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Chemical control of dieback and mango malformation in a semiarid region

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ABSTRACT

The São Francisco Sub medium Valley is a great mango exporter in Brazil. In this semiarid region, diseases such as dieback and mango malformation have reduced the production of this crop. In this work the effectiveness of different active ingredients (flutriafol, methyl-thiophanate, copper hydroxide and fluxapyroxad mixed with pyraclostrobin) was assessed for the control of these diseases in a mango orchard. Monthly assessments of disease incidence were carried out. There was a difference among treatments for the two diseases studied, with flutriafol as the most effective fungicide against dieback and, for the malformation, the mixture of fluxapyroxad and pyraclostrobin and methyl-thiophanate showed the best results.

Keywords: *Mangifera indica*; Botryosphaeriaceae; *Lasiodiplodia*; *Fusarium* spp.; fungicides.

The mango (*Mangifera indica*) crop has a great importance in the submedium region of the São Francisco valley in Brazil. In 2021, mango was the most exported fruit considering the financial rank, with a total of US$ 248 million exported (KIST et al., 2022). The semiarid climate of this region is unfavorable to most mango diseases. Nonetheless, dieback and malformation diseases, caused by fungi belonging to Botryosphaeriaceae family and *Fusarium* genus, respectively, are not affected by this climate. Therefore, this study aimed to assess the effectiveness of four fungicides with different action modes in dieback and malformation control, two most important mango diseases in semiarid regions.

The experiment began in July 2019 in a "Tommy Atkins" mango orchard located in the semiarid region of Petrolina, state of Pernambuco, Brazil. The orchard consisted of 10-year-old trees in a spacing of 8 × 6 m. Irrigation system was done by microsprinkler and each plant received 105 and 220 L of water per day in vegetative and flowering stages, respectively.

The experiment was carried out in a randomized block design, with five treatments consisting of four fungicides and a control treatment, with eight replicates (blocks) per treatment. Each block had eight mango trees and the four central trees were used as experimental replicates. Treatments consisted of the following fungicides and rates, according to manufacturer recommendation: flutriafol (0.75 mL·L^{-1}, Tenaz), fluxapyroxad and pyraclostrobin mixture (0.4 mL·L^{-1}, Orkestra), methyl-thiophanate (0.7 g·L^{-1}, Cercobin), copper hydroxide (0.25 g·L^{-1}, Kocide) and the control (trees without any fungicide spray).

Fungicide sprays began after first pruning, and were performed every 14 days until fruit set, totalizing 18 sprays. These sprays were conducted by a vertical bar sprayer model Condor 600 M12 (Jacto) using only one side of the bar, and, consequently, a side of the row being sprayed at a time. Each bar contained eight nozzles spacing 0.35 m from each other. The spray tip used was hollow-nozzle, model J4-2 (Jacto), with a flow of 1.64 L·min^{-1} in a working pressure of 150 lb·pol^{-2} and a tractor speed of 6.3 km·h^{-1}.

The pH from fungicide spray solution was measured using a paper tape (Macherey-Nagel). The solution pH was adjusted to 6.5 for the treatment with copper hydroxide and to 5.0 for the other fungicides using a pH reducer (Redufol),

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when necessary (ZAMBOLIM et al., 2007). Spray parameters coverage and drop density were measured using water sensitive papers and results were assessed by Gotas software. Thereafter, a surfactant (Dash) in a 2.5 $mL \cdot L^{-1}$concentration was added to the spray solution to improve the coverage. Weather parameters such as temperature, relative humidity and wind speed were measured and monitored before and during fungicide spraying with thermohygrometer and anemometer models HTH-240 (Hikari) and TAD-500 (Instrutherm), respectively.

Disease incidence assessment was performed monthly and began one month after first fungicide spraying until blossoming for dieback, and from blossoming to fruit set for malformation. Assessment was conducted by splitting the tree canopy of each replicate in four quadrants, two per row side, and evaluating the number of diseased branches and flowers per quadrant (TAVARES et al., 2005). The incidence data obtained for both diseases were used for the area under disease progress curve (AUDPC) calculation (CAMPBELL; MADDEN, 1990). The data were verified if fulfill assumptions of variance analysis (ANOVA). As the ANOVA assumptions were fulfilled, this analysis was performed. The means were compared by Student–Newman–Keuls (SNK) test at 5% significance using the R software (http://www.r-project.org/).

