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Plant Protection

Response of 'Prata-anã' banana to post-harvest phosphite application

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Abstract - The objective of the present study was to determine the best phosphite source and concentration to control anthracnose and its effects on the physical and chemical characteristics of 'Prata-anã' banana. Bouquets of banana fruits were immersed in solutions containing different formulations of copper phosphite FCu1 (4% Cu + 20% P_2O_5), FCu2 (4% Cu + 22% P_2O_5) at concentrations of 0.5; 1.0, 1.5- and 2.0-mL L^{-1} and potassium phosphite FK (42% P2O5 + 27.7% K_2O) at concentrations of 0.5; 1.0, 1.5 and 2.0 mg L^{-1}. Controls consisted of the application of pure water and Imazalil application (0.5 mL. L^{-1}). Subsequently, anthracnose incidence and severity were evaluated every three days. The physical and chemical characteristics of fruits were evaluated at the end of the anthracnose intensity evaluation. The experimental design used was completely randomized. The results showed that the different phosphite sources FCu1, FCu2 and FK at the concentrations tested were not effective in controlling anthracnose. The physical and chemical characteristics of fruits were influenced by the different phosphite sources and concentrations applied. Fresh fruit mass loss is proportional to the applied phosphite concentration.

Index terms: *Musa* spp., post-harvest, *Colletotrichum musae.*

Respostas da banana 'Prata-anã' à aplicação de fosfitos em pós-colheita

Resumo - Objetivou-se com o presente estudo determinar a melhor fonte e concentração de fosfito no controle da antracnose e seus efeitos nas características físicas e químicas em banana 'Prata-anã'. Buquês de frutos de banana foram imersos em soluções contendo as diferentes formulações de fosfito de cobre FCu1 (4% de Cu + 20% de P_2O_5), FCu2 (4% de Cu + 22% de P_2O_5), nas concentrações de 0,5; 1,0; 1,5 e 2,0 mL L^{-1}, e fosfito de potássio FK (42 % de P_2O_5 + 27,7% de K_2O) nas concentrações de 0,5; 1,0; 1,5 e 2,0 mg L^{-1}. As testemunhas consistiram na aplicação de água pura e aplicação do Imazalil (0,5 mL.L^{-1}). Posteriormente, foram avaliadas a incidência e a severidade da antracnose a cada três dias. As características físicas e químicas dos frutos foram realizadas no término da avaliação da intensidade de antracnose. O delineamento experimental utilizado foi o inteiramente casualizado. Os resultados demonstraram que as diferentes fontes de fosfito FCu1, FCu2 e FK, nas concentrações testadas, não apresentaram eficácia no controle da antracnose. As características físicas e químicas dos frutos foram influenciadas pelas diferentes fontes e concentrações de fosfito aplicadas. A perda de massa fresca dos frutos é proporcional à concentração de fosfito aplicada.

Termos para indexação: *Musa* spp., pós-colheita, *Colletotrichum musae.*

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Introduction

Banana farming stands out in the Brazilian fruit farming activity as one of the most produced and consumed crops in all regions of the country. In 2021, the area cultivated with the fruit was 474,303 hectares, showing variation of 1.7% compared to 2020 and production of more than six million tons (IBGE, 2021). In the first quarter of 2021 alone, Brazil exported 9,600 tons of bananas to Mercosur (CAIRES; BARBIERI, 2021).

Despite the large production and consumption, bananas have high rate of post-harvest loss, which limits their marketing in the fresh form (SOUSA et al., 2018). One of the main causes of reduced fruit exports is the lack of technologies and inefficient control of post-harvest diseases.

Among the causes of post-harvest banana losses, anthracnose stands out. The disease is caused by the fungus *Colletotrichum musae* (Berk and Curtis) von Arx. The symptoms observed are dark and depressed lesions, which with the progress of the disease and under favorable environmental conditions such as high humidity, become covered with pink color (PESSOA; OLIVEIRA, 2006; PLOETZ; THOMAS, SLABAUGH, 2003).

The control of banana anthracnose is carried out with measures that prevent infection and the development of the pathogen (MAQBOOL et al., 2010). The various methods of disease management include reduction in fruit storage temperature (SILVA et al., 2008), application of chemical fungicides such as Thiabendazole, Imazalil and Azoxystrobin (strobilurin) + fludioxonil (phenylpyrrole), which are those recorded for post-harvest treatment (AGROFIT, 2021), and use of extracts and essential oils derived from plants with antifungal potential (RODRIGUES et al., 2021; RODRIGUES et al., 2018; OLIVEIRA et al., 2016; SILVA et al., 2008).

The application of chemicals to control pests and plant diseases is still the most used method in conventional fruit growing. The indiscriminate use of these products in the short term has a beneficial effect; however, in the long term, they can select resistant populations of pathogens, in addition to causing environmental problems and food contamination (BORSOI, et al., 2014; BETTIOL, 2011). Furthermore, the isolated use of fungicide does not guarantee total anthracnose control, and the interaction of available methods and also the prospection of new control strategies is recommended.

