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# Does the sunblock alleviate abiotic stress in mango trees grown in the tropical semiarid?

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## ABSTRACT

Mango is the most exported fruit of Brazil, especially grown in São Francisco Valley (tropical semiarid) where there is high temperatures and low air humidity, a condition that can cause stress to plants. Thus, the current study aimed to evaluate the effectiveness of different sunblocks to alleviate the abiotic stress of "Palmer" mango trees grown in a semiarid environment. The experimental design consisted of randomised blocks with six treatments, four repetitions and three plants per plot. The treatments consisted of different strategies of sunblocks as follows: (T1) control (no sunblock); (T2) calcium carbonate (50 g · $L^{-1}$); (T3) sunblock (5 mL · $L^{-1}$); (T4) sunblock (5 mL · $L^{-1}$) + calcium carbonate (50 g · $L^{-1}$); (T5) sunblock (5 mL · $L^{-1}$) + sunblock silicon concentrated (20 mL · $L^{-1}$) and (T6) sunblock (20 mL · $L^{-1}$). The results indicate a clear action of sunblock in attenuating the abiotic stress of mango, with a persistent effect with time elapsing, considering the evaluated interval. The sunblock clearly promotes a differentiated leaf coverage pattern, protecting the photosynthetic apparatus and increasing its performance and consequently improving the production of plant reserves. The use of calcium carbonate individually promotes a very short protective effect, without positive reflexes after a few days of application. Mango fruit yield is affected by the sunblock with an increase of 4.2 t · $ha^{-1}$ from the treatment with sunblock (20 mL · $L^{-1}$) in relation to the control treatment.

**Keywords:** enzyme activity, *Mangifera indica* L, photosynthesis, soluble carbohydrates

**Abbreviations:** *A*, net photosynthesis; ANOVA, analysis of variance; APX, ascorbate peroxidase; BSh, hot semi-arid; CAT, catalase; DAT, days after treatments; *E*, leaf transpiration; Etc, evapotranspiration; FM, fresh mass; IRGA, infrared gas analyser; KM, Michaelis–Menten; PBZ, paclobutrazol; TSC, total soluble carbohydrate concentrations; UV, ultraviolet.

## INTRODUCTION

Mango is one of the most appreciated tropical fruits due to its characteristic flavour and aroma, attractive colouring and high nutritional value (Lobo et al., 2019). Brazil is the seventh largest producer and sixth largest world exporter of mangoes (FAOSTAT, 2019), especially from São Francisco Valley where approximately 87% of Brazilian exported mangoes are harvested (Carvalho et al., 2019).

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The climate of São Francisco Valley is hot semi-arid (BSh), with an average temperature of 34.7°C and an average relative humidity of 23.7% in the hottest period of the day during the final quarter of the year, a condition that can cause stress to plants. However, moderate exposure to water stress induces the flowering of mango trees in this region (Ramírez and Davenport, 2010).

Despite the positive outlook for mango production in the São Francisco Valley, the high temperatures associated with the water blade reduction during branch maturation phase (Cavalcante et al., 2018) have caused problems with excessive mango stress. When exposed to adverse grown conditions, plants activate different protection mechanisms, among which is the accumulation of low-molecular-weight organic solutes (proline, protein, carbohydrates) in tissues (Marijuan and Bosch, 2013) is one.

This defence mechanism has been studied especially in relation to water, thermal, saline stress or stresses caused by pathogens, anaerobiosis, nutrient deficiency, atmospheric pollution and ultraviolet (UV) radiation, and even to all these stresses in a combined manner "multiple stresses" (Salisbury and Ross, 2013; Kanayama and Kochetov, 2015). In this sense, Tripathi et al. (2020) argue that the negative impact of UV-B radiation on most organisms is mediated by free radicals which induce oxidative stress.

Within these scenarios, management strategies have been adopted and studied with the objective of mitigating stresses, especially caused by high temperatures and excessive light intensities, such as sunblocks (Costa et al., 2018). Navarro-Morillo et al. (2022) studied the efficacy of the protective product Archer® Eclipse against experimentally induced sunburn conditions and concluded that the protective effect of the pit-dye mechanism is evident, with 3°C lower leaf temperatures, higher photosynthesis performance and 88% more water use efficiency. Specifically, for mango trees, the research studies are scarce. Abd-Allah et al. (2013) observed that spraying kaolin or 5% magnesium carbonate had a positive effect in reducing the sunburned skin area and in the percentage of fruit falling.

The use of sunblock against sunburn could be an interesting low-cost tool to reduce the abiotic stress and improve the physiological and agronomic characteristics of fruit crops grown under abiotic stresses. Hence, the present study aimed to evaluate the effectiveness of different sunblocks to alleviate the abiotic stress of "Palmer" mango trees grown in semiarid regions.

