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RESEARCH ARTICLE / *ARTIGO*

Temporal analysis and fungicide management strategies to control mango anthracnose epidemics in Guerrero, Mexico

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ABSTRACT

The temporal progress of anthracnose (*Colletotrichum gloeosporioides*) epidemics was studied in mango (*Mangifera indica*) orchards treated with fungicides from different chemical groups, mode of action, and application sequences in two regions of contrasting climates (sub-humid and dry tropics) in Guerrero, Mexico. Full flowering, initial setting, and 8-15mm Ø fruits were identified as critical stages for infection. Epidemics started 20-26 days after swollen buds, and maximum severity was attained at 40-42 days after the first symptoms were detected. The Weibull model described ($r^2 \geq 0.89$) anthracnose epidemics in both floral and vegetative flushes. Active ingredients of different fungicide groups, mode of action, and residuality such as myclobutanil, azoxystrobin, cyprodinil+fludioxonil, quinoxyfen, and chlorotalonil + sulfur led to significantly low values (LSD≤0.05%) in the Y_p, AUDPC and b^{-1} parameters. The best strategy was to initiate a preventive treatment with a systemic ingredient, independently of its chemical group. Severity of the disease in floral (Fl) and vegetative flushing (Veg) in the sub-humid tropic was related with temperature ≥30°C (r_{Fl}=0.79-0.86; r_{Veg}=0.80-0.95) and relative humidity ≥ 90% (r_{Fl}=0.66-0.86; r_{Veg}=0.67-0.94). In both regions, conidial sporulation was related to temperature ≥30°C (r=0.72-0.74), relative humidity <60% (r=0.66), severity (r_{Fl}=0.62-0.98; r_{Veg}=0.75-0.97) and dew point ≤25°C (r=0.68-0.69).
Key words: *Colletotrichum gloeosporioides*, *Mangifera indica,* epidemics, fungicides.

INTRODUCTION

Mango (*Mangifera indica* L.) crops, originally from India, are grown in most tropical and sub-tropical zones in the world (Galan, 1999), where they represent the third most important tropical fruit group after banana (*Musa* spp.) and orange (*Citrus sinensis* L.) (FAOSTAT, 2010). The main producers are India, China, Thailand, Pakistan, Mexico, Indonesia and Brazil (FAOSTAT, 2010). In Mexico, mango was grown in 183,108 ha with a total production of 1,632,649 ton and a value of $312 million dollars in 2010. States of Guerrero, Nayarit, Sinaloa, Chiapas, Oaxaca, Michoacan, and Veracruz produce over 90% of the national volume. Guerrero is the main producer, and the principal crop regions in this State are Costa Grande (sub-humid tropic), Tierra Caliente (dry tropic) and Costa Chica (SIAP, 2010).

Anthracnose (*Colletotrichum gloeosporioides* Penz.) is the most important disease of the crop in all mango production areas in the world (Arauz, 2000; Mora et al., 2002). It is more severe with high relative humidity and abundant rainfall and the symptoms can be observed on leaves, flowers, fruits, and branches of all ages. The disease can cause losses varying from 50% to 100% in unmanaged orchards under a favorable environment (Arauz, 2000; Benitez et al., 2003; Mora et al., 2002). Symptom in the foliage consist of dark angular spots, 3-5 mm long, which can coalesce and necrose more extended areas generally surrounded by a yellow chlorotic halo. In the inflorescence it appears as tiny black spots, which cause extensive necrosis (blight) of flowers and small fruit fall off easily because of wind or rain leaving only the rachis attached to the tree. Affected fruits in early development can remain mummified in necrotic panicles or be aborted altogether. In the case of fruits nearing maturity the infections are quiescent and cause irregular dark spots that quickly rot the pulp of the fruit when it reaches senescence. In young vegetative stems, it causes canker lesions (Jeffries et al., 1990; Holguín et al., 2009).

Colletotrichum gloeosporioides produces conidia and ascospores in acervula and perithecia in leaves, inflorescences and aborted or mummified fruits, which are spread mainly through rain water splashing or the wind. Germination, production of germinating tubes and appressoria optimum at 25 and 30ºC and 90 to 100% relative humidity (Jeffries et al., 1990). The infected organs constitute a reservoir of propagules for later infections (Estrada et al., 2000; Sangeetha & Rawal, 2009).

Epidemiological studies of anthracnose are scarce in Mexico. In Iguala, Guerrero, severity of anthracnose was influenced by conidial density and rainfall, and showed monomolecular and Gompertz temporal progress curves (Acosta, 2002). In Michoacan, epidemics of anthracnose in flowering stage were adequately described by the Weibull model ($r^2 \geq 0.93$), and conidial density was positively related with the severity (r=0.74) (Guillen, 2000).

In Mexico, management of anthracnose has been mainly based on the use of benzimidazole fungicides (Vega, 1994). However, resistance to benzimidazole in *C. gloeosporioides* isolates has been previously reported (Hsin et al., 2009; Gutierrez et al., 2003). Contrastingly, triazole, imidazole, estrobilurine, and multi-sites protecting compounds have shown satisfactory control and low risk of resistance (Frac, 2006; Gutierrez et al., 2003; Nieto et al., 2003; Sundravadana et al., 2009).

The high aggressiveness of the pathogen, as well as the presence of susceptible tissue in different vegetative or floral flushing in the same growing season limits the rotation of active ingredients with a low risk of resistance. The intensity of epidemics depends on the susceptibility of varieties, the number and intensity of grow flushing and weather, among other relevant factors, and it is indispensable generate studies to improve control efficiency by zones of economic importance of the crop. Thus, the objectives of the present work were to 1) study the temporal progress of anthracnose epidemics under the influence of an alternation of fungicides from different groups, mode of action and application sequence; and 2) determine the relationship between meteorological factors and pathogen and disease intensity variables in two regions with contrasting climates (sub-humid and dry tropics) in Guerrero, Mexico.

