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Management of white mold in processing tomatoes by *Trichoderma* spp. and chemical fungicides applied by drip irrigation

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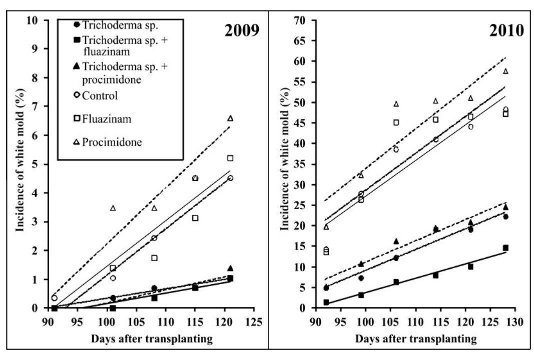
HIGHLIGHTS

- White mold on processing tomato was controlled by *Trichoderma* spp.
- Control was achieved by chemigation in a drip-irrigated field, in 2009 and 2010.
- White mold control was not improved by fungicides applied via chemigation.
- The use of *Trichoderma* spp. increased processing tomato yields in up to 25 t ha^{-1}.
- Biological control increased pulp yield from 1.0 (2009) to 7.0 t ha^{-1} in 2010.

GRAPHICAL ABSTRACT



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ABSTRACT

Field trials were carried out to evaluate six treatments combining biological agents and chemical fungicides applied via chemigation against white mold (*Sclerotinia sclerotiorum*) on processing tomatoes. The experiment was performed in Goiânia, Brazil, with tomato hybrid Heinz 7155 in 2009 and 2010 in a field previously infested with *S. sclerotiorum* sclerotia. Treatments were arranged in a randomized complete block design in a 2 × 3 factorial structure (with and without *Trichoderma* spp. 1.0 × 10^{9} viable conidia mL^{-1} ha^{-1}) × fluazinam (1.0 L ha^{-1}), procimidone (1.5 L ha^{-1}) and control, applied by drip irrigation. Treatments were applied three times 10 days apart, starting one month after transplanting. Each treatment consisted of plots with three 72-meter rows with four plants m^{-1} and 1.5 m spacing between rows, with three replications. Based on disease incidence evaluated weekly, the area under the disease progress curve (AUDPC) was obtained. Yield and its components were evaluated in addition to fruit pH and °Brix. Results were subjected to ANOVA, Scott-Knott (5%), and regression analysis. Biocontrol using *Trichoderma* spp. via chemigation singly or in combination with synthetic fungicides fluazinam and procimidone reduced AUDPC and increased fruit yield up to 25 t ha^{-1}. The best treatment for controlling white mold also increased pulp yield around 1.0 and 7.0 t ha^{-1} in 2009 and 2010, respectively. The present work demonstrated the advantages of white mold biological control in processing tomato crops, where drip irrigation favored *Trichoderma* spp. delivery close to the plants and to the inoculum source.

1. Introduction

Brazil ranks ninth in the world in tomato (*Solanum lycopersicum* L.) production. The majority of the crop is intended for industry, where transformation into value-added products renders this

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species the most economically important vegetable in the Brazilian Central-West Region. Approximately 80% of the irrigated processing tomato crop is concentrated in the states of Minas Gerais and Goiás, which is the largest producer, averaging yields of 92 t ha^{-1}. To attain such high yields, however, large amounts of inputs are necessary, which elevate production costs (FAEG/GETEC, 2010).

Disease incidence figures among the many factors limiting tomato production and fungicide utilization account for 17% of the total costs of producing a crop (FAEG/GETEC, 2010). Among the relevant pathogens causing damage to processing tomato crops, *Sclerotinia sclerotiorum* (Lib.) De Bary stands out as a soil-borne fungus that causes white mold disease. Under mild temperatures and high soil moisture content, environmental conditions commonly found in tomato crops, *S. sclerotiorum* sclerotia germinate in the infested soil, producing hyphae, which may directly infect hosts or, in most cases, apothecia, which in turn release ascospores colonizing senescent flowers (Jones et al., 1991). Affected shoots present a cotton-like white mycelium, which is easily broken later on, and originate numerous black sclerotia, structures used for long-term survival in the soil, externally and/or within the stem.

Since the pathogen is polyphagous and considering the absence of resistance in tomato hybrids, chemical control has been the most common method employed for disease management. Despite aerial plant protection, fungicides rarely impact sclerotia in the soil, leaving an ample source of initial inoculum for the next host crop. For this reason, infested areas depend annually on several spraying operations to control disease and limit pathogen multiplication. In areas subjected to drip irrigation, it is possible that difficulties in reaching the pathogen structures in the soil may be overcome using fungicides via irrigation water, known as chemigation.

Specifically for white mold control, chemigation may present the advantage of reaching the soil surface and the first 5 cm soil depth, considered the maximum depth for carpogenic germination of sclerotia (Abawi and Grogan, 1975), directly affecting sclerotia, mycelia, and apothecia. Chemigation is also economically recommended over conventional chemical applications because it reduces hand labor and time in addition to preventing soil compaction caused by tractors that may negatively affect crop yield (Pinto, 1994). However, its practicability and efficacy have not yet been estimated for white mold in processing tomato crops.

