USE OF BIOPESTICIDES FOR THE MANAGEMENT OF ANTHRACNOSE (*Colletotrichum gloeosporioides*) IN MANGO FOR EXPORT

FINAL REPORT

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CONTENT

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IN VITRO TESTS OF BIOLOGICAL EFFECTIVENESS OF NATURAL INGREDIENTS WITH FUNGICIDE ACTIVITY

Isolation of *Colletotrichum* strains

Mango fruits with symptoms of anthracnose were collected in commercial orchards of the municipalities of Santiago Ixcuntla, Compostela, San Blas and Tepic, Nayarit, Mexico. The fruits were processed and isolated in the laboratory of phytopathology of the Experimental Field Santiago Ixcuintla, Nayarit of INIFAP. The fruits were washed with distilled water, disinfected with 2.0% sodium hypochlorite for 5 min and washed three consecutive times with sterile distilled water. Diseased tissue samples of 1.0 cm^2 were placed in Petri dishes with potato-dextrose-agar (PDA) culture medium (BD Bioxon®) and in Petri dishes with selective culture medium for each experimental fungus. The material was incubated at 25 °C for 5 days with constant white light. The developed isolates were transferred individually to PDA and subsequently purified by the monosporic culture technique and preserved in tubes with PDA and silica gel.

Selection of virulent strains

Isolates of *C. gloeosporioides* were obtained from the main mango producing areas in Nayarit. Subsequently, the strains with higher sporulation speed and mycelial growth of the fungus were selected. Strains with greater growth and sporulation were inoculated in mango fruits, to select those with greater virulence (Figure 1).

Figure 1. Mango fruits inoculated with virulent strains of *C. gloeosporioides*.

In Vitro tests of biological effectiveness of biopesticides

Partial tests were carried out to determine which active ingredients had an effect on mycelial growth and sporulation of *Colletotrichum* spores (Table 1 and 2). 200 mL flasks were prepared with PDA culture medium (potato dextrose agar), when the medium reached a temperature of 45 °C, an active ingredient was added per flask at concentrations of 5,000 and 10,000 ppm, then they were emptied into petri dishes. The control only contained PDA culture medium. Subsequently, a conidial solution was prepared at $1x10^5$ spores. mL^{-1} of the selected strains. 100 µL (microliters) of spores were taken and placed at four equidistant points on the petri dish with PDA culture medium; the drops were covered with a coverslip, then the boxes were covered and incubated at 25 ± 1 °C for 24 and 48 hours with constant white light.

Results obtained

In Table 1, it can be observed that the active ingredients that showed the highest sporicidal activity and mycelial growth inhibition were the essential oil of orange, essential oil of cinnamon, oil of wintergreen, monoterpenes of conifers, geraniol, citral, thymol, extract of rosemary, eugenol, pepper extract and menthol. On the other hand, in table 2, the most effective ingredients were copper, clove extract plus

copper at 10,000 ppm, laurel plus copper at 10,000 ppm, oregano at 10,000 ppm, copper plus oregano at 10,000 ppm, governor at 10,000 ppm, governor plus copper in both concentrations and governor plus oregano at 10,000 ppm. In Figures 2 and 3, some images of mycelial growth are observed with some of the active ingredients used.

Table 1. In Vitro biological effectiveness of essential oils and botanical extracts on the growth of mycelium and germination percentage of spores of *Colletotrichum gloeosporioides* in mango fruit.

Active ingredients	Mycelium growth		Percentage of spore germination (%)	
	Dosage (ppm)			
	5000	10000	5000	10000
Control	MG[X]	MG	100	100
Orange terpenes	MG	MG	20	10
Orange essential oil	NG[Z]	NG	0	0
Governor plant extract (*Larrea tridentata*)	MG	NG	80	0
Cinnamon essential oil (*Cinnamomum verum*)	NG	NG	0	0
Wintergreen Oil	NG	NG	0	0
Conifer monoterpenes	NG	NG	0	0
Geraniol	NG	NG	0	0
Citral	NG	NG	0	0
Thymol	NG	NG	0	0
Extract of Rue (*Ruta* spp.)	MG	MG	90	0
Rosemary Extract (*Rosmarinus officinalis*)	NG	NG	0	0
Eugenol	NG	NG	0	0
Pepper Extract (*Piper nigrum*)	MG	NC	0	0
Menthol	NG	NG	0	0
Citric acid + Ascorbic acid	MG	MG	80	60

[X]MG= there was mycelial growth; [Z]NG= There was no mycelial growth

Table 2. In Vitro biological effectiveness of essential oils, copper and botanical extracts on the mycelial growth and germination percentage of spores of *Colletotrichum gloeosporioides* in mango fruit.

Active ingredients	Mycelium growth		Percentage of spore germination (%)	
	Dosage (ppm)			
	5000	10000	5000	10000
Control	MG[X]	MG	100	100
Copper	MG	NG[Z]	0	0
Clove Extract (*Syzygium romaticum*)	MG	MG	95	70
Clove Extract (*Syzygium romaticum*) + Copper	MG	NG	95	0
Extracto de Laurel (*Laurus nobilis*)	MG	MG	100	90
Laurel Extract (*Laurus nobilis*) + Copper	MG	NG	85	0
Oregano Extract (*Origanum vulgare*)	MG	NG	100	0
Oregano Extract (*Origanum vulgare*) + Copper	MG	NG	95	0
Governor plant extract (*Larrea tridentata*)	MG	NG	30	0
Governor plant extract (*Larrea tridentata*) + Copper	NG	NG	0	0
Governor plant extract (*Larrea tridentata*) + Oregano Extract (*Origanum vulgare*)	MG	NG	95	0

[X]MG= there was mycelial growth; [Z]NG= There was no mycelial growth

PHOTOGRAPHIC APPENDIX

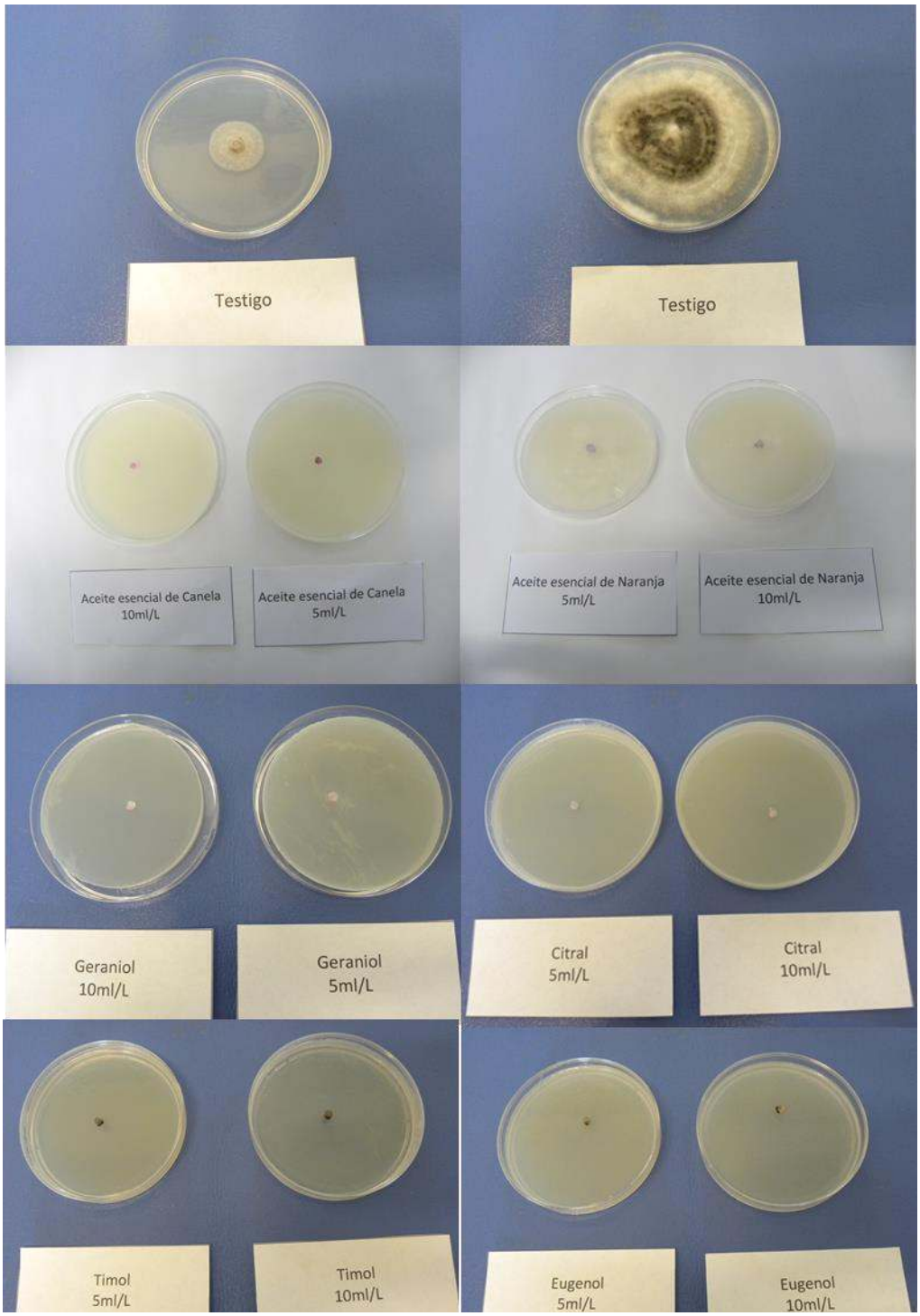

Figure 2. Biological effectiveness of some active ingredients on mycelial growth of *C. gloeosporioides*.

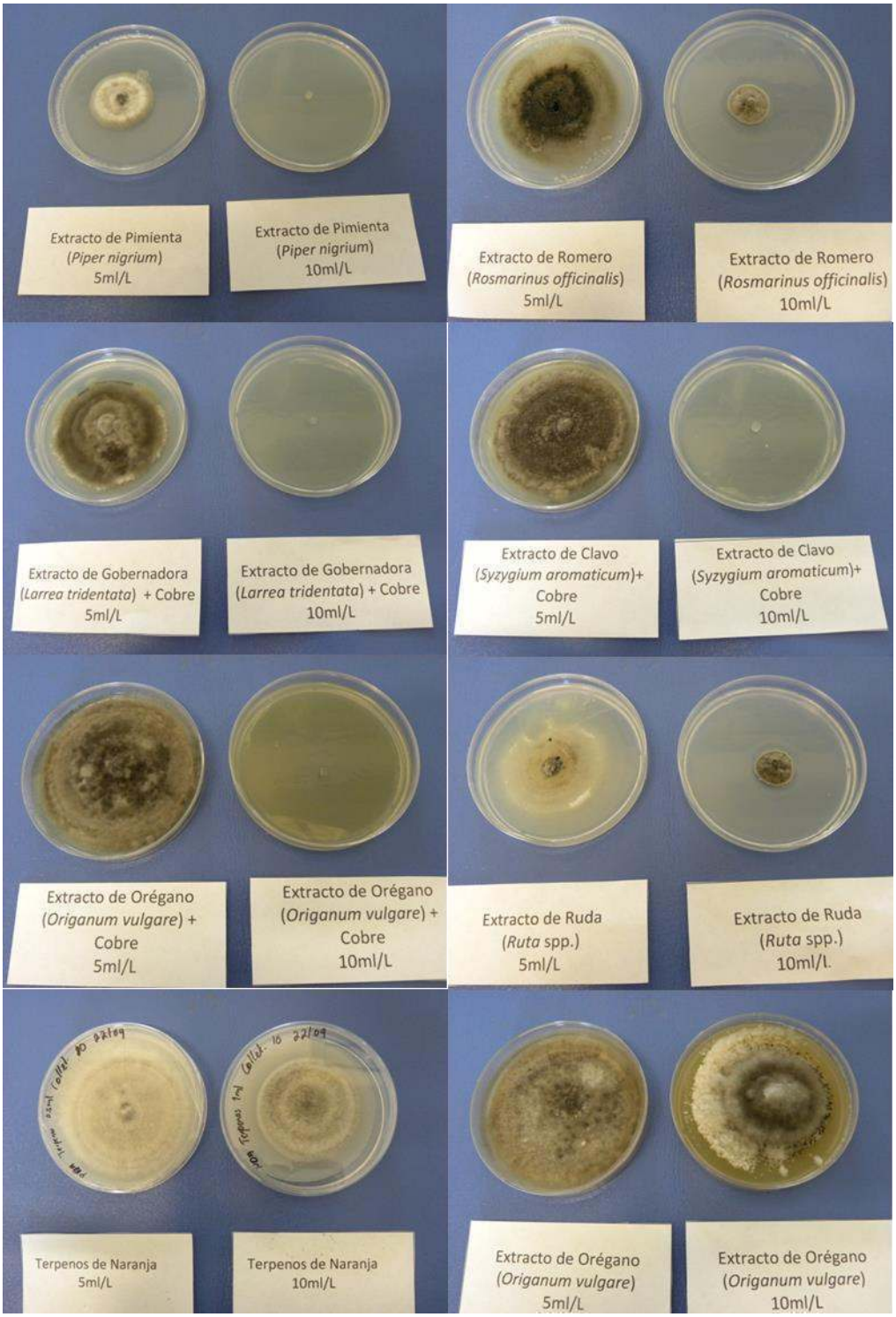

Figure 3. Biological effectiveness of some active ingredients on mycelial growth of *C. gloeosporioides*.

IN VITRO TESTS OF BIOLOGICAL EFFECTIVENESS OF BIOPESTICIDE FORMULATIONS

Reduction of spore germination

For the in vitro tests, active ingredients with biofungicidal activity were used, with which formulations were elaborated (Table 1), and sporicidal effectiveness was determined against virulent strains of *C. gloeosporioides* that showed a higher speed of sporulation and growth of the mycelium of the fungus. For the effectiveness tests, PDA (potato dextrose agar) culture medium was prepared in 250 mL flasks at 121 °C for 15 minutes; they were allowed to cool down to 45 °C and the biopesticide formulation was added to each flask at doses of 250, 500, 1000, 2500 and 5000 parts per million (ppm). The flasks were in constant agitation for 5 minutes, then the contents were poured into Petri dishes. A conidial solution was made at $1x10^5$ spores. mL^{-1} of the selected strains. Four samples (repeats) of 100 µL (microliters) were taken and placed in four equidistant points on the Petri dish with the formulations and their concentrations; subsequently the samples were covered with a coverslip. For the control, the conidial solution was deposited in Petri dishes with PDA culture medium. Then the boxes were capped and incubated at 25 ± 1 °C for 24 and 48 hours with constant white light.

Variable to be evaluated

The percentage reduction in spore germination was estimated. The estimate was made by counting 100 spores in the light field of the microscope. The experimental unit was a coverslip with eight repetitions. The number of germinated spores on the PDA culture medium was recorded after 24 and 48 hours.

Outstanding results

Most of the treatments tested reduced the germination of spores in some of the concentrations, however there were differences in effectiveness between treatments (Table 1). The treatments that reduced 100% the germination of spores in the concentration ranges from 250 to 5000 ppm in 24 and 48 hours were the formulations of Cinnamon Oil + Governor Extract, Cinnamon Oil + Rosemary Extract, Cinnamon Oil + Pepper Extract, Citral + Governor Extract, Citral + Pepper Extract and Governor Extract + Ammonium Quaternary Salts. On the other hand, the formulations that reduced the germination to 100% in the ranges of 500 to 5000 ppm were Copper Gluconate + Wintergreen Oil, Citral + Geraniol + Rosemary Extract, Citral + Rosemary Extract, Governor Extract + Quaternary Salts of Ammonium + Ac Perácetico, Eugenol + Citral + Extract of Romero and Eugenol + Thymol + Citral + Extract of Romero. For their part, the formulations of Cinnamon Oil + Orange Oil,

Geraniol + Rosemary Extract, Governor Extract + Percetic Acid + Hydrogen Peroxide and Eugenol + Geraniol + Rosemary Extract reduced germination to 100% at concentrations from 1000 to 5000 ppm. The rest of the formulations showed effectiveness in reducing spores from 2500 to 5000 ppm, except for Copper Sulfate + Copper Gluconate, whose highest effectiveness was recorded at 5000 ppm. In the spores of the control, germination of the spores was not inhibited.

Table 1. Percentage reduction in germination of *C. gloeosporioides* spores of mango fruits.

Treatments	Reduction in spore germination (%)									
	Concentrations (ppm)									
	24 h					48 h				
	250	500	1000	2500	5000	250	500	1000	2500	5000
Control	1.67	1.67	0.76	0.97	0.76	0	0	0	0	0
Cinnamon Oil + Orange Oil	30.38	94.88	100	100	100	6.21	93.98	100	100	100
Tea Terpenes + Wintergreen Oil + Orange Oil	9.87	94.89	93.70	100	100	6.60	65.34	78.52	100	100
Geraniol + Rosemary Extract	3.19	6.6	100	100	100	0	2.80	100	100	100
Copper Gluconate (Fercupo®) + Wintergreen Oil	84.99	100	100	100	100	7.98	100	100	100	100
Citral + Geraniol + Rosemary Extract	4.48	100	100	100	100	2.97	100	100	100	100
Copper Sulfate + Copper Gluconate	9.56	19.70	8.26	50.51	100	0	0	0	17.34	100
Cinnamon Oil + Governor's Extract	100	100	100	100	69.3	100	100	100	100	100
Cinnamon Oil + Rosemary Extract	100	100	100	100	100	100	100	100	100	100
Cinnamon Oil + Pepper Extract	100	100	100	100	100	100	100	100	100	100
Wintergreen Oil + Pepper Extract	0	3.41	88.91	100	100	0	0	21.63	100	100
Wintergreen Oil + Pepper Extract	30.73	9.78	69.97	100	100	0	0	20.21	100	100
Wintergreen Oil + Governor Extract	0	1.36	100	100	100	0	0	3.21	100	100

Continuation Table 1.

Treatments	Reduction in spore germination (%)									
	Concentrations (ppm)									
	24 h					48 h				
	250	500	1000	2500	5000	250	500	1000	2500	5000
Citral + Governor extract	0	100	100	100	100	100	100	100	100	100
Citral + Rosemary Extract	100	100	100	100	100	5.91	100	100	100	100
Citral + Pepper Extract	100	100	100	100	100	100	100	100	100	100
Governor extract + Quaternary Ammonium Salts	98.87	100	100	100	100	99.19	100	100	100	100
Governor Extract + Quaternary Ammonium Salts + Peracetic Acid	98.56	100	100	100	100	79.87	100	100	100	100
Governor Extract + Peracetic Acid + Hydrogen Peroxide	0.98	39.98	100	100	100	0.00	0.00	100	100	100
Peracetic acid	1.69	11.87	78.54	100	100	0.00	4.09	59.76	100	100
Eugenol + Citral + Rosemary Extract	48.11	100	100	100	100	4.72	100	100	100	100
Eugenol + Geraniol + Rosemary Extract	0.00	7.96	100	100	100	1.46	87.24	100	100	100
Eugenol + Thymol + Citral + Rosemary Extract	90.35	100	100	100	100	8.47	100	100	100	100

Diameter of the radial growth of the mycelium

Active ingredients with biofungicidal activity were used, with which formulations were elaborated (Table 2), and their effectiveness was determined in the mycelial growth of virulent strains of *C. gloeosporioides* that showed a higher velocity of sporulation and growth of mycelium of the fungus. For the effectiveness tests, PDA culture medium was prepared in 250 mL flasks at 121 °C for 15 minutes; they were allowed to cool down to 45 °C and the biopesticide formulation was added to each flask at doses of 250, 500, 1000, 2500 and 5000 parts per million (ppm). The flasks were in constant agitation for 5 minutes, then the contents were poured into petri dishes. Once the medium was dried, a 0.5 cm diameter agar disk with *C. gloeosporioides* mycelium was taken with a punch and placed in the middle of the petri dish. The sowing of the fungus was carried out for each of the concentrations of the formulations. The control was planted in petri dishes with PDA medium. Then the boxes were capped and incubated at 25 ± 1 °C for 12 days with constant white light.

Variables to be evaluated

The radial growth diameter of the mycelium was determined. The estimate was made by measuring the growth diameter of the mycelium, which was expressed in centimeters. The measurements were made eight and twelve days after sowing. The experimental unit was a petri dish with six repetitions.

Outstanding results

Most of the treatments tested reduced mycelial growth in at least one of the concentrations, however there were differences in effectiveness between treatments (Table 2). In all treatments there was mycelial growth in the concentration ranges from 250 to 500 ppm. The treatments that reduced 100% mycelial growth in the range of 1000 to 5000 ppm were the formulations of Cinnamon Oil + Governor Extract, Governor Extract + Ammonium Quaternary Salts, Eugenol + Thymol + Citral + Rosemary Extract and Citral + Geraniol + Rosemary Extract. For their part the formulations of Citral + Rosemary Extract, Citral + Governor Extract, Citral + Pepper Extract, Cinnamon Oil + Rosemary Extract, Cinnamon Oil + Pepper Extract, Citral + Geraniol + Rosemary Extract, Geraniol + Rosemary Extract, Eugenol + Geraniol + Rosemary Extract, Eugenol + Citral + Rosemary Extract and Geraniol + Rosemary Extract inhibited mycelial growth at 2500 and 5000 ppm. The formulations that inhibited the growth of mycelium at 5000 ppm were Cinnamon Oil + Orange Oil, Copper Sulfate + Copper Gluconate, Copper Gluconate + Wintergreen Oil and Governor Extract + Quaternary Ammonium + Peracetic Acid. The rest of the formulations registered growth of mycelium in all their concentrations. In Figures 1

you can see some examples of the formulations and their concentrations that showed effectiveness on the inhibition of mycelial growth. On the other hand, Figure 2 shows some concentrations of the formulations that had no effect on mycelial growth.

Table 2. Growth of mycelium of *C. gloeosporioides* of mango fruits.

Treatments	Diameter of the radial growth of the mycelium (cm)									
	Concentrations (ppm)									
	8 days					12 days				
	250	500	1000	2500	5000	250	500	1000	2500	5000
Control	7.40	7.40	7.12	7.12	7.12	8.25	8.25	8.05	8.05	8.05
Tea Terpenes + Wintergreen Oil + Orange Oil	7.17	6.95	6.05	3.82	1.78	8.22	8.27	7.60	5.90	4.17
Cinnamon Oil + Orange Oil	7.13	6.97	4.95	0.57	0.00	8.15	8.18	7.28	0.95	0.00
Wintergreen Oil + Governor's Extract	7.12	6.38	6.02	2.80	1.20	7.97	7.73	7.45	5.42	3.43
Oil of Wintergreen + Rosemary Extract	7.07	6.08	5.55	1.50	1.13	7.97	7.43	7.40	3.25	3.17
Wintergreen Oil + Pepper Extract	6.82	6.15	5.63	2.58	0.00	7.78	7.78	7.43	5.05	0.35
Citral + Governor Extract	6.38	5.65	5.40	0.00	0.00	7.80	7.58	7.35	0.00	0.00
Citral + Extract Rosemary	6.28	5.23	1.60	0.00	0.00	7.38	7.35	2.38	0.00	0.00
Citral + Pepper Extract	5.88	4.68	2.72	0.00	0.00	7.13	6.85	4.33	0.00	0.00
Cinnamon Oil + Governor's Extract	5.45	4.95	0.00	0.00	0.00	6.40	6.00	0.00	0.00	0.00
Cinnamon Oil + Rosemary Extract	6.45	4.65	0.47	0.00	0.00	6.70	5.48	0.93	0.00	0.00
Cinnamon Oil + Pepper Extract	6.25	4.33	0.72	0.00	0.00	7.30	5.45	1.55	0.00	0.00
Copper Sulfate + Copper Gluconate (Fercupo®)	5.40	5.72	4.90	2.75	0.00	7.72	7.82	7.60	4.77	0.00

Continuation of Table 2.

Treatments	Diameter of the radial growth of the mycelium (cm)									
	Concentrations (ppm)									
	8 days					12 days				
	250	500	1000	2500	5000	250	500	1000	2500	5000
Citral + Geraniol + Rosemary Extract	6.75	3.93	0.85	0.00	0.00	8.47	6.12	2.08	0.00	0.00
Geraniol + Rosemary Extract	6.77	6.33	4.07	0.00	0.00	8.70	8.30	7.15	0.00	0.00
Copper Gluconate (Fercupo®) + Wintergreen Oil	2.63	1.87	1.23	0.07	0.00	3.72	3.00	2.12	0.47	0.00
Governor Extract + Quaternary Ammonium Salts	1.28	0.70	0.00	0.00	0.00	2.25	1.62	0.00	0.00	0.00
Governor Extract + Quaternary Ammonium + Peracetic Acid	1.73	1.20	0.48	0.47	0.00	2.82	1.98	0.73	0.50	0.00
Governor Extract + Percetic Acid + Hydrogen Peroxide	6.80	6.03	5.53	2.47	0.52	8.17	7.73	7.40	4.22	1.05
Percetic Acid	5.05	4.47	3.67	3.75	0.00	6.83	6.50	4.58	2.93	1.05
Eugenol + Geraniol + Rosemary Extract	8.20	7.77	2.75	0.00	0.00	8.20	8.20	6.89	0.00	0.00
Eugenol + Thymol + Citral + Rosemary Extract	5.28	1.02	0.00	0.00	0.00	8.02	3.18	0.00	0.00	0.00
Eugenol + Citral + Rosemary Extract	7.43	6.47	2.52	0.00	0.00	8.20	8.15	6.13	0.00	0.00
Citral + Geraniol + Rosemary Extract	7.07	7.07	0.00	0.00	0.00	8.7	8.7	0.00	0.00	0.00
Geraniol + Rosemary Extract	6.75	3.93	0.85	0.00	0.00	8.47	6.12	2.08	0.00	0.00

PHOTOGRAPHIC APPENDIX

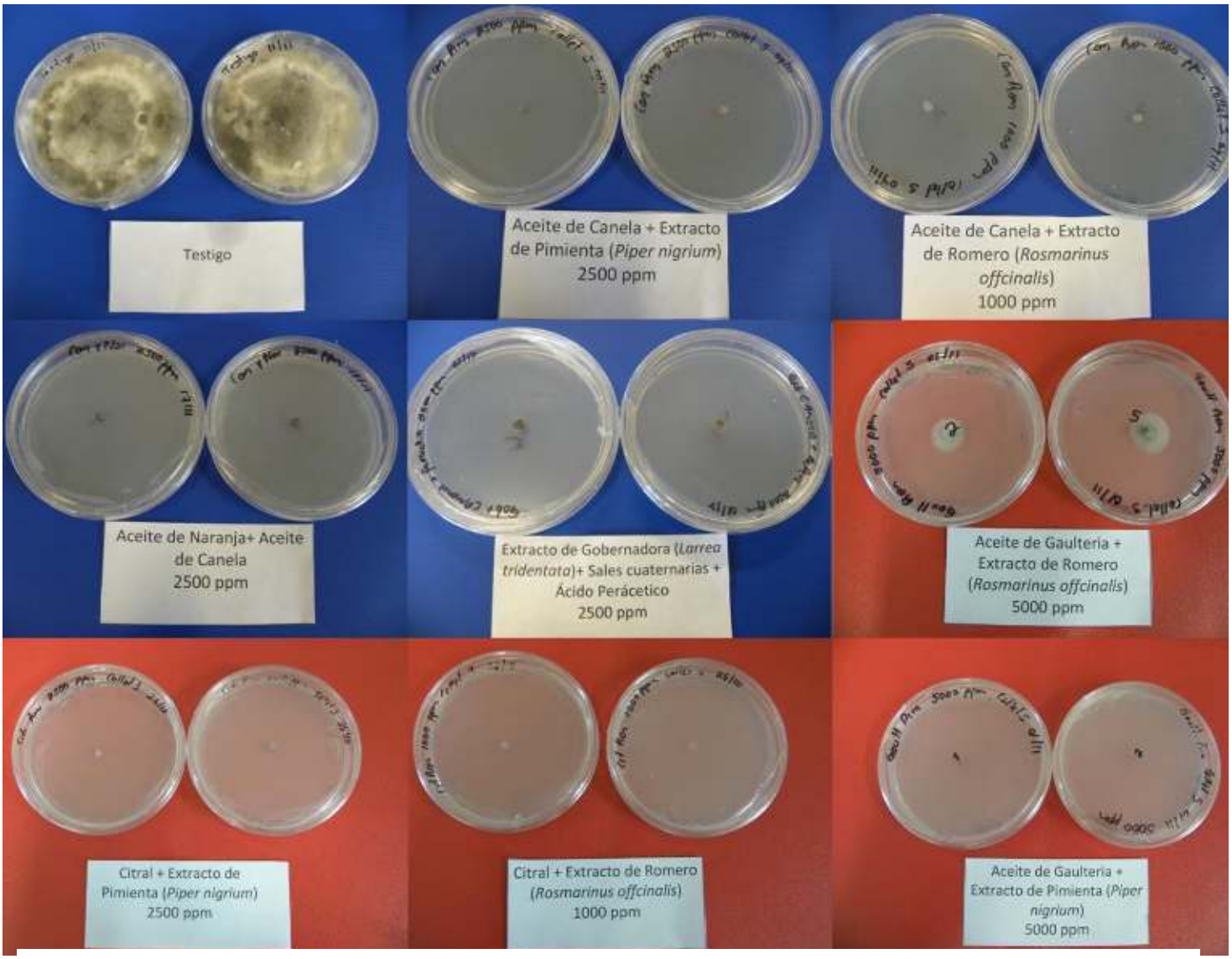

Figure 1. Some formulations and their concentrations that showed an effect on the radial growth of the mycelium of *C. gloeosporioides*.

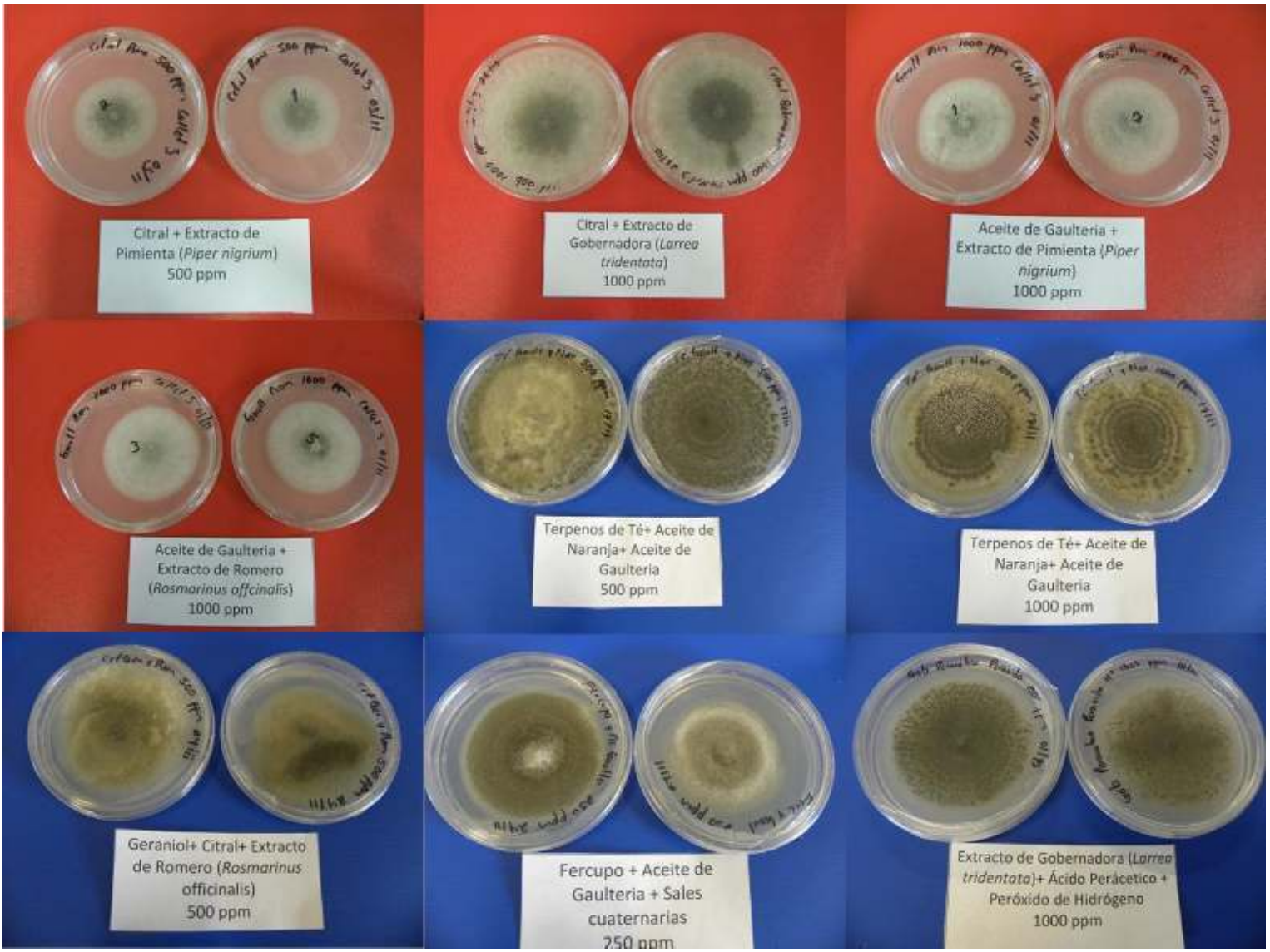

Figure 2. Some formulations and their concentrations that showed no effect on the radial growth of the mycelium of *C. gloeosporioides*.