MATERIALS AND METHODS

Study area

The study was carried out during the 2010-2011 productive cycle in two orchards: 1) Commercial orchard "Las Tunas" with Manila cv. trees, 14-15 years old established in a grid pattern 10 x 10 m, located in Tecpan de Galeana (17º16' N, 100º33' W) in the Costa Grande, Guerrero, Mexico, altitude 20 m. Mean annual rainfall and temperature are 1199 mm and 27ºC (sub-humid tropics) and the soil is reddish sandy loam (SMN, 1971-2012). 2) Commercial orchard "Zozontla 1" with Haden cv. trees, 30-40 years old planted in staggered rows 10 x 10 m located in Arcelia (18° 18.9' N, 100° 18.6' W) in the Tierra Caliente region (dry tropic), Guerrero, Mexico, at an altitude of 320 m. Mean annual rainfall and temperature are 1158 mm and 27.7ºC and the soil is dark brown sandy loam (SMN, 1971-2012).

In the orchards, the agronomic management consisted of: a) sanitary pruning; b) major and foliar chemical fertilization according to soil and plant analysis, and weekly watering; d) collection and elimination of harvest residues or infected fruits from the ground (inoculum); e) flowering induction (KNO_3, 3%). Additionally, five experimental treatments were applied for chemical control of anthracnose based on the rotation of active ingredients from different chemical groups and modes of action (Table 1). Fungicide management strategies was based on the floral phenology model proposed by Guillen (2000), who considered from swollen buds until fruit with a diameter of 8 mm. However, in this study the record was extended to fruits diameter of ≈15 mm. The systemic ingredients were applied every 15 days, and the contact ingredients were applied every eight days. Sprayings were made with a Swissmex® agricultural handbarrow with a capacity of 500 L and flow of 34.2 L/min at 20 bar, motor 5.5 HP (4.1 kw) at 3,600 rpm, two 50 m hoses with aspersion handles. The fungicides were applied in commercial doses: azoxystrobin 0.25 g/L, myclobutanil 0.08 g/L, cyprodynil+fludioxonil 0.075 g/L, quinoxyfen 0.05 mL/L, copper oxychloride 2.5 g/L, mancozeb 0.8 g/L, captan 1.25 g/L, chlorotalonil 2.88 g/L and elemental sulfur 1.35 mL/L.

Experimental design and disease severity assessment

Trees with similar trunk diameter and foliage volume were selected. Five chemical control treatments were evaluated in three growth flushing (vegetative and floral) in Tecpan de Galeana and one in Arcelia, Guerrero. A randomized block design with four replicates was used, in it each tree was the experimental unit. To evaluate the severity of each floral rhythm, classes 5 and 7 logarithm scales were used (Table 2), as proposed by Guillen (2000). These classes considered the ratio of affected foliar area (where 0= healthy tissue and 5= >5% damaged area), as well as flowers and fruits with necroses (where 0= healthy tissue and 7= >97% necrotic panicles). Five inflorescences and five vegetative shoots were randomly tagged in each experimental tree on each date because of the lack effect of orientation (Guillen, 2000). Severity evaluations were done weekly from the detection of swollen buds until the fruits reached 8-15 mm Ø with the formula.

$$S = \frac{\sum_{i=1}^{k} X_{ki} * N_{ki}}{N_i}$$

In which S= severity at time i, X_{ki}= damage level k at time i, N_{ki}= # inflorescences with damage level k at time i, N_i= # inflorescences evaluated at time i.

Temporal analysis and effect of treatments

The disease progress curves were described by the Weibull model (Pennypecker et al., 1980), the area under disease progress curve (AUDPC) (Campbell & Madden, 1990), variance analyses and mean separation of final severity (y_f), ratio (b^{-1}) and AUDPC were done using the LSD model with a reliability of 95% with SAS® software v.9.1.3 (SAS Institute Inc, 2003).

TABLE 1 - Treatments applied per floral flushing in mango orchards in each region (sub-humid and dry tropics) of Guerrero México

Treatments	Tecpan de Galeana (sub-humid tropic)	Arcelia (dry tropic)
	Floral flushing I (induced)	Floral flushing I (natural)
t1a	$C^1+S^{1a}+C^1+S^{2a}$	$C^1+S^{1a}+C^1+S^{2a}$
t2a	$S^{1a}+C^1+S^{2a}+C^1$	$S^{1a}+C^1+S^{2a}+C^1$
t3a	$S^{1a}+C^1+C^{2a}+S^1$	$S^{1a}+C^1+C^{2a}+S^1$
t4a	$C^1+S^{1a}+S^{2a}+C^1$	$C^1+S^{1a}+S^{2a}+C^1$
t5a	Check S^{1a}=myclobutanil, C^1=copper oxychloride + sulfur, S^{2a}= azoxystrobin, C^2=clorotalonil + sulfur	Check S^{1a}=myclobutanil, C^1=copper oxychloride + sulfur, S^{2a}= azoxystrobin, C^2=clorotalonil + sulfur
	Floral flushing II (induced)	
t1b	Cu+S	
t2b	Clo+S	
t3b	Ma+S	
t4b	Ca+S	
t5b	Check Cu+S=copper oxychloride + sulfur, Clo+S=chlorotalonil + sulfur, Ma+S= mancozeb+ sulfur, Ca+S= captan + sulfur	
	Floral flushing III (natural)	
t1c	$C^2+S^{1c}+C^2+S^{2c}$	
t2c	$S^1+C^{2c}+S^2+C^{2c}$	
t3c	$S^1+C^{2c}+C^2+S^{2c}$	
t4c	$C^2+S^{1c}+S^{2c}+C^2$	
t5c	Check C^2= chlorotalonil + sulfur, S^{1c}= (cyprodinil+fludioxonil), S^{2c}=quinoxyfen	

