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Review

Pythium soft rot of ginger: Detection and identification of the causal pathogens, and their control

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ABSTRACT

Ginger is considered by many people to be the outstanding member among 1400 other species in the family Zingiberaceae. Not only it is a valuable spice used by cooks throughout the world to impart unique flavour to their dishes but it also has a long track record in some Chinese and Indian cultures for treating common human ailments such as colds and headaches. Ginger has recently attracted considerable attention for its anti-inflammatory, antibacterial and antifungal properties. However, ginger as a crop is also susceptible to at least 24 different plant pathogens, including viruses, bacteria, fungi and nematodes. Of these, *Pythium* spp. (within the kingdom Stramenopila, phyllum Oomycota) are of most concern because various species can cause rotting and yield loss on ginger at any of the growth stages including during postharvest storage. *Pythium gracile* was the first species in the genus to be reported as a ginger pathogen, causing Pythium soft rot disease in India in 1907. Thereafter, numerous other *Pythium* spp. have been recorded from ginger growing regions throughout the world. Today, 15 *Pythium* species have been implicated as pathogens of the soft rot disease. Because accurate identification of a pathogen is the cornerstone of effective disease management programs, this review will focus on how to detect, identify and control *Pythium* spp. in general, with special emphasis on *Pythium* spp. associated with soft rot on ginger.

1. Introduction

Ginger (*Zingiber officinale* Roscoe) is a perennial monocotyledonous herb belonging to the Zingiberaceae, a family comprised of 47 genera and 1400 species (Hogarth, 2000). Other important spices in the family include turmeric (*Curcuma longa*), cardamom (*Elettaria* sp.), mioga (*Zingiber mioga*), and galangal (*Alpinia galanga*). The entire family, including ginger, is presumed to be native to either Asia in general (Singletary, 2010) or specifically to India; however its exact origin is still unclear (Zachariah, 2008). Today ginger is cultivated worldwide throughout the subtropics and tropics where it plays an important role in agricultural economic systems in these regions (Kavitha and Thomas, 2008b). The usable part of the plant is the underground stem or rhizome which can be consumed either fresh for culinary purposes or as a processed product where it may be salted, dried, and/or powdered, used as a paste, or extracted as ginger oil or oleoresin (Kizhakkayil and Sasikumar, 2011). Ginger is planted and traded mainly in the form of fresh rhizomes in India, China, Indonesia and in other countries where it is grown. When imported into the United States, the European Union and Japan it is usually marketed in a processed form (De-Guzman and Siemonsma, 1999).

Flavour and pungency can vary considerably but it is not just cultivar, that contributes to this as environmental factors such as soil type, season, climate, cultivation practice, location, maturity and postharvest processes have also been shown to contribute to differences in these properties (Singletary, 2010; Vasala, 2010; Zachariah, 2008). In general the genetic diversity within *Z. officinale* is actually considered to be limited. Sasikumar et al. (2000) found this to be the case when they evaluated 14 ginger accessions in India, looking for differences in relative quantities of polyphenol oxidase, super oxidase dismutase and peroxidase. Similarly, Wahyuni et al. (2003) found relatively close genetic relationship of 28 apparently diverse accessions of big, small and red ginger cultivars in Indonesia based on AFLP (amplified fragment

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length polymorphism) analysis of their respective DNA. Many other types of molecular markers have been used to assess levels of polymorphism in ginger, and in general the results show only low to moderate variation with just a few exceptions (Kizhakkayil and Sasikumar 2011).

The ginger rhizome contains carbohydrates, proteins, fats, fibre, water, and essential oils. In addition to its nutritional and flavour aspects, it has long been considered to have potential for multiple health benefits as illustrated by its use as a traditional medicine against headache, nausea, colds, and arthritis for as long as a thousand years by traditional people in Asia. More recent assessments by health scientists have shown that ginger may have a role in reducing certain cancers, diabetes, and high blood pressure and also have anti-inflammatory properties (Anonymous, 2010; Hamilton, 2011; Krell and Stebbing, 2012; Langner et al., 1998; Nicoll and Henein, 2009; Shukla and Singh, 2007; Vasala, 2010; Wright, 2011; Zachariah, 2008). However, there are still a few, albeit uncommon, minor adverse effects resulting from the consumption of ginger; these include slight gastrointestinal distress, heartburn, and oral irritation.

Properties of note associated with ginger are its antimicrobial aspects. It has been shown to act as an antibacterial agent (Park et al., 2008; Shaista et al., 2010) where it has been shown to inhibit growth of *Escherichia coli*, *Proteus* spp., *Staphylococci*, and *Salmonella* in vitro assays (Bhatia and Sharma, 2012; Janes et al., 1999; Stoilova et al., 2007; Voravuthikunchai et al., 2006). It has also been shown to have antifungal properties, inhibiting growth of *Aspergillus* spp., *Saccharomyces* spp., *Mycoderma* spp., and Candida spp. (Atai et al., 2009). Despite its antimicrobial properties, ginger is still a host of at least 24 known plant pathogens (Dake, 1995) including viruses (Nambiar and Sarma, 1974; Nishino et al., 1984; Suryanarayana and Pant, 2008), bacteria (Kumar and Sarma, 2004; Nishijima et al., 2004; Stirling, 2002), Oomycota (Sharma and Jain, 1977; Stirling et al., 2009; Wang et al., 2003) and fungi (Gao et al., 2006; Overy and Frisvad, 2005; Rai, 1993; Sharma and Jain, 1977; Stirling, 2004).