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APPLICATION OF BIOPESTICIDES IN MANGO ORCHARDS IN VARIETY "ATAULFO"

FIELD PHASE

(January to May 2017)

Establishment of the experiment

Three experiments were established in commercial mango orchards of the variety "Ataulfo" (Figure 1) in the last week of January and the second week of February 2017. Two orchards were located in the town of Las Palmas, municipality of San Blas, Nayarit, Mexico in 7 year-old trees. The other orchard was located in the town of Guadalupe, San Blas, Nayarit, Mexico, with 9-year-old trees. The selection of the aforementioned orchards was made based on the high incidences of anthracnose that had occurred in the last two years (production cycles 2015 and 2016).

Application of treatments

The formulation of the biopesticides was made based on the results of the In vitro tests. Tables 1 and 2 show the treatments, active ingredients and application doses for each of the orchards and their locations. Applications were made every 15 days, with a total of 8 applications from flowering to harvest (Figure 2).

Design of treatments

A completely randomized design with five repetitions per treatment (five trees) was used. In each tree, 10 fully developed panicles (50 panicles per treatment) were selected and marked.

Evaluations and variables

The evaluations were made to determine the incidence of anthracnose in panicles and fruits. The variables evaluated were: a) Incidence of anthracnose in panicles; b) Number and percentage of fruits set; c) Incidence of anthracnose in fruits of more than 3 to 10 cm in length (pre-harvest fruits); d) Incidence of anthracnose in fruits of physiological maturity (ready for harvest). The evaluations were made every 15 days, one week after each application of the treatments. In the orchard of the town of Guadalupe, only the incidence of anthracnose was evaluated in fruits of physiological maturity, one week before harvest in the month of May. To determine the incidence of anthracnose, fruits that showed two or more lesions per fruit equal to or greater than 3 millimeters in diameter were considered.

The incidence was expressed as a percentage, for which the following equation was used:

$$\text{Incidence of anthracnose (\%)} = \frac{\text{Fruits with symptoms of anthracnose}}{Total\ fruits} X\ 100 \ldots$$

Table 1. Application of treatments on trees of the variety "Ataulfo", located in two orchards in the town of Las Palmas, San Blas, Nayarit, Mexico, from February to May 2017.

TREATMENTS	ACTIVE INGREDIENTS	DOSE mL/ L OF WATER
T1	Control	No application
T2	Copper gluconate	5
T3	Trifloxystrobin	0.6
T4	Wintergreen oil, cinnamon oil and governor plant extract	2.5
T5	Governor plant extract, citral, thymol and eugenol	2.5
T6	Governor plant extract, peracetic acid and hydrogen peroxide	2.5
T7	Copper gluconate and phosphites	2.5 + 2.5
T8	Governor plant extract, citral and geraniol	2.5
T9	Calcium polysulfide	5
T10	Wintergreen oil, Cinnamon oil and governor plant extract	5
T11	Governor plant extract, citral, thymol and eugenol	5
T12	Governor plant extract, peracetic acid and hydrogen peroxide	5
T13	Copper gluconate and phosphites	5 + 5
T14	Calcium polysulfide	7.5
T15	Governor plant extract, citral and geraniol	5

Table 2. Application of treatments on trees of the variety "Ataulfo", located in an orchard of the town of Guadalupe, San Blas, Nayarit, Mexico from January to May 2017.

TREATMENTS	ACTIVE INGREDIENTS	DOSE mL/ L OF WATER
T1	Control	Sin aplicación
T2	Copper gluconate	2.5
T3	Copper gluconate and phosphites	2.5 + 2.5
T4	Trifloxystrobin	0.6
T5	Wintergreen oil, Cinnamon oil and governor plant extract	2.5
T6	Wintergreen oil, Cinnamon oil and governor plant extract	5
T7	Governor plant extract, citral, thymol and eugenol	2.5
T8	Governor plant extract, citral, thymol and eugenol	5
T9	Governor plant extract, peracetic acid and hydrogen peroxide	2.5
T10	Governor plant extract, peracetic acid and hydrogen peroxide	5
T11	Copper gluconate and phosphites	5 + 5

Incidence of anthracnose in fruits set

In all the evaluated treatments (in the three plots) no anthracnose symptoms were observed in panicles, which is why only the incidences in fruits are presented. In the results of the first evaluation in the town of Guadalupe, anthracnose incidences greater than 5% were not observed in fruits of more than 1.5 cm in diameter (Table 3). In the second evaluation, treatment with governor extract, citral, thymol and eugenol (5 mL / L) and governor extract, citral and geraniol (5 mL / L) presented the highest incidences (> 7%); the rest of the treatments, including the control, had less than 5% incidence (Table 4). For the third evaluation, treatments with trifloxystrobin, governor extract, peracetic acid and hydrogen peroxide (2.5 mL / L), copper gluconate and phosphites (2.5 + 2.5 mL / L) and governor extract, citral and geraniol (2.5 mL / L) obtained the fruits with the lowest incidence of anthracnose in the two orchards (Table 5). In the fourth and last evaluation, trees treated with trifloxystrobin showed the lowest incidences of anthracnose (≤ 5%), and the highest number of fruits tied, followed by the governor extract, peracetic acid and hydrogen peroxide (2.5 mL / L) (< 7%), copper gluconate and phosphites (2.5 + 2.5 mL / L) (<7% incidence), and governor extract, citral and geraniol (2.5 mL / L) (< 7%) (Table 4) .

Incidence of anthracnose in fruits in physiological maturity

In the plot located in the town of Guadalupe, differences between treatments were observed. Fruits treated with trifloxystrobin, copper gluconate and phosphites (5 + 5 mL / L) and governor extract, citral, thymol and eugenol (2.5 mL / L) showed the lowest incidence of anthracnose (Figure 1). It should be mentioned that in this orchard only the incidence in fruits of physiological maturity was evaluated, and unlike the two orchards of Las Palmas, only one harvest was made.

The results of orchard one in the town of Las Palmas, showed that in the first evaluation (three days before the first harvest), fruits treated with trifloxystrobin had no symptoms with anthracnose (Figure 2). The formulations that showed the lowest incidence (≤ 8%) were copper gluconate and phosphites (2.5 + 2.5 mL / L) and governor extract, citral and geraniol (2.5 mL / L). For the second evaluation (second harvest), the treatments with governor extract, peracetic acid and hydrogen peroxide (2.5 mL / L), copper gluconate and phosphites (2.5 + 2.5 mL / L) and governor extract, citral and geraniol (2.5 mL / L) presented the fruits with the lowest incidence of anthracnose (≤ 5.5%) (Figure 3).

In the orchard two of the town of Las Palmas, it was observed that in the first evaluation trees treated with trifloxystrobin, governor extract, peracetic acid and hydrogen peroxide (2.5 mL / L) and copper gluconate and phosphites (2.5 + 2.5) mL

/ L) recorded the lowest incidence of anthracnose in fruits (< 12%) (Figure 4). For the second evaluation (second harvest) there was a behavior similar to that of the first evaluation, where the treatments T3, T4, T6 and T7 recorded the fruits with lower incidences of anthracnose (< 8%) (Figure 5).

Table 3. First evaluation of incidence of anthracnose in trees of the variety "Ataulfo", located in two orchards in the town of Las Palmas, San Blas, Nayarit, Mexico, from January to May 2017.

Treatments	Orchard 1		Orchard 2	
	Fruit set/ tree	Anthracnose incidence (%)	Fruit set/ tree	Anthracnose incidence (%)
control	269	0.00 a	46	0.00 b
Copper gluconate (5 mL/L)	478	0.31 a	243	0.00 b
Trifloxystrobin (0.6 mL/L)	480	0.00 a	114	0.41 b
Wintergreen oil, cinnamon oil and governor extract (2.5 mL/L)	235	0.00 a	53	0.00 b
Governor extract, citral, thymol and eugenol (2.5 mL/L)	286	0.00 a	103	0.00 b
Governor extract, peracetic acid and hydrogen peroxide (2.5 mL/L)	146	3.33 a	184	0.00 b
Copper gluconate and phosphites (2.5 + 2.5 mL/L)	154	0.00 a	179	0.00 b
Governor extract, citral and geraniol (2.5 mL/L)	105	0.83 a	112	0.00 b
Calcium polysulfide (5 mL/L)	255	0.00 a	77	0.30 b
Wintergreen oil, cinnamon oil and governor extract (5 mL/L)	188	0.33 a	139	0.00 b
Governor extract, citral, thymol and eugenol (5 mL/L)	252	0.00 a	165	0.00 b
Governor extract, peracetic acid and hydrogen peroxide (5 mL/L)	164	0.00 a	153	0.00 b
Copper gluconate and phosphites (5 + 5mL/L)	238	0.00 a	189	4.28 a
Calcium polysulfide (7.5 mL/L)	111	0.00 a	313	1.85 ab
Governor extract, citral and geraniol (5 mL/L)	121	0.56 a	243	1.79 ab

Table 4. Second evaluation of anthracnose in trees of the variety "Ataulfo", located in two orchards in the town of Las Palmas, San Blas, Nayarit, Mexico, from January to May 2017.

Treatments	Orchard 1		Orchard 2	
	Fruit-set/ tree	Anthracnose incidence (%)	Fruit set/ tree	Anthracnose incidence (%)
control	153	3.90 a	70	1.11 b
Copper gluconate (5 mL/L)	122	0.58 a	99	0.00 b
Trifloxystrobin (0.6 mL/L)	176	0.56 a	97	0.00 b
Wintergreen oil, cinnamon oil and governor extract (2.5 mL/L)	183	8.58 a	84	0.00 b
Governor extract, citral, thymol and eugenol (2.5 mL/L)	111	7.88 a	93	0.00 b
Governor extract, peracetic acid and hydrogen peroxide (2.5 mL/L)	55	0.67 a	86	0.00 b
Copper gluconate and phosphites (2.5 + 2.5 mL/L)	80	0.00 a	92	0.00 b
Governor extract, citral and geraniol (2.5 mL/L)	83	1.11 a	117	0.00 b
Calcium polysulfide (5 mL/L)	118	1.42 a	92	0.00 b
Wintergreen oil, cinnamon oil and governor extract (5 mL/L)	130	0.42 a	86	0.83 b
Governor extract, citral, thymol and eugenol (5 mL/L)	98	8.00 a	94	10.22 a
Governor extract, peracetic acid and hydrogen peroxide (5 mL/L)	103	1.39 a	103	1.94 b
Copper gluconate and phosphites (5 + 5mL/L)	49	0.00 a	88	0.00 b
Calcium polysulfide (7.5 mL/L)	40	0.56 a	93	3.13 ab
Governor extract, citral and geraniol (5 mL/L)	71	4.76 a	92	7.67 ab

Table 5. Third evaluation of anthracnose in trees of the variety "Ataulfo", located in two orchards in the town of Las Palmas, San Blas, Nayarit, Mexico, from January to May 2017.

Treatments	Orchard 1		Orchard 2	
	Fruit set/ tree	Anthracnose incidence (%)	Fruit set/ tree	Anthracnose incidence (%)
Control	42	3.33 a	49	0.0 b
Copper gluconate (5 mL/L)	36	2.50 a	68	0.0 b
Trifloxystrobin (0.6 mL/L)	83	0.00 a	83	0.0 b
Wintergreen oil, cinnamon oil and governor extract (2.5 mL/L)	72	5.48 a	71	0.0 b
Governor extract, citral, thymol and eugenol (2.5 mL/L)	60	2.60 a	63	0.0 b
Governor extract, peracetic acid and hydrogen peroxide (2.5 mL/L)	26	0.00 a	57	0.0 b
Copper gluconate and phosphites (2.5 + 2.5 mL/L)	37	0.00 a	53	0.0 b
Governor extract, citral and geraniol (2.5 mL/L)	45	0.00 a	77	0.0 b
Calcium polysulfide (5 mL/L)	73	7.00 a	66	3.3 b
Wintergreen oil, cinnamon oil and governor extract (5 mL/L)	44	3.56 a	58	17.5 a
Governor extract, citral, thymol and eugenol (5 mL/L)	33	6.67 a	64	12.6 ab
Governor extract, peracetic acid and hydrogen peroxide (5 mL/L)	35	0.00 a	64	0.8 b
Copper gluconate and phosphites (5 + 5mL/L)	21	3.33 a	83	0.0 b
Calcium polysulfide (7.5 mL/L)	16	1.67 a	79	7.5 ab
Governor extract, citral and geraniol (5 mL/L)	25	5.56 a	71	11.9 a

Table 6. Fourth assessment of anthracnose in trees of the variety "Ataulfo", located in two orchards in the town of Las Palmas, San Blas, Nayarit, Mexico, from January to May 2017.

Treatments	Orchard 1		Orchard 2	
	Fruit set/ tree	Anthracnose incidence (%)	Fruit set/ tree	Anthracnose incidence (%)
Control	16	6.67 ab	37	5.56 b
Copper gluconate (5 mL/L)	10	13.33 ab	49	9.00 b
Trifloxystrobin (0.6 mL/L)	38	0.00 b	50	3.05 b
Wintergreen oil, cinnamon oil and governor extract (2.5 mL/L)	22	22.77 ab	44	10.00 b
Governor extract, citral, thymol and eugenol (2.5 mL/L)	26	22.08 ab	49	13.00 b
Governor extract, peracetic acid and hydrogen peroxide (2.5 mL/L)	11	2.22 ab	56	6.67 b
Copper gluconate and phosphites (2.5 + 2.5 mL/L)	25	2.50 ab	36	3.33 b
Governor extract, citral and geraniol (2.5 mL/L)	10	6.67 ab	66	6.69 b
Calcium polysulfide (5 mL/L)	30	25.56 a	47	15.11 b
Wintergreen oil, cinnamon oil and governor extract (5 mL/L)	11	16.67 ab	39	14.72 ab
Governor extract, citral, thymol and eugenol (5 mL/L)	21	16.67 ab	53	12.22 b
Governor extract, peracetic acid and hydrogen peroxide (5 mL/L)	11	5.00 ab	52	8.90 b
Copper gluconate and phosphites (5 + 5mL/L)	14	3.33 ab	55	9.72 b
Calcium polysulfide (7.5 mL/L)	13	12.22 ab	65	13.89 ab
Governor extract, citral and geraniol (5 mL/L)	13	20.00 ab	48	31.66 a

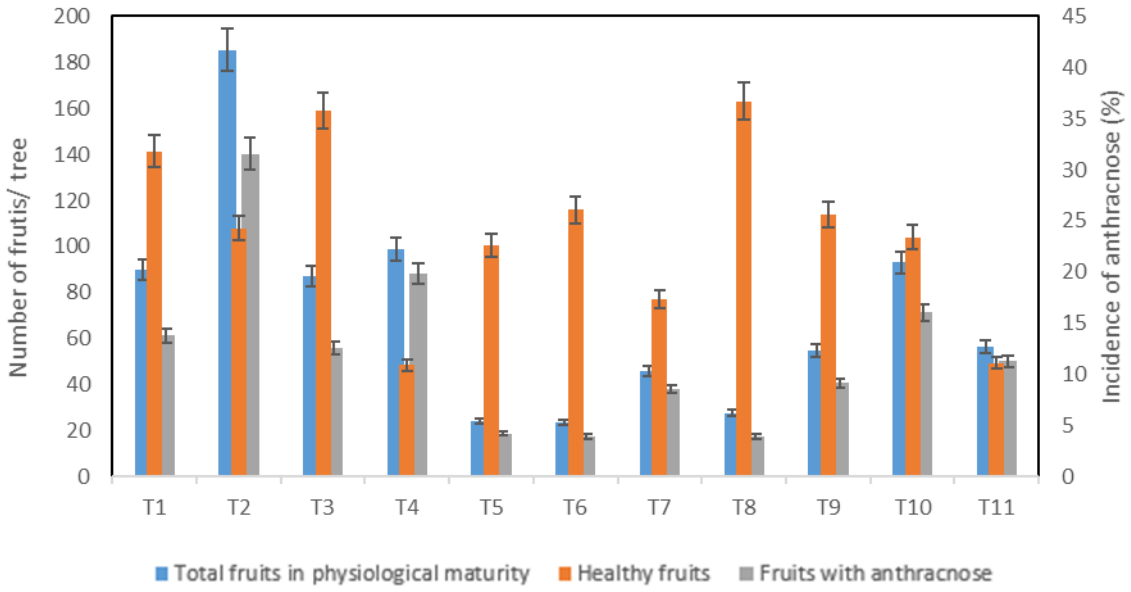

Figure 1: Incidence of anthracnose in fruit of physiological maturity in a commercial mango orchard "Ataulfo" in the town of Guadalupe, Municipality of San Blas, Nayarit. Treatments: T1 = Control fruits; T2 = Copper gluconate (5 mL / L); T3 = Copper gluconate and phosphites (2.5 + 2.5 mL / L); T4 = Trifloxystrobin (0.6 mL / L); T5 = Wintergreen oil, cinnamon oil and governor extract (2.5 mL / L); T6 = Wintergreen oil, cinnamon oil and governor extract (5 mL / L); T7 = Governor extract, citral, thymol and eugenol (2.5 mL / L); T8 = Governor extract, citral, thymol and eugenol (5 mL / L); T9 = Governor extract, peracetic acid and hydrogen peroxide (2.5 mL / L); T10 = Governor extract, peracetic acid and hydrogen peroxide (5 mL / L); T11 = Copper gluconate and phosphites (5 + 5 mL / L).

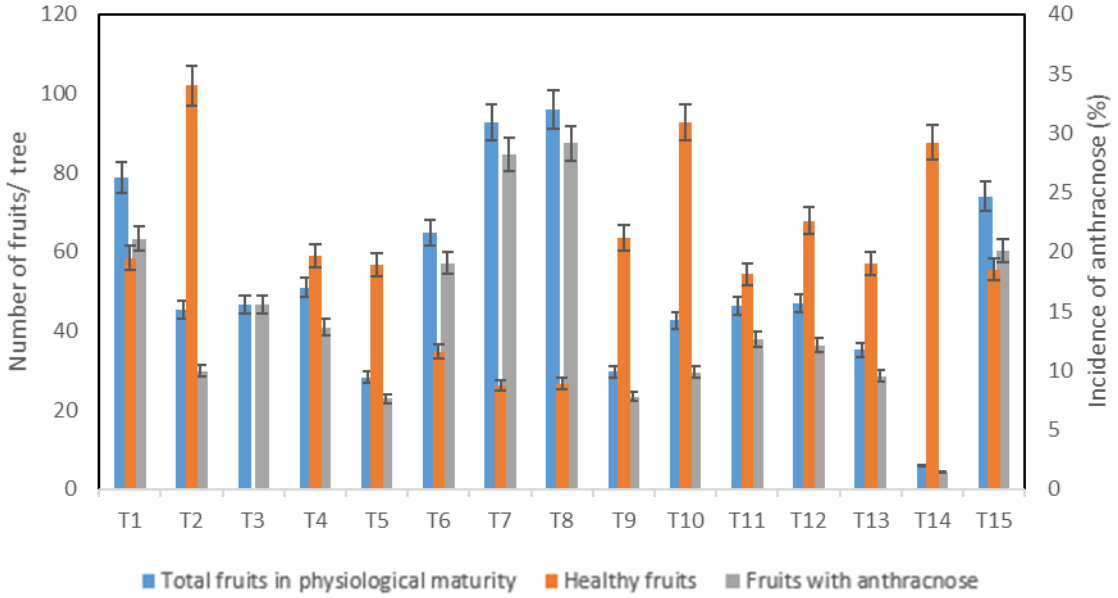

Figure 2. First evaluation of the incidence of anthracnose in fruits of physiological maturity (three days before the first harvest), from a commercial mango orchard "Ataulfo" in plot one in the town of Las Palmas, Municipality of San Blas, Nayarit. Treatments: T1 = Control fruits; T2 = Copper gluconate (5 mL / L); T3 = Trifloxystrobin (0.6 mL / L); T4 = Wintergreen oil, cinnamon oil and governor extract (2.5 mL / L); T5 = Governor extract, citral, thymol and eugenol (2.5 mL / L); T6= Governor extract, peracetic acid and hydrogen peroxide (2.5 mL / L); T7 = Copper gluconate and phosphites (2.5 + 2.5 mL / L); T8 = Governor extract, citral and geraniol (2.5 mL / L); T9 = calcium polysulfide (5 mL / L); T10 = Wintergreen oil, cinnamon oil and governor extract (5 mL / L); T11= Governor extract, citral, thymol and eugenol (5 mL / L); T12 = Governor extract, peracetic acid and hydrogen peroxide (5 mL / L); T13 = Copper gluconate and phosphites (5 + 5 mL / L); T14 = Calcium polysulfide (7.6 mL / L); T15 = Governor extract, citral and geraniol (5 mL / L).

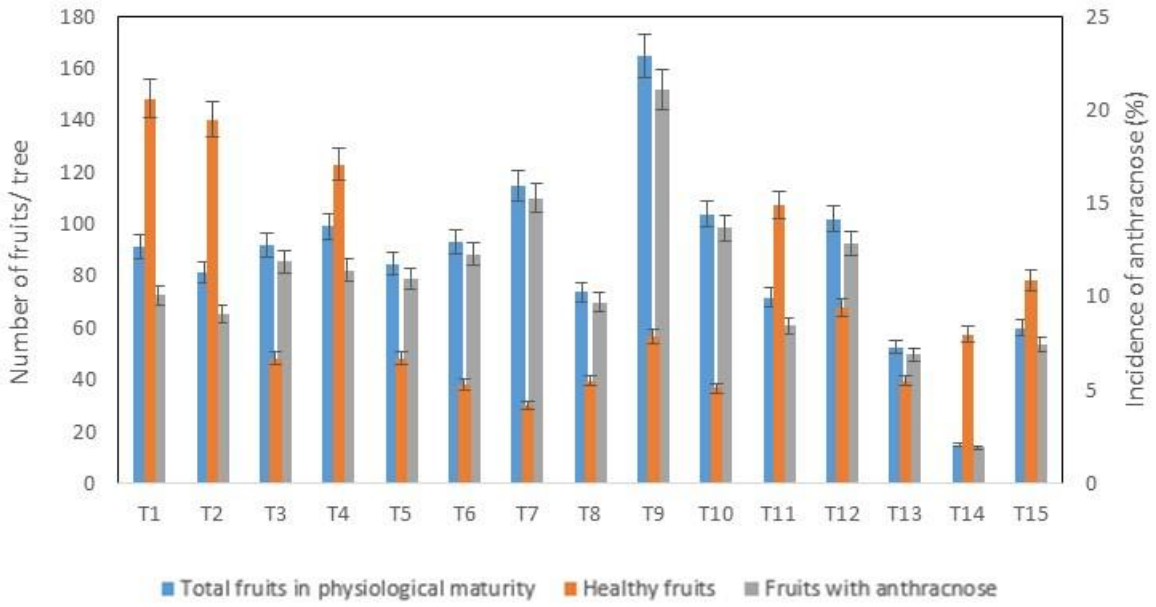

Figure 3. Second evaluation of the incidence of anthracnose in fruits of physiological maturity (three days before the first harvest), from a commercial mango orchard "Ataulfo" in plot one in the town of Las Palmas, Municipality of San Blas, Nayarit. Treatments: T1 = Control fruits; T2 = Copper gluconate (5 mL / L); T3 = Trifloxystrobin (0.6 mL / L); T4 = Wintergreen oil, cinnamon oil and governor extract (2.5 mL / L); T5 = Governor extract, citral, thymol and eugenol (2.5 mL / L); T6= Governor extract, peracetic acid and hydrogen peroxide (2.5 mL / L); T7 = Copper gluconate and phosphites (2.5 + 2.5 mL / L); T8 = Governor extract, citral and geraniol (2.5 mL / L); T9 = calcium polysulfide (5 mL / L); T10 = Wintergreen oil, cinnamon oil and governor extract (5 mL / L); T11= Governor extract, citral, thymol and eugenol (5 mL / L); T12 = Governor extract, peracetic acid and hydrogen peroxide (5 mL / L); T13 = Copper gluconate and phosphites (5 + 5 mL / L); T14 = Calcium polysulfide (7.6 mL / L); T15 = Governor extract, citral and geraniol (5 mL / L).

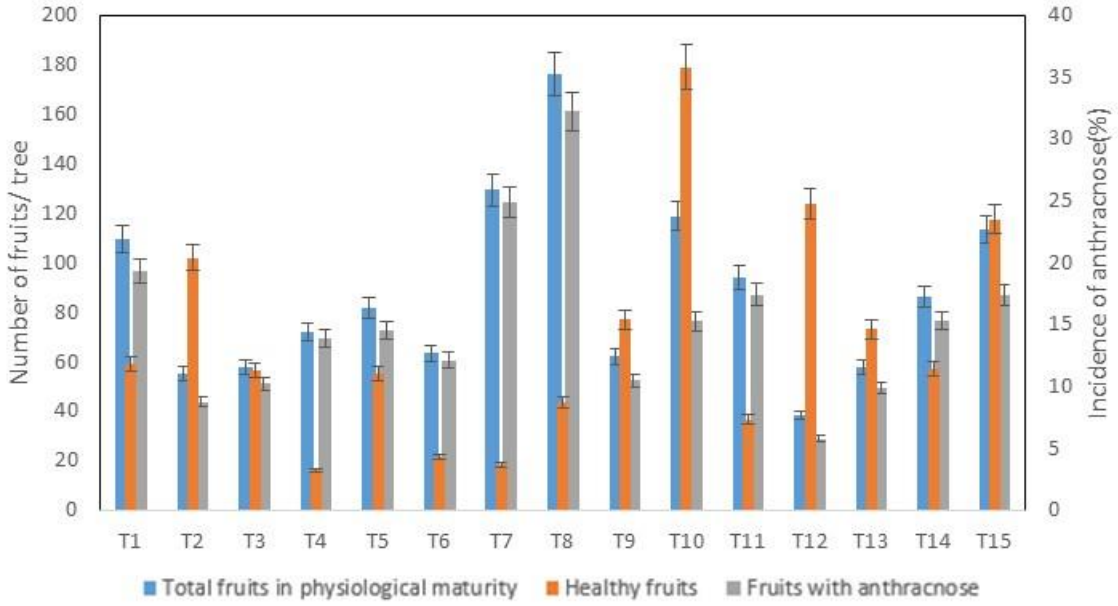

Figure 4. First evaluation of the incidence of anthracnose in fruits of physiological maturity (two days before the first harvest), from a commercial mango orchard "Ataulfo" in plot two in the town of Las Palmas, Municipality of San Blas, Nayarit. Treatments : : T1 = Control fruits; T2 = Copper gluconate (5 mL / L); T3 = Trifloxystrobin (0.6 mL / L); T4 = Wintergreen oil, cinnamon oil and governor extract (2.5 mL / L); T5 = Governor extract, citral, thymol and eugenol (2.5 mL / L); T6= Governor extract, peracetic acid and hydrogen peroxide (2.5 mL / L); T7 = Copper gluconate and phosphites (2.5 + 2.5 mL / L); T8 = Governor extract, citral and geraniol (2.5 mL / L); T9 = calcium polysulfide (5 mL / L); T10 = Wintergreen oil, cinnamon oil and governor extract (5 mL / L); T11= Governor extract, citral, thymol and eugenol (5 mL / L); T12 = Governor extract, peracetic acid and hydrogen peroxide (5 mL / L); T13 = Copper gluconate and phosphites (5 + 5 mL / L); T14 = Calcium polysulfide (7.6 mL / L); T15 = Governor extract, citral and geraniol (5 mL / L).

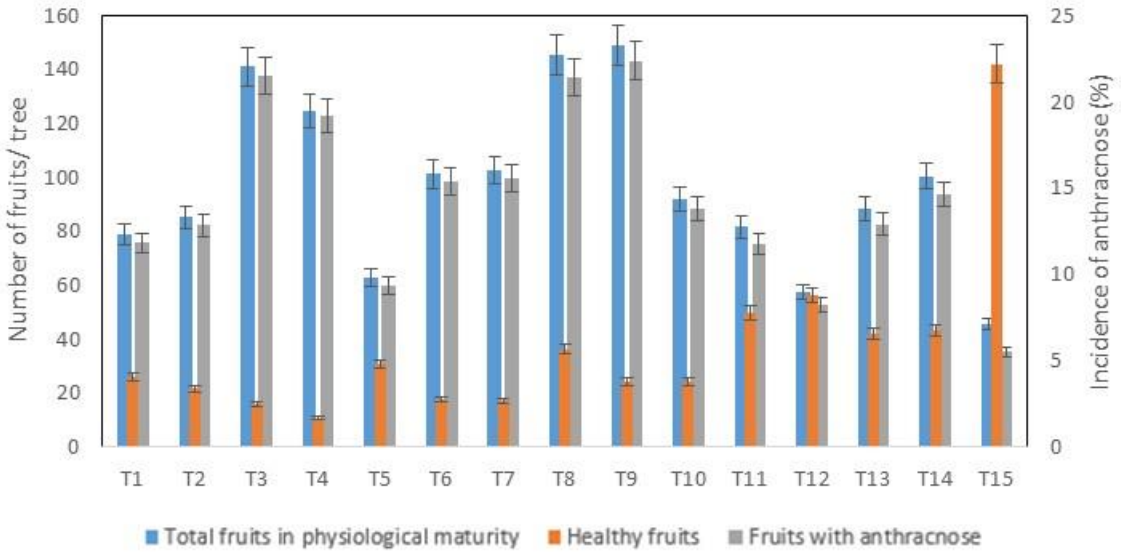

Figure 5. Second evaluation of the incidence of anthracnose in fruits of physiological maturity (five days before the second harvest), from a comercial mango orchard “Ataulfo”in plot two in the town of Las Palmas, Municipality of San Blas, Nayarit. Treatments : : T1 = Control fruits; T2 = Copper gluconate (5 mL / L); T3 = Trifloxystrobin (0.6 mL / L); T4 = Wintergreen oil, cinnamon oil and governor extract (2.5 mL / L); T5 = Governor extract, citral, thymol and eugenol (2.5 mL / L); T6= Governor extract, peracetic acid and hydrogen peroxide (2.5 mL / L); T7 = Copper gluconate and phosphites (2.5 + 2.5 mL / L); T8 = Governor extract, citral and geraniol (2.5 mL / L); T9 = calcium polysulfide (5 mL / L); T10 = Wintergreen oil, cinnamon oil and governor extract (5 mL / L); T11= Governor extract, citral, thymol and eugenol (5 mL / L); T12 = Governor extract, peracetic acid and hydrogen peroxide (5 mL / L); T13 = Copper gluconate and phosphites (5 + 5 mL / L); T14 = Calcium polysulfide (7.6 mL / L); T15 = Governor extract, citral and geraniol (5 mL/ L).

CONCLUSIONS

1. Of the formulations of biopesticides tested, none completely inhibited the incidence of anthracnose, both in pre-harvest fruits and in physiological maturity. The chemical fungicide Trifloxystrobin showed the best biological effectiveness for the control of anthracnose.

2. The results suggest that the biopesticides had fungicidal activity by contact, and due to their little residuality, their control effect was short, so it would be necessary to reduce the application intervals possibly to 7 days, in order to significantly reduce the incidence of fungus.

3. The treatments that presented greater biological effectiveness, except for Trifloxystrobien, were: T6 = Extract of governor, peracetic acid and hydrogen peroxide (2.5 mL / L); T7 = Copper gluconate and phosphites (2.5 + 2.5 mL / L); T8 = Extract of governor, citral and geraniol (2.5 mL / L); T5 = Governor, citral, thymol and eugenol extract (2.5 mL / L); T4 = Wintergreen oil, cinnamon oil and governor extract (2.5 mL / L).