TABLE 2 - Logarithmic scale for evaluation of anthracnose (*C. gloeosporioides*) (Guillén, 2000) during three floral flushes in mango (Mangifera indica) commercial orchards "Las Tunas" Tecpan de Galeana, Guerrero. cv. Manila and "Zozontla 1", Arcelia, Guerrero. cv. Haden. Productive cycle 2010-2011

Classes	Range on each tissue type	
	Leaf	Inflorescence
	[z] Severity (% of Leaf area affected)	[z] Severity (% of tissue affected)
0	0	0
1	>0 - 1.20	>0 - 3
2	>1.2 - 1.94	>3 - 11
3	>1.94 - 3.13	>11 - 33
4	>3.13 - 5.0	>33 - 67
5	>5.0	>67 - 89
6		>89 - 97
7		>97 - 100

Meteorological information

Temperature (ºC), rainfall (mm), relative humidity (RH%), dew point (ºC), and wind speed and direction (km/h) were recorded every two hours with a Vantage Pro2 Weather Station® (Davis Instruments® Hayward CA) computerized meteorological station equipped with the Wheatherlink® software for Windows®, v.7.1.

Seasonal conidia sampling

To estimate the conidial density of *C. gloeosporioides* in the air, a volumetric trap created by the Interdisciplinary Mango Research Group was used (Mora et al., 2003). The trap was placed 1.5 m above the ground level. Air suction was done with an industrial fan motor with a plastic frame of 8 x 8 cm, at 12v with a volumetric capacity of 2.3-3.5 L

air/min. Within the trap, the conidia impacted against an adhesive tape placed around a gyrating mechanical drum with a seven day periodicity. Every tape, 3.5 x 30.3 cm, was sectioned from transparent self-adhesive polypropylene rolls (Contac®) and placed on its non-adhesive side on a hygrothermograph sheet (weekly trapping set) to differentiate individual sampling days, and fitted around the drum. The tapes were removed weekly, and examined with a compound microscope at 40x (Master Olympus®) for daily and weekly quantification of conidia.

Correlation analysis

The Pearson correlation coefficient (r) was calculated between severity or conidial density of *C. gloeosporioides* in the air and the weather related variables: temperature, relative humidity, rainfall, dew point, and wind speed and direction using the following intervals (hours/weeks): temperature (<20, 20-26.9, 27-29.9, 30-34.9 and ≥35°C), relative humidity (<60%, 60-89.9% and ≥90%), dew point (<15, 15-19.9, 20-24.9 and ≥25°C), mean wind speed (<1.0, 1-1.9 and ≥2km/h) and direction.

RESULTS

Disease evaluation and temporal analysis

The severity scales (Table 2) allowed to estimate the temporal development of anthracnose epidemic and confirmed full flowering, initial set (3-5mm Ø fruit) and 8-15mm diameter fruit as the critical phenological stages for infection. In Tecpan de Galeana (sub-humid tropic), the first symptoms were visually detected at 23 days after swelling of buds (full flowering) and defined the beginning of epidemics, given the significant availability of susceptible tissue. Maximum severity varied between classes 3-6 (11-97%) in inflorescence (Fl) and 2-4 (1.2-5.0%) in vegetative shoots (Veg), and was reached between 42 and 50 days after onset of symptoms. In Arcelia (tropical dry) the first symptoms manifested 26 days after full flowering. Maximum severity varied between classes 4-5 (inflorescence) and 2-4 (vegetative) and was reached 40 days after the onset of symptoms. For both tissues (floral and vegetative shoots) and locations, the highest severity in inflorescence (89-97%) and vegetative shoots (>5%) were observed in the check treatment (without fungicides) (Figures 1 and 2, Table 2). The Weibull model well described floral and vegetative epidemics in Tecpan de Galeana (r_{Fl}=0.95-0.99; r_{Veg}=0.90-0.98) and Arcelia (r_{Fl}=0.89; r_{Veg}=0.92) with a reliability of 95% (Tables 3 and 4).

Effect of treatments

In Tecpan de Galeana, three mixed growth flushings (floral and vegetative) were present, while there was only one in Arcelia. The effectiveness of the experimental chemical treatments was similar in both phenology stages (floral shoots and vegetative). Treatments 3a and 3c ($S^{1a}+C^{1}+C^{1}+S^{2a}$; $S^{1c}+C^{2}+C^{2}+S^{2c}$), where; S^{1a}=myclobutanil, C^{1}=copper oxychloride + sulfur, S^{2a}= azoxystrobin, C^{2}=clorotalonil + sulfur, S^{1c}=quinoxyfen, S^{2c}= (cyprodinil+fludioxonil), showed the lowest values for Y_f, AUDPC and b^{-1} (Tables 3 and 4) in flushing one and three and were the most consistent in both regions. However, when it was necessary to apply only contact ingredients on the second growth flushing to reduce the risk of resistance from excessive use of systemic chemicals, treatment 2b (Clo+S), where Clo= Chlorotalonil, S= sulfur, showed the lowest values in Y_f, AUDPC, and b^{-1} on flushing tow (Tables 3 and 4).

