Fuzzy Pedicel: A New Postharvest Disease of Banana

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ABSTRACT

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Banana fruit of the Cavendish subgroup, *Musa acuminata*, are significant international commodities. Recently, a transnational company attempted to develop single fruit (fingers) as a product in the United States. In the summer of 2007, an unknown problem developed (hereafter, “fuzzy pedicel”), wherein mats of fluffy gray to white mycelial mats covered large portions of the pedicel surface of fruit when they were packed in gas-permeable containers. Fungi from two genera sporulated on examined pedicels: *Sporothrix*, which occurred on 72% of the affected pedicels, and *Fusarium* (6%); other fungi were sterile. From pedicel tissue, four genera of fungi were isolated on potato dextrose agar: *Sporothrix* and *Fusarium* and, less frequently, *Pestalotiopsis* and *Nigrospora*. Based on alignment with internal transcribed spacer and β -tubulin sequence data, the *Sporothrix* isolates were closely related to those in an environmental *Ophiostoma/Sporothrix* clade that contains *Sporothrix stylites*, *S. humicola*, and *S. pallida* but not the human pathogen *S. schenckii*. Based on EF1 α gene sequences, four species in the *Gibberella fujikuroi* species complex (*Fusarium proliferatum*, *F. pseudocircinatum*, *F. sacchari*, and *F. verticillioides*) and two unnamed taxa in the *F. incarnatum-equiseti* species complex were identified. After artificial inoculation, representative *Sporothrix* and *Fusarium* isolates caused fuzzy pedicel symptoms on fruit of ‘Grand Nain,’ a commercial Cavendish cultivar. Fuzzy pedicel development was inhibited at 14°C (temperature at which fruit are shipped) but developed at 25°C (temperature at which fruit are marketed). *Sporothrix* isolates were insensitive to thiophanate-methyl fungicide in vitro and when used to treat pedicel surfaces prior to inoculation. Thus, it appears that benzimidazole fungicides would be ineffective as postharvest treatments for this problem. In summary, a new postharvest disease of banana, fuzzy pedicel, affects single fingers. It is caused by *Sporothrix* sp. and several species of *Fusarium*. *Sporothrix* spp. and *F. pseudocircinatum* have not been reported previously on banana.

Banana (*Musa* spp.) is a valuable food and export commodity in the tropics. Only 15% of these fruit are traded internationally but they have an annual value of approximately \$5 billion.

Fruit of the Cavendish cultivars dominate the international banana trade. They possess desirable agronomic and organoleptic characteristics but are fragile and highly perishable (27). To ensure that a high-quality product with a long shelf life reaches terminal markets, these climacteric fruit go through a series of postharvest steps. Initially, “hands” (fused sets of a dozen or so fingers) of fruit are cut from harvested “bunches” (infructescences in which hands are distributed vertically along a peduncle), washed, and treated with a fungicide. Hands are then packed in padded cardboard boxes, moved in refrigerated

containers to ports, and transported in ships in which temperature, humidity, and gas environments are controlled (26).

The exposed, wounded area where hands were attached to the peduncle (i.e., the crown) is a significant site for pathogen invasion. Different postharvest rots develop at the wound site, depending on production region, season, and the responsible pathogens (12,26,29). *Colletotrichum musae*, the cause of anthracnose, is most important, but several other fungi can be significant, including, alphabetically: *Acremonium* spp., *Cephalosporium* spp., *Chalara paradoxa* (syn.: *Thielaviopsis paradoxa*; teleomorph: *Ceratocystis paradoxa*), *Deightonella torulosa*, *Fusarium concentricum*, *F. semitectum*, *F. verticillioides*, *Lasioidiplodia theobromae* (teleomorph: *Botryosphaeria rhodina*), *Musicillium theobromae* (syn.: *Verticillium theobromae*), and *Nigrospora sphaerica* (7,8,10–14,18,24,26,29,31).