## MATERIALS AND METHODS

### *Plant material and growing conditions*

Ten-year-old "Palmer" mango trees (*Mangifera indica* L.), with uniform size and vigour, were used in this study. The experiment was conducted between January and July in 2019 simultaneously in two experimental orchards located in Aracê farm (9°19'S and 40º 41'W; at an altitude of 423 m above sea level), Petrolina, Pernambuco State, Brazil. The climate of this region is classified as BSh (Köeppen), which corresponds to a semi-arid region. During the experiment, the meteorological data were monitored in an automatic meteorological station for air temperature (ºC), air humidity (%) and rainfall (mm) (Figure 1).

Table 1 contains the physical and chemical characteristics of the soil before the executions of the experiments.

The tree's nutritional status was determined through leaf analysis before the experiment, as can be seen in Table 2. Leaf samples were collected in the middle part of the canopy in the last vegetative flush of branches to perform the characterisation of plant nutritional status. Leaves were chemically analysed after they were washed and rinsed with distilled water and dried at 65°C until reaching constant mass, following the methodology described by Bataglia et al. (1983).

The plants, spaced by 6.0 m between the rows and 3.0 m between the plants, were daily irrigated (drip) with eight emitters per tree, for a flow of nearly 2 L · $h^{-1}$ each emitter. All management practices such as pruning,

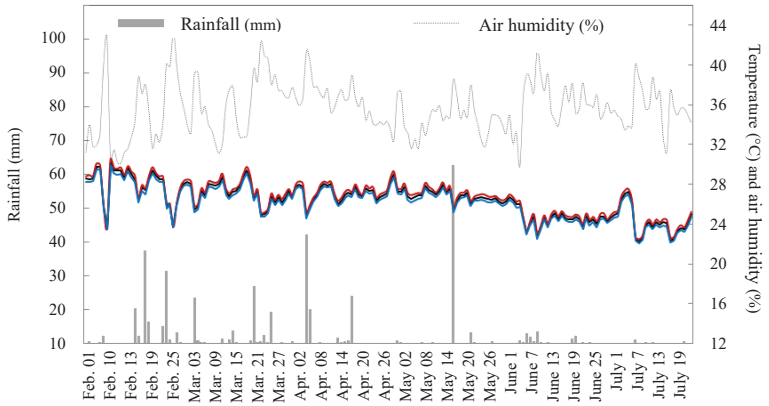


**Figure 1.** Maximum, minimum and average air temperature, air humidity and rainfall recorded during the execution of the experiment.

control of weeds, pests and diseases, plant growth regulators for gibberellin inhibition [paclobutrazol (PBZ), Cultar®] and dormancy break (calcium nitrate and potassium nitrate) were performed following the instructions of Genú and Pinto (2002). From 60 days to 90 days after PBZ, the water blade reduction was performed, irrigating 50% of crop evapotranspiration (Etc). Nutrient management was performed through a fertigation system, according to plant demand (Genú and Pinto, 2002; Barbosa et al., 2016; Carneiro et al., 2017). The production pruning was mechanically carried out, and manual tip pruning was performed to synchronise vegetative flush events in the canopy.

### *Experimental design and treatments*

The experiment followed a randomised block design with six treatments, four repetitions per treatment and three plants per replication. The treatments were defined considering the plant demands and physiological changes that occur during the mango phenological stages according to the production system conducted in the São Francisco Valley, properly described by Genú and Pinto (2002) and Cavalcante et al. (2018).

The treatments consisted of different strategies of sunblocks as follows: (T1) control (no sunblock); (T2) calcium carbonate (50 g · $L^{-1}$); (T3) sunblock (5 mL · $L^{-1}$); (T4) sunblock (5 mL · $L^{-1}$) + calcium carbonate (50 g · $L^{-1}$); (T5) sunblock (5 mL · $L^{-1}$) + sunblock silicon concentrated (20 mL · $L^{-1}$) and (T6) sunblock (20 mL · $L^{-1}$). All treatments were applied once, immediately after the flowering induction, which was performed with potassium nitrate (2.5%) foliar sprays (Cavalcante et al., 2018) on 21st February 2019, without adjuvants and using a Jacto Arbus® sprayer to completely wet the canopy.

The sunblock used was Humigel Plus A®, which is a foliar fertiliser that acts as a protective barrier by forming a film (biodegradable film) and also contains N (2%), CaO (4%), Zn (2.9%), $SiO_2$ (15%) and fulvic acids (12%). The sunblock silicon concentrator used was Humigel Plus Silício®, which also is a foliar fertiliser that acts as a protective barrier by forming a film (biodegradable film) and also contains N (2%), CaO (4%), Zn (2.9%), $SiO_2$ (27%) and fulvic acids (14%).

**Table 1.** Chemical and physical characteristics of the soil (0–30 cm soil depth) in the experimental site before the execution of the experiment.

| Soil characteristic | Value |
|---|---|
| Organic matter (%) | 2.61 |
| pH (in KCl) | 5.38 |
| $Ca^{2+}$ ($cmol_c$ · $dm^{-3}$) | 3.6 |
| $Mg^{2+}$ ($cmol_c$ · $dm^{-3}$) | 1.14 |
| $Al^{3+}$ ($cmol_c$ · $dm^{-3}$) | 0.06 |
| $K^{+}$ ($cmol_c$ · $dm^{-3}$) | 0.78 |
| $Na^{+}$ ($cmol_c$ · $dm^{-3}$) | 0.18 |
| P (mg · $dm^{-3}$) | 14.84 |

P, K: Melich-1; Al: calcium acetate (extractor) 0.5M, pH 7; Al, Ca, Mg: KCl 1 M extractor.