Correlation analysis

In Tecpan de Galeana, the severity of the disease in inflorescence and vegetative shoots increased for temperatures ≥30°C (r_{Fl}=0.79-0.88 y r_{Veg}=0.80-0.95); relative humidity ≥90% (r_{Fl}=0.66-0.86; r_{Veg}=0.67-0.94) and conidial density of *C. gloeosporioides* in the air (r_{Fl}=0.62-0.87; r_{Veg}=0.75-0.95). On the other hand, the seasonal density of conidia in the air was significantly correlated with temperature ≥30°C (r=0.72), relative humidity <60% (r=0.66), dew point <15°C (r=0.68) and wind <1km/h (r=0.55) with west direction (270°) (r=0.58) (Figure 3). In Arcelia, severity in floral and vegetative tissue was associated with the density of conidia in the air (r_{Fl}=0.96 y r_{Veg}=0.97), and this factor was associated with temperature ≥35°C (r=0.74), relative humidity ≤60% (r=0.66), dew point 20-24.9°C (r=0.69) and wind 1-1.9km/h (r=0.71) with SW direction (0.70) (Figure 4).

DISCUSSION

The scales were effective and facilitated the evaluation as reported by Guillen (2000) and allowed to discriminate the control effectiveness among fungicides. Conditions of temperature and humidity necessary for the development of anthracnose prevailed in Tecpan de Galeana (≥30°C and ≥90%) and Arcelia (≥35°C and <60%) during the winter 2010 – spring 2011 period (Estrada et al., 2000). Even when vegetative epidemics do not directly affect flowers or fruits in formation, they are very important as a source of inoculum for inflorescences in mixed budding (floral and vegetative) or fruits in early or late formation, besides contributing to increasing the inoculum in the same or following cycles, and thus its epidemic importance must be established and included in regular control programs.

Mango usually flowers between December and February in tropical and sub-tropical regions of the northern hemisphere (Osuna et al., 2000). However, the periodic presence of cold winds from the Pacific and the Gulf of Mexico in coastal zones significantly modify the plants' phenology given that there is a positive relationship between temperature decreasing below 20ºC and floral initiation and differentiation processes (Osuna et al., 2000). Additionally, the higher humidity of marine winds favors a most number of

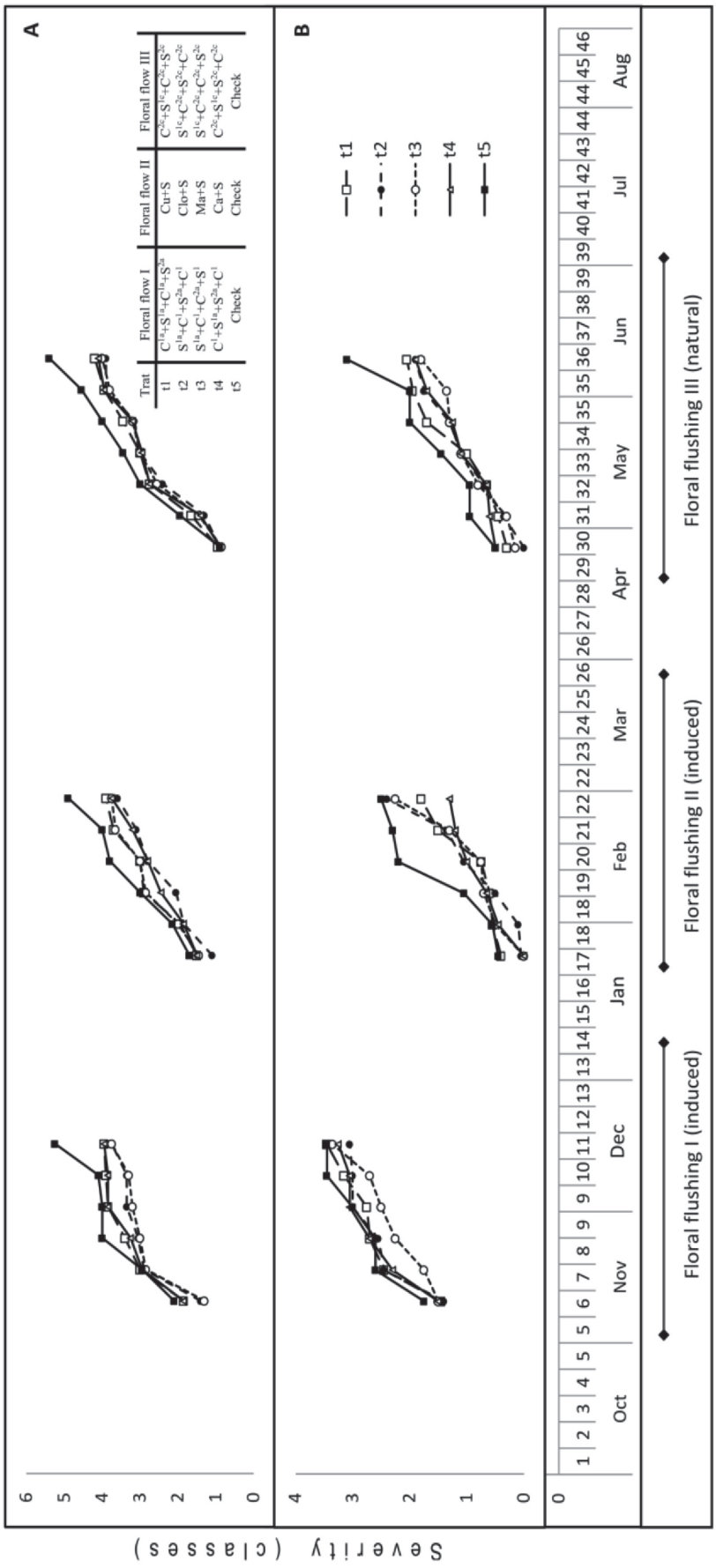

FIGURE 1 - *Colletotrichum gloeosporioides* temporal progress curves on flowers (**A**) and vegetative shoots (**B**) of mango (*Mangifera indica*) during three floral flushings in five treatments in the commercial orchard "Las Tunas", Tecpan de Galeana, Guerrero. cv. Manila. Productive cycle 2010-2011.
C^1=copper oxychloride+ sulfur, C^2=clorotalonil + sulfur, S^1=myclobutanil + azoxystrobin, S^2=quinoxyfen + (cyprodynil + fludioxonil), Cu+S= copper oxychloride + sulfur, Clo+S= clorotalonil + sulfur, Ma+S=mancozeb + sulfur, Ca+S=captan + sulfur.