Banana export companies experiment with new ways in which this fruit could be marketed and utilized by consumers. For example, undersized banana fruit have been sold as “lunch-box” fruit and banana juice has become an ingredient in some tropical fruit juice blends. To this end, Chiquita Fresh North America L.L.C. recently investigated single fingers, rather

than complete hands, as consumer products. Fingers were cut from hands of fruit that were shipped to Port Everglades, FL, such that the crown area was removed while retaining as much pedicel as possible. Fingers were then packed in gas-permeable plastic packages for shipment.

The present article describes a new postharvest disease of banana, “fuzzy pedicel,” that was observed during the development of the single-finger product. In general, light-gray lawns of mycelium were observed on the surface of the cut end of pedicels of Cavendish fruit after fingers were placed in plastic shipping packages (Fig. 1). Although affected pedicels usually did not necrose, the fungal growth was judged a significant aesthetic obstacle in the development of the product. We report the identity and frequency of isolation of different fungi from affected pedicels, indicate which fungi cause fuzzy pedicel, and describe the impacts of temperature and fungicide treatment on the disease’s development.

MATERIALS AND METHODS

Identification and frequency of isolates associated with fuzzy pedicels. In total, 32 symptomatic banana fruit from 16 consignments of prepackaged Cavendish banana were inspected to determine the species of fungi that colonized the cut surface of pedicels. Fruit were cultivated in two locations in Guatemala. Tissues from 2 and 4 mm below the cut surfaces were also examined to determine whether fungi colonized pedicels internally. Tissue pieces were surface disinfested, plated on potato dextrose agar (PDA) amended with ampicillin and streptomycin, and viewed after 7 days at room temperature. Fungi were identified with macroscopic and microscopic characters (1,15).

DNA extraction and sequencing. Isolates of the most commonly recovered fungal taxa were grown for 3 to 5 days in

Fig. 1. Pedicel surfaces of ‘Grand Nain’ fruit inoculated (left) and not inoculated (right) with an isolate of *Sporothrix* sp.

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The e-Xtra logo stands for “electronic extra” and indicates that Figure 1 appears in color in the online edition.

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potato dextrose broth at room temperature on a shaker at approximately 80 rpm. Mycelia were harvested and triple rinsed with sterile deionized water and dried on sterile filter paper. DNA was extracted using a simple DNA prep protocol from the University of Wisconsin Biotechnology Center. Briefly, mycelium was ground in 500 µl of Shorty DNA Extraction Buffer (0.2 M Tris-HCl, pH 9.0; 0.4 M LiCl; 25 mM EDTA and 1% sodium dodecyl sulfate) and incubated at 68°C for 10 min. Tissue was centrifuged at 14,000 rpm for 5 min, 400 µl of the supernatant was transferred to a new tube, and the DNA was precipitated with 400 µl of 99% isopropanol. The tubes were centrifuged for 10 min at 14,000 rpm and the supernatant was decanted. The DNA pellets were air dried for 5 min, then resuspended in 400 µl of Tris-EDTA buffer for 30 min at room temperature; 2 µl of DNA was used in polymerase chain reaction (PCR) reactions.

For *Sporothrix* isolates, the internal transcribed spacer (ITS)1-5S-ITS2 ribosomal region and the β-tubulin gene region were amplified by PCR in 50-µl reactions containing 38.25 µl of sterile distilled, deionized water, 6.5 µl of ThermoPol Reaction Buffer (New England Biolabs, Ipswich, MA), 1 µl of 10 mM dNTP mix (New England Biolabs), 0.25 µl of Taq DNA polymerase (concentration = 5,000 units/ml), 1 µl each of 15 µM primers, and 2 µl of DNA template using the following primers: ITS1 (5) and ITS4 (30) for ITS, and T1 and Btb2 (6) for β-tubulin. Standard cycling parameters with a 55°C annealing temperature were used. To sequence the EF1α locus of the *Fusarium* isolates, identical PCR reactions were carried out using primers EF-1 and EF-2 (17). PCR products were cleaned with ExoSap and sequenced