4. Formulations made with essential oils such as citral, geraniol, eugenol and thymol can induce phytotoxicity in fruits when they are applied in high doses.

5. The use of organic products with fungicidal action, such as those tested in this study, could be an alternative to chemical fungicides for the management of anthracnose in mango, since they offer biological effectiveness over the pathogen, and when degraded quickly, they do not there are risks of pesticide residues; in addition, whose ingredients of which they are constituted offer no health risks.

PHOTOGRAPHIC APPENDIX

Figure 6. Commercial orchards variety "Ataulfo", in the town of Las Palmas, San Blas, Nayarit.

Figure 7. Application of treatments in commercial mango orchards of the "Ataulfo" variety.

Figure 8. Fruit set in mango trees of the variety "Ataulfo".

Figure 9. Incidence of anthracnose in mango fruits of the variety "Ataulfo", with less than 6 cm in length.

Figure 10. Incidence of anthracnose in mango fruits of the variety "Ataulfo", with more than 6 cm in length.

APPLICATION OF BIOPESTICIDES IN MANGO ORCHARDS IN VARIETY "ATAULFO"

FIELD PHASE

(January to June 2018)

MATERIALS AND METHODS

Establishment of the experiment

Two experiments were established in commercial mango orchards of the variety "Ataulfo" in the last week of January and the first week of February 2018. The two orchards were located in the town of La Palma, San Blas, Nayarit, Mexico, with 8 year-old trees. The selection of the aforementioned orchards was made based on the high incidences of anthracnose that they had presented in the last two years (production cycles 2016 and 2017).

Application of treatments

The applications of the formulations of the biopesticides (Table 1 and 2) were made every 15 days, with a total of 10 applications from flowering to harvest. The applications were made with motor backpack with capacity of 20 liters.

Design of treatments

A completely randomized design with three repetitions per treatment (five trees) was used. In each tree, 15 fully developed panicles (75 panicles per treatment) were selected and marked.

Evaluations and variables

The evaluations were carried out to determine the incidence of anthracnose in fruits between 3 and 10 cm in length (pre-harvest fruits) and in physiological maturity (fruits close to harvest). Three evaluations were made 15 days after the application of the treatments. To determine the incidence of anthracnose, fruits that showed two or more lesions per fruit equal to or greater than 3 millimeters in diameter were considered. The incidence was expressed as a percentage, for which the following equation was used:

$$\text{Incidence of anthracnose (\%)} = \frac{\text{Fruits with symptoms of anthracnose}}{Total\ fruits} X\ 100 \ldots$$

Table 1. Application of treatments on trees of the variety "Ataulfo" in the orchard one, located in the town of Las Palmas, San Blas, Nayarit, Mexico, from January to May 2018.

TREATMENTS	DOSE (mL/L of water)	TYPE OF DOSE
1. CONTROL	No application	Only
2. TRIFLOXYSTROBIN	3	Only
3. CHITOSAN + PHOSPHITES	(3) + (3)	Only
4. CHITOSAN + COPPER GLUCONATE	(3) + (3)	Low
5. PERACETIC ACID (35%) + HYDROGEN PEROXIDE (15%) + ACETIC ACID (10%)	4	Low
6. HYDROGEN PEROXIDE (30%) + PERACETIC ACID (15%) + ACETIC ACID (10%)	4	Low
7. PERACETIC ACID (30%) + HYDROGEN PEROXIDE (15%) + ACETIC ACID (10%) + CHITOSAN (30%)	4	Low
8. COPPER GLUCONATE	4	Only
9. CHITOSAN + COPPER GLUCONATE	(5) + (5)	High
10. PERACETIC ACID (35%) + HYDROGEN PEROXIDE (15%) + ACETIC ACID (10%)	7	High
11. HYDROGEN PEROXIDE (30%) + PERACETIC ACID (15%) + ACETIC ACID (10%)	7	High
12. PERACETIC ACID (30%) + HYDROGEN PEROXIDE (15%) + ACETIC ACID (10%) + CHITOSAN (30%)	7	High

Table 2. Application of treatments on trees of the variety "Ataulfo" in the orchard two, located in the town of Las Palmas, San Blas, Nayarit, Mexico, from January to June 2018.

TREATMENTS	DOSE (mL/L of water)	TYPE OF DOSE
1.CONTROL	No application	Single
2. TRIFLOXYSTROBIN	3	Single
3. COPPER GLUCONATE + PHOSPHITES + SALICYLIC ACID	(4) + (2) + (1.5)	Single
4. CHITOSAN + COPPER GLUCONATE	(3) + (3)	Low
5. CHITOSAN + PHOSPHITES	(2) + (2)	Low
6. MUSTARD OIL (5%) + CUMIN OIL (10%) + EUCALYPTUS OIL (10%)	3	Low
7. PERACETIC ACID (35%) + HYDROGEN PEROXIDE (15%) + ACETIC ACID (10%)	4	Low
8. HYDROGEN PEROXIDE (30%) + PERACETIC ACID (15%) + ACETIC ACID (10%)	4	Low
9. PERACETIC ACID (30%) + HYDROGEN PEROXIDE (15%) + ACETIC ACID (10%) + CHITOSAN (30%)	4	Low
10. COPPER GLUCONATE	3	Single
11. CHITOSAN + COPPER GLUCONATE	(5) + (5)	High
12. PERACETIC ACID (35%) + HYDROGEN PEROXIDE (15%) + ACETIC ACID (10%)	7	High
13. HYDROGEN PEROXIDE (30%) + PERACETIC ACID (15%) + ACETIC ACID (10%)	7	High
14. PERACETIC ACID (30%) + HYDROGEN PEROXIDE (15%) + ACETIC ACID (10%) + CHITOSAN (30%)	7	High
15. MUSTARD OIL (5%) + CUMIN OIL (10%) + EUCALYPTUS OIL (10%)	5	High
16. CHITOSAN + PHOSPHITES	(4) + (4)	High

RESULTS

PRE-HARVEST FRUITS (ORCHARD ONE)

First evaluation: With respect to the control, all the treatments showed a reduction effect in the incidence of anthracnose, however, treatment 2 (Trifloxystrobin) completely inhibited the growth of anthracnose, followed by treatment 3 (Chitosan + Phosphites) presenting an incidence rate of 3% (Figure 1). The fruits of the control trees presented an incidence rate higher than 40%. Treatments 5, 6, 7, 12 and 13 were in the range of 13-21%.

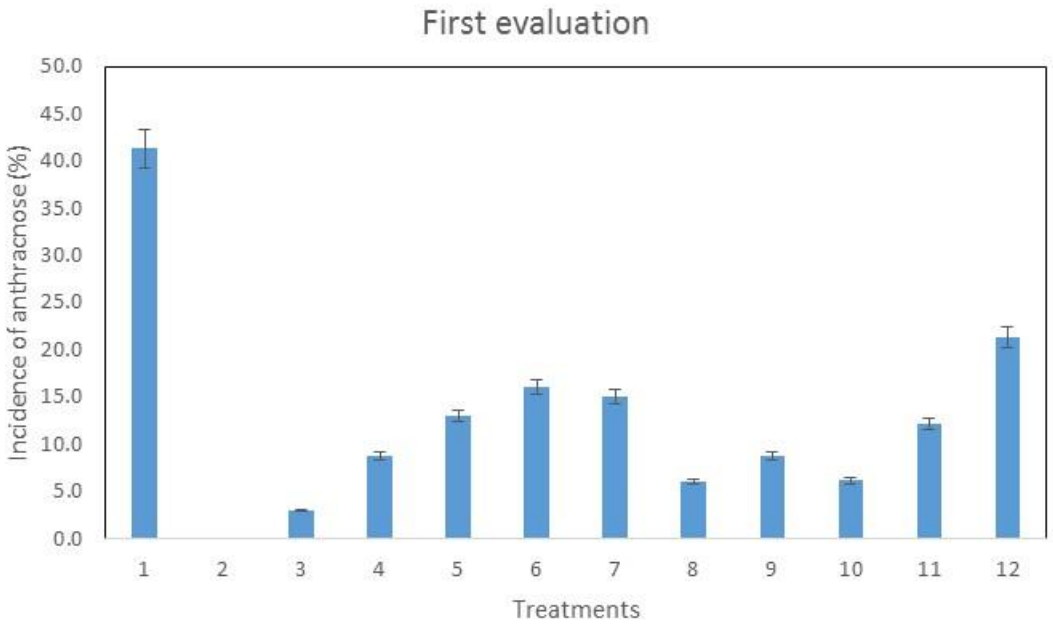

Figure 1. Incidence of anthracnose in pre-harvest fruits (3-10 cm) in a commercial mango orchard "Ataulfo" in the ejido of Las Palmas, Municipality of San Blas, Nayarit. Orchard one (Treatments): T1) Control; T2) Trifloxystrobin; T3) Chitosan + Phosphites; T4) Chitosan + Copper Gluconate (Low dose); T5) Peracetic acid + Hydrogen peroxide + Acetic acid (low dose); T6) Hydrogen Peroxide + Peracetic acid + Acetic acid (low dose); T7). Peracetic acid, Hydrogen Peroxide + Acetic acid + Chitosan (Low dose); T8). Copper Gluconate; T9). Chitosan + Copper Gluconate (High dose); T10). Peracetic acid + Hydrogen Peroxide + Acetic acid (high dose); T11). Hydrogen peroxide + Peracetic acid + Acetic acid (high dose); T12). Peracetic acid + Hydrogen Peroxide + Acetic acid + Chitosan (High dose).

Second evaluation: treatments 2, 3 and 4 presented the lowest incidence of anthracnose, which oscillated in a range of 1-6%, with treatment 4 [(Chitosan + Copper Gluconate (Low dose)] being the lowest incidence. Treatments 10 and 12 obtained the highest percentages of anthracnose incidence with 18-38% respectively, while the control treatment showed 13% (figure 2).

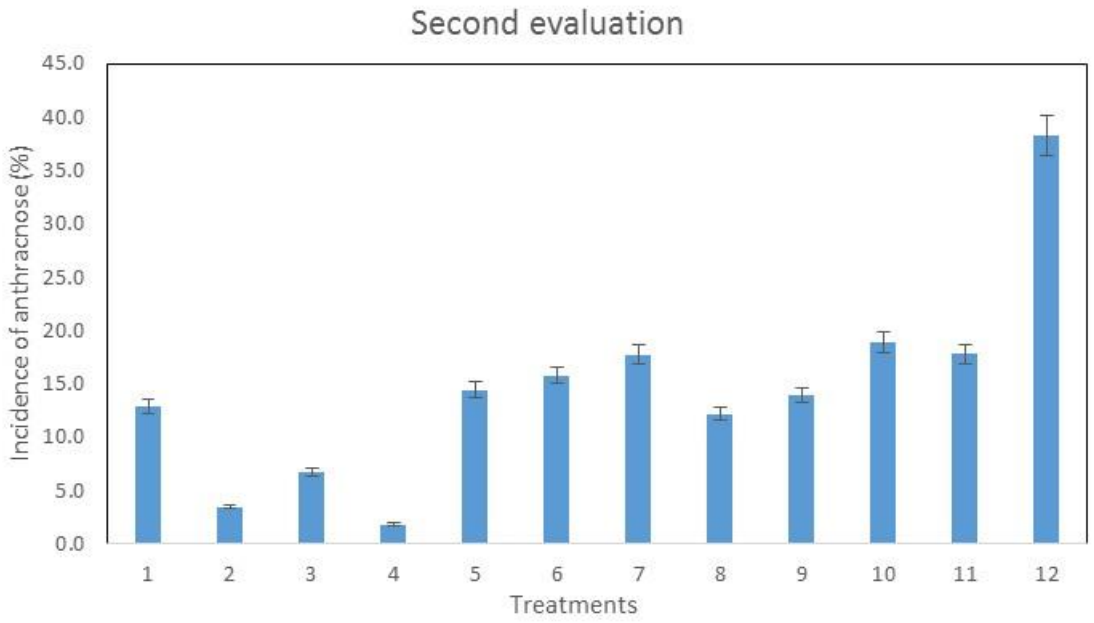

Figure 2. Incidence of anthracnose in pre-harvest fruits (3-10 cm) in a commercial mango orchard "Ataulfo" in the ejido of Las Palmas, Municipality of San Blas, Nayarit. Orchard one (Treatments): T1) Control; T2) Trifloxystrobin; T3) Chitosan + Phosphites; T4) Chitosan + Copper Gluconate (Low dose); T5) Peracetic acid + Hydrogen peroxide + Acetic acid (low dose); T6) Hydrogen Peroxide + Peracetic acid + Acetic acid (low dose); T7). Peracetic acid, Hydrogen Peroxide + Acetic acid + Chitosan (Low dose); T8). Copper Gluconate; T9). Chitosan + Copper Gluconate (High dose); T10). Peracetic acid + Hydrogen Peroxide + Acetic acid (high dose); T11). Hydrogen peroxide + Peracetic acid + Acetic acid (high dose); T12). Peracetic acid + Hydrogen Peroxide + Acetic acid + Chitosan (High dose).

Third evaluation: treatment 2 showed the lowest incidence with 3%, followed by treatments 10 (10%), 3 (12%) and 9 (12%). The rest of the treatments had incidences greater than 15%, where the control presented 20% (Figure 3). The irregular results that were observed in the incidence of anthracnose were due to the fact that the evaluations were made in different phenological stages of the fruits, so, many of the fruits increased in size and were not taken into account to be evaluated. On the other hand, there were also more than two blooms, so there were new fruits and consequently differences in size, which explains the increases and decreases in the percentages of incidence in the evaluations.

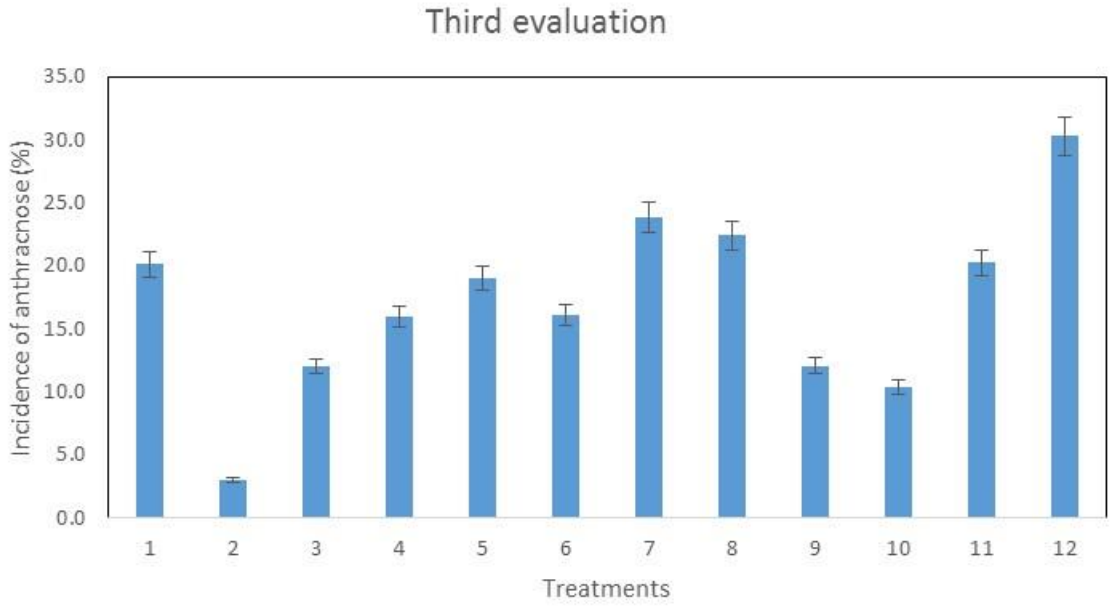

Figure 3. Incidence of anthracnose in pre-harvest fruits (3-10 cm) in a commercial mango orchard "Ataulfo" in the ejido of Las Palmas, Municipality of San Blas, Nayarit. Orchard one (Treatments): T1) Control; T2) Trifloxystrobin; T3) Chitosan + Phosphites; T4) Chitosan + Copper Gluconate (Low dose); T5) Peracetic acid + Hydrogen peroxide + Acetic acid (low dose); T6) Hydrogen Peroxide + Peracetic acid + Acetic acid (low dose); T7). Peracetic acid, Hydrogen Peroxide + Acetic acid + Chitosan (Low dose); T8). Copper Gluconate; T9). Chitosan + Copper Gluconate (High dose); T10). Peracetic acid + Hydrogen Peroxide + Acetic acid (high dose); T11). Hydrogen peroxide + Peracetic acid + Acetic acid (high dose); T12). Peracetic acid + Hydrogen Peroxide + Acetic acid + Chitosan (High dose).

PRE-HARVEST FRUITS (ORCHARD TWO)

First evaluation: treatments 2, 4, 11 and 16 stand out, which showed incidences of 0-1%. It is important to mention that treatment 11 [(Chitosan + Copper Gluconate)] presented a 0% incidence of anthracnose. The fruits treated with treatments 3, 8, 9, 10 and 15 presented incidences of 6-8%. On the other hand, the trees treated with treatment 7 had the highest percentage of incidence of anthracnose with 17-22%. The control fruits had around 6% incidence. (Figure 4).

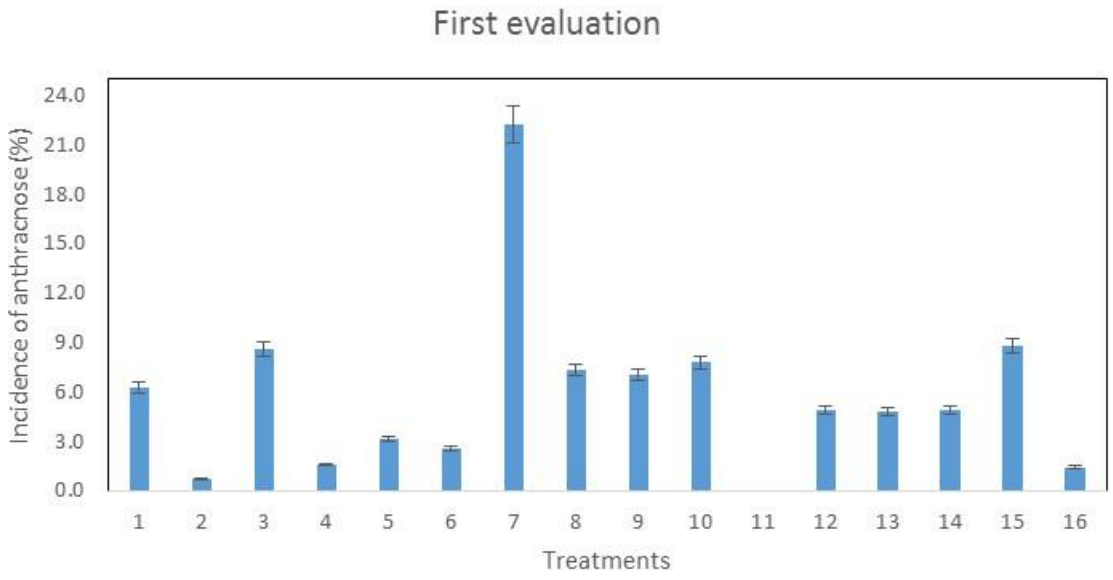

Figure 4. Incidence of anthracnose in pre-harvest fruits (3-10 cm) in a commercial mango orchard "Ataulfo" in the ejido of Las Palmas, Municipality of San Blas, Nayarit. Orchard two (Treatments): T1). Control; T2). Trifloxystrobin; T3). Copper gluconate + phosphites + Salicilyce acid; T4). Chitosan + Copper Gluconate (Low dose); T5). Chitosan + phosphites (Low dose); T6). Mustard oil + Cumin oil + Eucalyptus oil (Low dose); T7). Peracetic acid + Hydrogen peroxide + Acetic acid (Low dose); T8). Hydrogen peroxide + Peracetic acid + Acetic acid (Low dose); T9). Peracetic acid + Hydrogen peroxide + Acetic acid + Chitosan (Low dose); T10). Copper gluconate; T11). Chitosan + Copper gluconate (High dose); T12). Peracetic acid + Hydrogen peroxide + Acetic acid (High dose); T13). Hydrogen peroxide + Peracetic acid + Acetic acid (High dose); T14). Peracetic acid + Hydrogen peroxide + Acetic acid + Chitosan (High dose); T15). Mustard oil + Cumin oil + Eucalyptus oil (High dose); T16). Chitosan + Phosphites (High dose).

Second evaluation: it was observed that the control trees and those treated with treatments 3, 6, 9, 15 and 17 presented incidences greater than 9%. The rest of the treatments had incidences lower than 9%; however, it is important to note that the fruits of treatments 4 [Chitosan + Copper Gluconate] and 11 [Chitosan + Copper Gluconate (High dose)] had the lowest incidence (Figure 5).

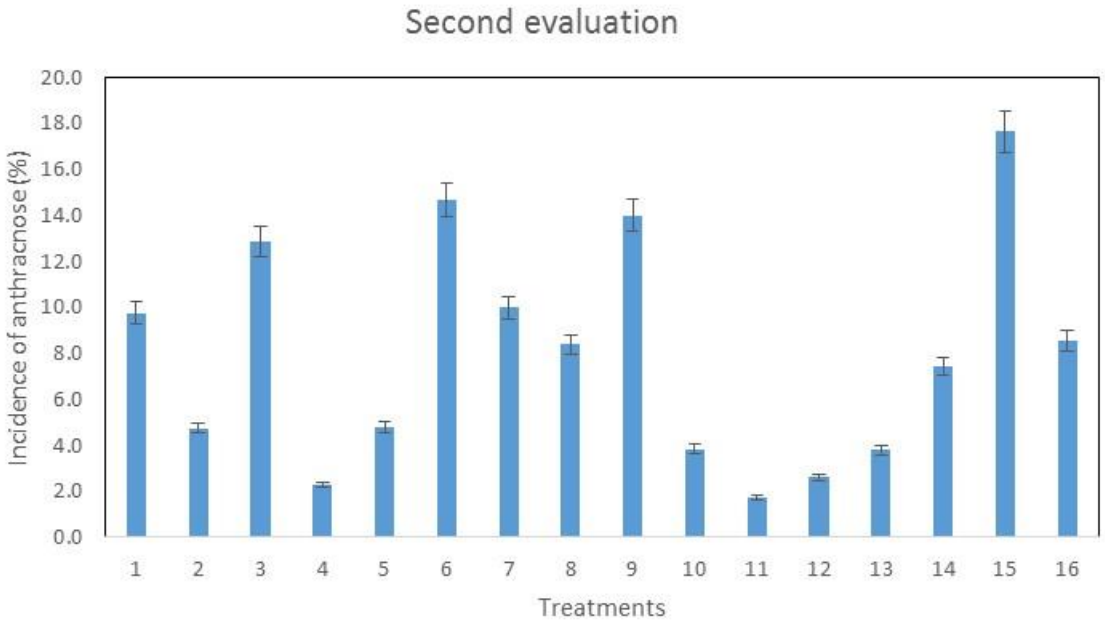

Figure 5. Incidence of anthracnose in pre-harvest fruits (3-10 cm) in a commercial mango orchard "Ataulfo" in the ejido of Las Palmas, Municipality of San Blas, Nayarit. Orchard two (Treatments): T1). Control; T2). Trifloxystrobin; T3). Copper gluconate + phosphites + Salicilyce acid; T4). Chitosan + Copper Gluconate (Low dose); T5). Chitosan + phosphites (Low dose); T6). Mustard oil + Cumin oil + Eucalyptus oil (Low dose); T7). Peracetic acid + Hydrogen peroxide + Acetic acid (Low dose); T8). Hydrogen peroxide + Peracetic acid + Acetic acid (Low dose); T9). Peracetic acid + Hydrogen peroxide + Acetic acid + Chitosan (Low dose); T10). Copper gluconate; T11). Chitosan + Copper gluconate (High dose); T12). Peracetic acid + Hydrogen peroxide + Acetic acid (High dose); T13). Hydrogen peroxide + Peracetic acid + Acetic acid (High dose); T14). Peracetic acid + Hydrogen peroxide + Acetic acid + Chitosan (High dose); T15). Mustard oil + Cumin oil + Eucalyptus oil (High dose); T16). Chitosan + Phosphites (High dose).

Third evaluation: in this last evaluation it was observed that the control fruits, and that of treatments 5, 8, 15 and 16 showed the highest incidences, which were higher than 8%. The rest of the treatments presented minor incidences. The fruits of treatments 2, 6, 11, 13 and 14 presented the lowest incidences, which were less than 5% (Figure 6).

As in the orchard one, there were more than two blooms, so different fruit sizes were presented; that is, in some evaluations there were several small fruits, while in the next evaluation there were already developed fruits which did not fit into the evaluation criteria.

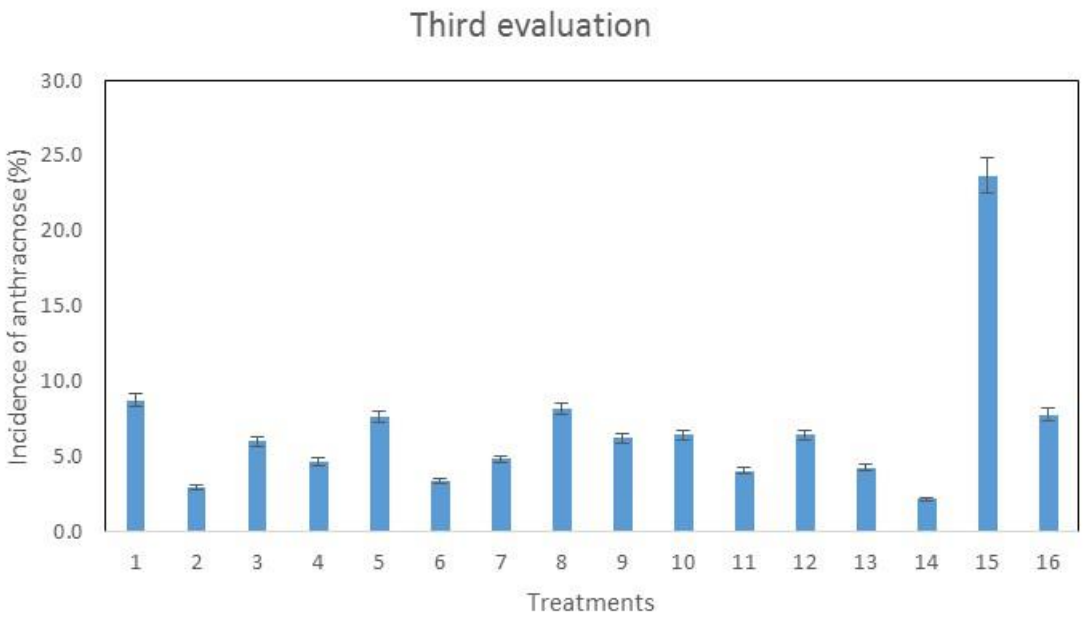

Figure 6. Incidence of anthracnose in pre-harvest fruits (3-10 cm) in a commercial mango orchard "Ataulfo" in the ejido of Las Palmas, Municipality of San Blas, Nayarit. Orchard two (Treatments): T1). Control; T2). Trifloxystrobin; T3). Copper gluconate + phosphites + Salicilyce acid; T4). Chitosan + Copper Gluconate (Low dose); T5). Chitosan + phosphites (Low dose); T6). Mustard oil + Cumin oil + Eucalyptus oil (Low dose); T7). Peracetic acid + Hydrogen peroxide + Acetic acid (Low dose); T8). Hydrogen peroxide + Peracetic acid + Acetic acid (Low dose); T9). Peracetic acid + Hydrogen peroxide + Acetic acid + Chitosan (Low dose); T10). Copper gluconate; T11). Chitosan + Copper gluconate (High dose); T12). Peracetic acid + Hydrogen peroxide + Acetic acid (High dose); T13). Hydrogen peroxide + Peracetic acid + Acetic acid (High dose); T14). Peracetic acid + Hydrogen peroxide + Acetic acid + Chitosan (High dose); T15). Mustard oil + Cumin oil + Eucalyptus oil (High dose); T16). Chitosan + Phosphites (High dose)

FRUITS IN PHYSIOLOGICAL MATURITY (ORCHARD ONE)

First evaluation: the fruits in physiological maturity with the highest incidence of anthracnose were treatments 4, 5 and 6 with 25%. The control showed 17% incidence. While treatments 2 and 3 showed the lowest degree of incidence of the disease (Less than 4%). Most of the treatments ranged between incidence values of 10-20% (Figure 7).

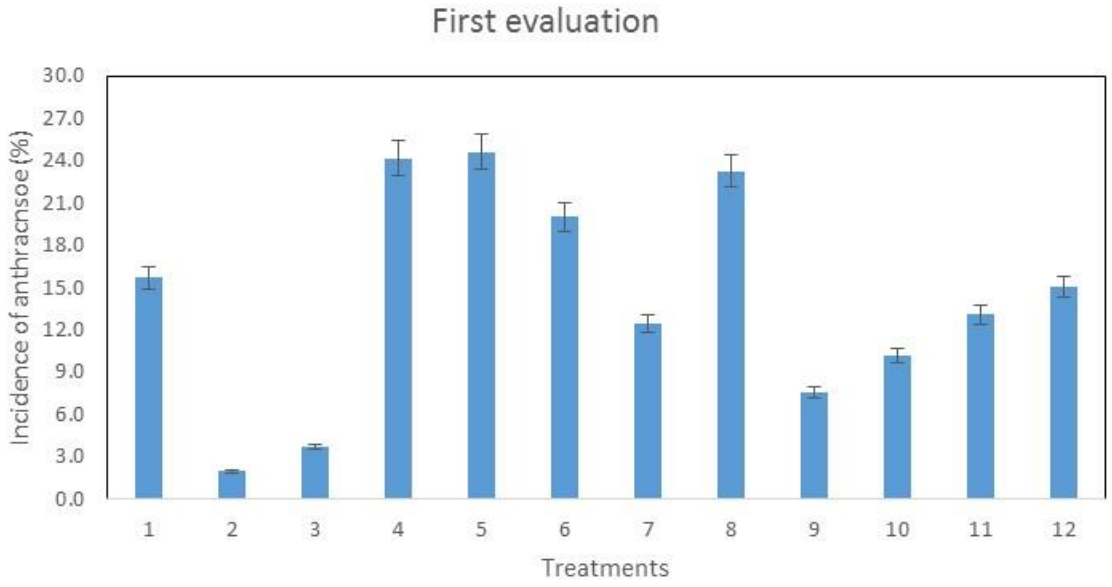

Figure 7. Incidence of anthracnose in fruits of physiological maturity in a commercial mango orchard "Ataulfo" in the ejido of Las Palmas, Municipality of San Blas, Nayarit. Orchard one (Treatments): T1) Control; T2) Trifloxystrobin; T3) Chitosan + Phosphites; T4) Chitosan + Copper Gluconate (Low dose); T5) Peracetic acid + Hydrogen peroxide + Acetic acid (low dose); T6) Hydrogen Peroxide + Peracetic acid + Acetic acid (low dose); T7). Peracetic acid, Hydrogen Peroxide + Acetic acid + Chitosan (Low dose); T8). Copper Gluconate; T9). Chitosan + Copper Gluconate (High dose); T10). Peracetic acid + Hydrogen peroxide + Acetic acid (high dose); T11). Hydrogen peroxide + Peracetic acid +Acetic acid (high dose); T12). Peracetic acid + Hydrogen peroxide + Acetic acid + Chitosan (High dose).

Second evaluation: Control trees reached the highest percentage of anthracnose incidence (35%), followed by treatment 5 (30%) and 11 (25%). While treatments 3, 4, 6, 7, 8, 9, 10 and 12 recorded ranges from 10 to 20% (Figure 8). The trees treated with Trifloxystrobin had incidence in fruits of 3%, followed by treatments 9 (10%) and 3 (11%).