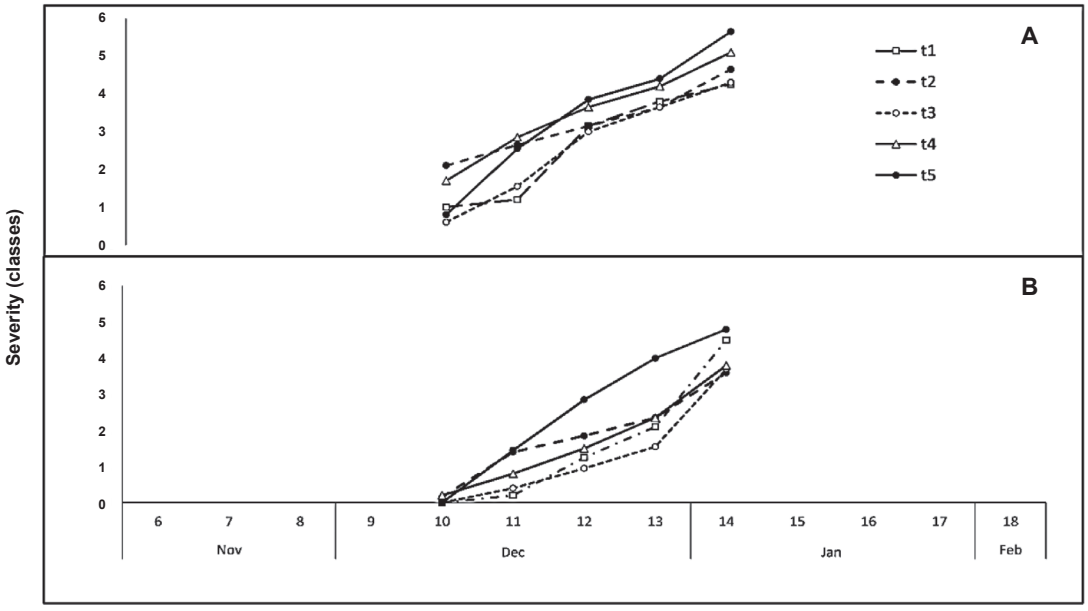

FIGURE 2 - *Colletotrichum gloeosporioides* temporal progress curves on flowers (**A**) and vegetative shoots (**B**) of mango (*Mangifera indica*) during one floral flushing in five treatments in the commercial orchard "Zozontla 1", Arcelia, Guerrero. cv. Haden. Productive cycle 2010-2011. [z]= Estimation of severity ranges by software Dos log for Windows®

TABLE 3 - Effect of treatments on parameters of the temporal progress of anthracnose (*Colletotrichum gloeosporioides*) epidemics on mango (*Mangifera indica*) inflorescence in the commercial orchards "Las Tunas", Tecpan de Galeana, cv. Manila and "Zozontla 1", Arcelia, cv. Haden, Guerrero. Productive cycle2010-2011

	Treatments	Sequence	Tecpan de Galeana (sub humid tropic)				Arcelia (dry tropic)			
			$r^{2\,a}$	y_f	(b^{-1})	AUDPC	$r^{2\,a}$	y_f	(b^{-1})	AUDPC
			Floral flushing I (induced)				Floral flushing I (natural)			
	t1a	$C^1+S^{1a}+C^1+S^{2a}$	0.99	3.95b	0.15a	169.50b	0.89	4.25d	0.18 b	107.75c
	t2a	$S^{1a}+C^1+S^{2a}+C^1$	0.99	3.75b	0.21a	152.25c	0.73	4.65dc	0.20ba	128.25bc
	t3a	$S^{1a}+C^1+C^{2a}+S^1$	0.99	3.75b	0.25a	148.75c	0.97	4.30d	0.35a	106.50c
	t4a	$C^1+S^{1a}+S^{2a}+C^1$	0.99	3.95b	0.15a	168.00b	0.89	5.10bc	0.29ba	141.00ba
	t5a	Check	0.99	5.25[a]	0.18a	187.25a	0.96	5.65ba	0.30ba	140.25ba
	S^{1a}=myclobutanil, C^1=copper oxychloride + sulfur, S^{2a}= azoxystrobin, C^2=clorotalonil + sulfur									
	Floral flushing II (induced)									
	t1b	Cu+S	0.99	3.90b	0.19b	142.50b				
	t2b	Clo+S	0.98	3.60c	0.23a	121.50d				
	t3b	Ma+S	0.97	3.75cb	0.19b	141.00b				
	t4b	Ca+S	0.99	3.75cb	0.18b	129.25c				
	t5b	Check	0.99	4.95a	0.18ba	162.75a				
	Cu+S=copper oxychloride + sulfur, Clo+S=chlorotalonil + sulfur, Ma+S= mancozeb+ sulfur, Ca+S= captan + sulfur									
	Floral flushing II (natural)									
	t1c	$C^2+S^{1c}+C^2+S^{2c}$	0.96	4.00b	0.24a	172.75b				
	t2c	$S^1+C^{2c}+S^2+C^{2c}$	0.95	4.00b	0.24a	162.00c				
	t3c	$S^1+C^{2c}+C^2+S^{2c}$	0.96	4.00b	0.25a	164.25c				
	t4c	$C^2+S^{1c}+S^{2c}+C^2$	0.97	4.00b	0.26a	167.00c				
	t5c	Check	0.99	5.10a	0.29a	199.50a				
	C^2= chlorotalonil + sulfur, S^{1c}= (cyprodinil+fludioxonil), S^{2c}=quinoxyfen									