on an ABI-3730-XL sequencer at the University of Florida National Center for Biotechnology Information Facility. Sequences were identified to species level by insertion into alignments with previously published GenBank sequences in the species complexes in which the taxa belong (Table 1). *Fusarium* isolates were identified to species level using alignment of EF1α sequences with those published in GenBank. Maximum parsimony analyses, using default parameters in MEGA v 4.0.1 (28) and 500 bootstrap replicates, were used to infer phylogenetic relationships of the *Sporothrix* isolates to previously described *Sporothrix* or *Ophiostoma* spp.

To confirm that the morphology of the above isolates corresponded to identities that were based on DNA sequences, their colony morphology, conidia, and conidiophores were examined. *Fusarium* isolates were grown on banana leaf agar (2% water agar with sterile banana leaf pieces on surface) and PDA for 7 to 10 days. Colony color, conidium shape, number of septa, and presence of mono- and polyphialides were then recorded and compared with those published for the corresponding species based on EF1α sequence data (15). *Sporothrix* isolates were grown on malt extract agar, and colony characteristics, as well as conidium shape and size, and conidiophore morphology were compared with those described for *Sporothrix humicola*, *S. pallides*, and *S. stylites*, three species that were most closely related to the pedicel isolates based on the ITS phylogeny (3).

Reproduction of fuzzy pedicel symptoms and effects of temperature and fungicide on *Fusarium* and *Sporothrix* isolates. Mature fruit of 'Grand Nain', a Cavendish cultivar, were harvested from an

experimental plot at the Tropical Research and Education Center in which fungicides had not been used. For the fungicide sensitivity assay, individual fingers were removed from hands and the associated pedicel was dipped in OHP 6672 (50% thiophanate methyl; OHP, Inc., Mainland, PA) at 1.04 g/liter (= label rate of 14 oz./100 gal.) or a water control and allowed to dry. Fruit were inoculated by submerging pedicels into suspensions of 10⁵ conidia ml⁻¹ of the indicated isolates in Table 1. The fruit were incubated in moist plastic bags at 25°C. Each treatment (all isolate–fungicide combinations) was replicated on five fingers in each of two experiments, and banana fruit were monitored for 14 days for mycelial growth on the cut pedicel surface. Incidence was recorded for treatments as the proportion of the five fruit that exhibited mycelial growth (i.e., fuzzy pedicels). The number of days for fuzzy pedicel development was recorded and growth of the inoculated isolated was confirmed microscopically. To determine whether isolates colonized pedicels internally, tissue was taken 4 mm below the cut surface, surface disinfested, and plated on antibiotic-amended PDA; plates were monitored for 7 days for growth of the inoculated isolate. The experimental design was a split plot in a randomized complete block design (RCBD) with fungicide being the main plot and isolate the subplot; the two repetitions of the experiment were treated as blocks. Analysis of variance (ANOVA) was performed on incidence data, internal colonization of pedicels, and number of days until sign development. Mean separation for dependent variables (fungicide treatment and isolate) was performed using Fisher's least significant difference (LSD)

Table 1. Identification of *Sporothrix* and *Fusarium* isolates recovered from fuzzy pedicel-affected banana fruit