### *Assessed variables*

#### *Biochemical analyses*

All variables for biochemistry, enzyme activity and gas exchange were recorded from the beginning of the experiment (characterisation) and at 0, 3, 4, 5, 6, 7, 13, 20, 34 and 46 days after treatments (DAT).

For biochemical and enzyme activity analyses, recently mature leaves were collected, their limb was separated and packaged in aluminium foil, identified, immediately deposited in liquid nitrogen for freezing, taken to the Plant Physiology Laboratory and stored in a freezer until the crude extract was prepared.

To prepare the crude extract, 2 g of fresh leaf limb matter was weighed per sample and macerated in a pistil porcelain crucible using liquid nitrogen to a fine powder, to which 10 mL of potassium phosphate buffer solution (0.1 M and pH 7.0), containing 0.0001 M EDTA. The material obtained was filtered on a muslin tissue, placed in 2 mL Eppendorf and centrifuged at 12,000 rpm for 15 min in a refrigerated centrifuge (Sigma 3-18K®). The precipitate was discarded, and the supernatant was used for the analysis of total soluble carbohydrate, free amino acid and total soluble protein content.

For total soluble carbohydrates [μmol · $g^{-1}$ of fresh mass (FM)], the methodology of Dubois et al. (1956) was used. The starch (g · $g^{-1}$ FM) analysis was performed according to the methodology of Neves and Moraes (2005). The enzymatic activities of ascorbate peroxidase (APX), catalase (CAT) (μmol $H_2O_2$ · $min^{-1}$ · $g^{-1}$ FM) and α-amilase (μg of starch hidro · $min^{-1}$ · $g^{-1}$ FM) were quantified according to Nakano and Asada (1981) and Beers and Sizer (1952).

#### *Gas exchange*

At each evaluation date, the net photosynthesis – *A* (μmol $CO_2$ $m^{-2}$ $s^{-1}$) – and transpiration – *E* (mmol

**Table 2**. Leaf nutrient concentrations of the "Palmer" mango orchard before the experiment.

| N | P | K | Ca | Mg | Mn | Fe | Zn | B |
|---|---|---|---|---|---|---|---|---|
| g · $kg^{-1}$ | | | | | mg · $kg^{-1}$ | | | |
| 8.82 | 2.48 | 11.58 | 28.78 | 2.76 | 426.17 | 55.01 | 26.98 | 108.72 |

N: Kjeldahl; P: spectrometry with vanadate yellow; K: flame photometry; Mg, Ca, Fe, Zn and Mn: atomic absorption spectrophotometry; B: spectrophotometry with azomethine-H.

$H_2O \cdot m^{-2} \cdot s^{-1}$) – also were determined through of an infrared gas analyser (IRGA) (Mod. Li-COR®6400 XT).

### *Fruit yield*

Fruit harvest was performed on 18th September 2019, when the fruits were in stage 2 of pulp maturation, characterised by the colouration of the cream-yellowed pulp following the fruit selection parameters recommended by the Brazilian Program for Horticulture Modernization (2004) for commercial farms. Fruits were weighed to obtain the estimated yield ($t \cdot ha^{-1}$), multiplying the fruit production per tree by the number of trees per hectare.

### ***Statistical analysis***

Data were submitted to analysis of variance (ANOVA). Statistical analyses were performed using software R (R CORE TEAM, 2018) at each evaluation date using combined data of both experiments simultaneously carried out, and the averages were compared by Tukey's test at $p < 0.05$.

## RESULTS AND DISCUSSION

### ***Gas exchange***

There was a significant effect of the treatments on the net photosynthesis of mango trees with different effects depending on the time elapsed after the treatments were applied (Figure 2). A significant increase on net photosynthesis was registered for all treatments at 3 DAT, except for the control, which remained practically stable (Figure 2A). After that, there was a decrease in all treatments, probably due to precipitation which occurred in the experiment area. After that, it is observed, especially for T6 maintenance and even an increase in photosynthetic rate over time, even after the rain that has elapsed after the application of the treatments. It is noteworthy that the biotic and abiotic stresses in

