of conidia not exposed to sunlight	Dimensionless
G_{S}	Percent germination of conidia exposed to sunlight	Dimensionless
G_{254}	Percent germination of conidia exposed to UV_{254}	Dimensionless
I_{solar}	Irradiance of incident solar radiation	W m^{-2}
I_{UV}	Irradiance of incident UV (290–385 nm) radiation	W m^{-2}
I_{UVB}	Irradiance of incident UV-B (280–320 nm) radiation	W m^{-2}
RH	Relative humidity	Dimensionless
S	Average wind speed at sample height	m s^{-1}
t	Exposure time	h
T_{air}	Outdoor air temperature	°C
T_{encl}	Enclosure air temperature	°C
T_{cs}	Temperature of coverslips exposed to sunlight	°C
VPD	Vapor pressure deficit of the air	kPa

TABLE 2. Estimated parameters (and standard errors) for equation 1 fitted to results of laboratory experiments in which *Venturia inaequalis* conidia were exposed to UV light (254 nm)

	Estimate (SE)		r^2 ^a	df ^a
	A_0 (%)	α_0 ($\text{m}^2 \text{kJ}^{-1}$)		
Experiment 1				
Exposed to UV	40.0 (5.4)	0.277 (0.093)	64	19
Not exposed to UV	62.4 (4.0)	0.020 (0.010)	20	19 ns
Experiment 2				
Exposed to UV	41.8 (5.5)	0.370 (0.117)	74	19
Not exposed to UV	49.7 (2.6)	−0.008 (0.006)	9	19 ns
Experiment 3				
Exposed to UV	50.0 (6.9)	0.323 (0.104)	74	19
Not exposed to UV	48.0 (2.8)	0.002 (0.007)	0.6	19 ns

^a Coefficient of determination and degrees of freedom of the regression. Slope parameters are significantly different from 0 at $P = 0.05$ unless indicated by ns (not significant).

Wind speed was measured with a cup anemometer (model 014A, Met-One, Grants Pass, OR) located at 1.5 m above the ground. These instruments were sampled at 10-s intervals and averaged to yield 1-h average values.

Radiation measurements. Global solar irradiance, I_{solar} (watts per square meter), was measured with a pyrheliometer (model 50, Eppley Laboratory, Newport, RI). Irradiance in the UV wavelengths (290 to 385 nm), I_{UV} (watts per square meter), was measured with an Eppley UV radiometer. UV-B irradiance (280 to 320 nm), I_{UVB} (watts per square meter), was measured with an UV pyranometer (model UVB-1, Yankee Environmental Systems, Turners Falls, MA). The radiometers were sampled every 2 s and averaged to yield 30-min average values with a data logger (model 21X, Campbell Scientific). They all were placed at a height of 2.5 m above the ground and were deployed with

Fig. 1. Germination of *Venturia inaequalis* conidia exposed to short-wavelength (254 nm) UV light in the laboratory. The experiment was repeated three times (A through C).

their sensors in the horizontal plane by leveling the bases with built-in bubble levels. The notation used to represent the radiation measurements made by each of these instruments is summarized in Table 1. The cumulative dose of radiation (irradiance $\times$ time, megajoules per square meter) during each exposure period was obtained by integration of the radiation signals over the appropriate time period.

Data analysis. The results of the germination tests for conidia exposed or not exposed to UV light (254 nm) in the laboratory were compared by fitting percent germination, G_{254} , versus the dose (irradiance $\times$ exposure time) of UV light, D_{254} (kilojoules per square meter), to the following equation:

$$G_{254} = A_0 \exp(-\alpha_0 D_{254}) \tag{1}$$

where A_0 and α_0 are parameters of the model that were estimated by nonlinear regression (16). Values of G were weighted by the total number of conidia examined in each replication.