[a]r^2= determination coefficient of the Weibull model, y_f= final incidence, AUDPC= area under disease progress curve, b^{-1}= increase ratio of the disease.
* Values with the same letter are not statistically different

TABLE 4 - Effect of the treatments on parameters of the temporal progress of the anthracnose (*Colletotrichum gloeosporioides*) epidemics in mango (*Mangifera indica*) vegetative shoots in the commercial orchards "Las Tunas", Tecpan de Galeana, cv Manila and "Zozontla 1", Arcelia, cv. Haden, Guerrero. Productive cycle 2010-2011

Treatments	Sequence	Tecpan de Galeana (sub-humid tropic)				Arcelia (dry tropic)			
		$r^{2\,a}$	y_f	(b^{-1})	AUDPC	$r^{2\,a}$	y_f	(b^{-1})	AUDPC
		Floral flushing I (induced)				Floral flushing I (induced)			
t1a	$C^{1a}+S^{1a}+C^{1a}+S^{2a}$	0.95	3.5a	0.07a	1.45b	0.95	4.50 a	58.00 b	0.76 ba
t2a	$S^{1a}+C^{1}+S^{2a}+C^{1}$	0.92	3.85a	0.24a	1.35ba	0.92	3.60 b	74.75 b	0.39 ba
t3a	$S^{1a}+C^{1}+C^{2a}+S^{1}$	0.90	3.65a	0.06a	1.15b	0.93	3.70 b	47.50 b	0.10 a
t4a	$C^{1}+S^{1a}+S^{2a}+C^{1}$	0.98	3.75a	0.09a	1.50ba	0.94	3.80 b	66.50 b	0.71 ba
t5a	Check	0.94	3.5a	0.06a	1.65a	0.99	4.80 a	107.00 a	0.40 ba
S^{1a}=myclobutanil, C^{1}=copper oxychloride + sulfur, S^{2a}= azoxystrobin, C^{2}=clorotalonil + sulfur									
Floral flushing II (induced)									
t1b	Cu+S	0.91	1.85bc	0.11b	0.10b				
t2b	Clo+S	0.97	2.40ba	0.25a	0.00b				
t3b	Ma+S	0.90	2.25ba	0.15b	0.00b				
t4b	Ca+S	0.97	1.55c	0.12b	0.00b				
t5b	Check	0.92	2.75a	0.14b	0.35a				
Cu+S=copper oxychloride + sulfur, Clo+S=chlorotalonil + sulfur, Ma+S= mancozeb+ sulfur, Ca+S= captan + sulfur									
Floral flushing III (natural)									
t1c	$C^{2c}+S^{1c}+C^{2c}+S^{2c}$	0.96	2.35ba	0.08a	0.0b				
t2c	$S^{1c}+C^{2c}+S^{2c}+C^{2c}$	0.98	2.25b	0.09a	0.0b				
t3c	$S^{1c}+C^{2c}+C^{2c}+S^{2c}$	0.96	1.85b	0.09a	0.0b				
t4c	$C^{2c}+S^{1c}+S^{2c}+C^{2c}$	0.91	2.20b	0.09a	0.0b				
t5c	Check	0.90	3.10a	0.09a	0.2a				
C^{2}= chlorotalonil + sulfur, S^{1c}= (cyprodinil+fludioxonil), S^{2c}=quinoxyfen									

[a]r^2= determination coefficient of the Weibull model, y_f= final incidence, AUDPC= area under disease progress curve, b^{-1}= increase ratio of the disease.
* Values with the same letter are not statistically different

epidemics. For example, in Tecpan de Galeana (sub-humid tropic), temperatures <20°C were recorded more frequently and with greater persistence (h/week) between January and March 2010 (winter) and caused up to three growth flushing which promoted a most number of epidemics (30 severity curves; 15 floral and 15 vegetative) (Figure 1).

Contrastingly, in Arcelia (where there is a uniform winter season) there was only one growth flushing and 10 epidemics (five floral and five vegetative) (Figure 2). Moreover, the timely and efficient application of management practices as floral flushing inducers (KNO_3, 3%) will also influence phenology: inadequate applications of this growth promoter will affect the ratio of vegetative and floral shoots in each growth flushing (Yeshitela et al., 2004), and therefore the intensity of the epidemics per tissue mode. For this reason, in places where there is more than one stage of epidemics (more than one vegetative or floral flushing) per reproductive or agronomical stage a greater use of systemic fungicides is needed, and it will be indispensable to diversify applications using different combinations and sequences of systemic and contact fungicide applications to reduce the risk of resistance as suggested by Muiño et al. (2007) and Sampath et al. (2007).

Anthracnose control in Mexico is mainly based on the use of benzimidazole fungicides, however, in these products it is reported many cases of resistance (Gutierrez et al., 2003; Hsin, 2009; Vega, 1994). The best results in this study were obtained with myclobutanil, azoxystrobin, quinoxyfen and cyprodynil+fludioxonil as documented Gengotti et al. (2008), Nieto et al. (2003), Sundravadana et al. (2009), Tsai et al. (2006) and Wong & Midland (2007). Moreover, these products are authorized for use with mango in Mexico (MRL, 2010; SAGARPA, 2010).