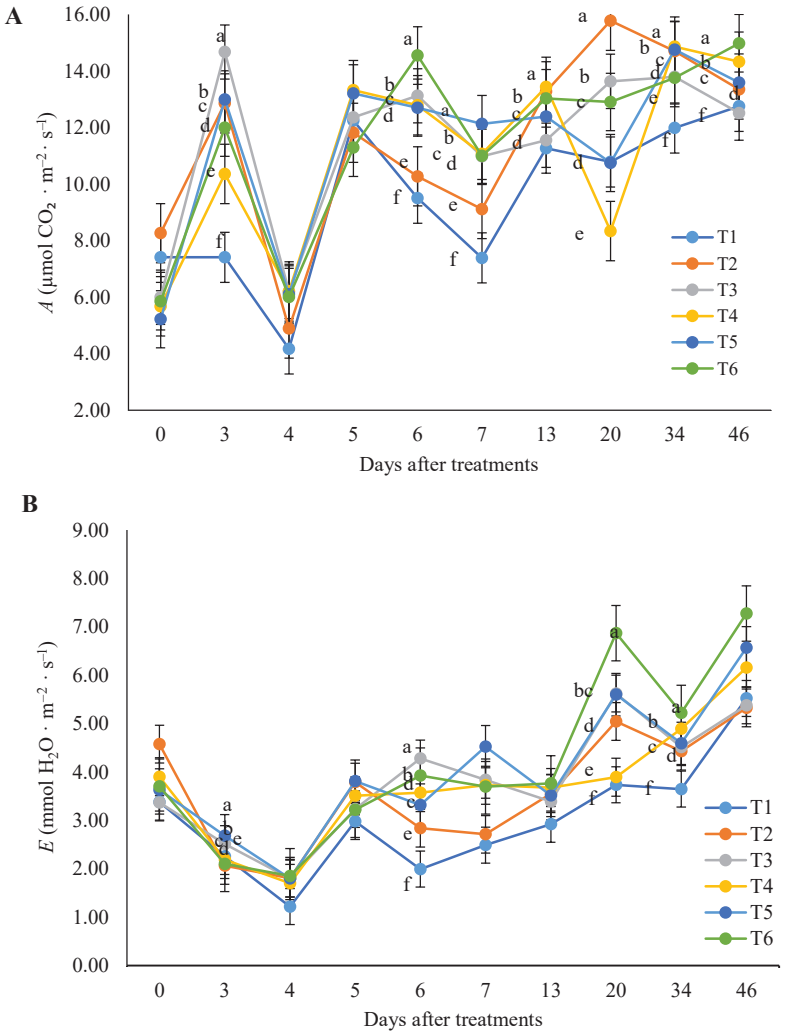


**Figure 2.** Net photosynthesis – *A* (A) and leaf transpiration – *E* (B) of "Palmer" mango trees as a function of sunblock strategies and days after treatments. Points with the same lowercase letters do not differ on each evaluation date by Tukey's test at 0.01 probability level. Vertical lines indicate error bars. (T1) control (no sunblock); (T2) calcium carbonate ($50 g \cdot L^{-1}$); (T3) sunblock ($5 mL \cdot L^{-1}$); (T4) sunblock ($5 mL \cdot L^{-1}$); (T5) sunblock ($5 mL \cdot L^{-1}$) + sunblock silicon concentrated ($20 mL \cdot L^{-1}$) and (T6) sunblock ($20 mL \cdot L^{-1}$).

which plants are submitted during their cycle cause several changes in their physiological functioning, as in net photosynthesis, for example, which reduces with increasing stress (Hayat et al., 2012). Thus, it appears that the application of treatments, especially T6, was able to provide protection against the effects of light and thermal stress, while allowing transmissions of sufficient sunlight for the net photosynthesis of mango trees.

The good gas exchange results of T6 in many evaluation dates could be caused by its higher silicon composition (27% of $SiO_2$) in relation to the other treatments. Silicon provides the mechanical strength to plants from various biotic and abiotic stresses (Diniz et al., 2020). According to Rajput et al. (2021), Si reduces the negative impacts of different stresses in plants, and its accumulation in plant tissue surface is primarily responsible for these positive influences in plants, such as increasing antioxidant activity.

Some treatments presented a pattern of distribution for leaf transpiration (Figure 2B) similar to that found for net photosynthesis, which occurred because, when exposed to stresses, the tendency of stomata to close and consequently to reduce sweating, preventing a decrease in the water plant content (Kerbauy, 2004). On the other hand, it is observed that T3 plants promoted high transpiration and net photosynthesis levels, which can be attributed to the adequate functioning of the photosynthetic apparatus, even under abiotic stress conditions.

### *Biochemical analyses*

As can be seen in Figure 3, carbohydrate concentrations recorded on the different days after treatments (DAT) showed a difference only at 5 DAT and 46 DAT. At 4 DAT, all treatments presented a peak of leaf carbohydrate concentration, when the highest value was promoted by T3, corresponding to 197.54 µmol · $g^{-1}$ FM. After reaching the peak, at 5 DAT, all treatments recorded a considerable reduction for carbohydrate concentration, except for T5, which in the previous evaluation had 136.66 µmol · $g^{-1}$ FM, showed the smallest data decay, only −4.64 µmol · $g^{-1}$ FM. At 6 DAT, T5 showed the strongest reduction (lowest value recorded); in the subsequent evaluations at 7, 13, 20 and 34 DAT, there were small variations in the carbohydrate concentration of the different treatments. On the last evaluation date (46 DAT), T6 presented the highest carbohydrate concentration of leaf (102.54 µmol · $g^{-1}$ FM), while T2 represented the lower average (60.67 µmol · $g^{-1}$ FM).