Unlike the laboratory tests in which the duration of each experiment was 64 min, exposures in the field extended from 0.5 h up to 16.5 h over a period of two consecutive days. To compare results obtained from different days throughout the season, the results of the germination tests for conidia exposed to sunlight in the field were standardized by dividing the germination found after each exposure by the germination found for unexposed conidia collected from the same leaf material, G_0 , that served as controls. The standardized germination for conidia exposed to sunlight, G_S/G_0 , and for conidia that were not exposed to sunlight, G_{NS}/G_0 , were compared for each exposure time by correlation analysis and by comparing independent linear and nonlinear regressions of G_S/G_0 (or G_{NS}/G_0) versus dose of incoming solar radiation and the UV (290 to 385 nm) and UV-B (280 to 320 nm) components of solar radiation, temperature, wind speed, and vapor pressure deficit, VPD (kilopascals).

The following equations were fitted to the data (weighted averages of the three replicates at each exposure) by nonlinear re-

gression (the terms are explained in Table 1). Percent germination for conidia exposed to sunlight in the field was described by

$$G_S/G_0 = B_1 \exp(-\beta_1 D_{solar}) \tag{2}$$

and

$$G_S/G_0 = B_2 \exp(-\beta_2 t) \tag{3}$$

For conidia that were not exposed to sunlight, the germination for the NS controls, G_{NS} , was described by

$$G_{NS}/G_0 = B_3 \exp(-\beta_3 t) \tag{4}$$

We also examined the behavior of the difference in germination of conidia exposed to sunlight versus the NS controls, i.e., $(G_S - G_{NS})/G_{NS}$, using

$$(G_{NS} - G_S)/G_{NS} = 1 - B_4 \exp(-\beta_4 t) \tag{5}$$

and

$$(G_{NS} - G_S)/G_{NS} = 1 - B_5 \exp(-\beta_5 D_{solar}) \tag{6}$$

where B and β are parameters determined by the regression. Identical analyses were done, with D_{solar} replaced by D_{UV} and D_{UVB} . All statistical tests were performed using SYSTAT statistical software (SPSS, Inc., Chicago).

RESULTS

Germinability of conidia exposed to UV light (254 nm) in the laboratory. Germinability of nonexposed controls did not decrease significantly during the tests (α_0 ranged from -0.008 to 0.020 ; Table 2). Germinability of conidia exposed to UV₂₅₄ decreased significantly, and the decrease was similar in each of the three experiments (α_0 ranged from 0.277 to 0.370 ; Table 2 and Fig. 1). Germinability was decreased by about 95% for doses of UV₂₅₄ of about 8.1 to 10.8 kJ m⁻².

Germinability of conidia exposed to sunlight in field tests. Detached conidia were exposed in the field, generally between the hours of 7:30 a.m. and 4:30 p.m., on 23 days between 12 June and 3 September 1996, to a range of environmental conditions (Table 3). Percent germination of nonexposed control conidia varied over the course of the tests from a low of 17% to a high of 85% (mean of 49%). Percent germination for conidia exposed to sunlight in the field decreased significantly with time and radiation dose (Fig. 2; Table 4). On the other hand, percent germination for conidia that were not exposed to sunlight did not decrease significantly with time (Fig. 2; Table 4). Germinability was decreased by about 95% for doses of solar radiation, D_{solar} , D_{UV} , and D_{UVB} , of about 62, 2.9, and 0.044 MJ m⁻², respectively (Table 5). The results of correlation analysis (Table 4) and stepwise linear regression (results not shown) indicated that G_{NS}/G_0 did not depend significantly on day

TABLE 3. Range of magnitude of environmental conditions encountered during the exposures of detached conidia of *Venturia inaequalis* in the field

Variable ^a	Unit	Range
T_{air}	°C	21–29
T_{encl}	°C	22–30
T_{cs}	°C	23.6–34.6
RH	Percent	41–89
VPD	kPa	0.3–1.9
S	m s ⁻¹	1.4–3.8
I_{solar}	W m ⁻²	15–1,000
I_{UV}	W m ⁻²	1.1–47.2
I_{UVB}	W m ⁻²	0.04–0.80

^a Variables are defined in Table 1.