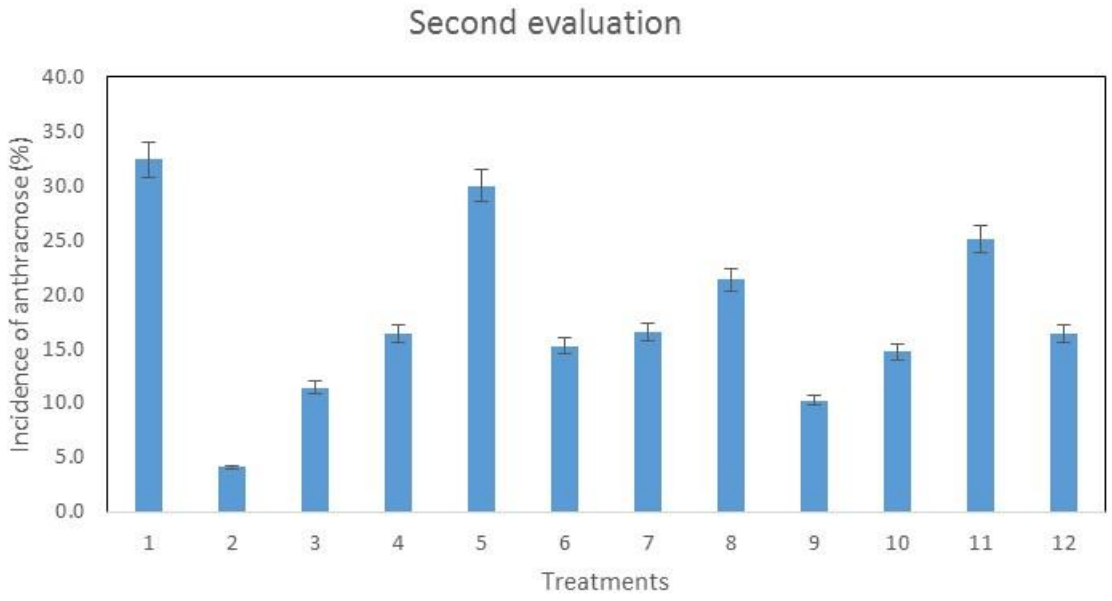

Figure 8. Incidence of anthracnose in fruits of physiological maturity in a commercial mango orchard "Ataulfo" in the ejido of Las Palmas, Municipality of San Blas, Nayarit. Orchard one (Treatments): T1) Control; T2) Trifloxystrobin; T3) Chitosan + Phosphites; T4) Chitosan + Copper Gluconate (Low dose); T5) Peracetic acid + Hydrogen peroxide + Acetic acid (low dose); T6) Hydrogen Peroxide + Peracetic acid + Acetic acid (low dose); T7). Peracetic acid, Hydrogen Peroxide + Acetic acid + Chitosan (Low dose); T8). Copper Gluconate; T9). Chitosan + Copper Gluconate (High dose); T10). Peracetic acid + Hydrogen peroxide + Acetic acid (high dose); T11). Hydrogen peroxide + Peracetic acid +Acetic acid (high dose); T12). Peracetic acid + Hydrogen peroxide + Acetic acid + Chitosan (High dose).

Third evaluation: it was observed that treatments 2 (Trifloxystrobin) and 3 (Chitosan + Phosphites) showed values lower than 5% of incidence (Figure 9). While the rest of the treatments presented incidences that ranged between 10 and 17%. The control reached 14% incidence.

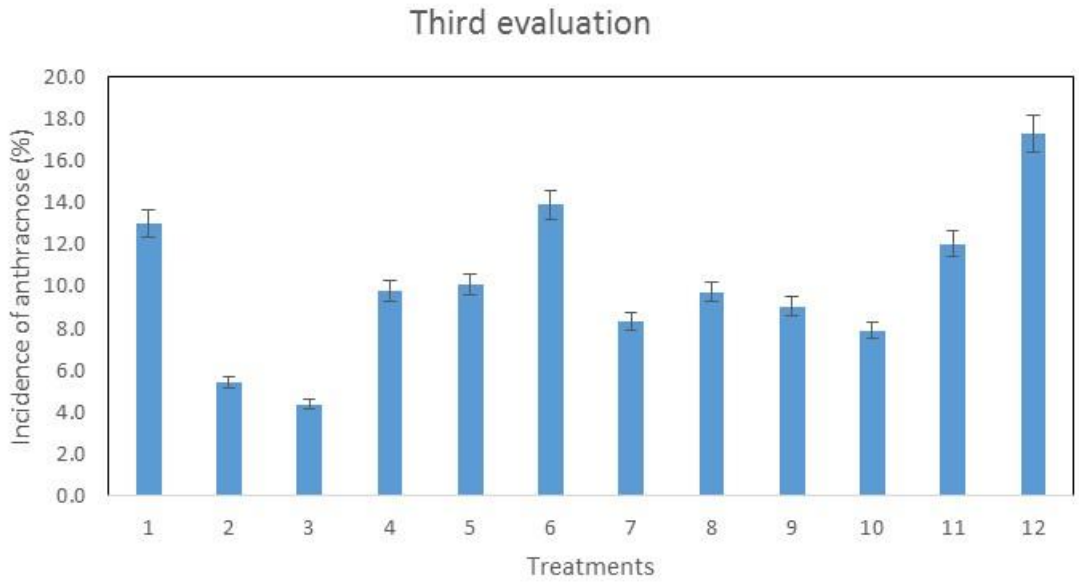

Figure 9. Incidence of anthracnose in fruits of physiological maturity in a commercial mango orchard "Ataulfo" in the ejido of Las Palmas, Municipality of San Blas, Nayarit. Orchard one (Treatments): T1) Control; T2) Trifloxystrobin; T3) Chitosan + Phosphites; T4) Chitosan + Copper Gluconate (Low dose); T5) Peracetic acid + Hydrogen peroxide + Acetic acid (low dose); T6) Hydrogen Peroxide + Peracetic acid + Acetic acid (low dose); T7). Peracetic acid, Hydrogen Peroxide + Acetic acid + Chitosan (Low dose); T8). Copper Gluconate; T9). Chitosan + Copper Gluconate (High dose); T10). Peracetic acid + Hydrogen peroxide + Acetic acid (high dose); T11). Hydrogen peroxide + Peracetic acid +Acetic acid (high dose); T12). Peracetic acid + Hydrogen peroxide + Acetic acid + Chitosan (High dose).

FRUITS IN PHYSIOLOGICAL MATURITY

(ORCHARD TWO)

First evaluation: the fruits of the treatments 9 {(Peracetic Acid + Hydrogen Peroxide + Acetic Acid + Chitosan (Low dose)} and 11 {Chitosan + Copper Gluconate (High dose)} showed no anthracnose damage, however, in the subsequent evaluations, there were incidences in fruits. All the treatments showed values no more than 10% of incidence of anthracnose, except the treatment 15 {Mustard Oils + Cumin + Eucalyptus (High dose)} that exceeded 20% (Figure 10).

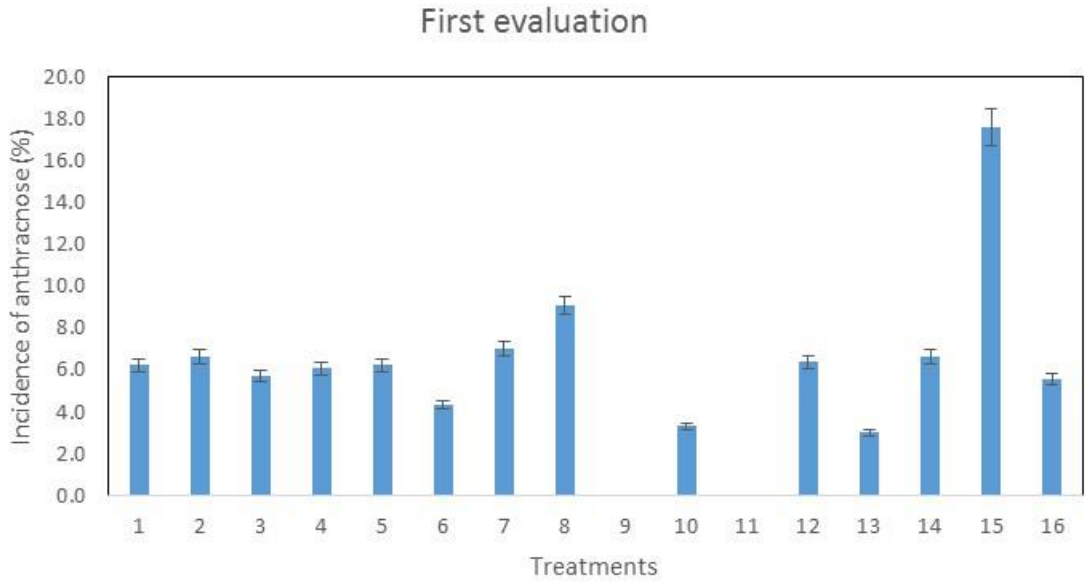

Figure 10. Incidence of anthracnose in fruits of physiological maturity in a commercial mango orchard "Ataulfo" in the ejido of Las Palmas, Municipality of San Blas, Nayarit. Orchard two. (Treatments): T1). Control T2). Trifloxystrobin; T3). Copper Gluconate + Phosphites + Salicylic Acid; T4). Chitosan + Copper Gluconate (Low dose); T5). Chitosan + Phosphites (Low dose); T6). Mustard Oil + Cumin oil + Eucalyptus oil (Low dose); T7). Peracetic acid + Hydrogen peroxide + Acetic acid (low dose); T8). Hydrogen peroxide + Peracetic acid + Acetic acid (low dose); T9). Peracetic acid + Hydrogen peroxide + Acetic acid + Chitosan (Low dose); T10). Copper Gluconate; T11). Chitosan + Copper Gluconate (High dose); T12). Peracetic acid + Hydrogen Peroxide + Acetic acid (high dose); T13). Hydrogen peroxide + Peracetic acid + Acetic acid (high dose); T14). Peracetic acid + Hydrogen peroxide + Acetic acid + Chitosan (High dose); T15). Mustard Oil + Cumin oil + Eucalyptus oil (High dose); T16). Chitosan + Phosphites (High dose).

Second evaluation: the data report that treatments 2, 7 and 11 did not exceed 5% of incidence of the disease; with treatment 11 standing out (Figure 11). Control trees reached 15%, as did treatment 14. While the rest of the treatments registered values lower than 15%.

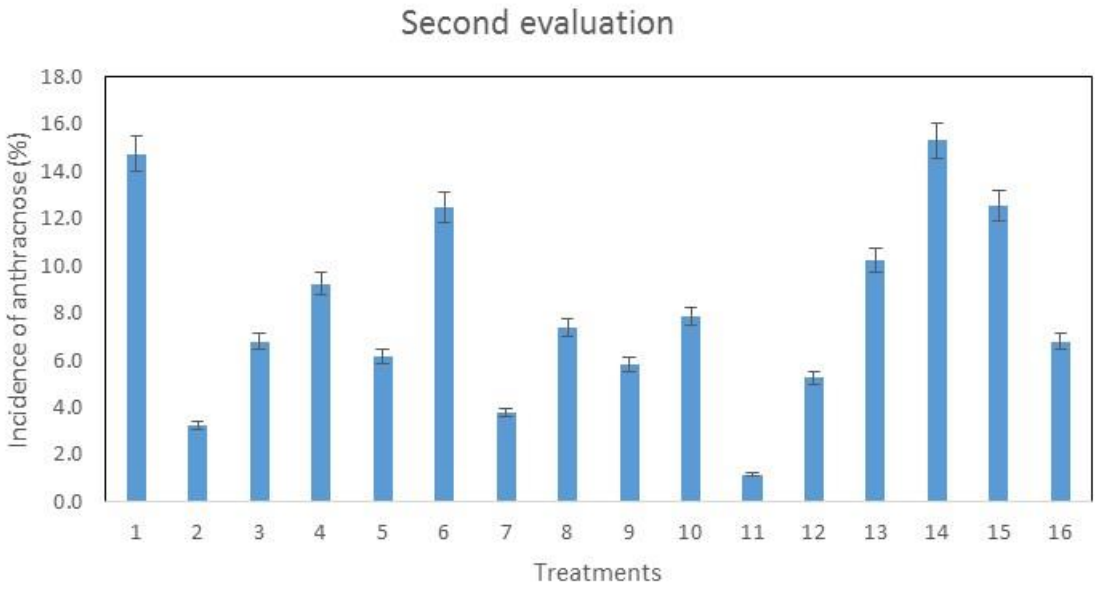

Figure 11. Incidence of anthracnose in fruits of physiological maturity in a commercial mango orchard "Ataulfo" in the ejido of Las Palmas, Municipality of San Blas, Nayarit. Orchard two. (Treatments): T1). Control T2). Trifloxystrobin; T3). Copper Gluconate + Phosphites + Salicylic Acid; T4). Chitosan + Copper Gluconate (Low dose); T5). Chitosan + Phosphites (Low dose); T6). Mustard Oil + Cumin oil + Eucalyptus oil (Low dose); T7). Peracetic acid + Hydrogen peroxide + Acetic acid (low dose); T8). Hydrogen peroxide + Peracetic acid + Acetic acid (low dose); T9). Peracetic acid + Hydrogen peroxide + Acetic acid + Chitosan (Low dose); T10). Copper Gluconate; T11). Chitosan + Copper Gluconate (High dose); T12). Peracetic acid + Hydrogen Peroxide + Acetic acid (high dose); T13). Hydrogen peroxide + Peracetic acid + Acetic acid (high dose); T14). Peracetic acid + Hydrogen peroxide + Acetic acid + Chitosan (High dose); T15). Mustard Oil + Cumin oil + Eucalyptus oil (High dose); T16). Chitosan + Phosphites (High dose).

Third evaluation: the data obtained in this evaluation show a null development of the disease in treatment 11, followed by treatments 2 and 16 with 4 and 3% respectively (Figure 12). However, treatment 10 had 5% incidence, 5 (5.9%) and 4 (6%). The rest of the treatments were in the range of 7-10%. The control and treatment 15 are the ones that recorded the highest incidence values with 12 and 14% respectively.

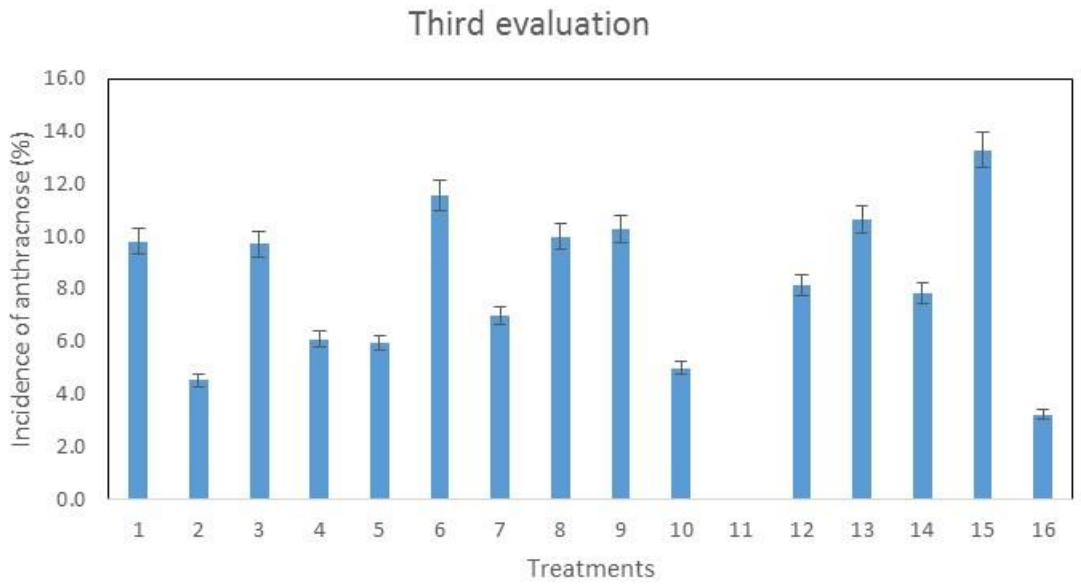

Figure 12. Incidence of anthracnose in fruits of physiological maturity in a commercial mango orchard "Ataulfo" in the ejido of Las Palmas, Municipality of San Blas, Nayarit. Orchard two. (Treatments): T1). Control T2). Trifloxystrobin; T3). Copper Gluconate + Phosphites + Salicylic Acid; T4). Chitosan + Copper Gluconate (Low dose); T5). Chitosan + Phosphites (Low dose); T6). Mustard Oil + Cumin oil + Eucalyptus oil (Low dose); T7). Peracetic acid + Hydrogen peroxide + Acetic acid (low dose); T8). Hydrogen peroxide + Peracetic acid + Acetic acid (low dose); T9). Peracetic acid + Hydrogen peroxide + Acetic acid + Chitosan (Low dose); T10). Copper Gluconate; T11). Chitosan + Copper Gluconate (High dose); T12). Peracetic acid + Hydrogen Peroxide + Acetic acid (high dose); T13). Hydrogen peroxide + Peracetic acid + Acetic acid (high dose); T14). Peracetic acid + Hydrogen peroxide + Acetic acid + Chitosan (High dose); T15). Mustard Oil + Cumin oil + Eucalyptus oil (High dose); T16). Chitosan + Phosphites (High dose).

CONCLUSIONS

1. Of the formulations of biopesticides tested, none completely inhibited the incidence of anthracnose, both in pre-harvest fruits and in physiological maturity.

2. The results suggest that the biopesticides had fungicidal activity by contact, and due to their little residuality, their control effect was short, so it would be necessary to reduce the application intervals possibly to 7 days, in order to significantly reduce the incidence of fungus.

3. The treatments in the orchard one that showed greater biological effectiveness were: T2) Trifloxystrobin; T3) Chitosan + Phosphites (single dose); T10). Ac. Peracetic + Hydrogen Peroxide + Ac. Acetic (high dose); T9). Chitosan + Copper Gluconate (High dose).

4. The treatments in the orchard two that presented greater biological effectiveness were: T11). Chitosan + Copper Gluconate (High dose); T4). Chitosan + Copper Gluconate (Low dose); T2). Trifloxystrobin; T6). Mustard Oils + Cumin + Eucalyptus (Low dose); T9). Ac. Peracetic + Hydrogen Peroxide + Ac. Acetic + Chitosan (Low dose); T5) Chitosan + phosphites (low dose).

5. The use of organic products with fungicidal action, such as those tested in the present study, could be an alternative to chemical fungicides for the management of anthracnose in mango, since they offer biological effectiveness on the pathogen, and when degraded quickly, there are no risks of pesticide residues; in addition, the ingredients of these pesticides present no health risks.

PHOTOGRAPHIC APPENDIX

Figure 13. Application of biopesticides in mango orchards of the variety "Ataulfo" in the town of Las Palmas, Municipality of San Blas, Nayarit, in February 2018.

Figure 14. Evaluation of incidence of anthracnose in mango fruits of the variety "Ataulfo" in the town of Las Palmas, Municipality of San Blas, Nayarit, in April 2018.

Figure 15. Symptoms of anthracnose in mango fruits of the variety "Ataulfo" in the town of Las Palmas, Municipality of San Blas, Nayarit, from April to May 2018.

SAGARPA
SECRETARÍA DE AGRICULTURA, GANADERÍA, DESARROLLO RURAL, PESCA Y ALIMENTACIÓN

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BIOLOGICAL EFFECTIVENESS OF BIOPESTICIDES ON ANTHRACNOSE IN POST-HARVEST FRUITS

(SEASON 2017)

MATERIALS AND METHODS

Healthy fruits in physiological maturity of the variety "Ataulfo", were harvested from different orchards of the state of Nayarit, in the period from June to August 2017. The fruits were transferred to the Laboratory of Phytopathology of the Experimental Field INIFAP-Santiago Ixcuntla, Nayarit. The fruits were washed with soap and water, and disinfected with 2% sodium hypochlorite (Chlorine), and then rinsed with clean water.

Inoculation of fruits

A spore solution of a virulent strain of *Colletotrichum gloeosporioides* previously selected in other tests was prepared. The concentration of spores was $1X10^6$ conidia / mL. The spore solution was poured into a plastic spray bottle with a capacity of 250 mL. Eight mango fruits were selected per treatment. With a sterile scalpel, eight equidistant incisions in the shape of a cross were made on the epidermis of one side of the fruits. The fruits were inoculated with the atomizer in each of the incisions, to be placed in a humid chamber in plastic trays and covered with 60 x 90 cm polyethylene bags.

Application of treatments

Twenty-two treatments (biopesticides) and one control (control) were used (Table 1). Five concentrations were used per treatment (250, 500, 1000, 2500 and 5000 ppm), and each concentration had a control. Six buckets were prepared with 10 liters of water with each of the concentrations. The bucket that was used with the control fruits only contained clean water. After 12 h the inoculation of the fruits (incubation period), the fruits were immersed in each of the concentrations for five minutes. After that, the fruits were removed and placed again in a humid chamber.

Variables evaluated

The incidence and severity of the disease were evaluated. To evaluate the incidence, the number of incisions with presence of anthracnose on the fruit was counted and expressed as a percentage. An incidence of anthracnose was considered when dark brown to black lesions with more than 2 mm length were observed on or next to the incisions. In the case of severity, two measurements were made per injury with a digital vernier in each of the incisions with the presence of anthracnose, whose diameter was expressed in centimeters. The evaluations were made at 3, 5 and 7 days after the fruits were immersed in the treatments.

Experiment design

In the statistical analysis for the phytopathogenic tests, a completely randomized unifactorial design was used, with the incidence and severity as response variables. Likewise, statistical comparison was made between methods A and B for all response variables previously described through a completely randomized block design.

Table 1. Treatments of biological effectiveness tests on mango fruits "Ataulfo" in postharvest.

1. Control	9. Essential oil of Eucalyptus (Eucalyptus spp.) (15%) + Cumin essential oil (*Cuminum cyminum*) (15%) + Extract of Governor (*Larrea tridentata*) (40%).	17. Peracetic acid (30%), Hydrogen peroxide (10%), Governor Extract (50%) and Thymol (3%)
2. Geraniol (15%) + Eugenol (10%) + Thymol (10%) + Organic acids (15%) + Governor extract (*Larrea tridentata*) (45%).	10. Mustard essential oil (*Sinapis alba*) (15%) + Comino essential oil (15%) + Governor extract (*Larrea tridentata*) (40%).	18. Peracetic acid (25%) + Hydrogen peroxide (5%) + Cinnamon essential oil (10%) + Governor extract (45%) + Thymol (3%).
3. Cinnamon essential oil (*Cinnamomum verum*) (35%) + Geraniol (15%).	11. Mustard essential oil (20%) + Ammonium Quaternary salts (7%) + Clove extract (43%).	19. Trifloxystrobin
4. Citronelal (15%) + Geraniol (15%)	12. Mustard essential oil (15%) Eucalyptus essential oil (15%) + Governor extract (40%).	20. Copper Oxychloride
5. Peracetic acid (35%) + Hydrogen peroxide (10%) + Clove extract (*Syzygium aromaticum*) (50%).	13. Essential oil of Mustard (20%) + Thymol (15%) + Governor extract (35%).	21. Thymol (10%) + Eugenol (15%) + Governor extract (35%).
6. Peracetic acid (40%) + Thymol (10%) + Governor extract (*Larrea tridentata*) (50%).	14.Peracetic acid (35%) + Hydrogen peroxide (10%) + Thymol (15%) + Governor extract (32%).	22. Quaternary ammonium salts (5%) + Peracetic acid (35%) + Hydrogen peroxide (10%) + Oregano extract (Origanum vulgare) (35%).
7. Peracetic acid (35%) + Hydrogen peroxide (10%) + Clove extract (*Syzygium aromaticum*) (35%) + Thymol (10%).	15. Governor extract (50%) + Peracetic acid (25%) + Hydrogen peroxide (5%) + Thymol (10%) + Wax (5%).	23. Quaternary ammonium salts (5%) + Eugenol (10%) + Clove extract (70%)
8. Peracetic acid (35%), Hydrogen peroxide (10%), Governor extract (*Larrea tridentata*) (30%) and Thymol (10%).	16. Peracetic acid (35%) + Hydrogen peroxide (10%) + Thymol (15%) + Governor extract (30%).	

INCIDENCE OF ANTHRACNOSE IN MANGO FRUITS IN POSTHARVEST

RESULTS

In the different concentrations of tested products (250, 500, 1000, 2500 and 5000 ppm) it was observed that there were differences between treatments in all the evaluations. In the concentration of 250 ppm, it was observed that the lowest incidence was observed in the fruits treated with treatment 19 (chemical fungicide Trifloxystrobin) with 60% incidence in the last evaluation (day 7), followed by treatment 6 (Peraccetic acid + Thymol + Extract of Governor) with 72%. The rest of the treatments showed incidences greater than 80% (Figure 1). At 500 ppm, the treatment 17 {Percetic acid (30%) + Hydrogen peroxide (10%) + Extract of Governor (50%)} showed the lowest incidence (67%), followed by the treatments (2, 15, 16 and 17) (Figure 2). In the 1000 ppm concentration, treatments 19 and 17 had the lowest incidence with around 55%, followed by treatments 6, 4 and 15 with incidences of 65-70%, respectively (Figure 3). In Fruits treated at 2500 ppm the lowest incidence was observed in treatment 17 (50%), followed by treatment 6 (77%). The rest of the treatments presented incidences greater than 80% (Figure 4). In the last concentration (5000 ppm), the fruits treated with treatments 17 and 19 obtained incidences of 55 and 60% respectively. On the other hand, the treatments that showed incidences lower than 76% were 4 (Citronelal + Geraniol) and 8 (Percetic acid (35%) + Hydrogen peroxide (10%) + Extract of Governor (30%)} (Figure 5). All the fruits of the treatments showed symptoms of anthracnose, including the fruits treated with the chemical fungicides Trifloxystrobin and copper oxychloride. However, there were treatments that had biological effectiveness similar to Trifloxystrobin, whose fungicide has systemic action and is one of the most used fungicides worldwide, and which has the best effect on anthracnose control. It is worth mentioning that several of the organic products tested were superior to copper oxychloride, which had no significant effect on the decrease in incidence. It is likely that after 12 h of the inoculation, which was when the fruits were treated by immersion, the spores of the fungus have germinated and penetrated the tissues of the fruits, which is why the products that showed greater effectiveness did not manage to stop the pathogen totally.

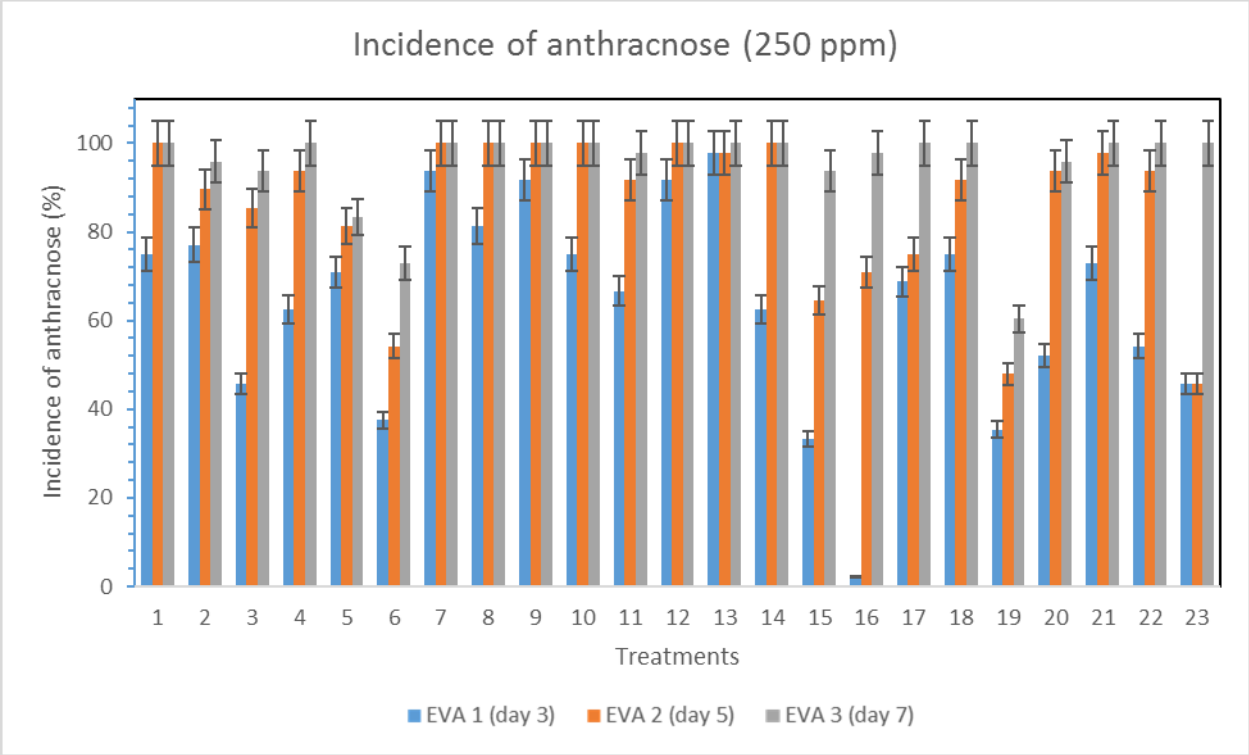
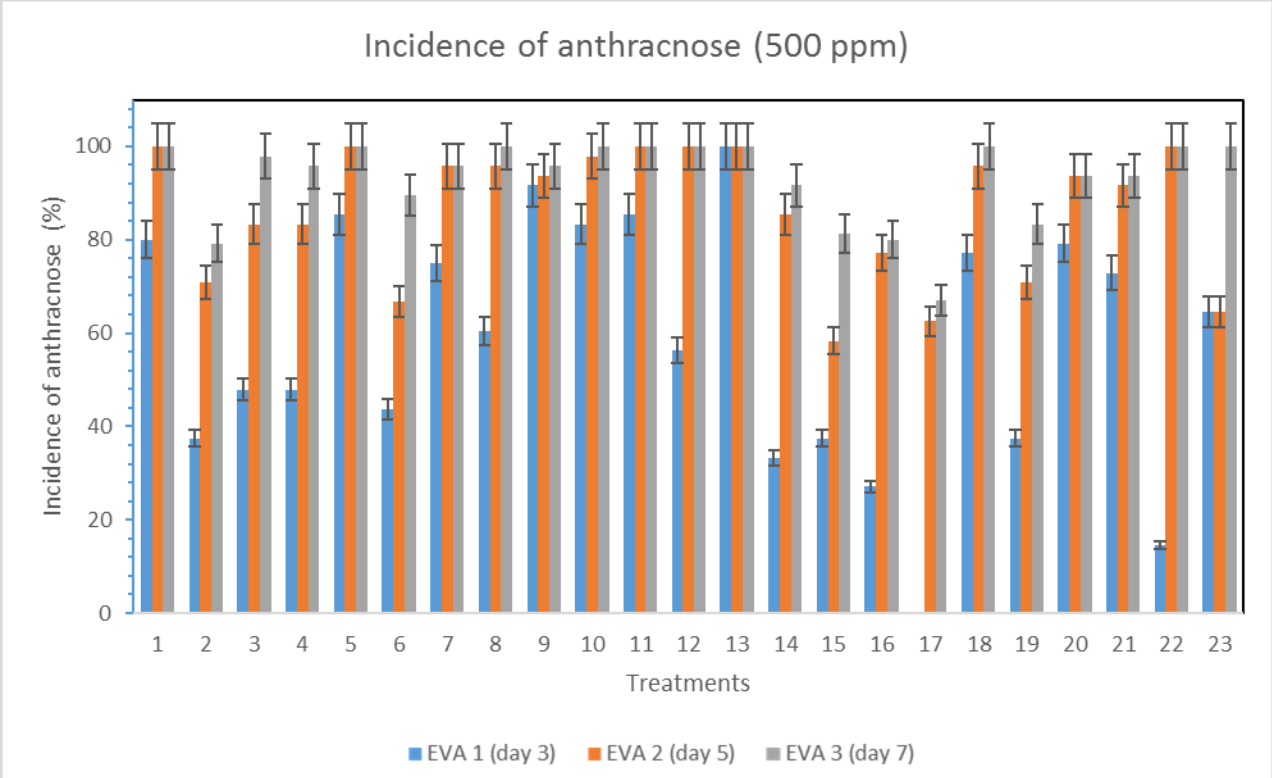


Figure 1. Evaluation of treatments in the incidence of anthracnose in postharvest fruits: T1) Control; T2) Geraniol (15%) + Eugenol (10%) + Thymol (10%) + Organic acids (15%) + Governor extract (*Larrea tridentata*) (45%); T3) Cinnamon essential oil (*Cinnamomum verum*) (35%) + Geraniol (15%), T4) Citronelal (15%) + Geraniol (15%); T5) Peracetic acid (35%) + Hydrogen peroxide (10%) + Clove extract (*Syzygium aromaticum*) (50%); T6) Peracetic acid (40%) + Thymol (10%) + Governor extract (50%); T7) Peracetic acid (35%) + Hydrogen peroxide (10%) + Clove extract (35%) + Thymol (10%); T8) Peracetic acid (35%) + Hydrogen peroxide (10%) + Governor extract (35%) + Thymol (10%); T9) Eucalyptus essential oil (*Eucalyptus* spp.) (15%) + Cumin essential oil (*Cuminum cyminum*) (15%) + Governor extract (40%); T10) Mustard essential oil (*Sinapis alba*) (15%) + Cumin essential oil (15%) + Governor extract (40%); T11) Mustard essential oil (20%) + Ammonium quaternary salts (7%) + Clove extract (43%); T12) Mustard essential oil (15%) Eucalyptus essential oil (15%) + Governor extract (40%); T13) Mustard essential oil (20%) + Thymol (15%) + Governor extract (35%); T14) Peracetic acid (35%) + Hydrogen peroxide (10%) + Thymol (15%) + Governor extract (32%); T15) Governor extract (50%) + Peracetic Acid (25%) + Hydrogen peroxide (5%) + Thymol (10%) + Wax (5%); T16) Peracetic acid (35%) + Hydrogen peroxide (10%) + Thymol (15%) + Governor extract (30%); T17) Peracetic acid (30%) + Hydrogen peroxide (10%) + Governor extract (50%) + Thymol (3%); T18) Peracetic acid (25%) + Hydrogen peroxide (5%) + Cinnamon essential oil (10%) + Governor extract (45%) + Thymol (3%); T19) Trifloxystrobin (100%); T20) Copper oxychloride (100%); T21) Thymol (10%) + Eugenol (15%) + Governor extract (35%); T22) Quaternary ammonium salts (5%) + Peracetic acid (35%) + Hydrogen peroxide (10%) + Oregano extract (*Origanum vulgare*) (35%); T23) Quaternary ammonium salts (5%) + Eugenol (10%) + Clove extract (70%).



