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Efficacy and timing of application of fungicides for control of citrus postbloom fruit drop

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ABSTRACT

Citrus postbloom fruit drop (PFD) caused by *Colletotrichum* spp. occurs in several countries in the Americas reducing yields by as much as 80%. Fungicide application is the main strategy for PFD control. Two field trials were performed to assess the timing of applications and another two were set up to investigate the efficacy of fungicides for PFD control in São Paulo State, Brazil. The percentage of symptomatic flowers per branch, the number of persistent calyces per branch, the number of fruit per branch and yield were evaluated. Four sprays of trifloxystrobin + tebuconazole, carbendazim, difenoconazole or cyprodinil + fludioxonil were effective in reducing yield losses due to PFD, however the trifloxystrobin + tebuconazole mixture was significantly more effective than all other treatments. The conventional PFD control programme, with one spray of difenoconazole followed by up to three carbendazim applications at different intervals, showed variable results, probably due to rainfall. The trifloxystrobin + tebuconazole mixture was effective at controlling PFD under favourable conditions for infection and can be recommended in PFD control programmes.

1. Introduction

Citrus postbloom fruit drop (PFD), caused by *Colletotrichum acutatum* J. H. Simmonds (Brown et al., 1996) and *Colletotrichum gloeosporioides* (Penz.) Penz. & Sacc. (Lima et al., 2011; McGovern et al., 2012), is one of the most important fungal diseases of citrus in the Americas (Timmer et al., 1994). The disease was first observed in Belize in 1956/1957 (Fagan, 1979). In Brazil, yield losses caused by PFD can reach 80% when rain occurs during flowering (Goes et al., 2008). The pathogen infects blossoms before buds are open (Fagan, 1979) but more than 95% of the symptoms are observed at the anthesis stage or later (Denham and Waller, 1981). Typical symptoms are orange-brown lesions on petals (Fagan, 1979; Timmer, 2000) and small peach-brown to dark-brown necrotic spots on the stigma and style (Lin et al., 2001; Marques et al., 2013). Flower infection leads to hormonal changes and causes fruit abscission (Lahey et al., 2004; Li et al., 2003). The calyx remains attached to the branch for several months (Timmer et al., 1994).

In Brazil and the USA, PFD is controlled by protective fungicide sprays (Peres et al., 2004; Timmer et al., 1994). Concomitantly, systemic fungicides applied singly or in mixture such as carbendazim and thiophanate-methyl (MBC - methyl benzimidazole carbamates or benzimidazoles), folpet (phthalimides) and difenoconazole (DMI – demethylation inhibitors or triazoles), have been the main fungicide groups used for PFD control in Brazil (Feichtenberger and Spósito, 2000; Goes et al., 2008). Carbendazim was registered for use on citrus in Brazil in 1991. The usage of this fungicide in the country increased significantly after benomyl, another MBC-fungicide, was withdrawn from the market in 2002. However, due to the variable efficacy of the MBC-fungicides (Goes et al., 2008) and the restriction of this fungicide group in some countries, the Brazilian Citrus Pesticide Board withdrew its use on citrus crops in 2012 (Anonymous, 2012). Currently, in Brazil and the USA, quinone-outside inhibitor (QoI) or strobilurin fungicides applied singly are recommended for the control of PFD (Anonymous, 2013; Peres and Dewdney, 2012). Therefore, the assessment of alternative fungicides and QoI-fungicides in mixtures for PFD control has become necessary. The number of field applications required for the control of PFD depends on the weather conditions as well as the uniformity and duration of the flowering period (Goes et al., 2008). Aiming to protect extensive citrus-growing areas in São Paulo State, growers usually spray

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according to the calendar every 7–14 days during flowering. Nonetheless, the effect of fungicide sprays applied at intervals greater than 7 days for the control of PFD remains unknown. This study is aimed at assessing alternative fungicides, singly or in mixtures, and the timing of applications, for the control of PFD in commercial groves.