Taxa or isolate	Accession ^x	Equivalent no. ^y	Locus sequenced ^z	GenBank accession no.	Species	Frequency of pedicel recovery (%)	
						Surface	Subsurface
<i>Sporothrix</i> sp.	...	...	ITS	...	...	71.9	71.9
*Spor1	...	...	ITS, β-tub	GU377301, GU045499	<i>Sporothrix</i> sp.	...	...
*Spor3	...	...	ITS, β-tub	GU377300, GU045500	<i>Sporothrix</i> sp.	...	...
Spor4	...	...	ITS, β-tub	GU377302, GU045502	<i>Sporothrix</i> sp.	...	...
GFSC	...	...	...	...	...	3.1	9.4
*GF1	NRRL 54198, M-8893	...	EF1α	GU377296	<i>Fusarium sacchari</i>	...	...
*GF2	NRRL 54199, M-8894	...	EF1α	GU377299	<i>F. verticillioides</i>	...	...
*GF3	NRRL 54200, M-8895	...	EF1α	GU377298	<i>F. pseudocircinatum</i>	...	...
*GF4	NRRL 54201, M-8896	...	EF1α	GU377297	<i>F. proliferatum</i>	...	...
FIESC	...	...	...	...	...	3.1	9.4
*FIESC1	NRRL 54202, R-10098	...	EF1α	GU045503	FIESC sp. 15C	...	...
FIESC3	R-10100	...	EF1α	GU045502	FIESC sp. 16	...	...
FIESC4	R-10101	...	EF1α	GU045505	FIESC sp. 16	...	...
<i>Nigrospora</i> spp.	...	...	...	...	...	0.0	21.9
<i>Pestalotia</i> spp.	...	...	...	...	...	0.0	15.6

^x Asterisk (*) indicates isolate used in artificial inoculation studies. GFSC = *Gibberella fujikuroi* species complex and FIESC = *Fusarium incarnatum-equiseti* species complex.

^y Accessions beginning with "NRRL" are deposited in the USDA-ARS, NCAUR collection in Peoria, IL, and those beginning with an "M" or "R" are deposited at the Fusarium Research Center, Pennsylvania State University, University Park, PA. The three accessions of *Sporothrix* sp. have been deposited in both the Centraalbureau voor Schimmelcultures, Utrecht, The Netherlands, and the culture collection of the Forestry and Agricultural Biotechnology Institute (FABI), University of Pretoria, Pretoria, South Africa (accession nos. forthcoming).

^z ITS = internal transcribed spacer and β-tub = β-tubulin.

using PROC GLM in SAS (v. 9.2; SAS Institute, Cary, NC).

The temperature sensitivity assay was performed similarly to the fungicide experiment, except that no fruit were treated with fungicide. Inoculated fruit were incubated at 14°C (the temperature at which exported fruit are shipped) or 25°C (approximately room temperature), and fuzzy pedicel incidence, days to colonization, and internal colonization variables were measured and analyzed as above, with temperature as the main plot and isolate as the subplot.

In vitro temperature and fungicide studies. The effect of temperature and fungicide on mycelial growth of isolates

used in fruit inoculations was evaluated in vitro. Isolates were grown on PDA in plastic petri dishes. Plugs, 5 mm in diameter, were taken from the edges of actively growing PDA cultures and placed in the center of 10-cm-diameter plates containing approximately 20 ml of PDA. For temperature experiments, plates were incubated in the dark at 14 and 25°C. Three replicates per isolate were evaluated at each temperature. The experiments were conducted twice. Radial growth measurements were initiated 24 h after colony growth began at the different temperatures. The experimental design was a split-plot RCBD with experiments as blocks, temperature as the main plot, and isolate as the subplot. My-

celial growth rate was calculated by dividing colony radius by days of growth. ANOVAs were performed to evaluate the relationships between growth rates and temperatures among isolates.

In fungicide studies, seven fungicide concentrations of OHP 6672 (0.0, 0.1, 0.5, 0.75, 1.0, 5.0, 10.0, and 15.0 g a.i. liter⁻¹) were tested in vitro. Fungicide that was suspended in sterile distilled water was added to previously cooled, autoclaved PDA to give the desired concentrations. Fungicide impact on linear growth rate and the 50% effective dose (ED₅₀) were determined for isolates of *F. sacchari* (GF1), *F. verticillioides* (GF2), *F. pseudocircinatum* (GF3), *F. proliferatum* (GF4), the *Fusa-*