The aims of this review are to provide an overview of one particular problematic disease of cultivated ginger that occurs wherever ginger is grown. The disease is commonly known as “soft rot” and although the name suggests involvement of just one pathogen, it is actually caused by several species in the genus *Pythium* (Stramenopila: Oomycota). Historical and contemporary information on the biology and management of the respective pathogens will be discussed.

2. Impacts of Pythium soft rot on ginger production

2.1. Economic impacts

Pythium soft rot of ginger is also known as soft rot or rhizome rot of ginger. Hereafter, the name Pythium soft rot (PSR) will be used to refer to the disease in question in order to avoid confusion with other common ginger diseases caused by *Fusarium* spp. and *Ralstonia* spp. where a rot is involved.

PSR was recorded in scientific literature for the first time when it was found in India more than a hundred years ago (Butler, 1907). Presently, PSR occurs in ginger growing countries throughout the world (Dohroo, 2005). The pathogens responsible for PSR can infect host plants at any stages of growth and even during postharvest storage when growth from latent infections can cause severe losses. Most *Pythium* spp. flourish in the field when the soil temperature is high (26–30 °C) and soil moisture is near or at saturation (Lin et al., 1971; Sarma, 1994; Stirling et al., 2009). Such conditions occurred in the ginger growing region of Queensland, Australia during the summer of 2007–08 and resulted in 5–30% losses of immature ginger in some infested fields (Stirling et al., 2009). This was the first formal report of PSR in Australia, and the relatively high losses caused alarm among growers. However, consistently higher field losses have been reported in other countries; for example losses of 5–30% in Japan (Ichitani and Goto, 1982), 18–54% in Korea (Kim et al., 1996), 25% in Nepal (Nepali et al., 2000), 70% in Taiwan Lin et al. (1971), 90% in India (Rajan and Agnihotri, 1989) and 100% in some fields in Fiji (Fullerton and Harris, 1998; Stirling et al., 2009). Stirling et al. (2009) also reported more than 50% loss of plants used for seed ginger production in Australia. In most cases these heavy losses have occurred in years when weather conditions were favourable for pathogen growth (Fig. 1). The impact of *Pythium* spp. can also be high in storage; losses ranging from 24 to 50% have been reported with rates occasionally exceeding 90% in India (Dohroo, 2005; Nepali et al., 2000).

2.2. Ecological impacts

Pythium spp. are able to persist in soil for long periods and the assumptions have been that this is mostly by means of encysted zoospores, oospores and sporangia (Hendrix and Campell, 1973; Madsen et al., 1995). Evidence for this has been shown by Stanghellini (1971) who found that sporangia of *Pythium ultimum* can remain viable in air dried soil for a year without reduction in germination. Hoppe (1966) also reported that some *Pythium* spp. survived in air dried soil for up to 12 years and Garren (1971) reported that *Pythium myriotylum* remained infectious for approximately a year when it was held in soil enclosed in a plastic bag at room temperature. Persistence is also influenced by survival on host tissue. For example, *Pythium zingiberis* oospores lost capability to germinate within 70 days after burying in soil in the absence of susceptible hosts (Samejima and Ichitani, 1988). *Pythium* spp. in general have quite a wide host range, so they can survive long periods of time in the field on alternative hosts including weeds. Consequently, susceptible crops may still be affected if replanted into an infested field years after fallows or rotations. Certainly, Lin et al. (1971) in Taiwan observed that ginger yields were still not acceptable in the year following a serious disease outbreak caused by *P. myriotylum*. In Australia, yields were still impacted up to 7 years after a serious outbreak of PSR. In Japan, Ichitani and Goto (1982) found that *P. zingiberis* was still detectable from previously infested soils 4–5 years after rotations with non-host crops and consequently induced PSR developed when ginger was re-introduced to these fields.

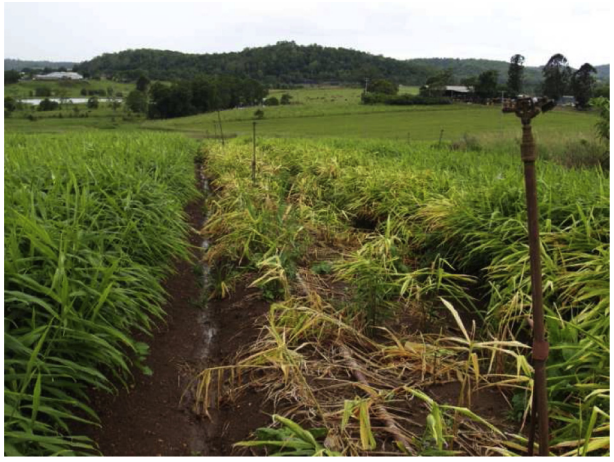

Fig. 1. A ginger crop in Australia showing symptoms of Pythium soft rot illustrating disease progress down a row which associated with saturated soils after a prolonged, heavy rainfall event.