According to Da Cunha et al. (2022), the higher carbohydrate concentration during the initial flowering stage, the period in which panicles are formed, may be due to the higher activities of hydrolytic enzymes and also the mobilisation of leaf metabolites for the panicle development. Davenport (2007) infers that those carbohydrates when accumulated in ideal amounts in leaves can provide the necessary energy for reproductive development, especially for panicle formation. Thus, as can be seen in Figure 3, the carbohydrate concentration peak in the early stages (0–5 DAT) indicates that the treatments enable the plants to obtain more uniform and vigorous flowering. In addition, carbohydrate metabolism provides energy to ATP synthesis, in addition to reducing agents and intermediate compounds that assist in $NO_{3-}$ assimilation (Phavaphutanon and

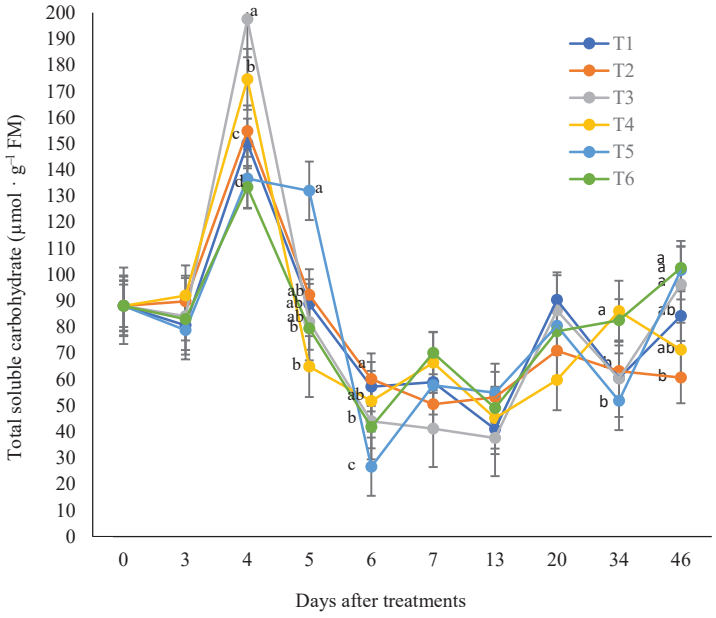


**Figure 3.** Total soluble carbohydrate concentrations (TSC) in "Palmer" mango leaves as a function of sunblock strategies and days after treatments. Points with the same lowercase letters do not differ on each evaluation date by Tukey's test at 0.01 probability level. Vertical lines indicate error bars. (T1) control (no sunblock); (T2) calcium carbonate (50 g · $L^{-1}$); (T3) sunblock (5 mL · $L^{-1}$); (T4) sunblock (5 mL · $L^{-1}$) + calcium carbonate (50 g · $L^{-1}$); (T5) sunblock (5 mL · $L^{-1}$) + sunblock silicon concentrated (20 mL · $L^{-1}$) and (T6) sunblock (20 mL · $L^{-1}$).

Krisanapook, 2000) which justifies the reduction of its contents during the initial panicle development (5–13 DAT), as it constitutes a strong drain.

For leaf starch contents (Figure 4A), unlike what happened for the total soluble carbohydrate concentration, the treatments peaked on different evaluation dates, i.e., the peak for T1, T2, T3 and T4 was recorded at 3 DAT, while T5 and T6 showed a low increase on that date when compared with the control. The evaluation at 4 DAT was the only one in which the treatments were affected by treatments, where T6 was superior to the other treatments, with an increase of 323.14% in relation to its content in the previous evaluation date; however, its value at 5 DAT returned to decrease. The variations recorded at the later dates did not promote significant changes in the comparisons between treatments. Regardless of when they reached their highest values, all treatments showed an increase in the initial phase, indicating that even after the end of induction, starch continued to be accumulated. The concomitant reduction at the beginning of panicle development was reported by Urban et al. (2004) who evaluated the starch concentration of those leaves close to the floral buds and verified a reduction of 74% at 5 days after the flowering beginning; according to Ruiz et al. (2001), the starch content during pre-flower stage is one of the most important factors for flowering and fruit development. Thus, T6, by promoting the highest starch content, enabled better conditions for flowering.