Thus, some alternative methods for controlling post-harvest diseases have been researched. Among alternative methods that have shown potential in anthracnose control is the use of phosphites. These substances are capable of inhibiting mycelial growth and sporulation of different pathogens and/or inducing plant defense mechanisms (JACKSON et al., 2000).

The fungicidal and fungistatic effect of potassium salts has been demonstrated in several pathosystems (DUTRA et al., 2018; SPOLTI et al., 2015; LOPES et al., 2017; FISCHER et al., 2016; RODRIGUES et al., 2020). However, there are no studies in literature related to copper phosphite to control anthracnose in bananas by post-harvest application.

Due to the evidence of the potential of phosphites in the control of phytopathogens, the objective of the present study was to determine the best phosphite formulation and concentration to control anthracnose in 'Prata anã' banana and its effects on the physical and chemical characteristics of fruits.

Material and methods

The fruits used in tests were harvested in a commercial ´Prata anã´ banana plantation in the municipality of Nova Porteirinha - Minas Gerais, at 15°41'21.4"S and 43°16'23.3"W, with average altitude of 500 m a.s.l., average annual rainfall of 800 mm, and Aw type climate, according to the international Köppen classification (tropical savannah) (ANTUNES, 1986).

Bunches were harvested in the pre-climacteric stage, according to the Von Loesecke scale (PBMH; PIF, 2006). The second and third hands of each bunch were selected to standardize fruits. Bunches were packed in plastic boxes and transported to the Laboratory of Post-Harvest Pathology. Subsequently, they were divided into bouquets of three fruits, washed in solution of neutral detergent and water (3 $mL.L^{-1}$). Then, they were rinsed and placed on the bench and air dried.

Fruits were inoculated with a spore suspension at concentration of $2.5x10^5$ spores. mL^{-1} using a micropaint gun to the run-off point. To prepare the conidia suspension, *C. musae* was indirectly isolated in Potato Dextrose Agar (PDA) culture medium using 'Prata anã' banana fruits showing anthracnose symptoms. After the mycelial growth had reached the entire plate (seven days of cultivation), the spore suspension was prepared. Then, a drop of the suspension was collected to count the number of conidia in field C of the Neubauer chamber, which was performed using a microscope and the concentration of the suspension applied to fruits was adjusted to $2.5x10^5$ spores. mL^{-1}.

After inoculation, fruits were kept in humid chamber (relative humidity of 95%) for 15 hours. After removing bouquets from the humid chamber, they were immersed in solutions containing treatments for five minutes. Treatments consisted of dilution in water of copper phosphite FCu1 (4% Cu + 20% P_2O_5) and FCu2 (4% Cu + 22% P_2O_5) at concentrations 0.5; 1.0, 1.5 and 2.0 mL L^{-1} and potassium phosphite FK (42% P_2O_5 + 27.7% K_2O) at concentrations of 0.5, 1.0, 1.5 and 2, 0

mg. L^{-1}. Then, they were placed to dry on the bench. Controls consisted of the immersion of fruits in pure water and in Imazalil solution at concentration of 0.5 mL. L^{-1}. Subsequently, fruits were taken to the refrigerated chamber at temperature of 25°C ± 1°C and relative humidity of 80 ± 5%, where they remained for 12 days.

The experiment was carried out in a completely randomized design in a factorial scheme with three phosphite formulations (FCu1, FCu2 and FK), four concentrations (0.5; 1.0, 1.5 and 2.0 mL L 1 and mg. L^{-1}) and controls (bananas treated only with water and with fungicide Imazalil (0.5 mL L^{-1}) respectively. Four replicates were used, each consisting of a bouquet of three fruits.

Anthracnose intensity was evaluated by incidence and severity. Incidence was obtained by the number of diseased fruits per replicate, with values being expressed as percentage per treatment. For severity, the diagrammatic scale developed by Moraes et al. (2008) was used, with disease severity ranging from 0.5 to 64%. Results were used to calculate the areas under the incidence progress curve (AUIPC) and area under the severity progress curve (AUSPC), according to formula developed by Shaner and Finney (1977). Assessments were performed every three days during a 12-day period.

At the end of the anthracnose intensity evaluation, fruits were removed from the refrigerated chamber and submitted to physical and chemical analyses. The variables analyzed were:

Fresh mass loss: Each bouquet was weighed on GEHAKA electronic scale, model BK6000, with capacity of 6100g and precision of 0.01g, on the day of storage and on the day fruits were removed from the refrigeration chamber. Fresh mass loss was determined by the difference between initial weight and final weight of fruits. Results were expressed as fresh mass loss percentage (%).