Fig. 2. One of the 1,520 most parsimonious trees from the β -tubulin data set, which included 37 isolates and 262 characters, 76 of which were parsimony informative. Tree length was 156 (CI = 0.77, RI = 0.94). Fuzzy pedicel *Sporothrix* isolates are marked with a closed circle, and GenBank accession numbers appear after other isolates that were used in this analysis. *Sporothrix* sp. AM498344 was recently described as *S. mexicana* (16).

rium incarnatum-equiseti species complex (FIESC)1, and *Sporothrix* sp. (SPOR1 and SPOR3). The experimental design was a split plot in an RCBD with fungicide concentration as the main plot and isolate as the subplot. The experiment was repeated twice and each experiment was treated as a block. Colonies were grown in the dark at 25°C and their radial growth was recorded after 7 days. Linear regressions were performed for colony growth versus fungicide concentration, and ED₅₀ values were calcu-

lated as the fungicide concentration at which mycelia growth was 50% of colonies grown on nonamended PDA. ED₅₀ values of isolates were compared with ANOVAs. Also, percent inhibition of mycelia growth was calculated according to Edington et al. (4).

RESULTS

Identification and frequency of isolates associated with fuzzy pedicels. Based on conidium and conidiophore mor-

phology, fungi examined directly on fuzzy pedicels were identified as *Sporothrix* sp. (71.8% of fruit) and *Fusarium* spp. (9.4%); the remaining samples did not sporulate and could not be identified from hyphal morphology alone. The most common genera that colonized pedicel tissue were, in descending order: *Sporothrix*, 71.8%; *Nigrospora*, 21.9%; *Fusarium*, 15.6%; and *Pestalotiopsis*, 15.6%. Due to their prevalence on the pedicel surface, representative isolates of the *Fusarium* and *Sporothrix* spp. were examined further; colony morphology and conidium and conidiophore characteristics were compared with published descriptions, and the respective EF1 α , and β -tubulin and ITS sequences were compared with those published in GenBank (Table 1). Sequence-based identifications of the *Fusarium* taxa matched their morphological identities (15).

Among the *Fusarium* taxa, members of the FIESC were most common, followed by species in the *Gibberella fujikuroi* species complex (GFSC). FIESC isolates were assigned to species reported in O'Donnell et al. (19), based on EF1 α sequence alignment with species that were resolved in that study; two species were identified, corresponding to *Fusarium* spp. 15 (FIESC 1) and 16 (FIESC3 and 4) in the Incarnatum clade. FIESC 1 was used in the present inoculation studies and was placed in haplotype 15C based on multilocus sequence data, as described by O'Donnell et al. (19) (Stacy Sink, NCAUR United States Department of Agriculture–Agricultural Research Service, Peoria IL; *personal communication*). FIESC 1 is deposited in the NCAUR collection as NRRL 54202. Representative accessions of the GFSC were also deposited in the NCAUR collection: *F. proliferatum* (GF4 = NRRL 54201), *F. pseudocircinatum* (GF3 = NRRL 54200), *F. sacchari* (GF1 = NRRL 54198), and *F. verticillioides* (GF2 = NRRL 54199).

The *Sporothrix* β -tubulin data set included 37 accessions and 262 characters, 76 of which were parsimony informative. Maximum parsimony analysis resulted in 1,520 most parsimonious trees (MPTs) with a length of 156 (CI = 0.77, RI = 0.94; Fig. 2). The fuzzy pedicel *Sporothrix* isolates (SPOR1, SPOR3, and SPOR 4) had identical β -tubulin sequences and resolved into a highly supported clade (96% bootstrap support [BS]) with *Sporothrix mexicana*, isolate CBS120341, which was recovered from soil in Mexico (16) and is closely related to *S. pallida*, *S. stylites*, and a clade that contains *S. humicola*, *S. stylites*, *Ophiostoma palmiculminatum*, *O. gemellus*, and *Ophiostoma protea-sedis* (23).