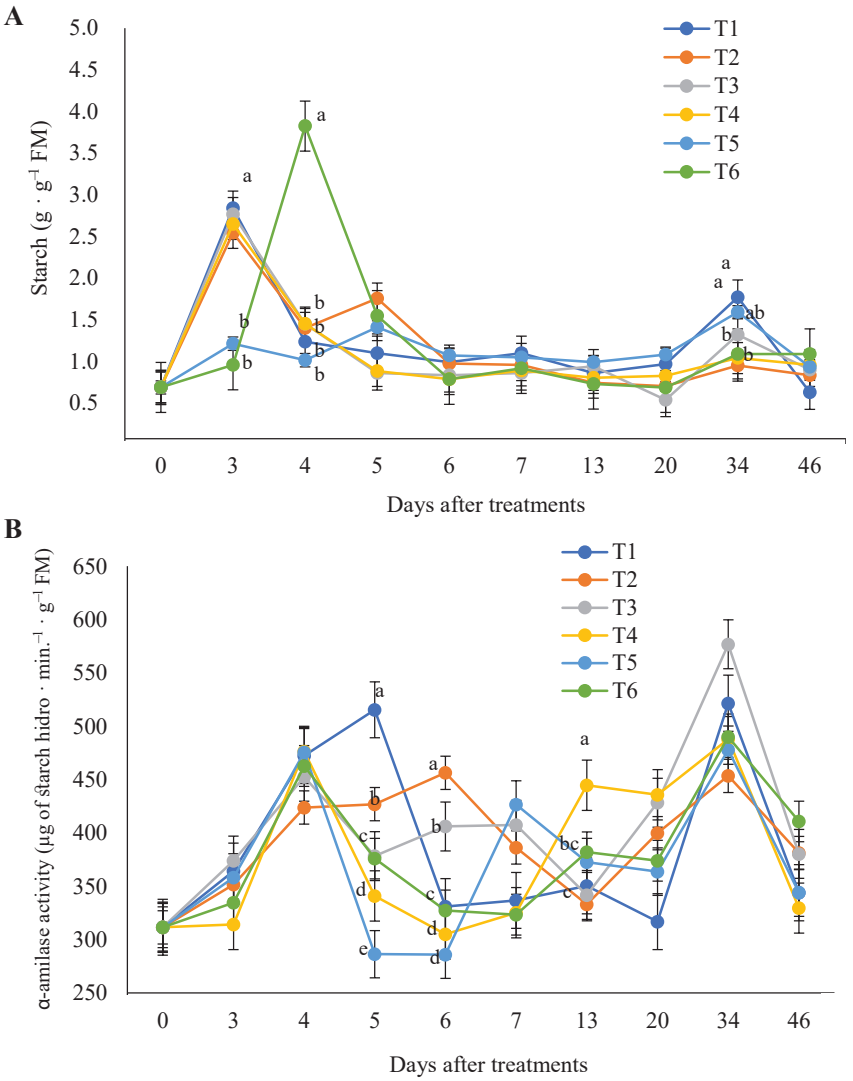


**Figure 4.** Leaf concentrations of starch (A) and α-amylase activity (B) of "Palmer" mango trees as a function of sunblock strategies and days after treatments. Points with the same lowercase letters do not differ on each evaluation date by Tukey's test at 0.01 probability level. Vertical lines indicate error bars. FM = fresh mass; (T1) control (no sunblock); (T2) calcium carbonate (50 g · $L^{-1}$); (T3) sunblock (5 mL · $L^{-1}$); (T4) sunblock (5 mL · $L^{-1}$) + calcium carbonate (50 g · $L^{-1}$); (T5) sunblock (5 mL · $L^{-1}$) + sunblock silicon concentrated (20 mL · $L^{-1}$) and (T6) sunblock (20 mL · $L^{-1}$).

The results of α-amylase were not affected by treatments on the evaluated dates (Figure 4B); it is clear that for all treatments there was an increase of up to 4 DAT, with different data distributions in the subsequent evaluations; the control treatment however continued increasing to 5 DAT; the second peak for all treatments occurred at 34 DAT, followed by a sharp reduction at 46 DAT, the stage in which the second physiological fruit fall occurred.

As can be seen in Figure 5A, the activity of the CAT enzyme was significantly affected by the treatments evaluated on the different evaluation dates. When comparing the treatments specifically on the dates when there was a significant effect (4, 6, 7 and 46 DAT), it is impossible to identify different responses depending on the time of assessment. Initially, the CAT activity was significantly reduced by T2, characterising this effect as a physical barrier with a short-lasting effect, since CAT remains relatively high in this treatment and presents activity quite high at 46 days DAT. At the same time, the T6 treatment, in addition to providing a significant increase in CAT activity 4 days after application, keeps it among the lowest values on the other dates, even with the lowest activity at 46 DAT. In general, when comparing the values of CAT (Figure 5A) with net photosynthesis (Figure 2A), especially for T1 and T6, an inversely proportional correction is observed, that is, on the dates when the enzymatic activity of CAT was high net photosynthesis was lower, which can be characterized as indicative of abiotic stress.

It is pertinent to infer that CAT is the most active enzyme produced by nature and converts $H_2O_2$ into $H_2O$ and $O_2$. In plants, catalases are present in various isoforms and are the main $H_2O_2$ detoxification enzymes able directly dismute $H_2O_2$ or oxidize substrates, such as methanol, ethanol, formaldehyde and formic acid