TABLE 4. Pearson correlation matrix (and Bonferroni adjusted probabilities) for standardized germination of *Venturia inaequalis* conidia exposed, G_S/G_0 , or not exposed, G_{NS}/G_0 , to sunlight in the field^a

Exposed to sunlight	G_S/G_0	t	D_{solar}	D_{UV}	T_{air}	T_{CS}	VPD
G_S/G_0	1.00						
t	-0.73 (<10 ⁻⁵)	1.00					
D_{solar}	-0.74 (<10 ⁻⁵)	0.95 (<10 ⁻⁵)	1.00				
D_{UV}	-0.73 (<10 ⁻⁵)	0.95 (<10 ⁻⁵)	0.99 (<10 ⁻⁵)	1.00			
T_{air}	-0.48 (0.01)	0.32 (0.56)	0.33 (0.44)	0.30 (0.75)	1.00		
T_{CS}	-0.33 (0.44)	0.15 (1.00)	0.28 (1.00)	0.26 (1.00)	0.82 (<10 ⁻⁵)	1.00	
VPD	-0.33 (0.50)	0.17 (1.00)	0.38 (0.18)	0.37 (0.22)	0.31 (0.69)	0.50 (0.01)	1.00
Not exposed to sunlight	G_{NS}/G_0	t	T_{encl}	VPD			
G_{NS}/G_0	1.00						
t	-0.23 (0.68)	1.00					
T_{encl}	-0.34 (0.10)	0.26 (0.43)	1.00				
VPD	-0.31 (0.20)	0.17 (1.00)	0.38 (0.05)	1.00			

^a Variables are defined in Table 1.

of year (DOY), T_{enc} , or VPD of the air. These analyses also indicated that G_s/G_0 did not depend significantly on DOY, T_{cs} , or VPD of the air.

As another way to try to control for the effects of time and temperature, we compared paired samples of conidia either exposed or not exposed to sunlight using the variable $(G_{NS} - G_s)/G_{NS}$. This test again showed a highly significant decrease in germination of conidia with increasing exposure (Table 6). The results of nonlinear regression (equations 2 through 6) indicated a significant decrease in germinability for conidia exposed to sunlight and a nonsignificant decrease for conidia not exposed to sunlight (Table 5).

DISCUSSION

Production and survival of conidia are of paramount importance in the build-up of apple scab. Temperature and moisture (free water and RH) are the two physical factors that have been investigated the most in relation to conidial survival (9). Very little is known about the role of sunlight in the survival of these conidia. As far as we know, the current study is the first to quantitatively assess the effect of solar radiation on germination of *V. inaequalis* conidia. Conidia collected on glass microscope-slide coverslips were used to represent conidia naturally deposited on the upper surface of a leaf and were either exposed or not exposed to sun-

Fig. 2. Percent germination of *Venturia inaequalis* conidia exposed in an enclosure out of the sun, G_{NS} , or outdoors in direct sunlight, G_s , to various doses of solar radiation. Germination **A**, versus exposure time in an enclosure; **B**, versus exposure time in the sun; **C**, versus dose of total solar irradiance; **D**, versus dose of UV irradiance (290 to 385 nm); and **E**, versus dose of UV-B irradiance (280 to 320 nm). Variables are defined in Table 1.

light. These tests also were used to represent survival of conidia in the atmosphere. The method of sample collection could have included conidia of different ages and conidia that normally would not be detached by natural, dry-removal processes. Although there may have been differences in the ability of conidia of different ages to germinate, our use of germination of conidia not exposed to sunlight as a base line helped to compensate for these differences. Under the conditions of our study, survival (germinability) of conidia was reduced significantly by exposure to sunlight.

That sunlight greatly affects the survival (success) of plant pathogens has been reported in other pathosystems (2,3,6,10,11,13, 17). Bashi and Aylor (2) showed that strong (630 to 900 W m⁻²) and moderate (280 to 630 W m⁻²) solar irradiance induced a rapid decline in germination of detached sporangia of *Peronospora destructor* and *P. tabacina*, whereas these sporangia survived several hours under weak solar irradiance (70 to 280 W m⁻²). On a cloudy day, germination was reduced to about 68% in 6 h, whereas it was reduced to 0% in 6 h on a sunny day. *P. destructor* sporangia apparently survived and infected onion plants on cloudy days but not on dry, sunny days (6). Sporangia of *P. destructor* exposed to direct sunlight lost viability in a few hours, but those kept in the shade germinated even after 24 h (16). Similarly, Visser et al. (17) reported that exposure of spores of *Exobasidium vexans* to sunlight for up to 3 h did not affect germination; however, spore germination decreased rapidly for exposures lasting longer than 3 h.