The *Sporothrix* ITS data set contained 43 accessions and 371 characters, of which 71 were parsimony informative. Maximum parsimony analysis resulted in 3,202 MPTs with a length of 119 (CI = 0.79, RI = 0.94; Fig. 3). The fuzzy pedicel *Sporothrix* iso-

Fig. 3. One of the 3,202 most parsimonious trees from the internal transcribed spacer data set, which included 43 isolates and 371 characters, 71 of which were parsimony informative. Tree length was 119 (CI = 0.79, RI = 0.94). *Sporothrix* isolates that were associated with fuzzy pedicel are marked with a closed circle, and GenBank accession numbers appear after other isolates that were used in this analysis.

lates had ITS sequences that differed by 1 to 3 nucleotides and resolved in a well-supported clade (86% BS) with *S. pallida*, *S. humicola*, and *S. stylites*; the former two species were described by de Meyer et al. (3).

Reproduction of fuzzy pedicel symptoms and affects of temperature and fungicide on *Fusarium* and *Sporothrix* isolates. Fungicide treatment had a significant impact on the internal colonization of pedicels and the incidence of and days to fuzzy pedicel development ($P = 0.0243$, P

< 0.0001 , and $P = 0.0245$, respectively). Blocks significantly affected days to sign development ($P = 0.0035$). Symptoms did not develop on fungicide-treated fruit that were inoculated with *Fusarium* spp. but did develop on those that were inoculated with isolates of *Sporothrix* sp. (Fig. 4A and B). Internal colonization of pedicels did not occur in fungicide-treated pedicels and never occurred in pedicels inoculated with *Sporothrix* sp. (Fig. 4B). The average days to fuzzy pedicel development was not significantly different among isolates and

ranged from 6 to 9 days after inoculation for nontreated fruit.

Temperature significantly impacted fuzzy pedicel incidence and percent internal colonization of pedicels by isolates ($P < 0.0001$ and $P = 0.0421$, respectively). Days to fuzzy pedicel development were affected significantly by blocks ($P = 0.0327$). Incidence and internal colonization were not affected significantly by the different isolates ($P = 0.0751$ and 0.0519) but were lower at 14 than 25°C (Fig. 5A). Fruit incubated at 14°C were generally not

Fig. 4. Fungicide sensitivity of fuzzy pedicel isolates: **A**, incidence of and **B**, days until fuzzy pedicel development; and **C**, percent internal colonization of pedicels. A and C were recorded after 14 days. F = treated with fungicide (0.52 g of thiophanate methyl liter⁻¹) and NF = no fungicide. Bars = $\pm$ standard errors.

Fig. 5. Influence of temperature on **A**, incidence of and **B**, days until fuzzy pedicel development; and **C**, percent internal colonization of pedicels. Bars = $\pm$ standard errors.

Table 2. Effect of thiophanate methyl on the in vitro growth of fuzzy pedicel isolates^x

Isolate ^y	Percent inhibition of radial growth at fungicide concentration (g liter ⁻¹)							ED ₅₀ (g/liter) ^z
	0.1	0.5	0.75	1.0	5.0	10.0	15.0	
GF1 (<i>Fusarium sacchari</i>)	30.4	98	100	100	...	...	...	0.31 bc
GF2 (<i>F. verticillioides</i>)	83.4	100	100	100	...	...	...	0.24 c
GF3 (<i>F. pseudocircinatum</i>)	8.5	70.7	93.7	100	...	...	...	0.47 bc
GF4 (<i>F. proliferatum</i>)	13.45	83.45	97.8	98.8	...	...	...	0.42 bc
FIESC1 (<i>Fusarium</i> sp. 15C)	52	66.4	77.7	80.4	...	...	...	0.56 ab
Spor1	...	...	...	7.9	16.5	21.2	34.3	N/A
Spor3	...	...	...	1.45	21.25	33.6	35.1	N/A