This is the first work assessing effectiveness of different fungicides to control two of the most important mango diseases in semiarid conditions. There was no significant difference for both diseases in the number of diseased branches among the four canopy quadrants of each tree. Thus, analyses were carried out with the mean incidence from the four quadrants. For the dieback, mean incidence per quadrant was one. There was a reduction of 16% in disease compared to the control treatment using all fungicides. There was a difference in AUDPC among treatments by ANOVA and SNK tests at 5% significance. Flutriafol was the most effective fungicide against dieback, while other fungicides did not show differences from each other and from the control (Fig. 1a).

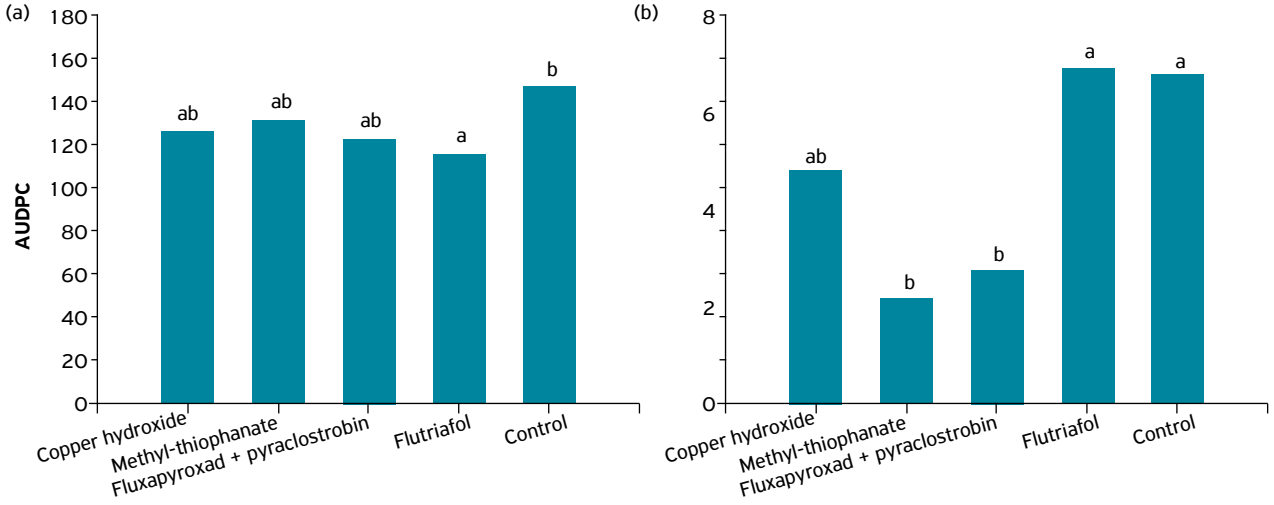

Figure 1. Effectiveness of different fungicides in management of two mango diseases in Petrolina, Pernambuco. Fungicides were assessed by the AUDPC of dieback (a) and malformation (b) of disease incidence. Means followed by the same letter did not differ from each other by SNK test ($P \geq 0.05$). Coefficient of variance = 15.91% (a) and 47.69% (b).

There is a variability regarding effectiveness of several active ingredients against dieback. SAEED et al. (2017) also found greater triazole (difenoconazole) effectiveness compared to other fungicides used (cyflufenamid and carboxamide). Triazoles had intermediate effectiveness in a study where different chemical groups (triazoles, strobilurins, benzimidazoles, dithiocarbamates) were compared, and methyl-thiophanate, a benzimidazole, was the most effective (ATEEQ et al., 2015). *In vitro* tests demonstrated that copper hydroxide was more effective than methyl-thiophanate in inhibiting mycelial growth of several *Lasiodiplodia theobromae* isolates (AL-JABRI et al., 2017). Nonetheless, these studies were held using only *L. theobromae* isolates and, as mentioned before, there are many Botryosphaeriaceae fungi species causing dieback, and these species can differ in fungicide sensitivity (COSTA et al., 2010). These studies were also conducted under greenhouse or *in vitro* conditions. Then, environmental effects, host phenology, climate and management were not the same as in this study. In an orchard under semiarid conditions, it was found that triazoles and strobilurins had the same effectiveness against stem-end-rot, a great mango problem also caused by Botryosphaeriaceae fungi (SALES JÚNIOR et al., 2009).

