Diseases Caused by Fungi and Fungus-Like Organisms

First Report of *Fusarium* Yellows and Rhizome Rot Caused by *Fusarium oxysporum* f. sp. *zingiberi* on Ginger in the Continental United States

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Ginger (*Zingiber officinale* Roscoe) is one of the most widely consumed medicinal herbs in the world, and the U.S. imports of ginger have risen in recent years because of its health benefits. Since ginger is propagated vegetatively through underground rhizomes and has a very low multiplication rate, seed rhizome and soilborne diseases are major concerns worldwide (Moreira et al. 2013; Stirling 2004). In October 2018 and October 2019, ginger plants of cultivar 'Chinese' with yellowing of leaf margins and stunted growth were uprooted from a 9.1 m × 14.6 m high tunnel (HT) and from an outdoor raised bed at Virginia State University's Randolph farm. Disease incidence in the HT and the raised bed was estimated between 5 and 70%. Small pieces (2 to 5 mm) of symptomatic rhizomes were disinfected with 0.6% sodium hypochlorite solution and placed on potato dextrose agar (PDA) Petri plates to recover the fungal isolate (Gf-VA-3). Hyphal tips from the isolate were transferred to fresh PDA to obtain pure cultures. The fungal colonies were pinkish-white initially, and turned purplish-pink after 5 to 7 days of incubation at 25°C. The microconidia were aseptate, oval or elliptical, hyaline, and measured 5.0 to 12.0 × 4.0 to 6.0 µm in size. Macroconidia were 3 to 5 septate, curved like a sickle toward the ventral side, hyaline, smooth and thin-walled, and 15.0 to 40.0 × 3.0 to 6.0 µm in size. Fungal genomic DNA was extracted from a 7-day-old culture of the isolate using PrepManUltra (Thermo Fischer Scientific, Cheshire, UK). Four conserved regions of the isolated fungus, i.e., internal transcribed spacer (ITS), translation elongation factor (EF), β-tubulin (Bt), and calmodulin (cal) gene regions were amplified using ITS1 and ITS4 (White et al. 1990),

ef1α and ef2α (O'Donnell et al. 1998), Bt2a and Bt2b (Glass and Donaldson 1995), and calA1 and calQ1 (Carbone and Kohn 1999) primers, respectively. PCR products were sequenced, and amplicons deposited in GenBank with the following accession numbers; MT337417 for ITS, MT436712 for Bt, MT802441 for cal, and MW816632 for EF. A 99 to 100% identity with *Fusarium oxysporum* isolates matched with the following accession numbers: MW776326 for ITS, MN646766 for the β-tubulin, MT010904 for the calmodulin, and MN258350 for the translation elongation factor genes. For pathogenicity test, six 6-week-old healthy ginger plants grown on sterilized potting mix in the greenhouse were inoculated by injecting 3 ml of suspension (1 × 10⁸ micro- and macroconidia/ml) at the crown area transcending to the rhizome. Another set of six plants were injected with distilled and autoclaved water in the same way. After 4 weeks, leaves withered, plants exhibited yellowing and wilt followed by stunted growth and eventually complete collapse of the six inoculated plants; however, control plants showed none of the symptoms. The same fungus was reisolated from the inoculated plants. The pathogenicity test was repeated, and the same results were observed. *Fusarium* yellows and rhizome rot has been reported from Hawaii in the U.S. (Trujillo 1963), Brazil (Moreira et al. 2013), Australia (Stirling 2004), China (Li et al. 2014), and India (Shanmugam et al. 2013). To our knowledge, this is the first report of *Fusarium* yellows and rhizome rot on ginger in the continental U.S. The disease is transmitted through seed rhizomes and the soil, resulting in poor establishment and economic losses in ginger production.

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