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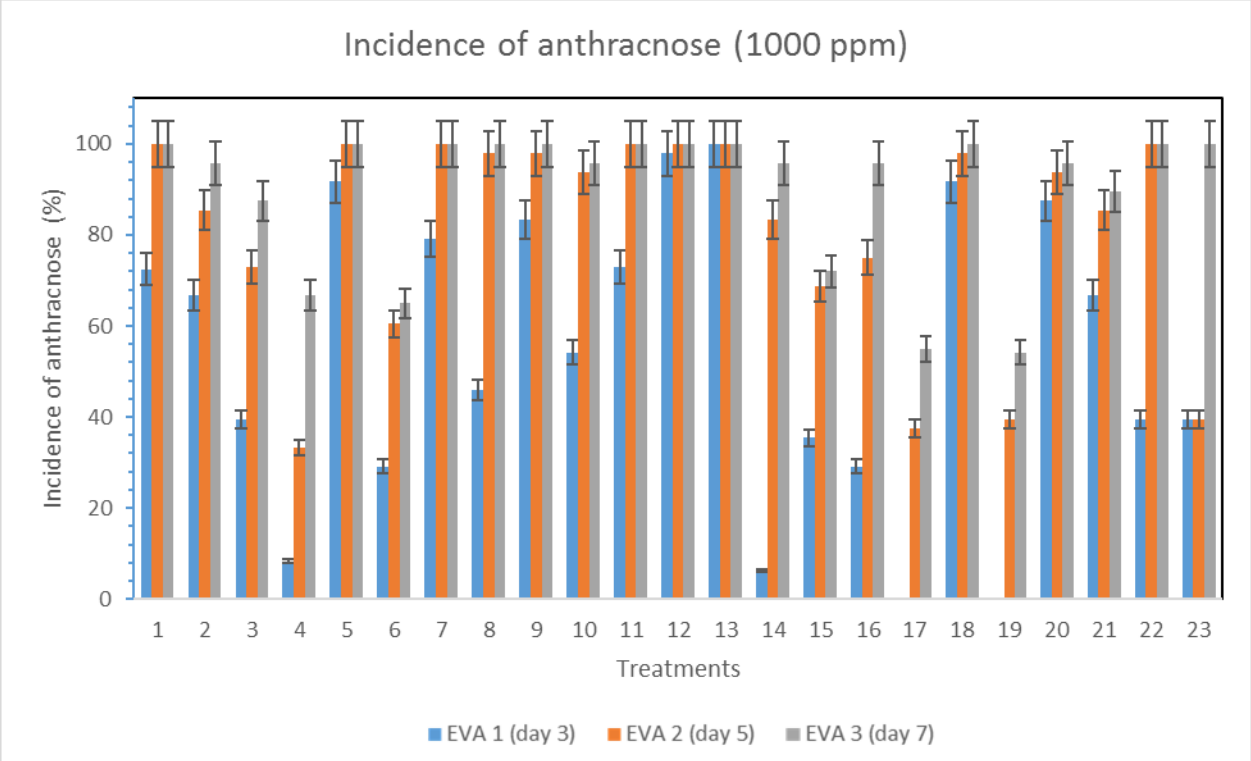

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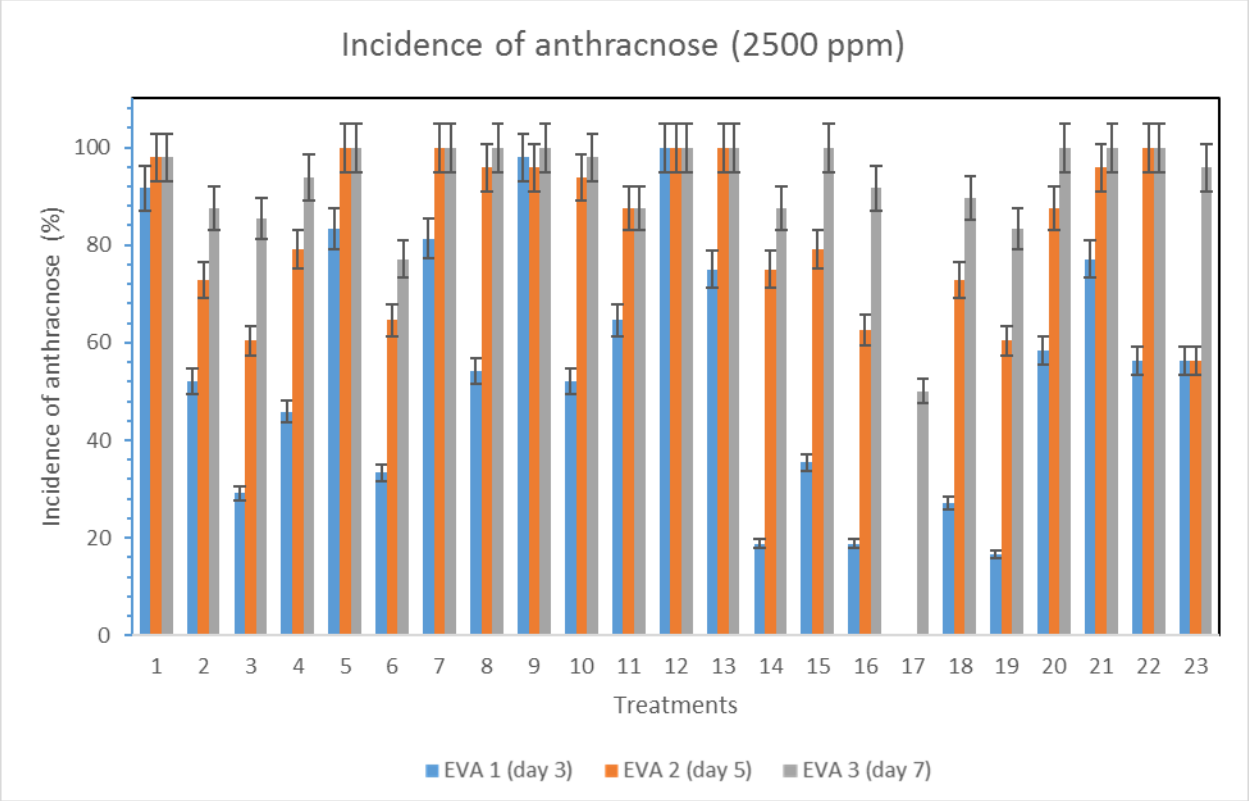


Figure 4. Evaluation of treatments in the incidence of anthracnose in postharvest fruits: T1) Control; T2) Geraniol (15%) + Eugenol (10%) + Thymol (10%) + Organic acids (15%) + Governor extract (*Larrea tridentata*) (45%); T3) Cinnamon essential oil (*Cinnamomum verum*) (35%) + Geraniol (15%), T4) Citronelal (15%) + Geraniol (15%); T5) Peracetic acid (35%) + Hydrogen peroxide (10%) + Clove extract (*Syzygium aromaticum*) (50%); T6) Peracetic acid (40%) + Thymol (10%) + Governor extract (50%); T7) Peracetic acid (35%) + Hydrogen peroxide (10%) + Clove extract (35%) + Thymol (10%); T8) Peracetic acid (35%) + Hydrogen peroxide (10%) + Governor extract (35%) + Thymol (10%); T9) Eucalyptus essential oil (*Eucalyptus* spp.) (15%) + Cumin essential oil (*Cuminum cyminum*) (15%) + Governor extract (40%); T10) Mustard essential oil (*Sinapis* alba) (15%) + Cumin essential oil (15%) + Governor extract (40%); T11) Mustard essential oil (20%) + Ammonium quaternary salts (7%) + Clove extract (43%); T12) Mustard essential oil (15%) Eucalyptus essential oil (15%) + Governor extract (40%); T13) Mustard essential oil (20%) + Thymol (15%) + Governor extract (35%); T14) Peracetic acid (35%) + Hydrogen peroxide (10%) + Thymol (15%) + Governor extract (32%); T15) Governor extract (50%) + Peracetic Acid (25%) + Hydrogen peroxide (5%) + Thymol (10%) + Wax (5%); T16) Peracetic acid (35%) + Hydrogen peroxide (10%) + Thymol (15%) + Governor extract (30%); T17) Peracetic acid (30%) + Hydrogen peroxide (10%) + Governor extract (50%) + Thymol (3%); T18) Peracetic acid (25%) + Hydrogen peroxide (5%) + Cinnamon essential oil (10%) + Governor extract (45%) + Thymol (3%); T19) Trifloxystrobin (100%); T20) Copper oxychloride (100%); T21) Thymol (10%) + Eugenol (15%) + Governor extract (35%); T22) Quaternary ammonium salts (5%) + Peracetic acid (35%) + Hydrogen peroxide (10%) + Oregano extract (*Origanum vulgare*) (35%); T23) Quaternary ammonium salts (5%) + Eugenol (10%) + Clove extract (70%).

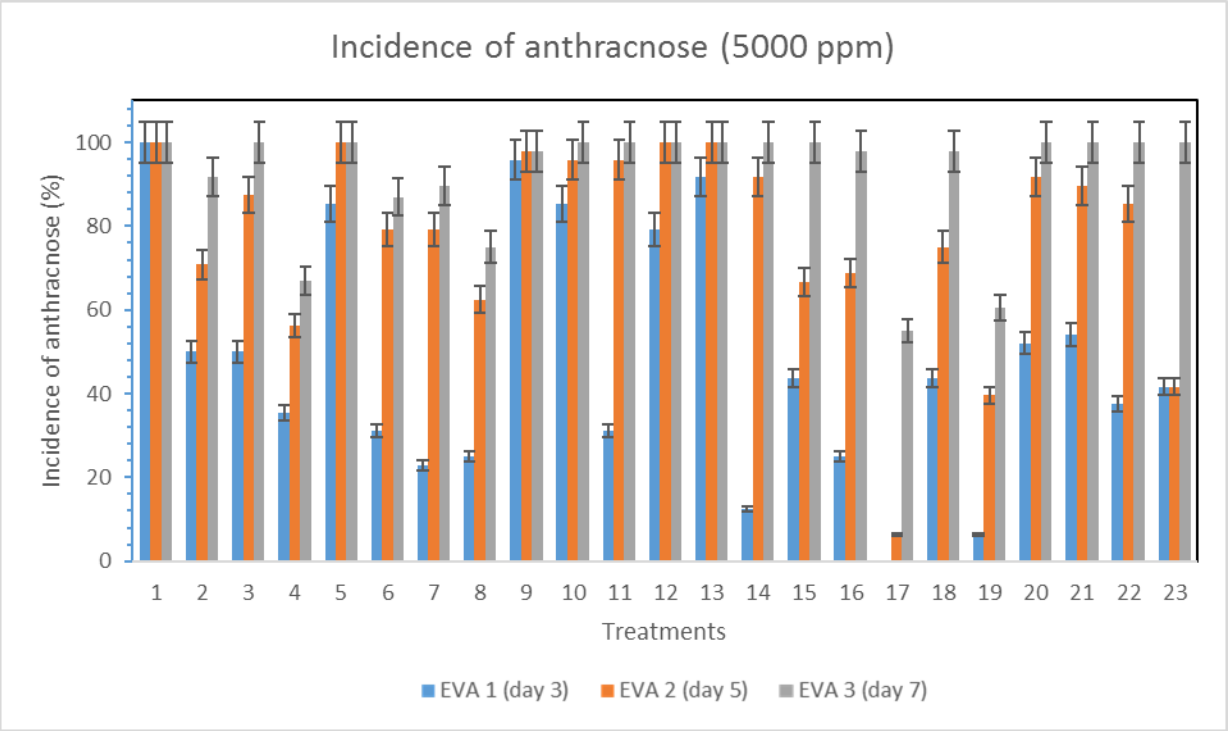


Figure 5. Evaluation of treatments in the incidence of anthracnose in postharvest fruits: T1) Control; T2) Geraniol (15%) + Eugenol (10%) + Thymol (10%) + Organic acids (15%) + Governor extract (*Larrea tridentata*) (45%); T3) Cinnamon essential oil (*Cinnamomum verum*) (35%) + Geraniol (15%), T4) Citronelal (15%) + Geraniol (15%); T5) Peracetic acid (35%) + Hydrogen peroxide (10%) + Clove extract (*Syzygium aromaticum*) (50%); T6) Peracetic acid (40%) + Thymol (10%) + Governor extract (50%); T7) Peracetic acid (35%) + Hydrogen peroxide (10%) + Clove extract (35%) + Thymol (10%); T8) Peracetic acid (35%) + Hydrogen peroxide (10%) + Governor extract (35%) + Thymol (10%); T9) Eucalyptus essential oil (*Eucalyptus* spp.) (15%) + Cumin essential oil (*Cuminum cyminum*) (15%) + Governor extract (40%); T10) Mustard essential oil (*Sinapis alba*) (15%) + Cumin essential oil (15%) + Governor extract (40%); T11) Mustard essential oil (20%) + Ammonium quaternary salts (7%) + Clove extract (43%); T12) Mustard essential oil (15%) Eucalyptus essential oil (15%) + Governor extract (40%); T13) Mustard essential oil (20%) + Thymol (15%) + Governor extract (35%); T14) Peracetic acid (35%) + Hydrogen peroxide (10%) + Thymol (15%) + Governor extract (32%); T15) Governor extract (50%) + Peracetic Acid (25%) + Hydrogen peroxide (5%) + Thymol (10%) + Wax (5%); T16) Peracetic acid (35%) + Hydrogen peroxide (10%) + Thymol (15%) + Governor extract (30%); T17) Peracetic acid (30%) + Hydrogen peroxide (10%) + Governor extract (50%) + Thymol (3%); T18) Peracetic acid (25%) + Hydrogen peroxide (5%) + Cinnamon essential oil (10%) + Governor extract (45%) + Thymol (3%); T19) Trifloxystrobin (100%); T20) Copper oxychloride (100%); T21) Thymol (10%) + Eugenol (15%) + Governor extract (35%); T22) Quaternary ammonium salts (5%) + Peracetic acid (35%) + Hydrogen peroxide (10%) + Oregano extract (*Origanum vulgare*) (35%); T23) Quaternary ammonium salts (5%) + Eugenol (10%) + Clove extract (70%).

SEVERITY OF ANTHRACNOSE IN MANGO FRUITS IN POSTHARVEST

RESULTS

In the severity of anthracnose, which refers to the intensity of the disease, it was observed that there were variants in the levels of severity in the different evaluations of the treatments, in the concentrations tested (250, 500, 1000, 2500 and 5000 ppm). In the concentration of 250 ppm, the lowest severity (diameter of the lesion with anthracnose) occurred in the fruits treated with Trifloxystrobin (0.5 cm), followed by the treatments 15 {Governor Extract + Peracetic Acid + Hydrogen Peroxide + Thymol + Wax} (0.8 cm), 6 (Peracetic Acid + Thymol + Governor Extract} (0.9 cm) and 16 (Peracetic Acid + Hydrogen Peroxide + Thymol + Governor Extract) (1 cm), in the case of the control and the Most of the treatments, the severity was greater than 1.5 cm (Figure 6) In the treated fruits at 500 ppm, treatment 18 (Peracetic acid + Hydrogen peroxide + Cinnamon essential oil + Governor extract + Thymol) registered the lowest severity (0.7 cm), followed by treatments 15 and 16 (0.7-0.8 cm) (Figure 7) At the concentration of 1000 ppm, treatments 19 and 17 obtained the lowest severity (0.5-0.7 cm), while treatments 6, 14, 15 and 16 presented severities close to 0.8 cm, the rest of the treatments had severities greater than 1 cm (Figure 8). In the case of the fruits treated at 2500 ppm, the lowest severity was found in the fruits of treatment 17, where anthracnose symptoms appeared until the last evaluation with a severity of 0.5 cm; while treatments 16, 19, 6, 14 and 15 presented severities that oscillated in the 0.8 cm diameter of the lesion (Figure 9). In the last evaluated concentration, 5000 ppm, treatments 17, 19 and 4 presented the minor incidences with around 0.5 cm; these were followed by treatments 16, 15 and 6 (0.6 cm), and treatments 8 (0.7 cm) and 7 (0.8 cm) (Figure 10). In the present study it was observed that no product totally inhibited the incidence and severity of anthracnose, including treatments with the chemical fungicides Trifloxystrobin and copper oxychloride. However, some of the organic treatments showed that in some concentrations, they have a similar or superior effect in reducing anthracnose severity than the chemical fungicide Trifloxystrobin.

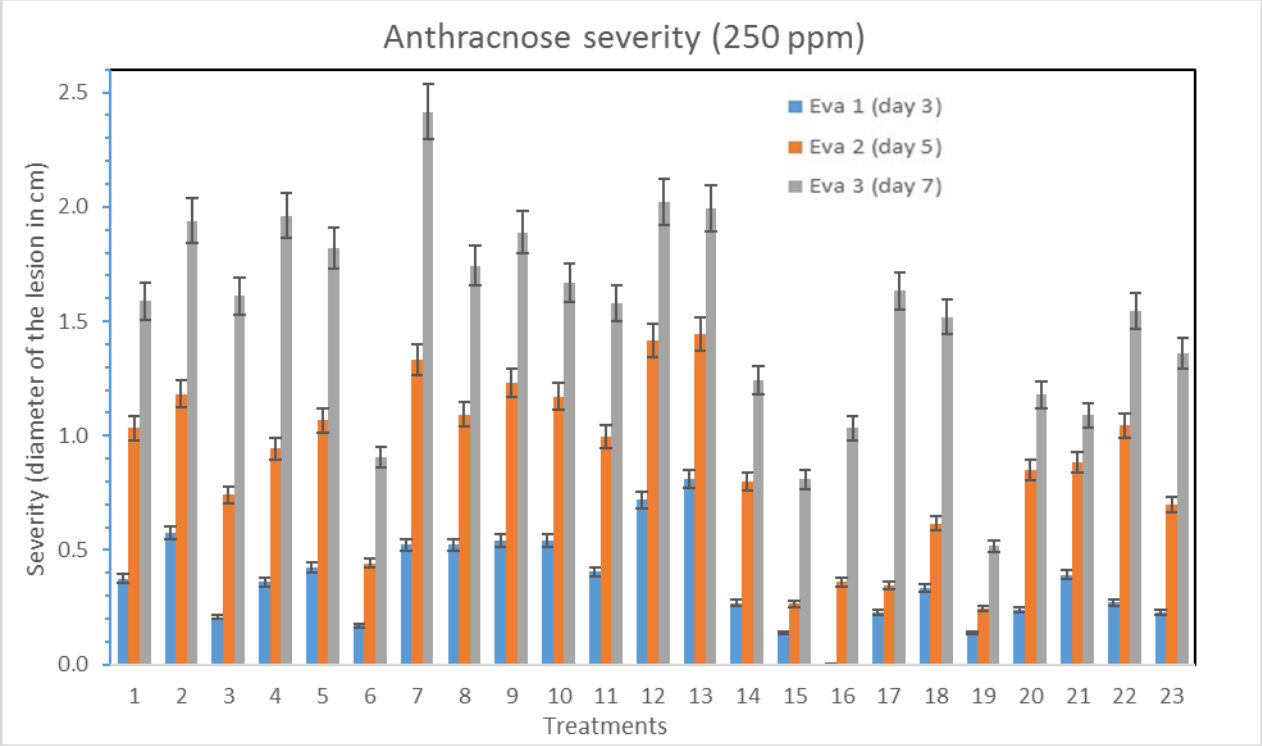
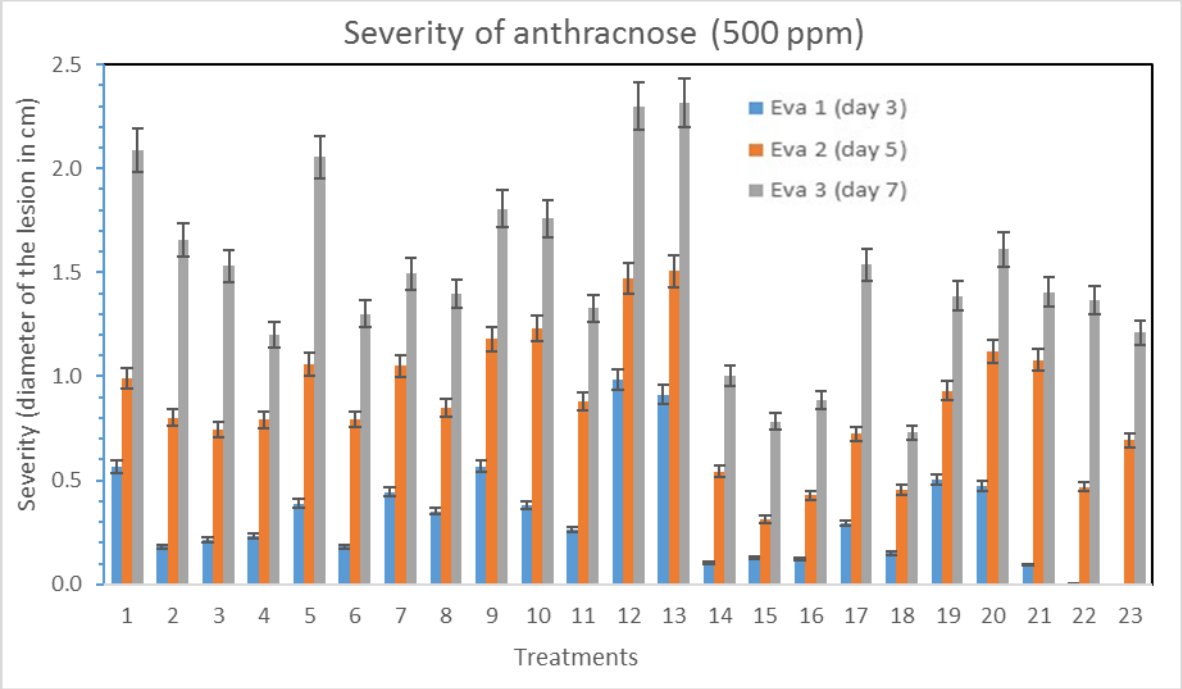


Figure 6. Evaluation of treatments in the severity of anthracnose in postharvest fruits: T1) Control; T2) Geraniol (15%) + Eugenol (10%) + Thymol (10%) + Organic acids (15%) + Governor extract (*Larrea tridentata*) (45%); T3) Cinnamon essential oil (*Cinnamomum verum*) (35%) + Geraniol (15%), T4) Citronelal (15%) + Geraniol (15%); T5) Peracetic acid (35%) + Hydrogen peroxide (10%) + Clove extract (*Syzygium aromaticum*) (50%); T6) Peracetic acid (40%) + Thymol (10%) + Governor extract (50%); T7) Peracetic acid (35%) + Hydrogen peroxide (10%) + Clove extract (35%) + Thymol (10%); T8) Peracetic acid (35%) + Hydrogen peroxide (10%) + Governor extract (35%) + Thymol (10%); T9) Eucalyptus essential oil (*Eucalyptus* spp.) (15%) + Cumin essential oil (*Cuminum cyminum*) (15%) + Governor extract (40%); T10) Mustard essential oil (*Sinapis alba*) (15%) + Cumin essential oil (15%) + Governor extract (40%); T11) Mustard essential oil (20%) + Ammonium quaternary salts (7%) + Clove extract (43%); T12) Mustard essential oil (15%) Eucalyptus essential oil (15%) + Governor extract (40%); T13) Mustard essential oil (20%) + Thymol (15%) + Governor extract (35%); T14) Peracetic acid (35%) + Hydrogen peroxide (10%) + Thymol (15%) + Governor extract (32%); T15) Governor extract (50%) + Peracetic Acid (25%) + Hydrogen peroxide (5%) + Thymol (10%) + Wax (5%); T16) Peracetic acid (35%) + Hydrogen peroxide (10%) + Thymol (15%) + Governor extract (30%); T17) Peracetic acid (30%) + Hydrogen peroxide (10%) + Governor extract (50%) + Thymol (3%); T18) Peracetic acid (25%) + Hydrogen peroxide (5%) + Cinnamon essential oil (10%) + Governor extract (45%) + Thymol (3%); T19) Trifloxystrobin (100%); T20) Copper oxychloride (100%); T21) Thymol (10%) + Eugenol (15%) + Governor extract (35%); T22) Quaternary ammonium salts (5%) + Peracetic acid (35%) + Hydrogen peroxide (10%) + Oregano extract (*Origanum vulgare*) (35%); T23) Quaternary ammonium salts (5%) + Eugenol (10%) + Clove extract (70%).



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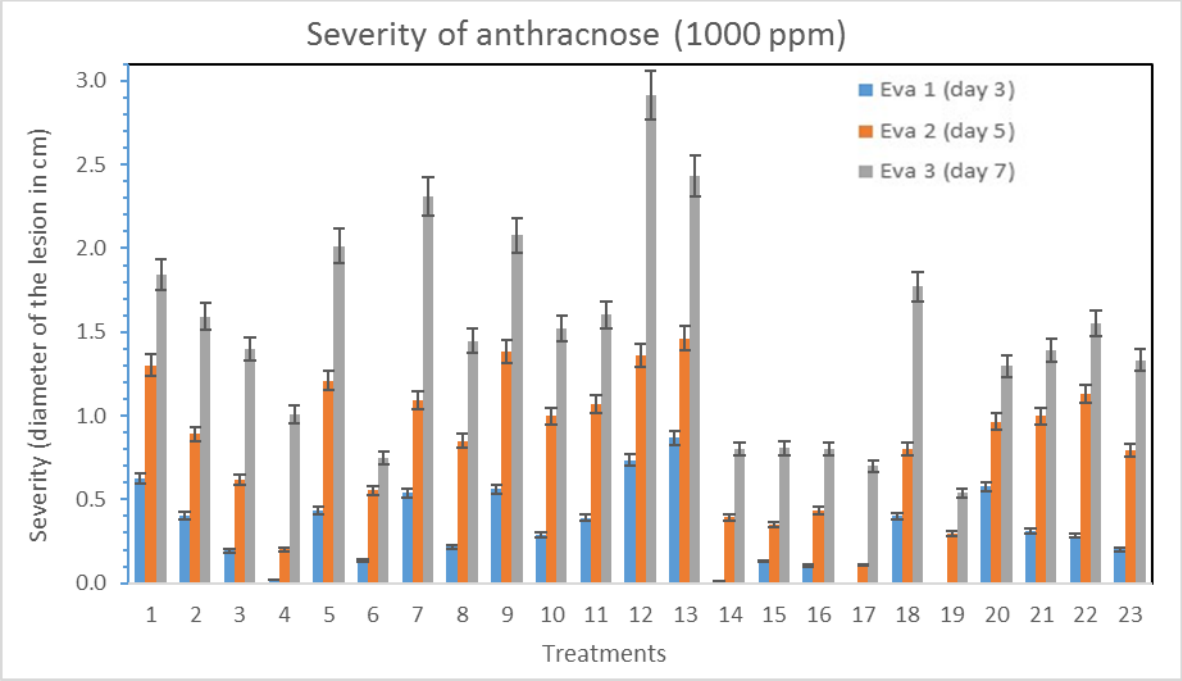

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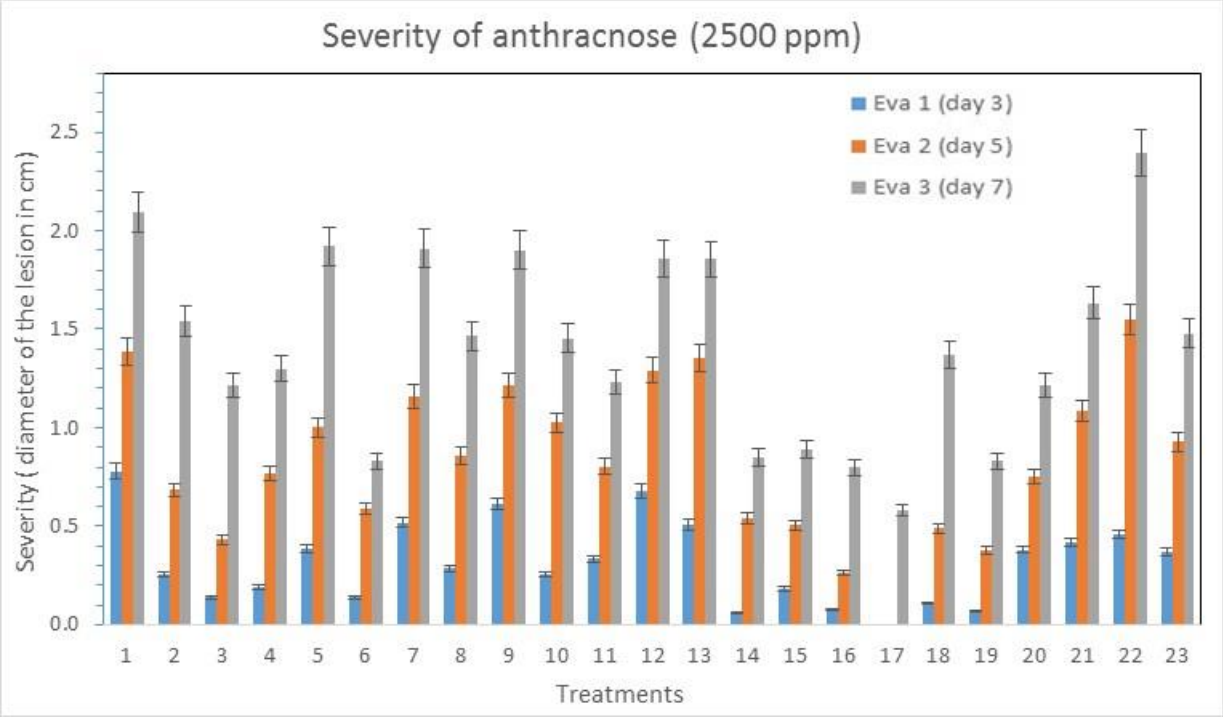

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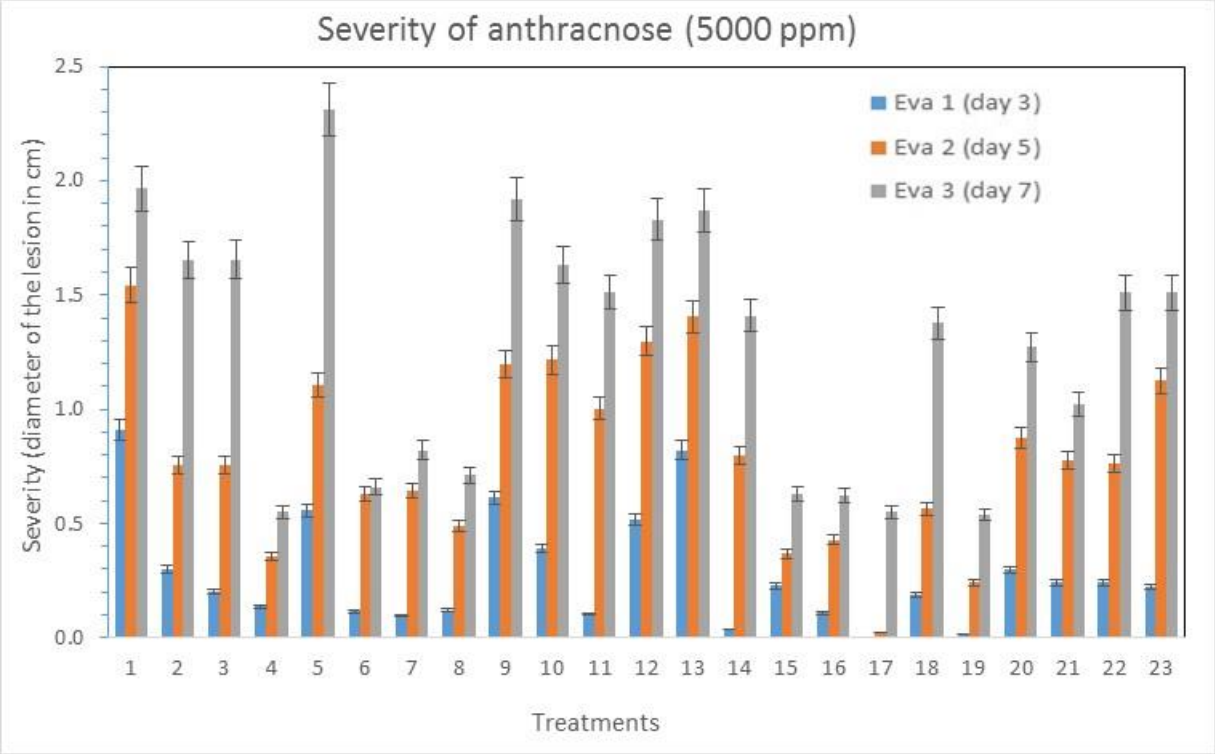

Figure 10. Evaluation of treatments in the severity of anthracnose in postharvest fruits: T1) Control; T2) Geraniol (15%) + Eugenol (10%) + Thymol (10%) + Organic acids (15%) + Governor extract (*Larrea tridentata*) (45%); T3) Cinnamon essential oil (*Cinnamomum verum*) (35%) + Geraniol (15%), T4) Citronelal (15%) + Geraniol (15%); T5) Peracetic acid (35%) + Hydrogen peroxide (10%) + Clove extract (*Syzygium aromaticum*) (50%); T6) Peracetic acid (40%) + Thymol (10%) + Governor extract (50%); T7) Peracetic acid (35%) + Hydrogen peroxide (10%) + Clove extract (35%) + Thymol (10%); T8) Peracetic acid (35%) + Hydrogen peroxide (10%) + Governor extract (35%) + Thymol (10%); T9) Eucalyptus essential oil (*Eucalyptus* spp.) (15%) + Cumin essential oil (*Cuminum cyminum*) (15%) + Governor extract (40%); T10) Mustard essential oil (*Sinapis alba*) (15%) + Cumin essential oil (15%) + Governor extract (40%); T11) Mustard essential oil (20%) + Ammonium quaternary salts (7%) + Clove extract (43%); T12) Mustard essential oil (15%) Eucalyptus essential oil (15%) + Governor extract (40%); T13) Mustard essential oil (20%) + Thymol (15%) + Governor extract (35%); T14) Peracetic acid (35%) + Hydrogen peroxide (10%) + Thymol (15%) + Governor extract (32%); T15) Governor extract (50%) + Peracetic Acid (25%) + Hydrogen peroxide (5%) + Thymol (10%) + Wax (5%); T16) Peracetic acid (35%) + Hydrogen peroxide (10%) + Thymol (15%) + Governor extract (30%); T17) Peracetic acid (30%) + Hydrogen peroxide (10%) + Governor extract (50%) + Thymol (3%); T18) Peracetic acid (25%) + Hydrogen peroxide (5%) + Cinnamon essential oil (10%) + Governor extract (45%) + Thymol (3%); T19) Trifloxystrobin (100%); T20) Copper oxychloride (100%); T21) Thymol (10%) + Eugenol (15%) + Governor extract (35%); T22) Quaternary ammonium salts (5%) + Peracetic acid (35%) + Hydrogen peroxide (10%) + Oregano extract (*Origanum vulgare*) (35%); T23) Quaternary ammonium salts (5%) + Eugenol (10%) + Clove extract (70%).