The UV component of sunlight, especially UV-B (280 to 320 nm), has an important effect on the survival of spores (4). The values of β (α in the case of UV₂₅₄) found here reflect the strongly increasing amount of biological activity per unit of energy in the shorter wavelengths (5,12,13).

TABLE 5. Estimated parameters (and standard errors) for equations 2 through 6 fitted to results of field experiments in which *Venturia inaequalis* conidia were exposed to sunlight

Regression ^a	Parameter	Estimate (SE)	r ^{2b} (%)	df ^b
G_S/G_0 vs. D_{solar}	B_1 (%)	1.147 (0.113)	54	46
	β_1 (m ² MJ ⁻¹)	0.0483 (0.0084)		
G_S/G_0 vs. D_{UV}	B_1 (%)	1.141 (0.112)	53	46
	β_1 (m ² MJ ⁻¹)	1.041 (0.182)		
G_S/G_0 vs. D_{UVB}	B_1 (%)	1.129 (0.180)	45	35
	β_1 (m ² kJ ⁻¹)	0.0686 (0.0161)		
G_S/G_0 vs. t	B_2 (%)	1.136 (0.118)	52	46
	β_2 (h ⁻¹)	0.116 (0.0216)		
G_{NS}/G_0 vs. t	B_3 (%)	1.049 (0.113)	5	46 ns
	β_3 (h ⁻¹)	0.0237 (0.0155)		
$(G_{NS} - G_S)/G_{NS}$ vs. t	B_4 (%)	1.158 (0.144)	35	46
	β_4 (h ⁻¹)	0.0929 (0.0238)		
$(G_{NS} - G_S)/G_{NS}$ vs. D_{solar}	B_5 (%)	1.118 (0.141)	31	46
	β_5 (m ² MJ ⁻¹)	0.0354 (0.0096)		

^a Variables are defined in Table 1.

^b Coefficient of determination and degrees of freedom of the regression. The df for the UV-B measurements are fewer than the others because this instrument was not deployed during the first 11 exposure periods. Slope parameters are significantly different from 0 at $P = 0.05$ unless indicated by ns (not significant).

The conditions of our experiment, particularly with respect to temperature, were somewhat more stringent than would likely be experienced by conidia suspended in the atmosphere below a height of 2 km (1) or deposited on a leaf. The glass coverslips, which served as substrates for the conidia during exposure, were warmed by the sun to temperatures that were about 4°C warmer than the air temperature during the warmest part of the day. Actively transpiring leaves, on the other hand, can be 1 to 2°C cooler than the air temperature (5), depending on wind speed and VPD of the air. Although temperature may have contributed to a decline in germinability, its effect did not appear to be large compared to the direct effects of sunlight. Our analysis showed that temperature in the enclosure (range 20 to 30°C) did not significantly affect the germination of those conidia inside the enclosure and not exposed to the sun. Enclosure temperatures were 4 to 5°C cooler than temperatures indicated for the coverslips in the sun, however. There was no significant effect of air temperature, coverslip temperature, wind speed, or VPD of the air on survival (Table 4).

Investigations of the effect of solar irradiance in the field have the problem of a strong correlation between radiation and other physical variables, especially temperature. In the current study, we used both experimental (controls) and statistical methods to separate the effects of radiation and temperature. The magnitude of the range of temperatures for the nonexposed conidia in the enclosure was similar to that of the coverslips holding the sunlight-exposed conidia, although there was a displacement of about 4°C. Within the range of temperatures encountered, the difference in germinability between the sun and NS treatments was not significantly affected (Table 6). Thus, temperature accounted for very little of the variation, and solar radiation accounted for most of the variation in germinability.