Fungicide application via irrigation has been beneficial for disease management in many pathosystems, including tomato early blight (*Alternaria solani*) (Tolentino Júnior et al., 2011), late blight (*Phytophthora infestans*), gray mold (*Botrytis cinerea*) in potatoes, Cercospora leaf spot (*Cercospora beticola*), and Rhizoctonia crown rot (*Rhizoctonia solani*) in beet roots, among others (Johnson et al., 1986). However, reduction in disease severity and yield gains have usually been obtained using synthetic fungicides by sprinkling, as reported by Vieira et al. (2003), who worked with white mold in dry beans. Biological control may be used as an alternative to chemical utilization for white mold management because it reduces inoculum density in the soil and prevents selection of resistant isolates, such as reported for *S. sclerotiorum* in canola and alfalfa (Gossen and Rimmer, 2001) and in horticultural crops (Porter et al., 2002).

Besides its larger spectrum, biological control uses different methods of reaching the target, restricting the chances of selecting fungicide-resistant lines (Fravel, 2005). In 90% of the antagonists used in plant disease biological control, there is participation of different species of the genus *Trichoderma*, as reported by Benítez et al. (2004). *Trichoderma* species, necrotrophic mycoparasites easily isolated from the soil, are efficient in controlling plant pathogens, especially those with resistance structures such as sclerotia or chlamidospores, because they act through several antagonism mechanisms such as antibiosis, antibiotic production, competition, and induction of resistance in addition to growth promotion of some plants (Howell, 2003).

Many reports describe the efficiency of *Trichoderma* spp. to control sclerotia from *S. sclerotiorum*. Clarkson et al. (2004) demonstrated that two isolates of *Trichoderma viride* and one of *T. pseudokoningii* degraded up to 80% of sclerotia from four isolates of *Sclerotium cepivorum* in a silty clay soil and up to 60% of sclerotia in three other different soil types. Clarkson et al. (2002) also verified up to 60% sclerotia degradation in soil using *T. viride*; they also observed a significant reduction of white rot in garlic seedlings.

The suitability of application of antagonists and synthetic fungicides to control white mold has never been demonstrated before in areas under drip irrigation; therefore, the objective of this work was to evaluate biological control of white mold using *Trichoderma* spp., associated or not with chemical control, in drip-irrigated processing tomatoes via chemigation.

2. Materials and methods

Trials were conducted at an experimental farm (altitude 816 m 16° 43′ 07.1″ S and 49° 24′ 37.9″ W) in Goiânia, (Goiás State, Brazil) from April to September 2009 and from April to August 2010, in a medium-texture soil. The hybrid used was Heinz 7155 (Heinz Company), drip irrigated, transplanted on 2009 April 27 and 2010 April 26. The irrigation equipment (Plastro Brasil) used hydro PC water emitters ND, model 16/45, adjusted for 1.35 L h^{-1} flow and spaced 0.40 m.

Experiments were initiated by transplanting 30-day-old seedlings produced in substrate for vegetable production (Silva et al., 2003) and carried out according to technical crop recommendations for the Brazilian Central-West Region. Soil tillage was performed with disc harrow and subsoiler; soil was amended with 1300 kg ha^{-1} of lime and 1500 kg ha^{-1} fertilizer formula 04-30-16 + 0.5% boron. Seedlings were sprayed with thiametoxam (450 g ha^{-1}) + metalaxyl + mancozeb (3 g L^{-1}) before manual transplanting; irrigation was started just before transplanting to facilitate crop establishment.

The climate from May to September is dry with mild night temperatures averaging 22.2 °C and average precipitation of 22.3 mm (Freemeteo, 2009). These factors, in addition to moisture supplied by irrigation, provide adequate conditions for white mold occurrence. The experimental area was previously infested with pathogen sclerotia obtained from soybean residue on grain cleaning units, with a completely randomized block design. To facilitate treatment applications via irrigation (chemigation), treatments were arranged in a 2×3 factorial combination of biological and chemical treatments, with three replications. Biological treatments were conducted with or without a *Trichoderma* spp. formulation (1×10^9 CFU mL^{-1}, three applications of 1.0 L ha^{-1}) and combined or not with chemical treatments (fluazinam 1.0 L ha^{-1} or procimidone 1.5 kg ha^{-1} used singly) and the control. The biological treatment was based on three distinct isolates of *Trichoderma* spp., comprising two (T10 and T11) of *Trichoderma harzianum* and one (T9) of *T. viride*. Each plot consisted of three rows of 72 m long spaced 1.5 m, containing four plants m^{-1}. *Trichoderma* spp. treatments consisted of three applications performed at 10-day intervals, with the first taking place 30 days after transplanting (dat). Their matching applications of fluazinam or procimidone were done the following day after application of the antagonist.

Treatment assessment started when the first white mold symptoms were observed. The procedure was carefully performed, since it is necessary to observe plant's lower third portion covered by the canopy as the crop develops. The rate of diseased plants was evaluated weekly in the central plot rows by recording every plant with symptoms. From these evaluations, the areas under the