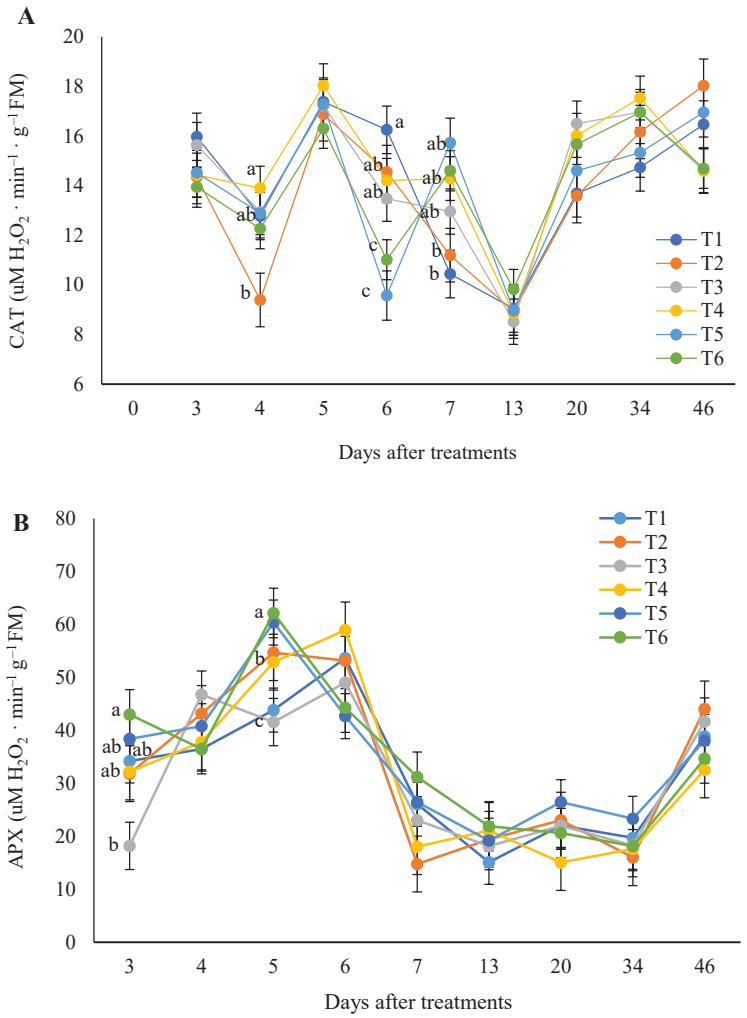


**Figure 5.** Leaf activity of catalase – CAT (A) and ascorbate peroxidase – APX (B) enzymes of "Palmer" mango trees as a function of sunblock strategies and days after treatments. Points with the same lowercase letters do not differ on each evaluation date by Tukey's test at 0.01 probability level. Vertical lines indicate error bars. (T1) control (no sunblock); (T2) calcium carbonate (50 g · $L^{-1}$); (T3) sunblock (5 mL · $L^{-1}$); (T4) sunblock (5 mL · $L^{-1}$) + calcium carbonate (50 g · $L^{-1}$); (T5) sunblock (5 mL · $L^{-1}$) + sunblock silicon concentrated (20 mL · $L^{-1}$) and (T6) sunblock (20 mL · $L^{-1}$).

(Nunes Júnior et al., 2017). Thus, higher plant CAT activity values indicate higher $H_2O_2$ concentration and, consequently, greater plant stress.

CAT and APX are very important enzymes among the $H_2O_2$ detoxification components (Bhatt and Tripathi, 2011). The action of CAT and peroxidases highlights the basic difference between the two main metabolic pathways of cell $H_2O_2$. The $H_2O_2$ removal by peroxidases requires a small reducing molecule (or proteins such as cytochrome and/or thioredoxin) to act as a regeneration cofactor and does not lead to the evolution of $O_2$ because water is the product of the reaction (Mhamdi et al., 2012).

The APX activity was significantly affected by the application of treatments only on two evaluation dates (3 and 5 days after the application of treatments), as shown in Figure 5B. When comparing the CAT and APX results in Figure 5, it is possible to infer that CAT presented results contrary to those presented for APX, especially T1 and T6. According to Herzog and Fahimi (1976), the activity conditions for these enzymes are different; therefore, in a medium that is conducive to the activity of one of the enzymes, it is not conducive to another, which explains the opposition of the results presented. This is because while APX has a high affinity with $H_2O_2$, with a Michaelis–Menten (KM) constant in the order of µM, allowing the elimination of $H_2O_2$ even at low concentrations, CAT has a high KM for $H_2O_2$; thus, it only acts when this molecule is found in high concentrations. This may explain, for example, the fact that APX activity (Figure 5A) was higher than CAT activity (Figure 5B).

When compared with the results of Cunha et al. (2022), also in a study with mango, the averages contained in Figure 5 are much lower since the referred author recorded values between 60 and 120 (µM $H_2O_2 \cdot min^{-1} \cdot g^{-1}$ FM). On the other hand, it should be noted that the study by Cunha et al. (2022) was carried out during the "branch maturation" phase, when characteristically there is a reduction in water depth in the mango crop. On the other hand, the lowest data quoted in Figure 5A are compatible to results of Silva et al. (2020) who evaluated the use of a plant biostimulant containing yeast extract and amino acids to alleviate abiotic stress in mango cv. Tommy Atkins, grown in semiarid environment.