CONCLUSIONS

1. In the present study it was observed that no product totally inhibited the incidence and severity of anthracnose, including treatments with the chemical fungicides Trifloxystrobin and copper oxychloride.

2. The results suggest that all tested products, including chemical fungicides, acted on contact, that is, eliminated the fungus when it came into contact with the products. However, there were organic treatments that in certain concentrations showed greater biological effectiveness on anthracnose than Trifloxystrobin and Copper oxychloride.

3. Organic treatments with greater biological effectiveness obtained in the experiment could be an alternative to eliminate anthracnose spores in mango fruits in postharvest treatments, with equal or greater biological effectiveness than Trifloxystrobin, and much more effective than Copper oxychloride.

4. The best treatments, without taking into account Trifloxystrobin, were:

- T17: Peracetic acid (30%) + Hydrogen peroxide (10%) + Extract of Governor (50%) + Thymol (3%);
- T16: Peracetic acid (35%) + Hydrogen peroxide (10%) + Thymol (15%) + Extract of Governor (30%);
- T15: Governor Extract (50%) + Percetic Acid (25%) + Hydrogen Peroxide (5%) + Thymol (10%) + Wax (5%);
- T14: Peracetic acid (35%) + Hydrogen peroxide (10%) + Thymol (15%) + Extract of Governor (32%).

5. The use of organic products with fungicidal action, such as those tested in the present study, could be an alternative to chemical fungicides for the management of anthracnose in postharvest mango, since they offer biological effectiveness on the pathogen, and when degraded quickly, it does not present any risks of pesticide residues; in addition, their ingredients offer no health risks.

PHOTOGRAPHIC APPENDIX

Figure 11. Fruits of treatment 17 (Percetic acid (30%) + Hydrogen peroxide (10%) + Extract of Governor (50%) + Thymol (3%), treated at 250, 500, 1000, 2500 and 5000

Figure 12. Examples of different treatments compared to the control, in treated fruits at 2500 ppm.

Figure 13. Examples of different treatments compared with the control, in treated fruits at 5000 ppm.

BIOLOGICAL EFFECTIVENESS OF BIOPESTICIDES ON ANTHRACNOSE IN POSTHARVEST FRUITS (SEASON 2018)

MATERIALS AND METHODS

Healthy fruits in physiological maturity of the variety "Ataulfo", were harvested from different orchards of the state of Nayarit, in the period from June to August 2018. The fruits were transferred to the Laboratory of Phytopathology of the Experimental Field INIFAP-Santiago Ixcuntla, Nayarit. The fruits were washed with soap and water, and disinfected with a solution of 2% sodium hypochlorite (Chlorine), and then rinsed with clean water.

Inoculation of fruits

A spore solution of a virulent strain of *Colletotrichum gloeosporioides* previously selected in other tests was prepared. The concentration of spores was $1X10^6$ conidia / mL. The spore solution was poured into a plastic spray with a capacity of 250 mL. Eight mango fruits were selected per treatment. With a sterile scalpel, eight equidistant incisions in the shape of a cross were made on the epidermis of one side of the fruits. The fruits were inoculated with the atomizer in each of the incisions, to be placed in a humid chamber in plastic trays and covered with 60 x 90 cm polyethylene bags.

Application of treatments

Ten treatments (biopesticides) and one control (control) were used (Table 1). Five concentrations were used per treatment (250, 500, 1000, 2500 and 5000 ppm), and each concentration had a control. Six buckets were prepared with 10 liters of water with each of the concentrations. The bucket that was used with the control fruits only contained clean water. After 8 h after inoculation of the fruits (incubation period), the fruits were immersed in each of the concentrations for five minutes. After the time, the fruits were removed and placed again in a humid chamber

Variables evaluated

The incidence and severity of the disease were evaluated. To evaluate the incidence, the number of incisions with presence of anthracnose on the fruit was counted and expressed as a percentage. An incidence of anthracnose was considered when dark brown to black lesions with more than 2 mm length were observed on or next to the incisions. In the case of severity, two measurements were made per injury with a digital vernier in each of the incisions with the presence of anthracnose, whose diameter was expressed in centimeters. The evaluations were made at 3, 5 and 7 days after the fruits were immersed in the treatments.

Experiment design

In the statistical analysis for the phytopathogenic tests, a completely randomized unifactorial design was used, with the incidence and severity as response variables. Likewise, the statistical comparison was made for all the response variables previously described through a completely randomized block design.

Table 1. Treatments of biological effectiveness tests on mango fruits "Ataulfo" in postharvest.

1. Control.	5. Peracetic acid (30%) + Hydrogen peroxide (30%) + Acetic acid (10%).	9. Hydrogen peroxide (30%) + Peracetic acid (15%) + Acetic acid (10%) + HEDP (10%).
2. Peracetic acid (35%) + Hydrogen peroxide (15%) + Acetic acid (10%).	6. Chitosan (4%) + Phosphites.	10. Peracetic acid (15%) + Hydrogen peroxide (50%) + Acetic acid (10%) + HEDP (10%).
3. Hydrogen peroxide (30%) + Peracetic acid (15%) + Acetic acid (10%).	7. Peracetic acid (35%) + Hydrogen peroxide (15%) + Acetic acid (10%) + Phosphites.	11. Hydrogen peroxide (45%) + Acetic acid (15%) + Phosphoric acid (5%) + HEDP (5%).
4 Peracetic acid (35%) + Hydrogen peroxide (15%) + Acetic acid (10%) + Chitosan (4%).	8. Peracetic acid (35%) + Hydrogen peroxide (15%) + Acetic acid (10%) + HEDP[X] (10%).	

[X]HEDP: Etidronic acid

INCIDENCE OF ANTHRACNOSE IN FRUITS OF MANGO IN POSTHARVEST

RESULTS

The data obtained in the concentrations tested (250, 500, 1000, 2500 and 5000 ppm) for the evaluation of the incidence of anthracnose showed differences between treatments in each of the evaluations. It should be mentioned that in all the concentrations, except for the control, the treatments , delayed the appearance of symptoms of anthracnose on the first evaluation date (third day). In the concentration of 250 ppm, the behavior of the treatments was similar, since all exceeded 80% severity at the third evaluation (day 7) (Figure 1). On the other hand, at 500 ppm, the treatment 5 {Peracetic acid (30%) + Hydrogen peroxide (30%) + Acetic acid (10%)) showed the lowest incidence of anthracnose with 60% on the last evaluation date (day 7); the other treatments exceeded 80% (Figure 2). Meanwhile in the concentration of 1000 ppm, treatment 5 remained with the lowest percentage of incidence, with 60%, followed by treatment 4 {Peracetic acid (35%) + Hydrogen peroxide (15%) + Acetic acid (10%) + Chitosan (4%)} with 76% (Figure 3). At 2500 ppm, treatment 5 again showed the lowest percentage of incidence in the three evaluations, presenting 60% in the last evaluation, followed by treatments 4 (64%), 7 (Peracetic acid (35%) + Hydrogen peroxide (15 %) + Acetic acid (10%) + Phosphites} (72%) and 8 {Peracetic acid (35%) + Hydrogen peroxide (15%) + Acetic acid (10%) + HEDP (10%)} (72%)). The rest of the treatments reached 85% severity (Figure 4). For the last concentration (5000 ppm), it was observed that the lowest incidence was found in the fruits of treatment 4 (55%); 60% for treatment 9. They continue treatment 7 with 68%, and treatments 5, 8 and 10 with 72% (Figure 5).

INCIDENCE OF ANTHRACNOSE IN MANGO FRUITS IN POSTHARVEST

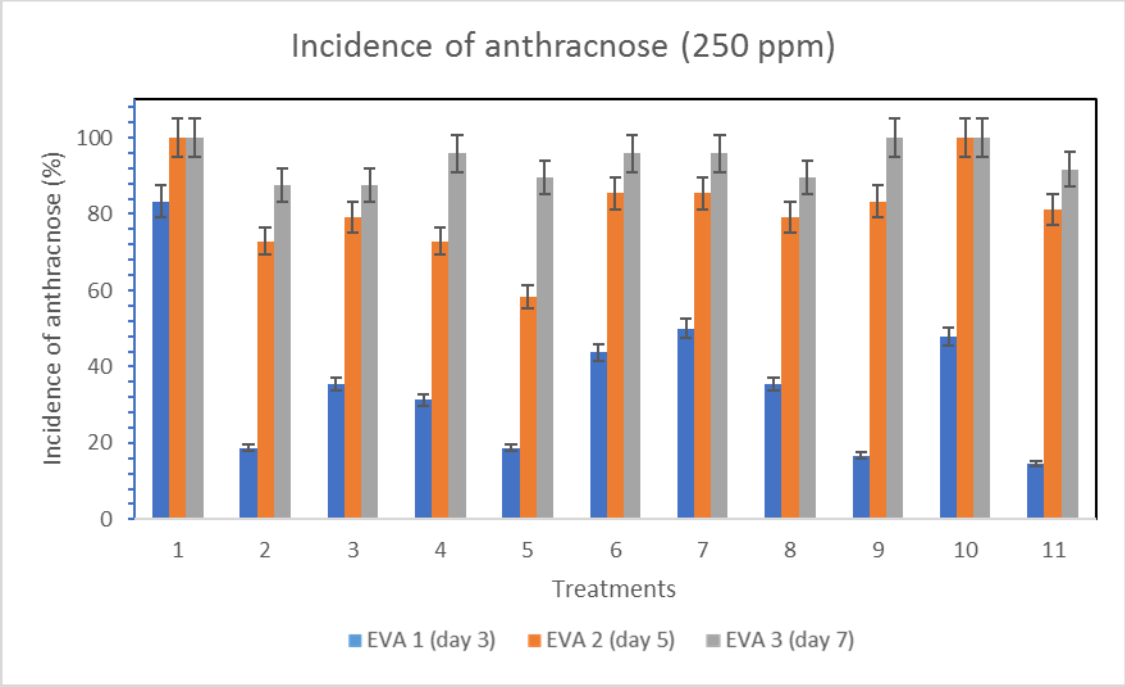

Figure 1. Evaluation of treatments in the incidence of anthracnose in postharvest fruits: T1) Control; T2) Peracetic acid (35%) + Hydrogen peroxide (15%) + Acetic acid (10%); T3) Hydrogen peroxide (30%) + Peracetic acid (15%) + Acetic acid (10%); T4) Peracetic acid (35%) + Hydrogen peroxide (15%) + Acetic acid (10%) + Chitosan (4%); T5) Peracetic acid (30%) + Hydrogen peroxide (30%) + Acetic acid (10%); T6) Chitosan (4%) + Phosphites; T7) Peracetic acid (35%) + Hydrogen peroxide (15%) + Acetic acid (10%) + Phosphites; T8) Peracetic acid (35%) + Hydrogen peroxide (15%) + Acetic acid (10%) + HEDP (10%); T9) Hydrogen peroxide (30%) + Peracetic acid (15%) + Acetic acid (10%) + HEDP (10%); T10)) Peracetic acid (15%) + Hydrogen peroxide (50%) + Acetic acid (10%) + HEDP (10%); T11) Hydrogen peroxide (45%) + Acetic acid (15%) + Phosphoric acid (5%) + HEDP (5%).

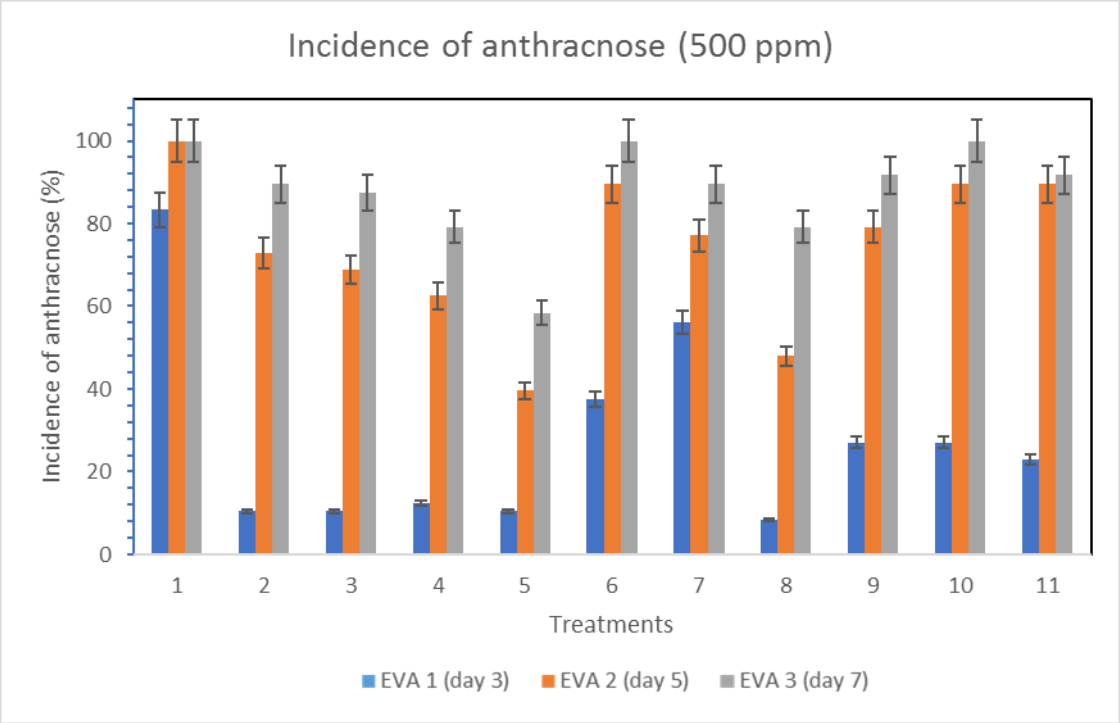

Figure 2. Evaluation of treatments in the incidence of anthracnose in postharvest fruits: T1) Control; T2) Peracetic acid (35%) + Hydrogen peroxide (15%) + Acetic acid (10%); T3) Hydrogen peroxide (30%) + Peracetic acid (15%) + Acetic acid (10%); T4) Peracetic acid (35%) + Hydrogen peroxide (15%) + Acetic acid (10%) + Chitosan (4%); T5) Peracetic acid (30%) + Hydrogen peroxide (30%) + Acetic acid (10%); T6) Chitosan (4%) + Phosphites; T7) Peracetic acid (35%) + Hydrogen peroxide (15%) + Acetic acid (10%) + Phosphites; T8) Peracetic acid (35%) + Hydrogen peroxide (15%) + Acetic acid (10%) + HEDP (10%); T9) Hydrogen peroxide (30%) + Peracetic acid (15%) + Acetic acid (10%) + HEDP (10%); T10)) Peracetic acid (15%) + Hydrogen peroxide (50%) + Acetic acid (10%) + HEDP (10%); T11) Hydrogen peroxide (45%) + Acetic acid (15%) + Phosphoric acid (5%) + HEDP (5%).

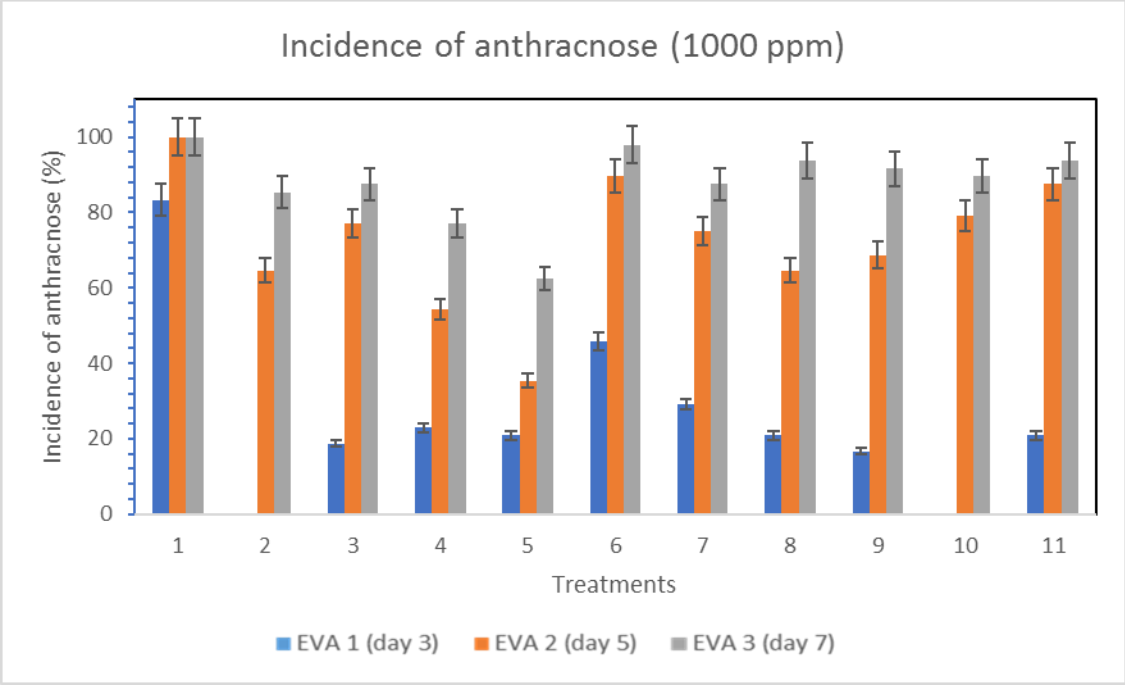

Figure 3. Evaluation of treatments in the incidence of anthracnose in postharvest fruits: T1) Control; T2) Peracetic acid (35%) + Hydrogen peroxide (15%) + Acetic acid (10%); T3) Hydrogen peroxide (30%) + Peracetic acid (15%) + Acetic acid (10%); T4) Peracetic acid (35%) + Hydrogen peroxide (15%) + Acetic acid (10%) + Chitosan (4%); T5) Peracetic acid (30%) + Hydrogen peroxide (30%) + Acetic acid (10%); T6) Chitosan (4%) + Phosphites; T7) Peracetic acid (35%) + Hydrogen peroxide (15%) + Acetic acid (10%) + Phosphites; T8) Peracetic acid (35%) + Hydrogen peroxide (15%) + Acetic acid (10%) + HEDP (10%); T9) Hydrogen peroxide (30%) + Peracetic acid (15%) + Acetic acid (10%) + HEDP (10%); T10)) Peracetic acid (15%) + Hydrogen peroxide (50%) + Acetic acid (10%) + HEDP (10%); T11) Hydrogen peroxide (45%) + Acetic acid (15%) + Phosphoric acid (5%) + HEDP (5%).

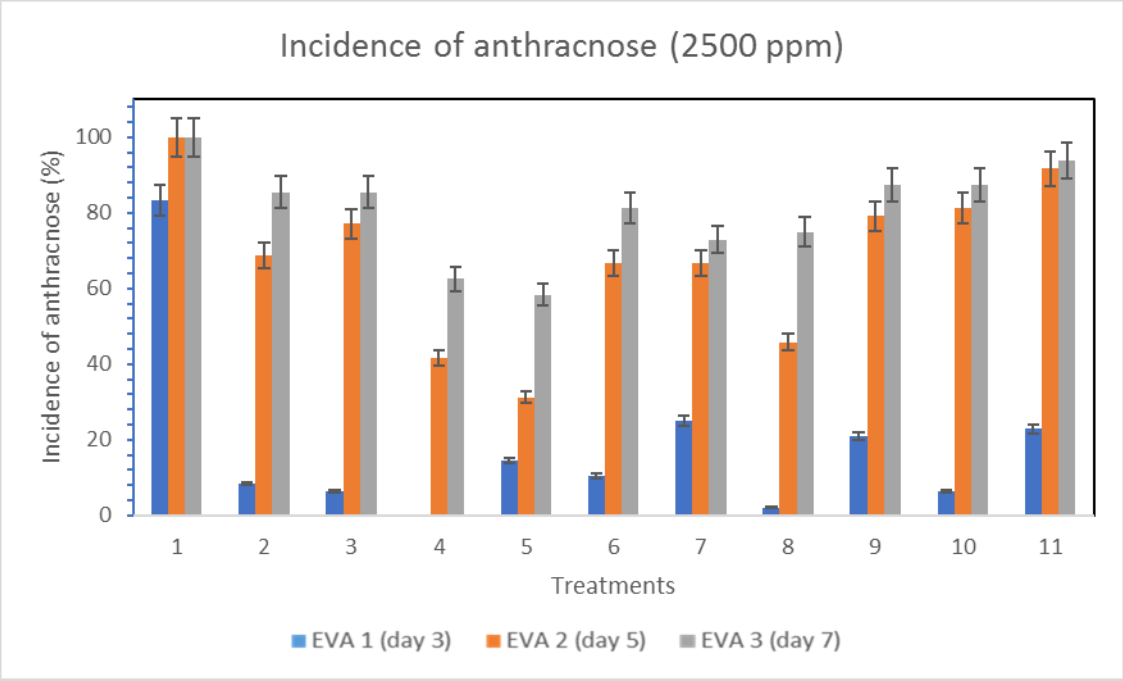

Figure 4. Evaluation of treatments in the incidence of anthracnose in postharvest fruits: T1) Control; T2) Peracetic acid (35%) + Hydrogen peroxide (15%) + Acetic acid (10%); T3) Hydrogen peroxide (30%) + Peracetic acid (15%) + Acetic acid (10%); T4) Peracetic acid (35%) + Hydrogen peroxide (15%) + Acetic acid (10%) + Chitosan (4%); T5) Peracetic acid (30%) + Hydrogen peroxide (30%) + Acetic acid (10%); T6) Chitosan (4%) + Phosphites; T7) Peracetic acid (35%) + Hydrogen peroxide (15%) + Acetic acid (10%) + Phosphites; T8) Peracetic acid (35%) + Hydrogen peroxide (15%) + Acetic acid (10%) + HEDP (10%); T9) Hydrogen peroxide (30%) + Peracetic acid (15%) + Acetic acid (10%) + HEDP (10%); T10)) Peracetic acid (15%) + Hydrogen peroxide (50%) + Acetic acid (10%) + HEDP (10%); T11) Hydrogen peroxide (45%) + Acetic acid (15%) + Phosphoric acid (5%) + HEDP (5%).

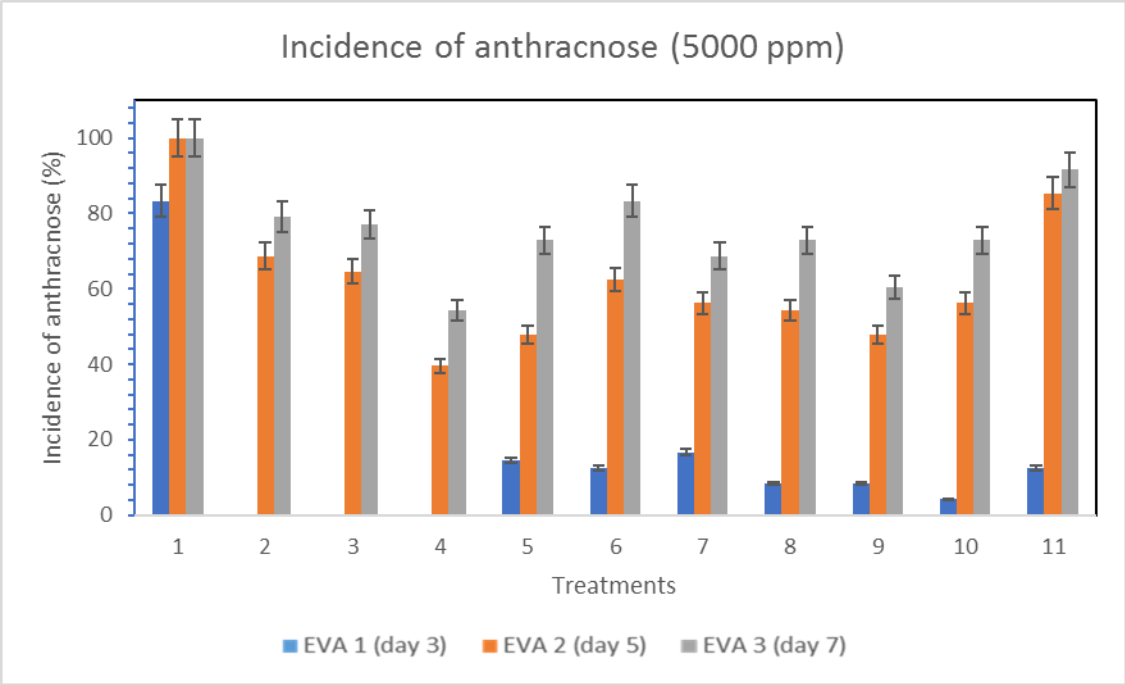

Figure 5. Evaluation of treatments in the incidence of anthracnose in postharvest fruits: T1) Control; T2) Peracetic acid (35%) + Hydrogen peroxide (15%) + Acetic acid (10%); T3) Hydrogen peroxide (30%) + Peracetic acid (15%) + Acetic acid (10%); T4) Peracetic acid (35%) + Hydrogen peroxide (15%) + Acetic acid (10%) + Chitosan (4%); T5) Peracetic acid (30%) + Hydrogen peroxide (30%) + Acetic acid (10%); T6) Chitosan (4%) + Phosphites; T7) Peracetic acid (35%) + Hydrogen peroxide (15%) + Acetic acid (10%) + Phosphites; T8) Peracetic acid (35%) + Hydrogen peroxide (15%) + Acetic acid (10%) + HEDP (10%); T9) Hydrogen peroxide (30%) + Peracetic acid (15%) + Acetic acid (10%) + HEDP (10%); T10)) Peracetic acid (15%) + Hydrogen peroxide (50%) + Acetic acid (10%) + HEDP (10%); T11) Hydrogen peroxide (45%) + Acetic acid (15%) + Phosphoric acid (5%) + HEDP (5%).

SEVERITY OF ANTHRACNOSE IN FRUITS OF MANGO IN POSTHARVEST

RESULTS

In all the concentrations tested there were significant differences in the severity of the disease between treatments. In the concentration of 250 ppm, it was observed that the severity was similar in most of the treatments compared with the control. Treatment 8 {Peracetic acid (35%) + Hydrogen peroxide (15%) + Acetic acid (10%) + HEDP (10%)}, showed the lowest severity with a diameter of 0.6 cm, followed by treatments 3 {Hydrogen Peroxide (30%) + Peracetic Acid (15%) + Acetic Acid (10%)} (0.7 cm) and 11 {Hydrogen Peroxide (45%) + Acetic Acid (15%) + Phosphoric Acid (5%) + HEDP (5%)} (0.7 cm). The control and the rest of the treatments ranged between 0.8 and 1.2 cm (Figure 6). In the case of 500 ppm, the treatments 5 {Peracetic acid (30%) + Hydrogen peroxide (30%) + Acetic acid (10%)} and 8 {Peracetic acid (35%) + Hydrogen peroxide (15%) + Acetic acid (10%) + HEDP (10%) showed the lowest severity of the disease with 0.38 and 0.46 cm respectively. The rest of the treatments, including the control, obtained a severity range between 0.6 and 0.9 cm (Figure 7). In the fruits treated at the 1000 ppm concentration, treatment 5 was found to have the lowest severity (0.3 cm), followed by the treatments 4 {Peracetic acid (35%) + Hydrogen peroxide (15%) + Acetic acid (10 %) + Chitosan (4%)}, 3 {Hydrogen Peroxide (30%) + Peracetic Acid (15%) + Acetic Acid (10%)} and 7 {Peracetic Acid (35%) + Hydrogen Peroxide (15%) + Acetic acid (10%) + Phosphites} with 0.5, 0.6 and 0.6 cm respectively (Figure 8). On the other hand, in 2500 ppm treatment 5 was maintained with the lowest value of anthracnose severity (0.4 cm). With 0.5 cm of diameter of the lesion, treatments 4, 7 and 8 followed; of which only treatments 4 and 8 registered symptoms of the disease from the second evaluation (day 5) (Figure 9). Finally, in the highest concentration (5000 ppm) treatments 4, 7, 9 and 5 presented the lowest severity compared to the control and the rest of the treatments, which oscillated around 0.4 cm in diameter of the lesion. Meanwhile, the other treatments were between 0.6 and 1 cm in diameter of the lesion. The control showed the highest severity (Figure 10).