2. Materials and methods

2.1. Timing of fungicide sprays

Two field trials were carried out during the season 2009/2010 in non-irrigated commercial groves in southwest São Paulo State, Brazil, where PFD frequently occurs. Field trial 1 was conducted on 18-yr-old Pera sweet orange [*Citrus sinensis* (L.) Osbeck] at Santa Cruz do Rio Pardo (22°49′ S and 49°22′ W), and field trial 2 was conducted at Taquarituba on 20-yr-old Pera sweet orange (23°41′ S and 49°12′ W). This variety, characterized by non-uniform and multiple flowering during the season, was chosen because it is planted in 50% of Brazilian sweet orange orchards and the trees are vigorous and very productive (Saunt, 2000). The number of trees per hectare was 350 (7.5 m × 3.8 m) and 444 (7.5 m × 3.0 m) in field trials 1 and 2, respectively. Treatments were arranged in a randomized complete block design with four replicates and 18 trees per plot (3 rows with 6 trees). A guard row between treated blocks was left unsprayed. Ten branches of the two innermost trees of each plot were marked on the main flowering from July to August, 2009. Fungicide sprays began when most of the flowers of the marked branches were at the phenological stages R1 and R2 (Fig. 1). As the trees showed large variation in the canopy height, a methodology adapted from tree-row-volume model (Sutton and Unrath, 1988) was used for delivering the same rate of fungicides per canopy volume. According to this method, the trees are cubes with no gaps in between and the sprays are continuous along the rows, even when the grove is young and trees are not touching each other within the row. The canopy volume (height × width × depth) of the trees was 82 and 65 m^3 tree at the onset of field trials 1 and 2, respectively. The fungicides carbendazim (Derosal 500SC, 50% carbendazim, Bayer CropScience) at 35 mg of active ingredient (a.i.) per m^3 of tree canopy (corresponding to 1000 g a.i. per ha) and difenoconazole (Score 250 EC; 25% difenoconazole, Syngenta Crop Protection) at 4.4 mg a.i. per m^3 of tree canopy (corresponding to 125 g a.i. per ha) were sprayed at different intervals and in different sequences (Tables 1 and 2). Nontreated trees were used as controls. Applications were performed with Martignani and Jacto Arbus 4000 sprayers in field trials 1 and 2, respectively, using 35–40 mL of spray.m^{-3} of tree canopy (low volume equivalent to 1000–1200 L ha^{-1}). The incidence of PFD on the flowers was assessed 7 days after the last spray by counting the numbers of open symptomatic and healthy flowers (R5 stage) on the marked branches. Three months after physiological fruit drop, the number of persistent calyces and the number of fruit were assessed for the same marked branches. Yield of the four innermost trees of each plot was measured at harvest in the next year. Only ripe fruits, from the main flowering, were harvested. For analysis of variance, the incidence of symptomatic flowers (proportion), the number of persistent calyces, the number of fruit, and the yield were transformed using $(x + 0.5)^{0.5}$. Treatments were compared using the Duncan multiple range test ($P \leq 0.05$).

2.2. Assessment of alternative fungicides

Two experiments (field trials 3 and 4) were carried out in 2009/2010 in the groves with same variety, density of trees and age of field trials 1 and 2, respectively, being neighbours of these field trials in each farm. The fungicides carbendazim at 35 mg a.i. per m^3 of tree canopy, difenoconazole at 4.4 mg a.i. per m^3 of tree canopy, trifloxystrobin + tebuconazole (Nativo, suspension concentrate, 10% of trifloxystrobin and 20% of tebuconazole, Bayer CropScience) at 2.8 + 5.6 mg a.i. per m^3 of tree canopy and cyprodinil + fludioxonil (Switch 62.5WG, 37.5% of cyprodinil and 25% of fludioxonil, Syngenta Crop Protection) at 3.3 + 2.2 mg a.i. per m^3 of tree canopy were sprayed two, three or four times at 7-day intervals, starting at development stage R1 to R2 (Fig. 1). The same experimental design, spray application and assessment protocols were used as described above.

Weather data was obtained from a weather station (Davis Instruments, Hayward, CA) equipped with a Datalogger/PC WeatherLink placed in each trial site.

3. Results

3.1. Timing of fungicide sprays

In field trial 1, only the number of fruit per branch did not differ significantly among the treatments and ranged from 0.09 to 0.38 fruits per branch. Overall, total fruit yield ranged from 28 to 58 kg/tree and only in T2, T4 and T6 fruit yield was similar to nontreated control. Nonetheless, the yield and the incidence of PFD symptomatic flowers (14–35%) were not significantly different among fungicide treatments, irrespective of the spray interval (Table 1). Rainfall occurred at days 18–21, 24 and 25 after the onset of flowering (Fig. 2A). In this field trial treating the trees at days 0, 7, and 14 did not result in better control of PFD than spraying at days 0 and 14 only. Likewise, similar levels of control were observed for trees treated at days 0, 11, and 18 as compared to those sprayed at

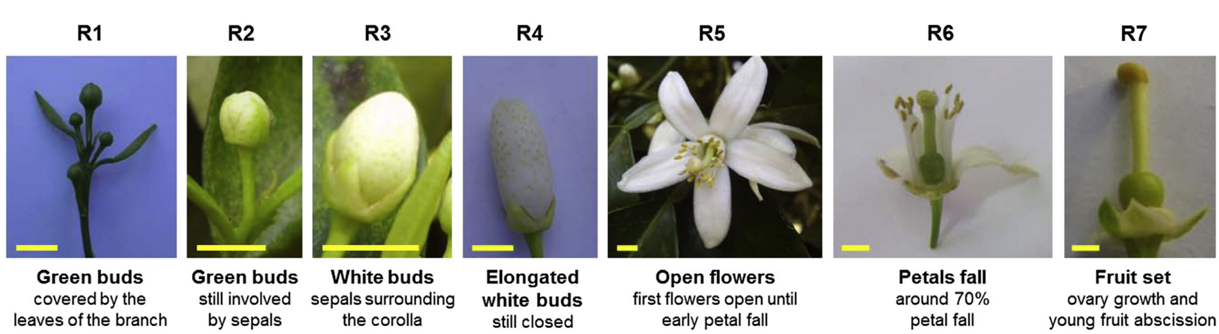

Fig. 1. Reproductive stages (R1 to R7) of a citrus flower adapted from Agustí et al. (2000) and the Stoller's Guide (www.stoller.com.br) used for timing of fungicide applications (Bar = 5 mm).