### *Visual aspects*

In relation to the visual aspects of treatment effects on mango leaves, as can be seen in Figure 6, the sunblock treatments promoted different visual effects on leaf surface coverage, highlighting the dispersion of particles


**Figure 6.** Details of treatment distribution on leaves of "Palmer" mango trees as a function of sunblock strategies. (T1) control (no sunblock); (T2) calcium carbonate (50 g · $L^{-1}$); (T3) sunblock (5 mL · $L^{-1}$); (T4) sunblock (5 mL · $L^{-1}$) + calcium carbonate (50 g · $L^{-1}$); (T5) sunblock (5 mL · $L^{-1}$) + sunblock silicon concentrated (20 mL · $L^{-1}$) and (T6) sunblock (20 mL · $L^{-1}$).

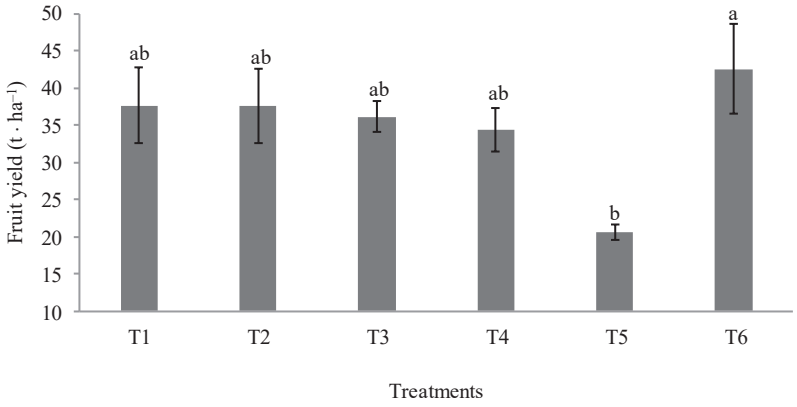


**Figure 7.** Fruit yield of "Palmer" mango trees as a function of sunblock strategies. Grey bars with the same lowercase letters do not differ by Tukey's test at 0.01 probability level. Vertical lines indicate error bars. (T1) control (no sunblock); (T2) calcium carbonate (50 g · $L^{-1}$); (T3) sunblock (5 mL · $L^{-1}$); (T4) sunblock (5 mL · $L^{-1}$) + calcium carbonate (50 g · $L^{-1}$); (T5) sunblock (5 mL · $L^{-1}$) + sunblock silicon concentrated (20 mL · $L^{-1}$) and (T6) sunblock (20 mL · $L^{-1}$).

in T4, the lack of particles in T2 and the uniformity of coverage in T3, T5 and T6, composed only of protective films, without adding carbonates. It is important to note that even with the leaf coverage, the plant photosynthetic activity was not affected, as well as the silicon contained in T5 promotes a different leaf coverage pattern in relation to the other treatments, but that did not reflect in additional protection to the leaf tissue. In the field, there was no visual symptoms of plant oxidative stress (data not shown) to any treatment, instead of the differences shown in Figure 6.

### *Fruit yield*

Fruit yield (t · $ha^{-1}$) of mango was affected by sunblock treatments (Figure 7). Although the lack of significant difference among T1, T2, T3, T4 and T6, the fruit yield promoted by T6 (42.6 t · $ha^{-1}$) is 4.2 t · $ha^{-1}$ higher than that of T1 (control treatment), while that of T5 had the worst performance, even lower than the control treatment.

Differentially, T6 has the highest dose of a protective film (20 mL · $L^{-1}$), four times higher than that applied in T3, T4 and T5 (5 mL · $L^{-1}$); given the results, it can be seen that the addition of the protective film containing Si (T5) was not beneficial for fruit yield. The fruit yield of T6 is compatible to the best results of Cavalcante et al. (2020) who studied the metconazole on inhibition of gibberellin biosynthesis and flowering management in "Palmer" mango; but the fruit yield of T6 is lower than that of the results of Silva et al. (2021) who evaluated the PBZ interaction with fulvic acids and free amino acids for mango, but it is important to detach that this last manuscript was performed with "Keitt" mango cultivar, which traditionally is a more productive cultivar in comparison with "Palmer".

## CONCLUSIONS

1. The results indicate a clear action of sunblock in attenuating the abiotic stress of mango, with a persistent effect with time elapsing, considering the evaluated interval.
2. The sunblock clearly promotes a differentiated leaf coverage pattern, protecting the photosynthetic apparatus and increasing its performance and consequently improving the production of plant reserves.
3. The use of calcium carbonate individually promotes a very short protective effect, without positive reflexes after a few days of application.
4. Mango fruit yield is affected by the sunblock with an increase of 4.2 t · $ha^{-1}$ from the treatment with sunblock (20 mL · $L^{-1}$) in relation to the control treatment.

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## AUTHOR CONTRIBUTIONS

A.R.L.S., V.B.P.N. and I.H.L.C. designed experiments and performed analytical measurements. I.H.L.C. performed statistical analysis. M.A.S., R.A.A. and L.Y.A.A. A.S. and G.P. performed analytical measurements. All authors equally contributed to manuscript writing.

## CONFLICT OF INTEREST

The authors declares no conflict of interest.

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