SEVERITY OF ANTHRACNOSE IN FRUITS OF MANGO IN POSTHARVEST

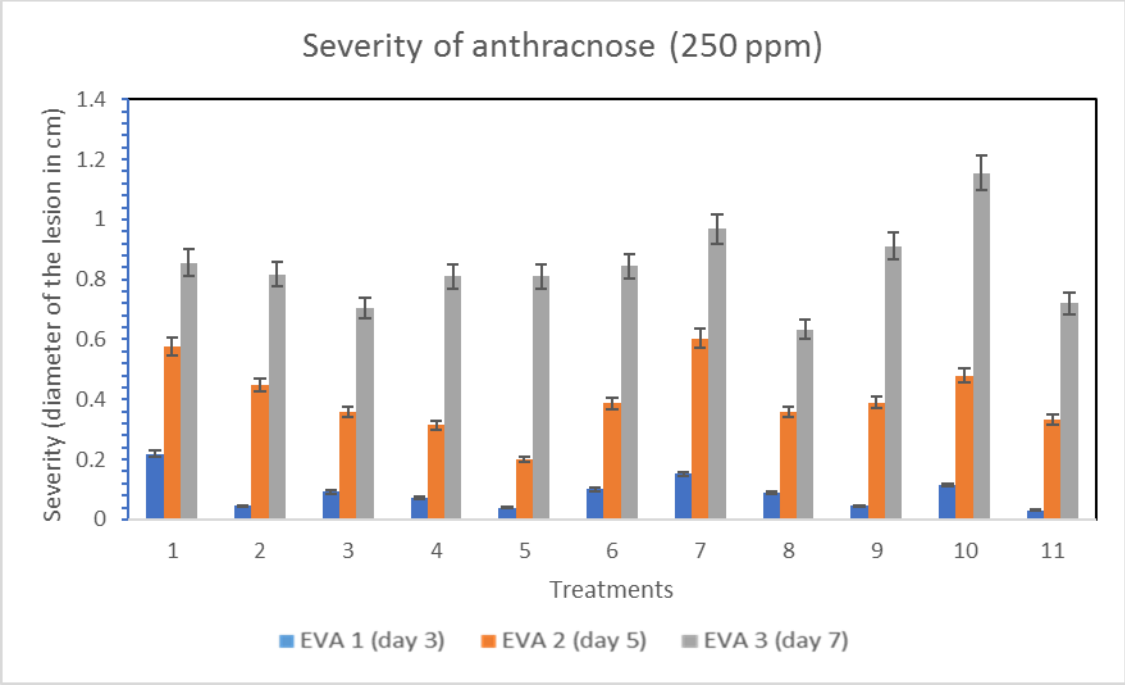

Figure 6. Evaluation of treatments in the severity of anthracnose in postharvest fruits: T1) Control; T2) Peracetic acid (35%) + Hydrogen peroxide (15%) + Acetic acid (10%); T3) Hydrogen peroxide (30%) + Peracetic acid (15%) + Acetic acid (10%); T4) Peracetic acid (35%) + Hydrogen peroxide (15%) + Acetic acid (10%) + Chitosan (4%); T5) Peracetic acid (30%) + Hydrogen peroxide (30%) + Acetic acid (10%); T6) Chitosan (4%) + Phosphites; T7) Peracetic acid (35%) + Hydrogen peroxide (15%) + Acetic acid (10%) + Phosphites; T8) Peracetic acid (35%) + Hydrogen peroxide (15%) + Acetic acid (10%) + HEDP (10%); T9) Hydrogen peroxide (30%) + Peracetic acid (15%) + Acetic acid (10%) + HEDP (10%); T10)) Peracetic acid (15%) + Hydrogen peroxide (50%) + Acetic acid (10%) + HEDP (10%); T11) Hydrogen peroxide (45%) + Acetic acid (15%) + Phosphoric acid (5%) + HEDP (5%).

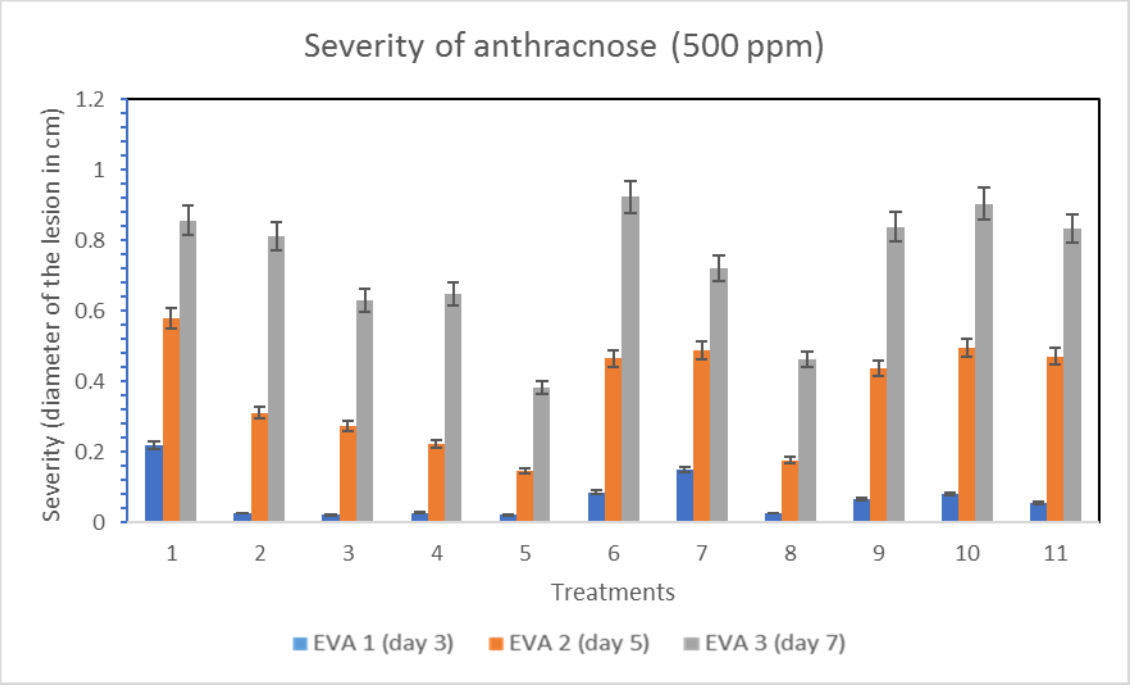

Figure 7. Evaluation of treatments in the severity of anthracnose in postharvest fruits: T1) Control; T2) Peracetic acid (35%) + Hydrogen peroxide (15%) + Acetic acid (10%); T3) Hydrogen peroxide (30%) + Peracetic acid (15%) + Acetic acid (10%); T4) Peracetic acid (35%) + Hydrogen peroxide (15%) + Acetic acid (10%) + Chitosan (4%); T5) Peracetic acid (30%) + Hydrogen peroxide (30%) + Acetic acid (10%); T6) Chitosan (4%) + Phosphites; T7) Peracetic acid (35%) + Hydrogen peroxide (15%) + Acetic acid (10%) + Phosphites; T8) Peracetic acid (35%) + Hydrogen peroxide (15%) + Acetic acid (10%) + HEDP (10%); T9) Hydrogen peroxide (30%) + Peracetic acid (15%) + Acetic acid (10%) + HEDP (10%); T10)) Peracetic acid (15%) + Hydrogen peroxide (50%) + Acetic acid (10%) + HEDP (10%); T11) Hydrogen peroxide (45%) + Acetic acid (15%) + Phosphoric acid (5%) + HEDP (5%).

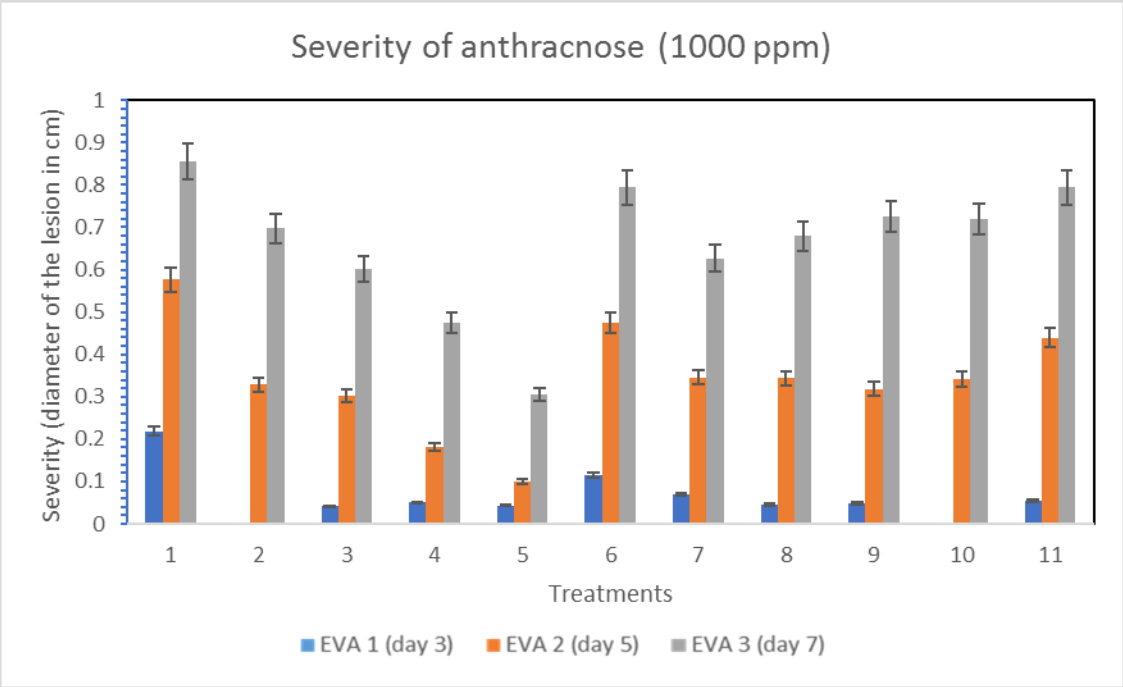

Figure 8. Evaluation of treatments in the severity of anthracnose in postharvest fruits: T1) Control; T2) Peracetic acid (35%) + Hydrogen peroxide (15%) + Acetic acid (10%); T3) Hydrogen peroxide (30%) + Peracetic acid (15%) + Acetic acid (10%); T4) Peracetic acid (35%) + Hydrogen peroxide (15%) + Acetic acid (10%) + Chitosan (4%); T5) Peracetic acid (30%) + Hydrogen peroxide (30%) + Acetic acid (10%); T6) Chitosan (4%) + Phosphites; T7) Peracetic acid (35%) + Hydrogen peroxide (15%) + Acetic acid (10%) + Phosphites; T8) Peracetic acid (35%) + Hydrogen peroxide (15%) + Acetic acid (10%) + HEDP (10%); T9) Hydrogen peroxide (30%) + Peracetic acid (15%) + Acetic acid (10%) + HEDP (10%); T10)) Peracetic acid (15%) + Hydrogen peroxide (50%) + Acetic acid (10%) + HEDP (10%); T11) Hydrogen peroxide (45%) + Acetic acid (15%) + Phosphoric acid (5%) + HEDP (5%).

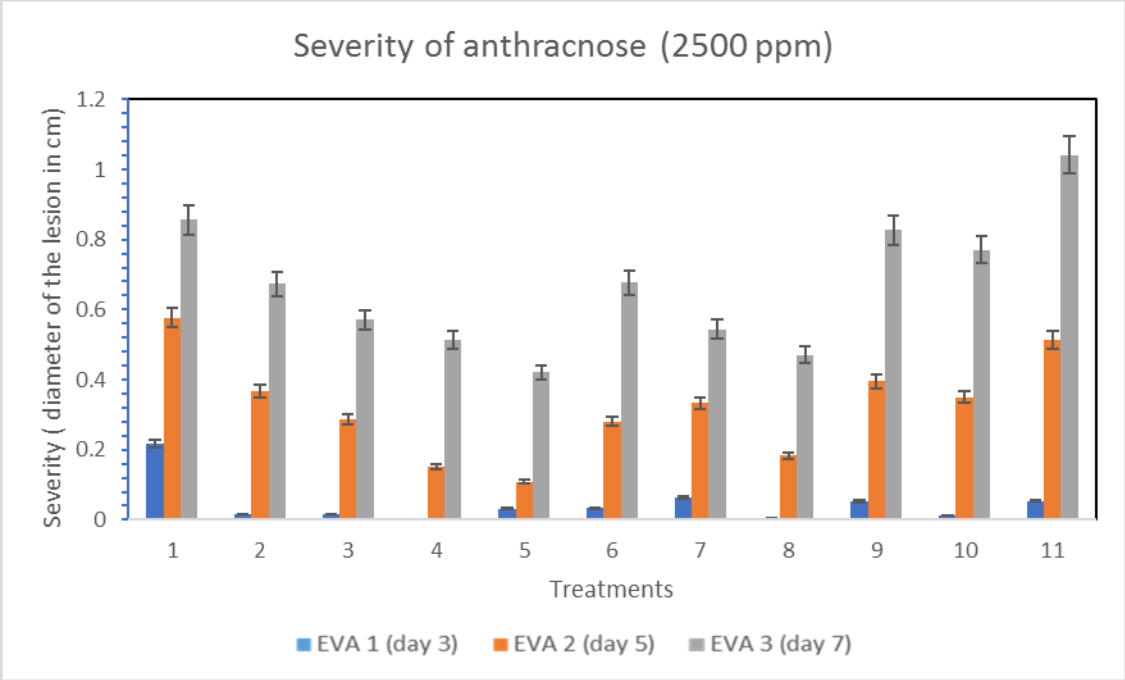

Figure 9. Evaluation of treatments in the severity of anthracnose in postharvest fruits: T1) Control; T2) Peracetic acid (35%) + Hydrogen peroxide (15%) + Acetic acid (10%); T3) Hydrogen peroxide (30%) + Peracetic acid (15%) + Acetic acid (10%); T4) Peracetic acid (35%) + Hydrogen peroxide (15%) + Acetic acid (10%) + Chitosan (4%); T5) Peracetic acid (30%) + Hydrogen peroxide (30%) + Acetic acid (10%); T6) Chitosan (4%) + Phosphites; T7) Peracetic acid (35%) + Hydrogen peroxide (15%) + Acetic acid (10%) + Phosphites; T8) Peracetic acid (35%) + Hydrogen peroxide (15%) + Acetic acid (10%) + HEDP (10%); T9) Hydrogen peroxide (30%) + Peracetic acid (15%) + Acetic acid (10%) + HEDP (10%); T10)) Peracetic acid (15%) + Hydrogen peroxide (50%) + Acetic acid (10%) + HEDP (10%); T11) Hydrogen peroxide (45%) + Acetic acid (15%) + Phosphoric acid (5%) + HEDP (5%).

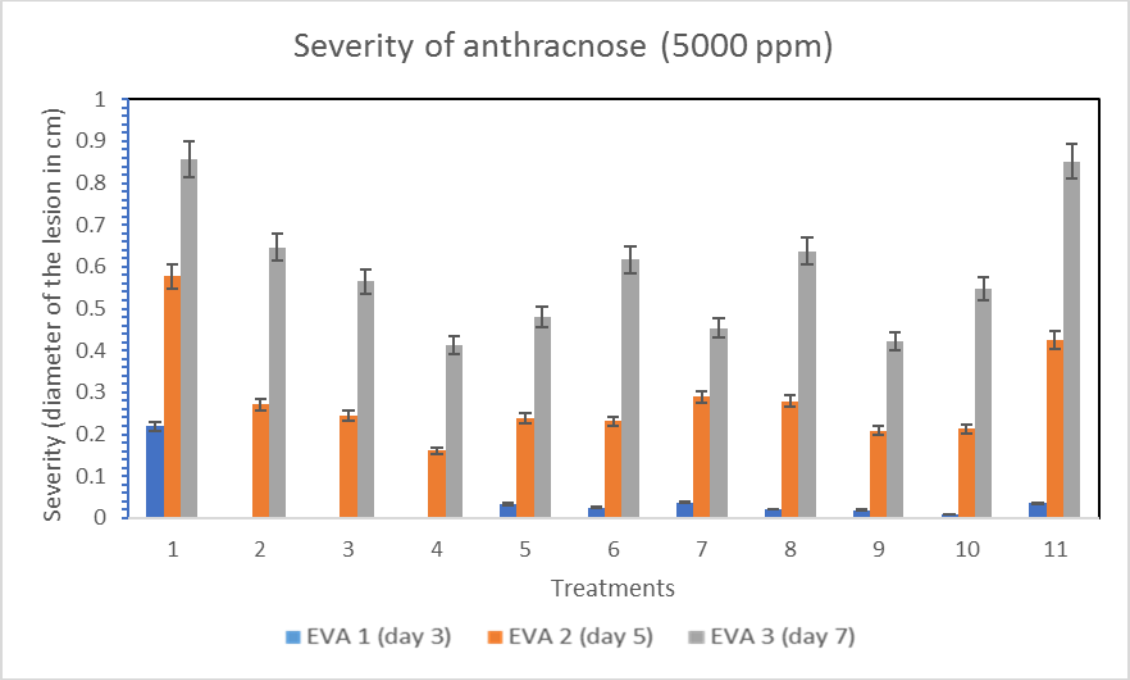

Figure 10. Evaluation of treatments in the severity of anthracnose in postharvest fruits: T1) Control; T2) Peracetic acid (35%) + Hydrogen peroxide (15%) + Acetic acid (10%); T3) Hydrogen peroxide (30%) + Peracetic acid (15%) + Acetic acid (10%); T4) Peracetic acid (35%) + Hydrogen peroxide (15%) + Acetic acid (10%) + Chitosan (4%); T5) Peracetic acid (30%) + Hydrogen peroxide (30%) + Acetic acid (10%); T6) Chitosan (4%) + Phosphites; T7) Peracetic acid (35%) + Hydrogen peroxide (15%) + Acetic acid (10%) + Phosphites; T8) Peracetic acid (35%) + Hydrogen peroxide (15%) + Acetic acid (10%) + HEDP (10%); T9) Hydrogen peroxide (30%) + Peracetic acid (15%) + Acetic acid (10%) + HEDP (10%); T10)) Peracetic acid (15%) + Hydrogen peroxide (50%) + Acetic acid (10%) + HEDP (10%); T11) Hydrogen peroxide (45%) + Acetic acid (15%) + Phosphoric acid (5%) + HEDP (5%).

CONCLUSIONS

1. No product totally inhibited the incidence and severity of anthracnose. The results suggest that all the tested products acted on contact, that is, they eliminated the fungus when they came into direct contact with the products.

2. The presence of anthracnose symptoms could be due to the fact that some spores of the fungus managed to germinate inside the inoculation wound, and the mycelium of the fungus was introduced into the fruit tissue; probably this event occurred before the immersions were made with the treatments, that is, before 8 hours after the inoculation.

3. The best treatments were:

- T5: Peracetic acid (30%) + Hydrogen peroxide (30%) + Acetic acid (10%);
- T4: Peracetic acid (35%) + Hydrogen peroxide (15%) + Acetic acid (10%) + Chitosan (4%);
- T3: Hydrogen peroxide (30%) + Peracetic acid (15%) + Acetic acid (10%).

4. The T5 treatment showed control effect from 500 ppm, while the T4 and T5 treatments showed their effectiveness from 1000 ppm. This effectiveness increased as the concentration was increased.

5. Organic treatments with greater biological effectiveness obtained in the experiment could be an alternative to eliminate anthracnose spores in mango fruits in post-harvest treatments, with equal or greater biological effectiveness than chemical fungicides.

6. The use of organic products with fungicidal action, such as those tested in the present study, could be an alternative to chemical fungicides for the management of anthracnose in postharvest mango, since they offer biological effectiveness on the pathogen, and when degraded quickly, it does not present any risks of pesticide residues; in addition, their ingredients offer no health risks.

PHOTOGRAPHIC APPENDIX

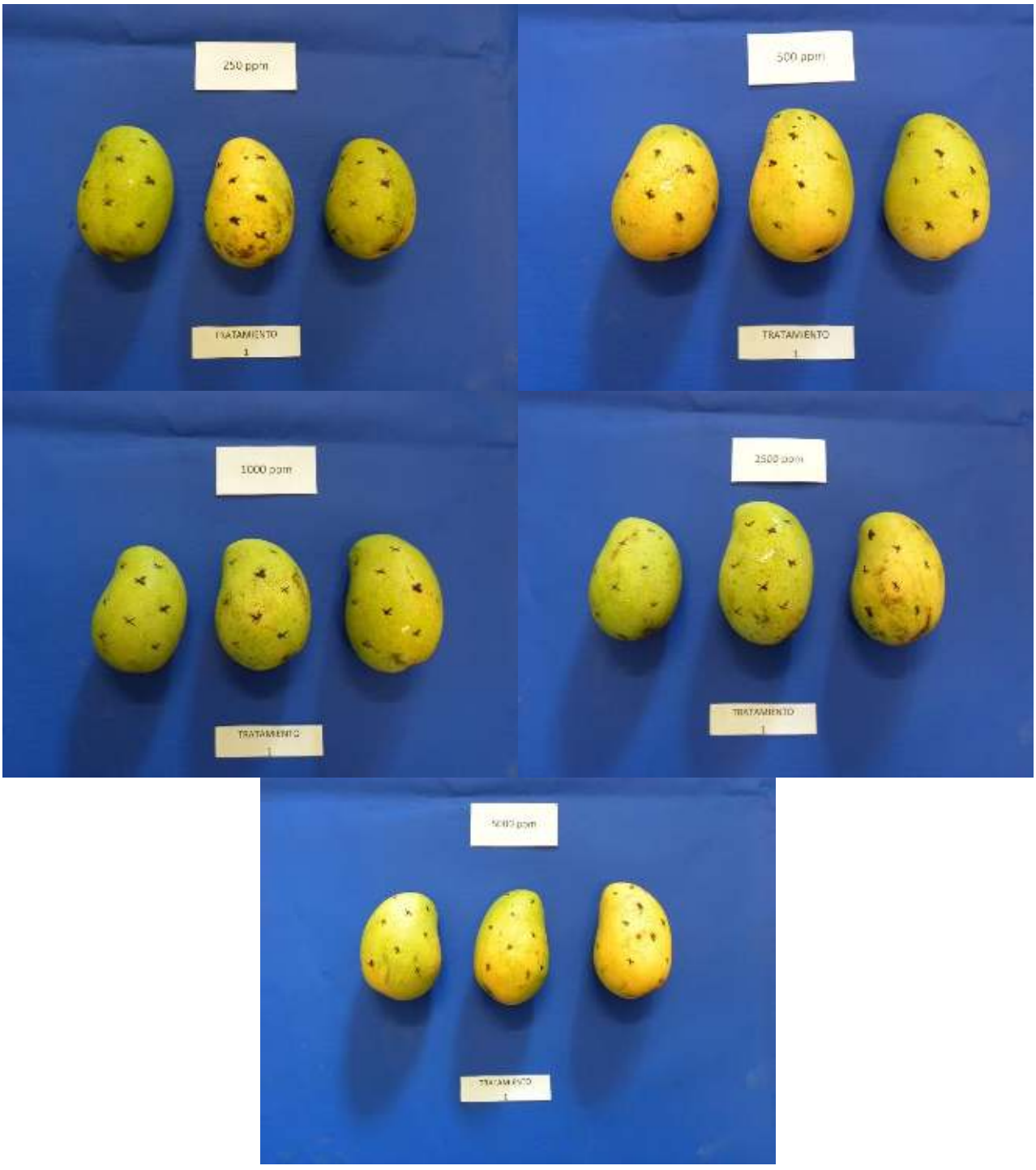

Figure 11. Incidence and severity of anthracnose at different concentrations (250, 500, 1000, 2500 and 5000 ppm) in treatment one: T1) Peracetic acid (35%) + Hydrogen peroxide (15%) + Acetic acid (10%).

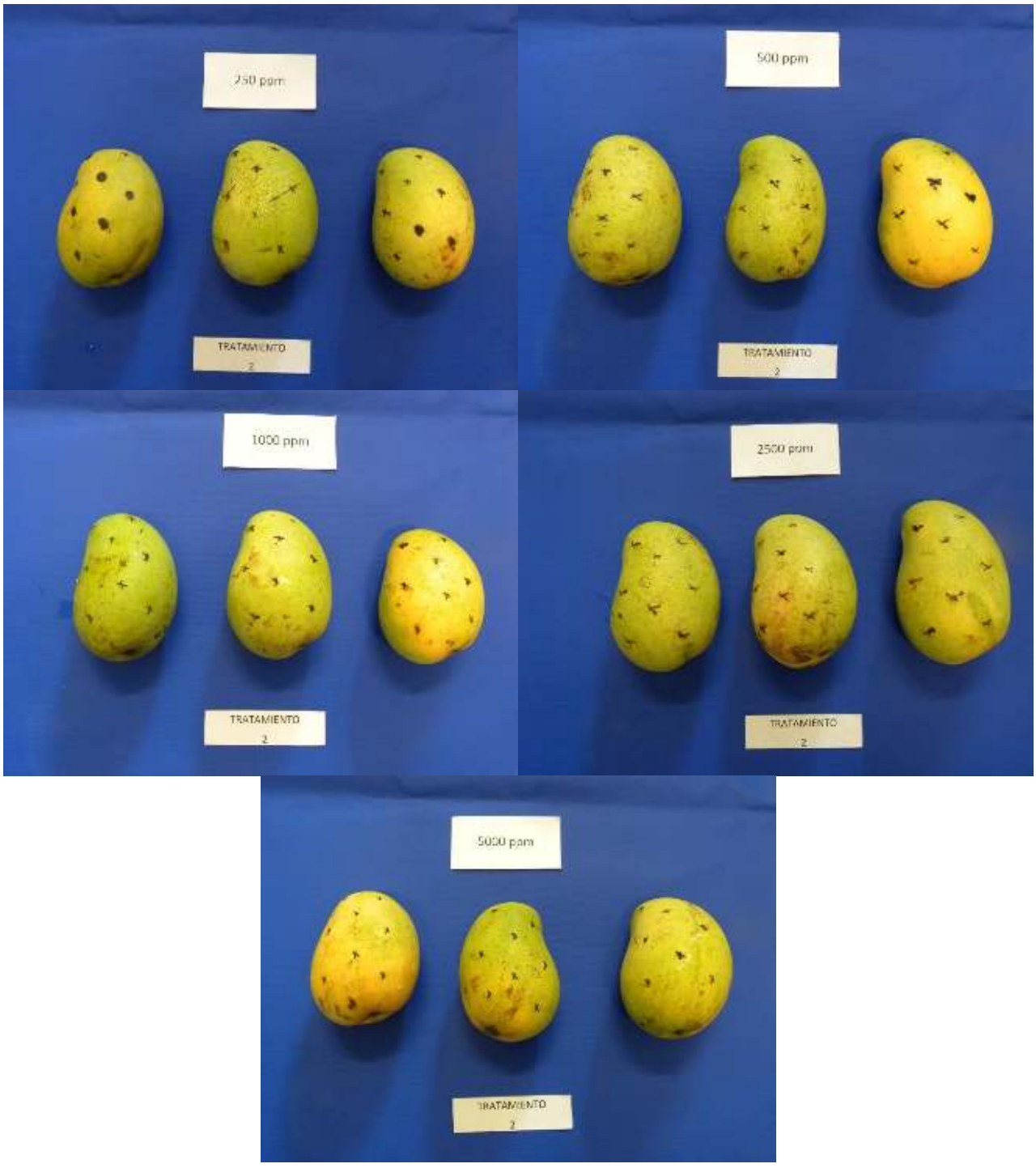

Figure 12. Incidence and severity of anthracnose at different concentrations (250, 500, 1000, 2500 and 5000 ppm) in treatment two: T2) Hydrogen peroxide (30%) + Peracetic acid (15%) + Acetic acid (10%).

Figure 13. Incidence and severity of anthracnose at different concentrations (250, 500, 1000, 2500 and 5000 ppm) in treatment three: T3) Peracetic acid (35%) + Hydrogen peroxide (15%) + Acetic acid (10%) + Chitosan (4%).

Figure 14. Incidence and severity of anthracnose at different concentrations (250, 500, 1000, 2500 and 5000 ppm) in treatment four: T4) Peracetic acid (30%) + Hydrogen peroxide (30%) + Acetic acid (10%).

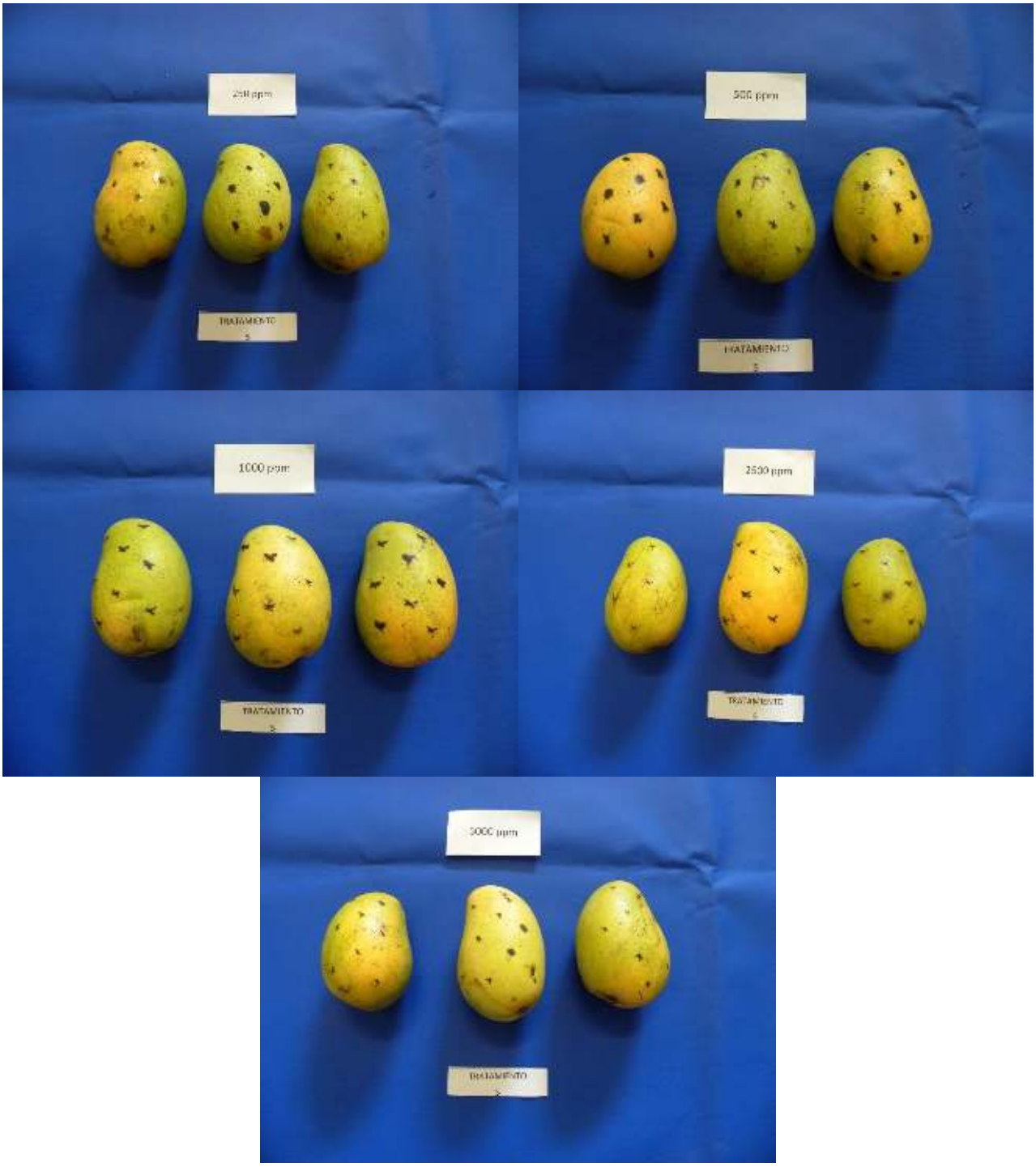

Figure 15. Incidence and severity of anthracnose at different concentrations (250, 500, 1000, 2500 and 5000 ppm) in treatment five: T5) Chitosan (4%) +

Figure 16. Incidence and severity of anthracnose at different concentrations (250, 500, 1000, 2500 and 5000 ppm) in treatment six: T6) Peracetic acid (35%) + Hydrogen peroxide (15%) + Acetic acid (10%) + Phosphites.

Figure 17. Incidence and severity of anthracnose at different concentrations (250, 500, 1000, 2500 and 5000 ppm) in treatment seven: T7) Peracetic acid (35%) + Hydrogen peroxide (15%) + Acetic acid (10%) + HEDP (10%).

