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Effect of cultural practices and fungicides on Phytophthora fruit rot of watermelon in the Carolinas

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Phytophthora fruit rot of watermelon, caused by *Phytophthora capsici*, is an important and emerging disease in Southeastern U.S.A. The effects of two cultural practices (raised bare ground and raised plastic mulched beds) used for growing watermelon and different fungicide treatments on development of Phytophthora fruit rot were evaluated. The experiments were conducted over three years (2005–2008) at research stations in North Carolina and South Carolina, U.S.A. Fungicides were applied at weekly intervals on the diploid cv. Mickey Lee for an average of five applications. Fruit rot incidence was recorded at the end of each experiment. Fruit rot incidence in the non-treated plots was 66% across two states and six trials. Overall, the levels of fruit rot on the raised bare ground and raised plastic mulched beds were not significantly different. Based on percent disease reduction relative to the non-treated check plots, the fungicide Captan was the most effective across years and locations (range = 23–70%, mean = 57%), followed by mandipropamid (25–65%, mean = 50%), fluopicolide (24–65%, mean = 43%) and cyazofamid (0–48%, mean = 31%). Mefenoxam, the current standard treatment reduced fruit rot by 8–28% (mean = 18%). The addition of copper hydroxide to the spray mix did not significantly enhance effectiveness of Captan or mandipropamid. The variability in fungicide efficacy observed in these experiments across locations and years demonstrates the importance of environmental conditions in disease development and management. Even when the most effective fungicides are used, heavy losses may occur when conditions are highly favorable for disease development. Ultimately, effective control of Phytophthora fruit rot of watermelon will require an integrated management strategy that includes well-drained fields, water management and crop rotation in addition to fungicides.

1. Introduction

Phytophthora capsici was first described by Leonian as a pathogen of chili peppers in the 1920s (Leonian, 1922). Since then, it has been documented on a wide variety of vegetable crops in the family Solanaceae (tomato, pepper, eggplant), Cucurbitaceae (cucumber, watermelon, squash, pumpkin, melon), and Fabaceae (Erwin and Riberio, 1996; Gubler and Davis, 1996; Hausbeck and Lamour, 2004). It also has been reported as pathogenic on several different weed species (French-Monar et al., 2006), and has recently been described as a pathogen of Frasier fir (Quesada-Ocampo et al., 2009). *P. capsici* can infect most parts of the plant and cause a wide variety of symptoms, including leaf blight and fruit and crown rots on cucurbits and pepper, and buckeye fruit rot on tomatoes (Erwin and Riberio, 1996; Gubler and Davis, 1996; McGrath, 1996; Hausbeck and Lamour, 2004; French-Monar et al., 2006; Keinath, 2007).

Fruit rot of watermelon [*Citrullus lanatus* var. *lanatus* (Thunberg) Matsum & Nakai] caused by *P. capsici*, was first reported in 1940 (Wiant, 1940) and now is an emerging disease in many watermelon growing regions, particularly in the Southeastern U.S.A. *P. capsici* has been reported to cause severe losses in cucurbit production since the 1940s to the extent that in some instances growers have ceased production in severely infested fields (Kreutzer et al., 1940; Babadoost, 2004; Hausbeck and Lamour, 2004; Babadoost and Zitter, 2009). Between 2003 and 2008, we observed several

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watermelon farms in Georgia, South Carolina and North Carolina where growers did not harvest the crop due to severe fruit rot. Such instances and many others led the National Watermelon Association, a grower's consortium, to rank Phytophthora fruit rot as a top research priority (Morrissey, 2006).

The loss of methyl bromide as a soil fumigant has greatly increased the difficulty of managing soil-borne diseases caused by pathogens such as *P. capsici*. Banning methyl bromide was anticipated to result in increased use of fungicides to manage soil-borne diseases. The loss of methyl bromide for pre-plant soil fumigation was estimated to result in annual yield losses of 15–20% for watermelon in Georgia and Florida (Lynch and Carpenter, 1999). Another report estimated losses of up to $235 million for strawberries, tomato and other vegetable crops (Osteen, 2003) due to loss of methyl bromide. This has prompted the search for alternatives to manage diseases caused by soil-borne pathogens. The current recommended strategies to manage *P. capsici* include: cultural practices that ensure well-drained soils in the field, crop rotation, soil solarization, reducing splash dispersed soil and various chemical controls (McGrath, 1996; Ristaino and Johnston, 1999; Babadoost, 2004). Crop rotation is of limited value because oospores of the pathogen persist in the soil for many years (Lamour and Hausbeck, 2000; Hausbeck and Lamour, 2004). Lamour and Hausbeck (2000) reported the rapid development of mefenoxam insensitivity in *P. capsici* under intense selection pressure. They also reported that crop rotation in combination with mefenoxam applications did not control *P. capsici* effectively.