We exposed conidia to short-wavelength UV light (UV₂₅₄) in the laboratory as a bench mark for comparison with studies on other fungi. Many studies have shown that short-wavelength UV light from an artificial light source has a strong inhibitory effect on spore germination (11–14). Osman et al. (11) found UV₂₅₄ from an artificial light source to be very effective in inhibiting germination of conidia of *Aspergillus flavus* (40 min at 0.4 W m⁻²) and *Penicillium notatum* (30 min at 0.4 W m⁻²). Rotem et al. (13) showed that germination of urediniospores of *Uromyces appendiculatus* was inhibited to about the same extent as was found here for *V. inaequalis* conidia by approximately the same dose of UV₂₅₄. In our tests, the biological activity of D_{254} for reducing the germinability of *V. inaequalis* conidia was about 4 to 5.4 times greater than that of D_{UVB} (estimated by comparing α values in Table 2 with the appropriate β values in Table 5).

Solar radiation apparently poses no strong impediment to the survival of detached conidia of *V. inaequalis* deposited on leaves or during aerial dispersal for time periods lasting up to 12 h. A significant percentage of conidia survived radiation doses equivalent to 12 h in full sun. During this time, it would not be unreasonable for conidia to be transported 120 to 240 km in the atmosphere (1). UV is reduced substantially on overcast days (5), and aerial transport distances under these conditions could be considerably greater (1). UV also is reduced greatly after passing through a leaf (5,13,18) or down into a canopy of vegetation (18). Therefore,

TABLE 6. Pearson correlation matrix (and Bonferroni adjusted probabilities) for normalized germination, $(G_{NS} - G_S)/G_{NS}$, of *Venturia inaequalis* conidia exposed to sunlight in the field^a

	$(G_{NS} - G_S)/G_{NS}$	t	D_{solar}	D_{UV}	T_{air}	VPD
$(G_{NS} - G_S)/G_{NS}$	1.00					
t	0.61 (<10 ⁻⁴)	1.00				
D_{solar}	0.58 (<10 ⁻³)	0.95 (<10 ⁻⁵)	1.00			
D_{UV}	0.57 (<10 ⁻³)	0.95 (<10 ⁻⁵)	0.99 (<10 ⁻⁵)	1.00		
T_{air}	0.27 (0.96)	0.38 (0.13)	0.38 (0.13)	0.35 (0.24)	1.00	
VPD	0.10 (1.00)	0.17 (1.00)	0.38 (0.13)	0.36 (0.16)	0.30 (0.60)	1.00

^a Variables are defined in Table 1.

there is good reason to believe that conidia that are transported several kilometers and deposited on leaves in the inner canopy in an apple orchard could survive for 2 days or more.

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Erratum

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In the manuscript entitled "Germinability of *Venturia inaequalis* Conidia Exposed to Sunlight" by D. E. Aylor and S. Sanogo (*Phytopathology* 87:628-633), to convert voltages to UV-B irradiances and obtain the correct UV-B doses, the numbers reported must be multiplied by 4. Portions of the manuscript should read as follows.

Page 628, next to last sentence of Abstract.

"Germinability of conidia in the field was reduced up to 95% by doses of UV-B of about 176 kJ m⁻²."

Page 630, last line of Table 3, column Range.

"0.16-3.2"

Page 630, second column, fifth line from end of text.

"Germinability was decreased by about 95% for doses of solar radiation, D_{solar} , D_{UV} , and D_{UVB} , of about 62, 2.9, and 0.176 MJ m⁻²."

Page 631, abscissa labels of Figure 2E.

"0.00, 0.04, 0.08, 0.12, 0.16"

Page 632, line 6 of Table 5, column Estimate (SE).

"0.0172 (0.004)"

Page 632, second column, last sentence of third paragraph.

"In our tests, the biological activity of D_{254} for reducing the germinability of *V. inaequalis* conidia was about 16 to 21.6 times greater than that of D_{UVB} (estimated by comparing α values in Table 2 with the appropriate β values in Table 5)."

These changes affect only the results involving the magnitude UV-B dose and do not affect the statistical analyses.