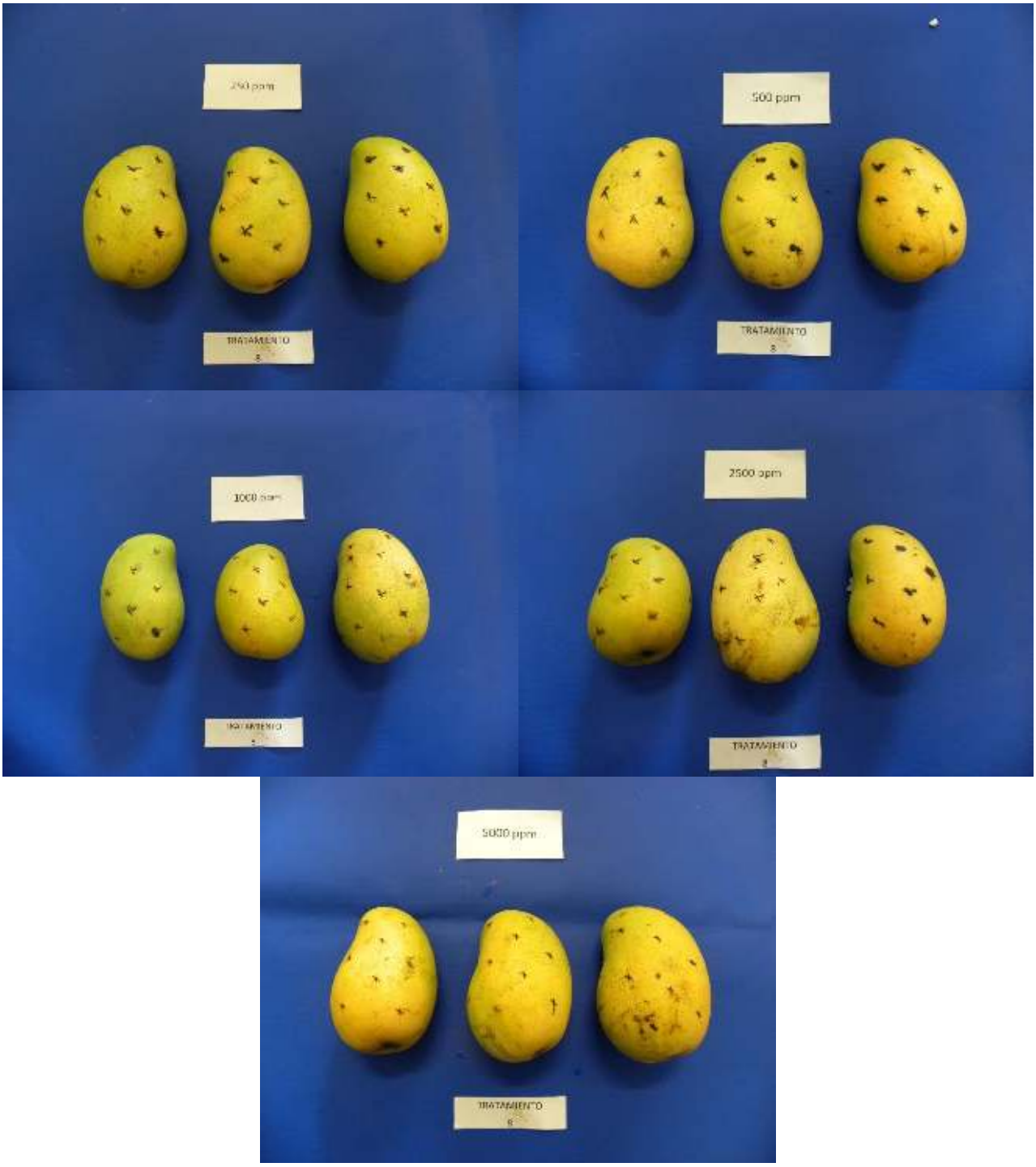

Figure 18. Incidence and severity of anthracnose at different concentrations (250, 500, 1000, 2500 and 5000 ppm) in treatment eight: T8) Hydrogen peroxide (30%) + Peracetic acid (15%) + Acetic acid (10%) + HEDP (10%).

Figure 19. Incidence and severity of anthracnose at different concentrations (250, 500, 1000, 2500 and 5000 ppm) in treatment nine: T9) Peracetic acid (15%) + Hydrogen peroxide (50%) + Acetic acid (10%) + HEDP (10%).

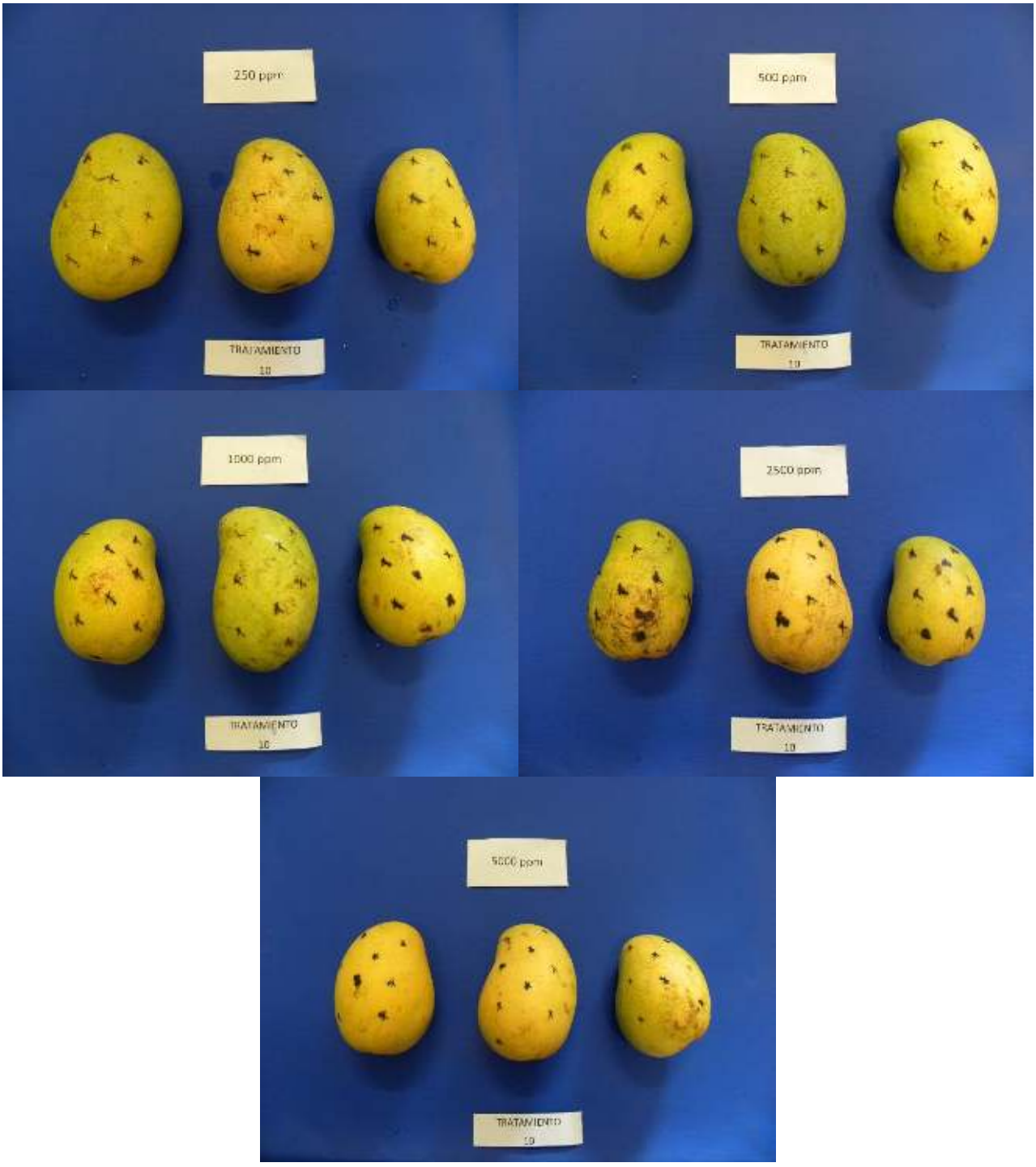

Figure 20. Incidence and severity of anthracnose at different concentrations (250, 500, 1000, 2500 and 5000 ppm) in treatment ten: T10) Hydrogen peroxide (45%) + Acetic acid (15%) + Phosphoric acid (5%) + HEDP (5%).

Figure 21. Incidence and severity of anthracnose in the control fruits.

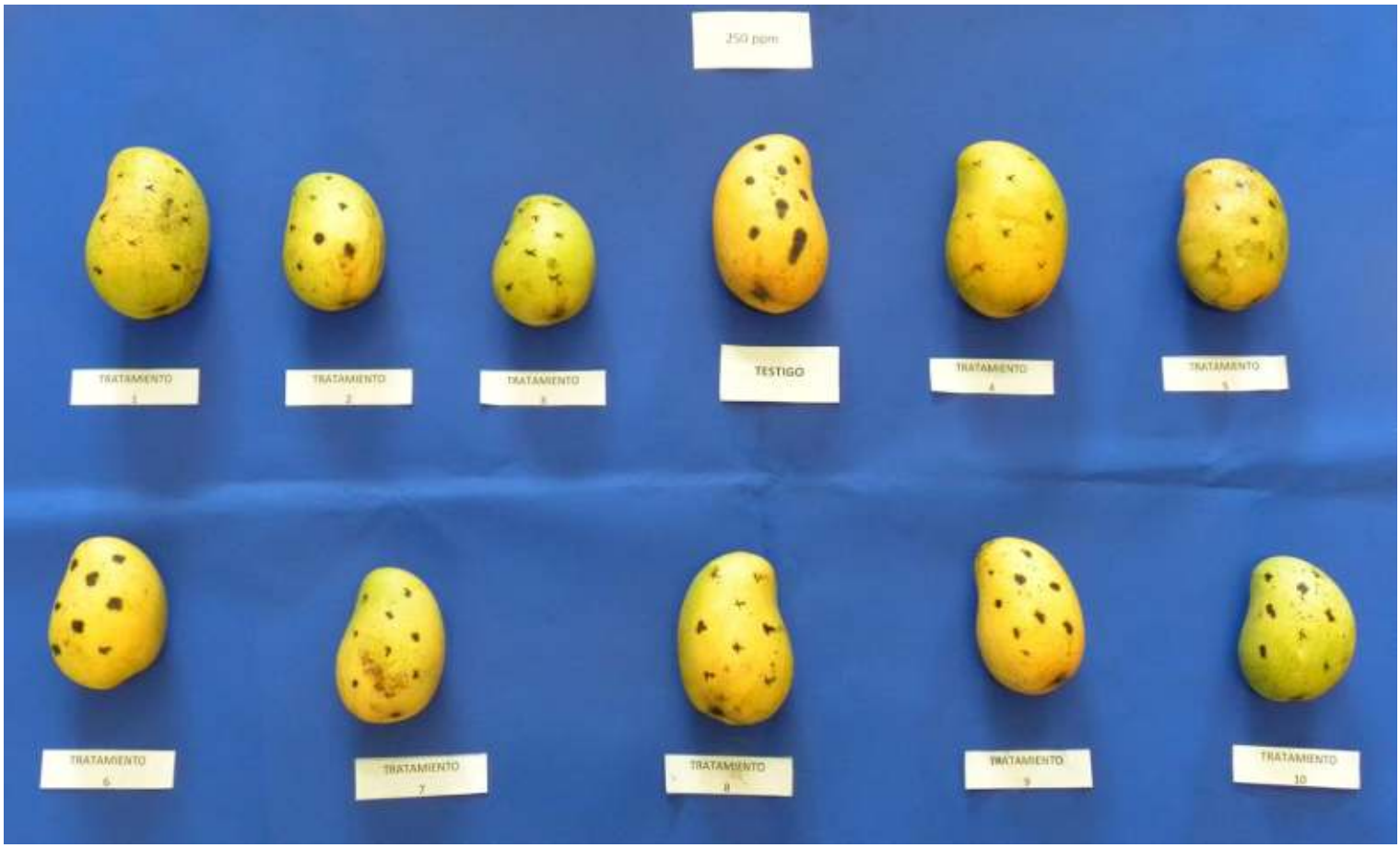

Figure 22. Treatments at 250 ppm in the incidence of anthracnose in postharvest fruits: T1) Peracetic acid (35%) + Hydrogen peroxide (15%) + Acetic acid (10%); T2) Hydrogen peroxide (30%) + Peracetic acid (15%) + Acetic acid (10%); T3) Peracetic acid (35%) + Hydrogen peroxide (15%) + Acetic acid (10%) + Chitosan (4%); Control; T4) Peracetic acid (30%) + Hydrogen peroxide (30%) + Acetic acid (10%); T5) Chitosan (4%) + Phosphites; T6) Peracetic acid (35%) + Hydrogen peroxide (15%) + Acetic acid (10%) + Phosphites; T7) Peracetic acid (35%) + Hydrogen peroxide (15%) + Acetic acid (10%) + HEDP (10%); T8) Hydrogen peroxide (30%) + Peracetic acid (15%) + Acetic acid (10%) + HEDP (10%); T9)) Peracetic acid (15%) + Hydrogen peroxide (50%) + Acetic acid (10%) + HEDP (10%); T10) Hydrogen peroxide (45%) + Acetic acid (15%) + Phosphoric acid (5%) + HEDP (5%).

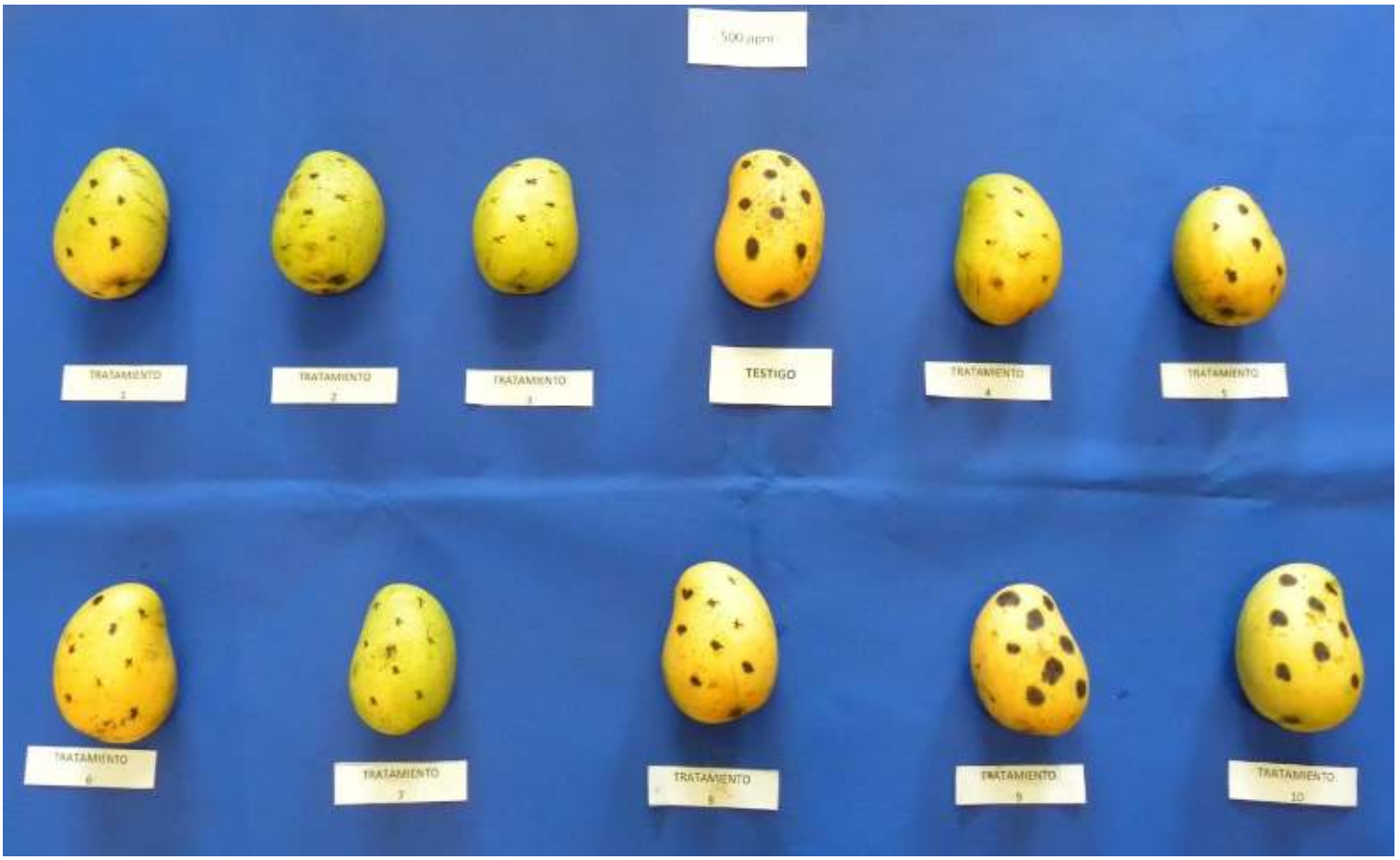

Figure 23. Treatments at 500 ppm in the incidence of anthracnose in postharvest fruits: T1) Peracetic acid (35%) + Hydrogen peroxide (15%) + Acetic acid (10%); T2) Hydrogen peroxide (30%) + Peracetic acid (15%) + Acetic acid (10%); T3) Peracetic acid (35%) + Hydrogen peroxide (15%) + Acetic acid (10%) + Chitosan (4%); Control; T4) Peracetic acid (30%) + Hydrogen peroxide (30%) + Acetic acid (10%); T5) Chitosan (4%) + Phosphites; T6) Peracetic acid (35%) + Hydrogen peroxide (15%) + Acetic acid (10%) + Phosphites; T7) Peracetic acid (35%) + Hydrogen peroxide (15%) + Acetic acid (10%) + HEDP (10%); T8) Hydrogen peroxide (30%) + Peracetic acid (15%) + Acetic acid (10%) + HEDP (10%); T9)) Peracetic acid (15%) + Hydrogen peroxide (50%) + Acetic acid (10%) + HEDP (10%); T10) Hydrogen peroxide (45%) + Acetic acid (15%) + Phosphoric acid (5%) + HEDP (5%).

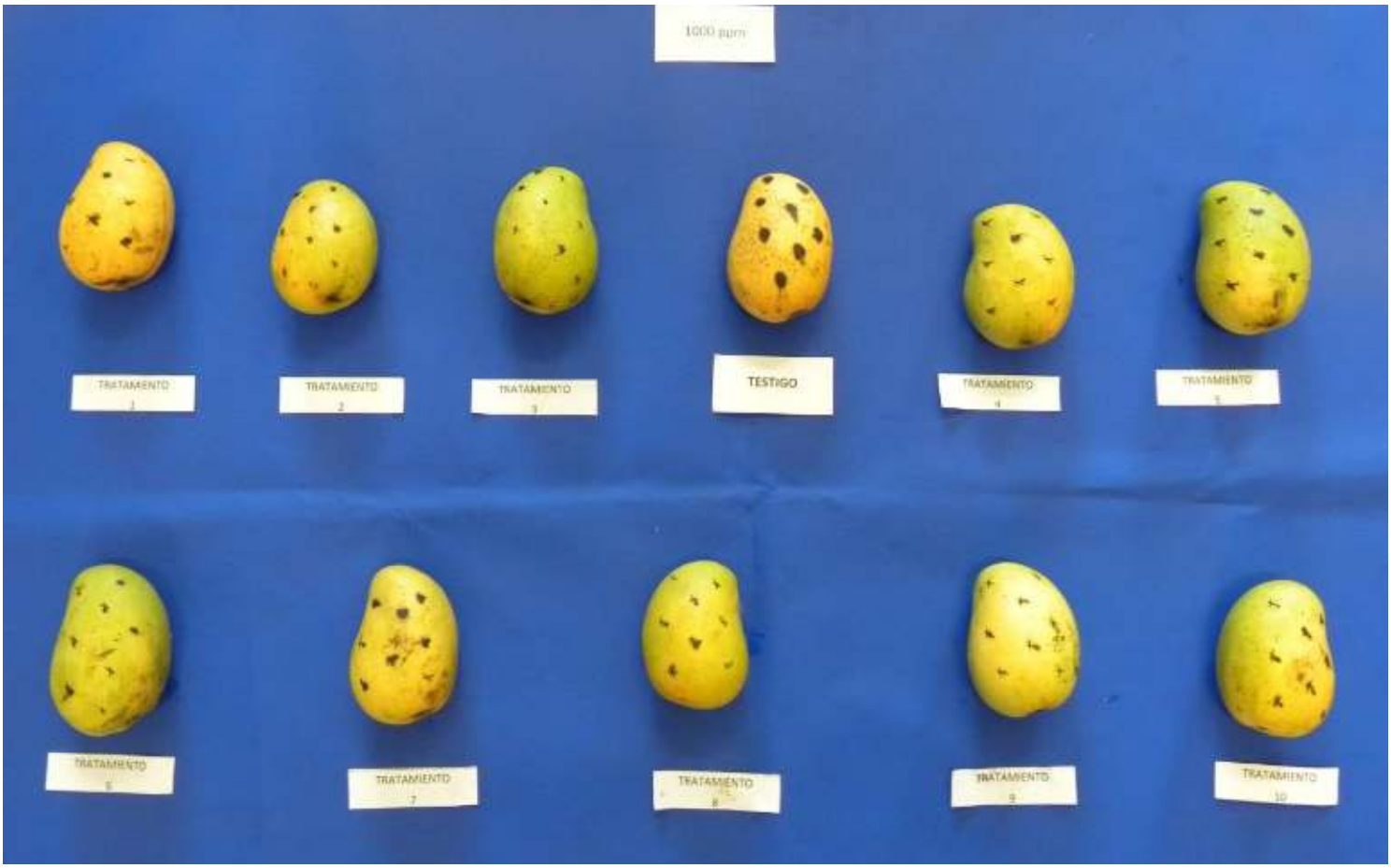

Figure 24. Treatments at 1000 ppm in the incidence of anthracnose in postharvest fruits: T1) Peracetic acid (35%) + Hydrogen peroxide (15%) + Acetic acid (10%); T2) Hydrogen peroxide (30%) + Peracetic acid (15%) + Acetic acid (10%); T3) Peracetic acid (35%) + Hydrogen peroxide (15%) + Acetic acid (10%) + Chitosan (4%); Control; T4) Peracetic acid (30%) + Hydrogen peroxide (30%) + Acetic acid (10%); T5) Chitosan (4%) + Phosphites; T6) Peracetic acid (35%) + Hydrogen peroxide (15%) + Acetic acid (10%) + Phosphites; T7) Peracetic acid (35%) + Hydrogen peroxide (15%) + Acetic acid (10%) + HEDP (10%); T8) Hydrogen peroxide (30%) + Peracetic acid (15%) + Acetic acid (10%) + HEDP (10%); T9)) Peracetic acid (15%) + Hydrogen peroxide (50%) + Acetic acid (10%) + HEDP (10%); T10) Hydrogen peroxide (45%) + Acetic acid (15%) + Phosphoric acid (5%) + HEDP (5%).

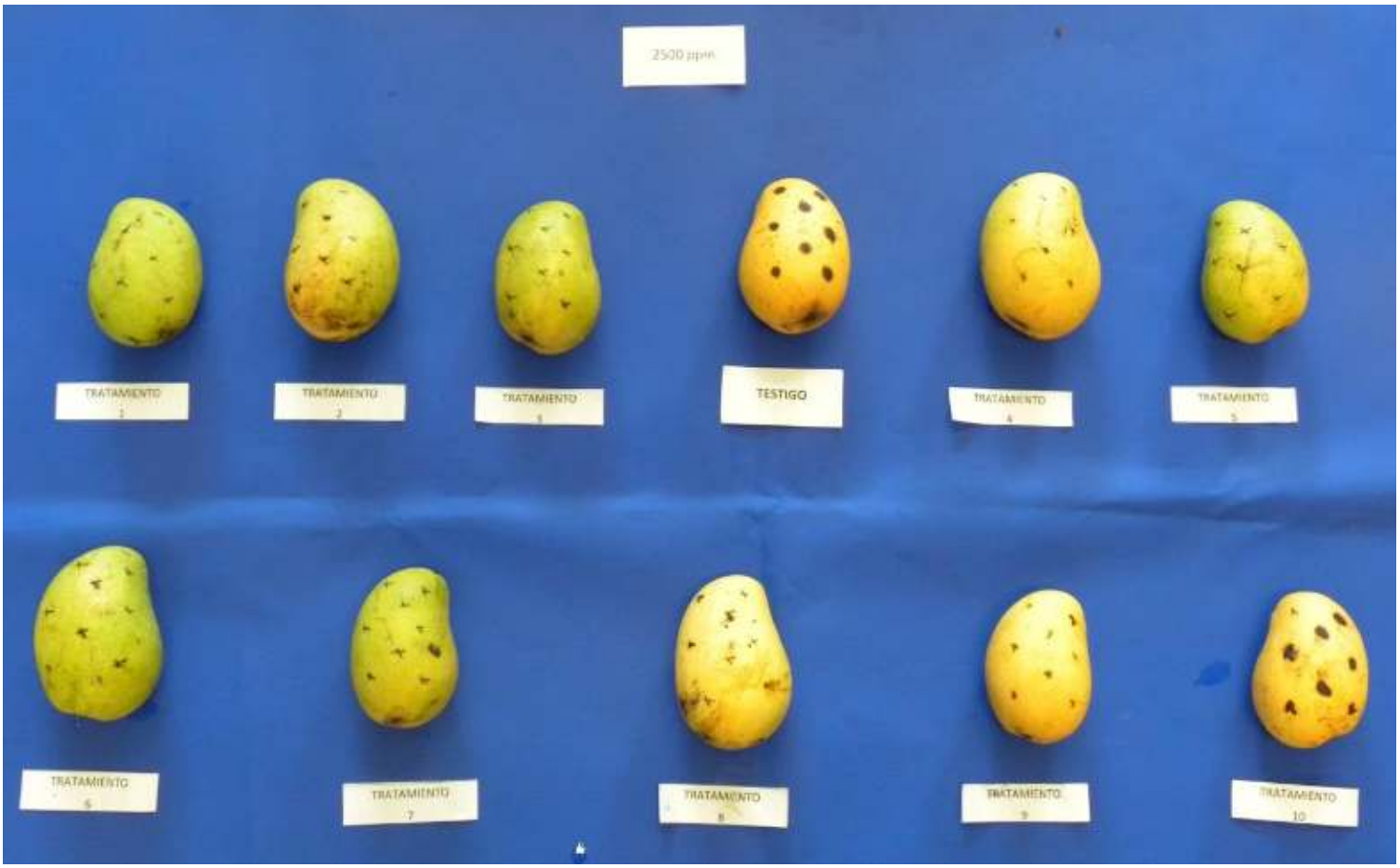

Figure 25. Treatments at 2500 ppm in the incidence of anthracnose in postharvest fruits: T1) Peracetic acid (35%) + Hydrogen peroxide (15%) + Acetic acid (10%); T2) Hydrogen peroxide (30%) + Peracetic acid (15%) + Acetic acid (10%); T3) Peracetic acid (35%) + Hydrogen peroxide (15%) + Acetic acid (10%) + Chitosan (4%); Control; T4) Peracetic acid (30%) + Hydrogen peroxide (30%) + Acetic acid (10%); T5) Chitosan (4%) + Phosphites; T6) Peracetic acid (35%) + Hydrogen peroxide (15%) + Acetic acid (10%) + Phosphites; T7) Peracetic acid (35%) + Hydrogen peroxide (15%) + Acetic acid (10%) + HEDP (10%); T8) Hydrogen peroxide (30%) + Peracetic acid (15%) + Acetic acid (10%) + HEDP (10%); T9)) Peracetic acid (15%) + Hydrogen peroxide (50%) + Acetic acid (10%) + HEDP (10%); T10) Hydrogen peroxide (45%) + Acetic acid (15%) + Phosphoric acid (5%) + HEDP (5%).

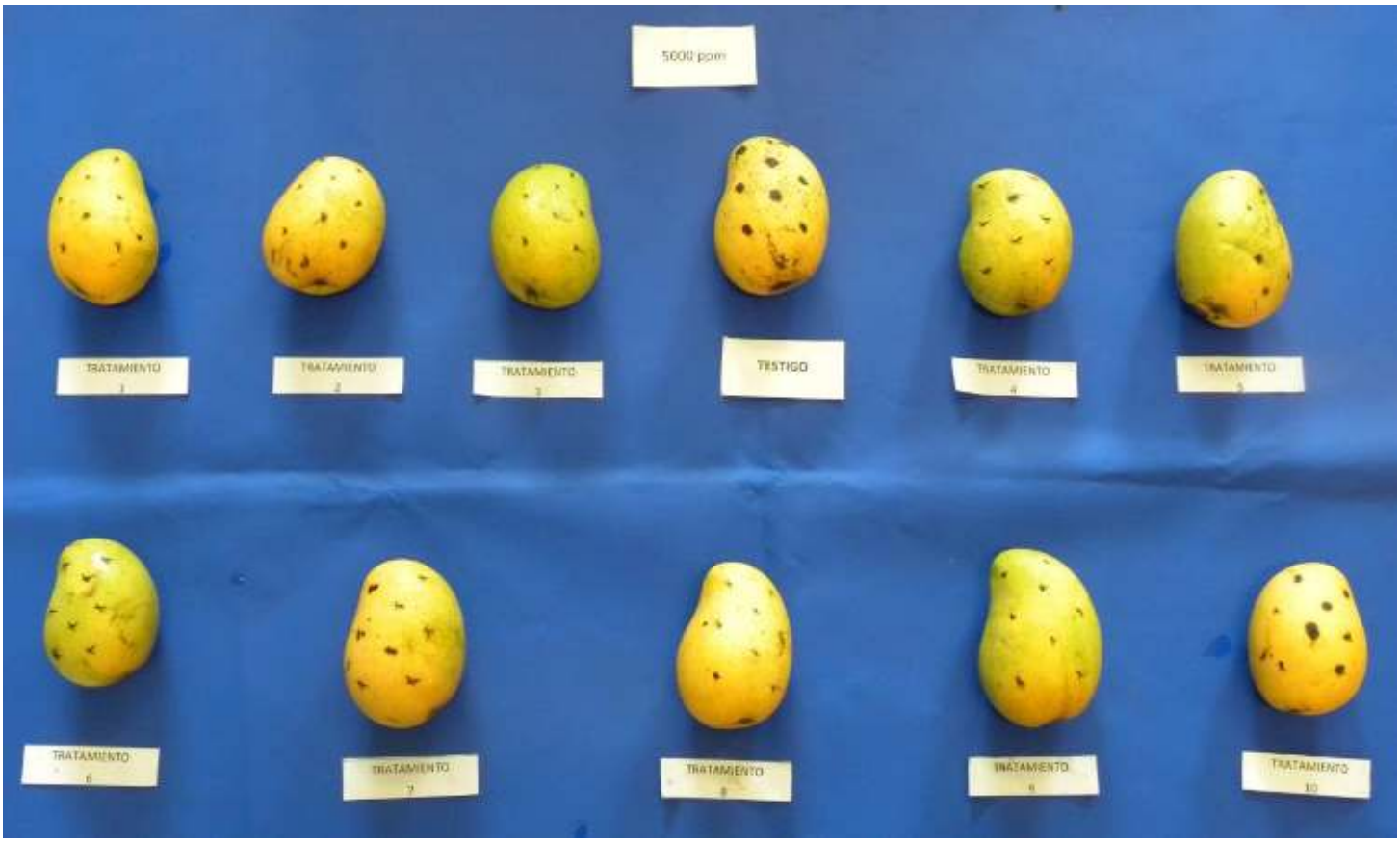

Figure 26. Treatments at 5000 ppm in the incidence of anthracnose in postharvest fruits: T1) Peracetic acid (35%) + Hydrogen peroxide (15%) + Acetic acid (10%); T2) Hydrogen peroxide (30%) + Peracetic acid (15%) + Acetic acid (10%); T3) Peracetic acid (35%) + Hydrogen peroxide (15%) + Acetic acid (10%) + Chitosan (4%); Control; T4) Peracetic acid (30%) + Hydrogen peroxide (30%) + Acetic acid (10%); T5) Chitosan (4%) + Phosphites; T6) Peracetic acid (35%) + Hydrogen peroxide (15%) + Acetic acid (10%) + Phosphites; T7) Peracetic acid (35%) + Hydrogen peroxide (15%) + Acetic acid (10%) + HEDP (10%); T8) Hydrogen peroxide (30%) + Peracetic acid (15%) + Acetic acid (10%) + HEDP (10%); T9)) Peracetic acid (15%) + Hydrogen peroxide (50%) + Acetic acid (10%) + HEDP (10%); T10) Hydrogen peroxide (45%) + Acetic acid (15%) + Phosphoric acid (5%) + HEDP (5%).