The best control in Guerrero was obtained by starting with a prophylactic spray of a systemic fungicide alternated with chlorotalonil + sulfur (Acosta et al., 2003). The rotation of active ingredients and timely application must be based on the presence of susceptible phenology stages, regardless the number of floral growths. It must be consider that to improve chemical management, it should be combined with crop practices that decrease environmental humidity in the orchard, such as ventilation pruning, avoiding excessive irrigation, improving drainage, timely weed control and destroy sources of the inoculum (Acosta et al., 2003; Arauz, 2000).

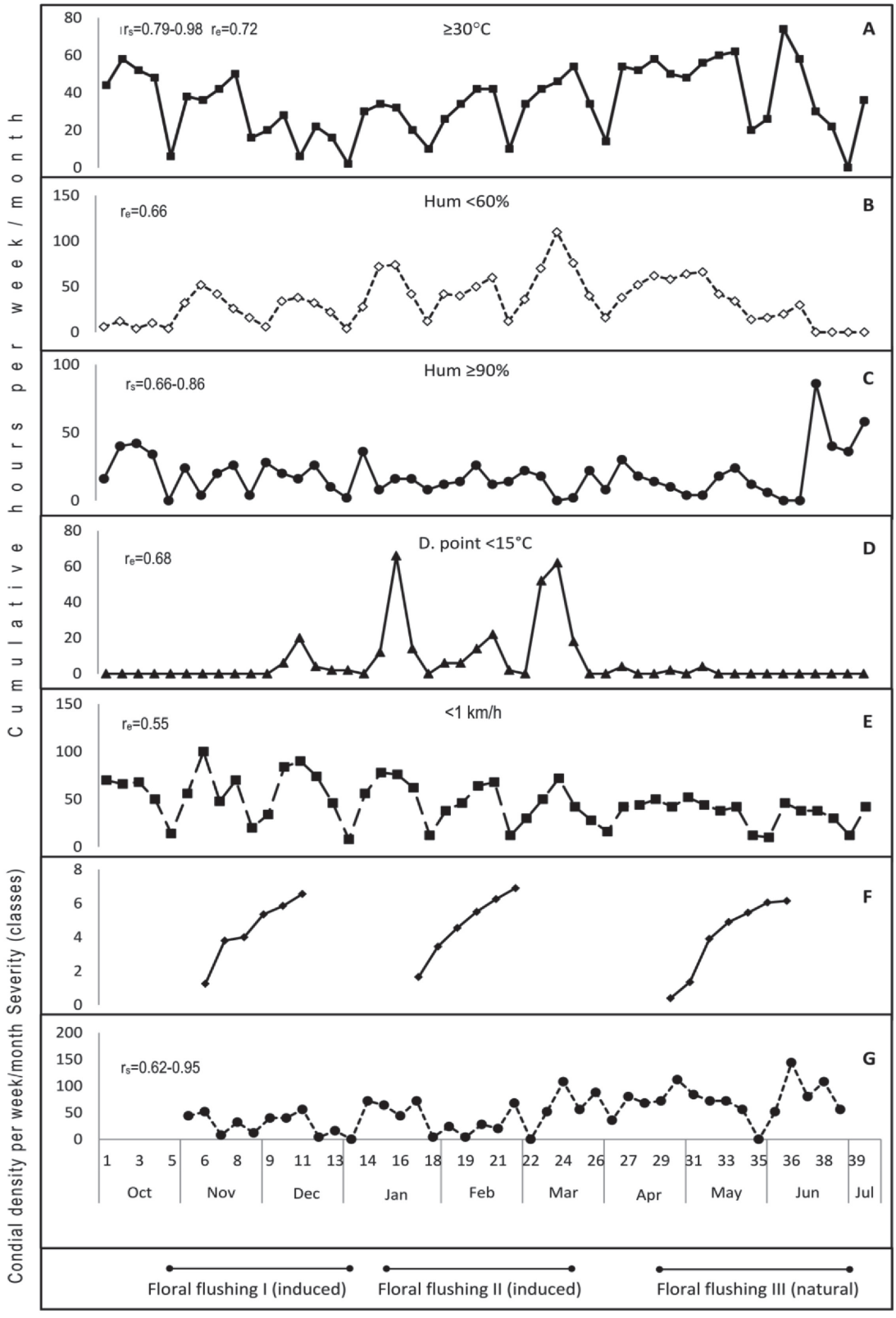

FIGURE 3 - *Colletotrichum gloeosporioides* conidial density (G), anthracnose severity in inflorescence (F) and relationship with temperature (A), relative humidity (B and C), dew point (D) and wind speed (E), during three floral flushings in the commercial mango (*Mangifera indica*) orchard "Las Tunas", Tecpan de Galeana, Guerrero. cv. Manila. Productive cycle 2010-2011.
r_s=correlation coefficient (Pearson) with severity, r_e=correlation coefficient (Pearson) with conidial density.