Active ingredients with several modes of action were used in this study; each having an inherent risk of pathogen resistance development. The fungicides from electron transport (fluxapyroxad mixed with pyraclostrobin) and cell division

(methyl-thiophanate) inhibition groups are classified as high risk to select isolates with less sensitivity (BRENT; HOLLOMON, 2007). Also, variability in sensitivity of isolates from mango and papaya to benzimidazoles and strobilurins, respectively, was observed (K. SANTOS et al., 2018; CHEN et al., 2020).

Systemic distribution of fungicides could also affect effectiveness, because dieback is a systemic disease and the fungus has an endophytic stage (SLIPPERS; WINGFIELD, 2007). Fungicides can have differences in their distribution inside the plant tissue, as demonstrated by P. SANTOS (2016) in grapevine. This is important to prevent the disease increase when the fungus is already inside the plant tissue.

For malformation, the mean incidence was four blossoms per quadrant. When fungicides were used, there was a reduction of 38.81% in the disease compared to control treatment. There was a difference in AUDPC among treatments by ANOVA and by SNK tests at 5% significance. The most effective fungicides against malformation were methyl--thiophanate and fluxapyroxad mixed with pyraclostrobin, while other fungicides did not differ from each other and from the control (Fig.1b).

Benzimidazole effectiveness against malformation was demonstrated for carbendazim, which the lower concentration assessed *in vitro* allowed 77% inhibition in fungus mycelial growth (MISRA; SINGH, 2002). As in this study, KHASKHELI et al.(2017) found methyl-thiophanate effectiveness in *Fusarium nivale* control, another species causing mango malformation, *in vivo* and *in vitro* conditions. Methyl-thiophanate was the most effective along with fosetyl-Al when compared with other fungicides, such as copper fungicides, as observed in this study.

Flutriafol less effectiveness for malformation could be probably caused by its effect in gibberellin level reduction in plant tissue, as demonstrated in soybean (PACENTCHUK et al., 2018), because one reason for malformation symptom development is the reduction in gibberellin levels, as demonstrated by a study where the levels in infected buds were fewer than in healthy buds (USHA et al., 2019).

Drop density (66.91 drops·cm^{-2}) and spray coverage (6.64%) were not following the recommended values for contact fungicides: 70–100 drops·cm^{-2} and coverage near 40% outside the canopy (ANDEF, 2004; SILVA JUNIOR et al., 2016). Temperature and relative humidity were suitable for the sprays; however, wind speed was below suitable range. The recommended conditions defined by JARDIM (2019) are wind speed ranging from 3 to 10 km·h^{-1}, relative humidity above 50% and air temperature below 30 °C. In this experiment, mean values of these variables were 29.28 °C, 64,87% and 2.8 km·h^{-1}, for temperature, relative humidity and wind speed, respectively.

Therefore, based on these results, it is recommended the use of flutriafol for dieback and fluxapyroxad mixed with pyraclostrobin and methyl thiophanate for malformation management in semiarid conditions.

AUTHORS' CONTRIBUTIONS

Conceptualization: Silva, L.A.B.; Capucho, A.S.; Leite, D.M. **Data curation:** Silva, L.A.B.; Capucho, A.S. **Formal analysis:** Silva, L.A.B. **Funding acquisition:** Capucho, A.S. **Investigation:** Silva, L.A.B.; Capucho, A.S. **Methodology:** Silva, L.A.B.; Capucho, A.S.; Leite, D.M. **Project administration:** Silva, L.A.B.; Capucho, A.S.; Leite, D.M. **Supervision:** Capucho, A.S.; Leite, D.M. **Validation:** Silva, L.A.B.; Capucho, A.S.; Leite, D.M. **Visualization:** Silva, L.A.B.; Capucho, A.S.; Leite, D.M. **Writing – original draft:** Silva, L.A.B. **Writing – review & editing:** Silva, L.A.B.; Capucho, A.S.; Leite, D.M.

AVAILABILITY OF DATA AND MATERIAL

The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

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CONFLICTS OF INTEREST

The authors certify that they have no commercial or associative interest that represents a conflict of interest in connection with the manuscript.

ETHICAL APPROVAL

Not applicable.

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