^x Thiophanate methyl as OHP 6672 (50% a.i.).^y FIESC = *Fusarium incarnatum-equiseti* species complex.^z ED₅₀ = 50% effective dose. Least significant difference, *P* = 0.0333; N/A = not applicable. **Fig. 6.** Effect of temperature on in vitro radial growth of seven isolates associated with fuzzy pedicel of banana.

colonized internally, with exception of isolates FIESC1 and GF1 (*F. sacchari*) (Fig. 5B). Days to fuzzy pedicel development varied from 4 to 11 days for a given isolate but there was no significant isolate effect (*P* = 0.8638). Temperature did not have a consistent impact on days to fuzzy pedicel development (Fig. 5C).

In vitro temperature and fungicide sensitivity assays. Thiophanate methyl inhibited the mycelial growth of all *Fusarium* isolates but had a relatively minor impact on *Sporothrix* sp. (SPOR1 and SPOR3) (Table 2). Growth of all isolates was at least 50% less at 14 than at 25°C (Fig. 6).

DISCUSSION

A new disease of banana, fuzzy pedicel, has been described which develops when single fingers are packaged in gas-permeable containers. Some of the fungi that were recovered from affected pedicels had been reported previously on banana, including several species of *Fusarium* and *N. sphaerica* (7,8,10–12,14,18,24). However, *Sporothrix* spp. and *F. pseudocircinatum* have not been reported previously on banana.

Sporothrix is an anamorphic genus associated with *Ophiostoma* teleomorphs. *S.*

schenkii, a member of the *O. stenoceras*–*S. schenkii* species complex, has been associated with soil, plant material, insects, and animals; it causes sporotrichosis, a dermatological or pulmonary mycosis that is most common in South and Central America (2,21). Cases of sporotrichosis most often develop from puncture wounds when handling colonized plant matter, although transmission from animals has also been implicated (22).

Although *S. schenkii* and nonpathogenic, morphologically similar *Sporothrix* isolates have been confused, recent systematic work distinguished four species from *S. schenkii*: *S. stylites*, *S. lignivora*, *S. pallida*, and *S. humicola* (3). Based on the β -tubulin phylogeny, it appears that the banana isolates may represent another species in a clade that contains three of the above *Sporothrix* spp. as well as *O. gemellus*, *O. palmiculatum*, and *O. protea-sedis* (23). The banana isolates were most closely related to and may be conspecific with *S. mexicana* (16). Species in this clade are saprotrophs and endophytes, and none have been identified as human pathogens. Thus, the banana isolates do not appear to pose a threat to human health. Their source and how infection of banana could be avoided are not known.

Fusarium spp. are frequent associates and causes of crown rot of banana (9,10,14,20,26). The fuzzy pedicel isolates fell in the GFSC and FIESC, which contain previously reported banana pathogens. Their relatively infrequent colonization of the pedicel surface in the present study may have been due to prior treatment of the shipped fruit with fungicides or from competition from *Sporothrix* sp. on the pedicel surface. The two FIESC species that were recovered had >99% EF1 α sequence homology with species that were recently reported in a study of clinical FIESC isolates (19); they have not been described formally.

The high relative humidity in the containers that were used to package individual fingers provided an ideal environment for fungal colonization. The high incidences of fuzzy pedicel that developed on noninoculated control fruit (Fig. 2A) indicates that this disease may be difficult to manage. In the primary survey, multiple species were isolated as internal colonizers of the pedicel, of which only *Sporothrix* and *Fusarium* spp. were identified as causes of fuzzy pedicel. Depending on the postharvest treatment of and storage conditions for fruit, other species could also cause fuzzy pedicel. For example, in control fruit that were produced in Florida and used in the fungicide/temperature study, species of *Alternaria*, *Fusarium*, and *Colletotrichum* were most often identified as pedicel colonizers (data not shown). This differs from the results for the fruit that were imported from Guatemala, and suggests that diverse fungi could cause fuzzy pedicel in different locations.

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