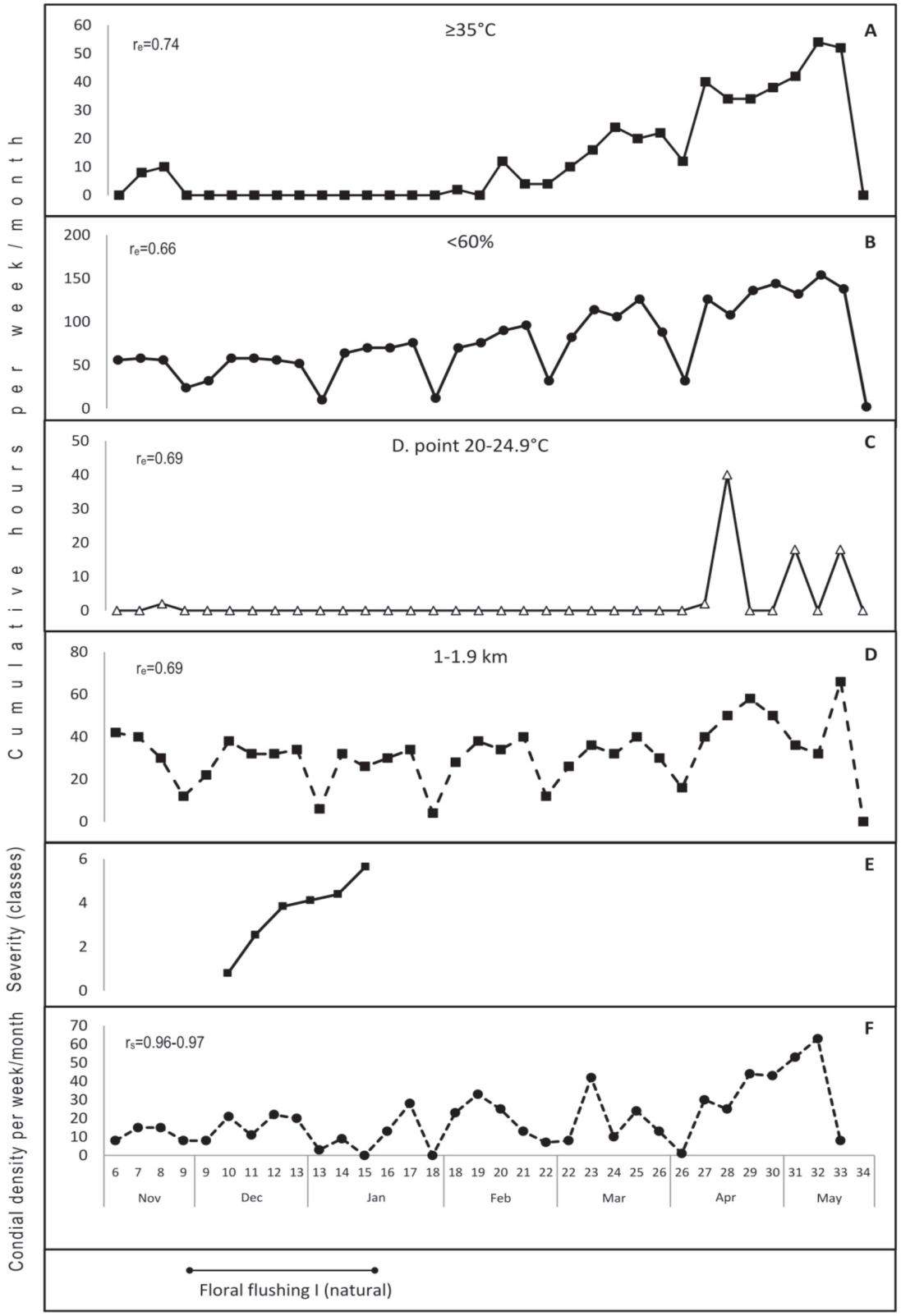

FIGURE 4 - *Colletotrichum gloeosporioides* conidial density (**F**), anthracnose severity in inflorescence (**E**) and relationship with temperature (**A**), relative humidity (**B**), dew point (**C**) and wind speed (**D**), during one floral flushing in the commercial mango (*Mangifera indica*) orchard "Zozontla 1", Arcelia, Guerrero. cv. Haden. Productive cycle 2010-2011.
r_s=correlation coefficient (Pearson) with severity, r_e=correlation coefficient (Pearson) with conidial density.

In this study, the best results were obtained when beginning applications with a systemic ingredient followed by a contact fungicide, as suggested Rivas & Carrizales (2007) in Venezuela. However, given the scarcity of studies that include such approach, it is suggested that further studies will be critical to adjust the efficiency of strategy. It is important to point out that in our study, the climatic conditions and inoculum availability do not constitute limiting factors during the emission periods of susceptible tissue in either study zone. Therefore, is obliged a preventive and more prolonged control of the disease. It also justifies prophylactic sprayings of fungicides of different chemical groups, mode of action, and application sequence.

Our data shows that sporulation and severity were correlated with temperature ≥30°C. This is a determinant in the mango-anthracnose system. It was observed that the inoculum was available during the whole study period in both regions (Figures 3 and 4), so that the severity of anthracnose epidemics will depend on susceptible tissue and favorable environment. In general, temperature and humidity in sub-humid (≥30°C and ≥90%RH) and dry (≥35°C y <60%RH) tropics were adequate for the disease development (Estrada et al., 2000), the sporulation is a constant pressure factor during the winter-spring growth flushing in Mexico. These results were similar to those reported by Holguin et al. (2009), who documented that the severity in vegetative growths coincided with humidity levels of 80-90% and dew point (22-26ºC) and partially coincided with Acosta (2002), who documented that the severity of anthracnose depended on conidial density, incidence and rainfall. In Michoacan, conidial density was positively related with severity and epidemics were adequately described by the Weibull model (Guillén, 2000). Estrada et al. (2000) in Philippines and Sangeetha & Rawal (2009) in India documented that temperature of 25-30°C and humidity ≥ 90% favor fungal sporulation. Due to the fact that our study was done in the dry season, correlation of severity and conidial density to precipitation could not be calculated. However, this factor is essential and must be included in future studies. Nevertheless, this research makes evident the capability of *C. gloeosporioides* to cause infections in the flowering stage with such low humidity (<60%) as that reported in the dry tropic.

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