About 50% of watermelons in U.S.A. (USDA, NASS, Vegetables 2010 summary) are produced in the Southeastern States (FL, GA, SC, NC and VA), where conditions are favorable for the development of Phytophthora fruit rot. Watermelons are generally grown on raised (90–95-cm wide and 15–20 cm high) plastic mulched beds or in some cases on raised bare ground beds in these states. In certain parts of Georgia, watermelons are grown on raised narrow (35-cm wide) plastic mulched beds. To date, most growers do not use fungicides to manage Phytophthora fruit rot of watermelon. One reason for this could be because the use of fungicides to mange Phytophthora fruit rot of watermelon has not been adequately investigated, and also because this disease has recently become an important limiting factor in watermelon production. The present study was conducted to determine the effects of raised bare ground or raised plastic mulched beds in combination with fungicides on the development of Phytophthora fruit rot of watermelon.

2. Materials and methods

2.1. Cultural practices and experimental design

Field experiments to determine the effect of cultural practices and fungicides on development of Phytophthora fruit rot of watermelon were conducted from 2005 to 2008 at the U.S. Vegetable Laboratory research farm, Charleston, South Carolina and at the NCSU Cunningham research farm, Kinston, North Carolina. These locations are approximately 480 km apart. Standard watermelon production practices with respect to irrigation, and weed management were followed at both locations (Sanders, 2006). The experiments were arranged in a split plot design with four replications. Two cultural systems; raised plastic mulched beds and raised bare ground beds (approx. 15-cm high) were the two main plot treatments and the fungicide sprays were the sub-plot treatments. The commercial diploid (seeded) and fruit rot susceptible cultivar 'Mickey Lee' (Willhiteseeds.com, Pooleville, TX, USA) was used in all the experiments. Transplants were grown in 72-cell plastic plug trays (LE 1803 Landmark Plastic Corp.) in North Carolina and 50-cell jiffy trays (Jiffy Products of America, Norwalk, OH) filled with Metro Mix (Sun Gro Horticulture, Bellevue, WA) in South Carolina. Seedlings were transplanted to the field approximately four weeks after seeding. Irrigation was provided by drip tape placed about 2.5-cm below the soil surface along the center of the raised beds at both locations. The transplanting and start of fungicide spray dates are provided in Table 1. In North Carolina, for all years (2005, 2007 and 2008), plots consisted of double rows on 2.4-m centers, 6-m long with 2.4-m borders on each side and 3-m borders on each end. Plants were spaced 90-cm apart within rows, resulting in 14 plants per two-row plot. In South Carolina, plots were single row raised beds with spacing of 4.3-m between beds in 2006, and 6.3-m in 2007 and 2008. The raised beds were 95-cm wide on top. Each raised bare ground or raised plastic mulched bed (main plots) was a replication and was 92-m long in 2006 and 104-m long in 2007 and 2008. Within each main plot the ten fungicide treatment plots (sub-plots) were arranged randomly. There were four replications per fungicide treatment with one row of 12 plants per plot that were 5.94-m long. Plants were spaced 45-cm apart within rows. There was 3.3-m spacing between each fungicide treated plot in the bed in 2006 and 4.5-m in 2007 and 2008. The watermelon vines were turned regularly to prevent them from growing into neighboring plots.

2.2. Fungicide treatments and spray applications

Fungicide treatments were initiated when the largest fruits were approximately 7.5-cm in diameter. Fungicides were applied on a 7-day interval at both locations over the entire crop canopy including the fruit. The start dates and number of applications for each experiment are presented in Table 1. In 2005 seven fungicide treatments were evaluated in North Carolina. In 2007 and 2008 eleven fungicide treatments were evaluated. Nine of the eleven fungicide treatments evaluated in North Carolina were also evaluated in 2006, 2007 and 2008 in South Carolina. The details of the individual fungicides, rate, and their trade names are presented in Table 2. Some of the fungicides were not labeled for use on watermelon. The rates of these fungicides were chosen based on the recommendations of the manufacturer or recommended rates for other crops. Fungicide treatments at both locations were

Table 1
Dates for transplanting, start of weekly fungicide spray applications, inoculation, evaluation date and the number of fungicide applications at the two locations of study in North and South Carolina from 2005 to 2008.

Year	State	Transplant date[a]	Start of fungicide applications[b]	Number of fungicide applications	Inoculation dates	Evaluation date
2005	NC	18 Jul.	25 Aug.	5	12 & 19 Sept.	26 Sept.
2007	NC	24 Jul.	4 Sept.	7	13 Sept. & 5 Oct.	10 Oct.
2008	NC	25 Jul.	5 Sept.	5	22 & 30 Sept.	10 Oct.
2006	SC	12 Jun.	21 Jul.	5	27 Jul. & 10 Aug.	23 Aug.
2007	SC	22 May	13 Jul.	5	2 Aug.	31 Aug.
2008	SC	19 Jun.	5 Aug.	4	26 Aug.	2 Sept.

[a] Approximately four-wk-old transplants of the diploid (seeded) cultivar Mickey Lee were used in both locations.
[b] Fungicide applications were started at both locations when fruit were approximately 7.5-cm in diameter.