Soluble solids (SS): The quantification of soluble solids (SS) was performed after grinding the pure pulp in a Mixer. An aliquot was collected from the pulp for direct reading in a Reichert digital bench refractometer (AR200), with automatic temperature compensation. After reading, the refractometer provided the results in °Brix, which correspond to grams of sucrose per 100 g of solution and can generally be used as grams of soluble solids per 100 g of solution (CARVALHO et al., 1990).

pH: The determination of the hydrogenic potential (pH) was carried out according to methodology of the Association of Official Analytical Chemistry – AOAC (1992). About 10g of sample were weighed, diluted in 90 mL of distilled water and homogenized in a mixer. The pH was measured using digital pH meter, calibrated with buffer solution pH 7 and buffer solution pH 4.

Titratable acidity (TA): Titratable acidity was determined by volumetric titration with 0.1N NaOH solution by methodology of the Association of Official Analytical Chemistry (AOAC, 1992). About 10 g of pulp were weighed and diluted in 90 mL of distilled water, homogenized with the aid of a mini processor and 3 drops of 1% phenolphthalein, used as indicator, were added. Titration with sodium hydroxide was carried out with constant agitation until obtaining pink color for 30 seconds in the titrate. Results were expressed as g of malic acid per 100g of $pulp^{-1}$.

Fruit with peel firmness: Fruit firmness was determined with Brookfield analogue bench penetrometer, model CT3 10K, being measured by the force necessary for a tip of 4 mm in diameter to penetrate the equatorial region of the fruit with peel, at depth of 8 mm. Results were expressed in Newton (N).

Data obtained were submitted to analysis of variance and, by means of the F test, the significance of interactions between tested factors was verified, with subsequent unfolding for significant results. Regression analysis was performed for the quantitative factor (concentration), and regression models were selected based on the significance of regression coefficients by the t test, on the determination coefficient and on the biological behavior ($p< 0.05$). The Tukey test was also performed for qualitative data ($p<0.05$) and the Dunnett's test ($p<0.05$) to compare control data (fruits immersed in water and fruits treated with Imazalil). Analyses were performed using the R software (R CORE TEAM, 2016).

Results and discussion

Table 1 presents the results of treatments with phosphite formulations compared to controls using the Dunnett's test at 5% probability for physical and chemical variables and assessment of disease intensity. Evaluating the anthracnose severity, it could be observed that only the concentration of 1.5 mL. L^{-1} of all formulations tested showed results similar to fungicide Imazalil in controlling the disease, which demonstrates that for severity, formulations and concentrations tested were not efficient in controlling this variable. Oliveira et al. (2016) obtained similar results applying 300µL of potassium phosphite on bananas and obtaining 28% anthracnose inhibition, while the fungicide used controlled 100% of the disease.

Table 1. Means of treatments compared by the Dunnett's test for the following variables: fresh mass loss (FML), pH, titratable acidity (TA), firmness (FIR), soluble solids (SS), Area under the severity progress curve (AUSPC), area under the incidence progress curve (AUIPC), of 'Prata anã' bananas, treated in post-harvest with different phosphite formulations and concentrations.

TREATMENT		PMF	pH	TA	FIR	SS	AUSPC	AUIPC
		%		g mallic acid 100g pulp^{-1}	N	° Brix		
FCu1	**0.5**	2.73 ^{A}	4.99	0.23	8.21	20.55	222.75 ^{B}	322,50
	1.0	5.07	5.06	0.22	5.64	23.18	261.00 ^{B}	335,25
	1.5	5.48	4.93	0.23	6.37	23.73	186.00	260,63
	2.0	7.60 ^{B}	4.91	0.23	5.64	23.90	274.88 ^{B}	348,00
FCu2	**0.5**	7.09	5.13	0.27	7.35	22.63	220.50 ^{B}	297,75
	1.0	6.39	4.94	0.25	6.13	23.70	250.88 ^{B}	298,50
	1.5	3.92	4.77	0.23	6.37	22.65	172.50	235,88
	2.0	8.83 ^{B}	5.14	0.30 ^{A}	4.17	22.53	309.00 ^{B}	360,00
FK	**0.5**	7.02	5.54 ^{B}	0.20	4.66	21.90	313.50 ^{B}	372,75
	1.0	7.64 ^{B}	5.22	0.20	5.64	22.50	247.50 ^{B}	330,00
	1.5	6.26	4.98	0.29 ^{A}	7.11	22.48	147.38	220,50
	20	787 ^{B}	5.28	0.19	4.41	20.95	360.00 ^{B}	420,00 ^{B}
Water		7.08	5.13	0.19	5.15	22.15	282.00	316.50
Imazalil		3.26	4.96	0.23	7.84	21.93	54.00	204.00

Means of treatments followed by letter A and letter B differ statistically from water and Imazalil controls by the Dunnett's test ($p<0.05$), respectively.

According to Blum et al. (2007), disease control through the application of phosphites would result from a mixed action involving fungistasis and also the activation of the plant's defense system through phytoalexins. In the present experiment, the mode of action of phosphites in fruits was probably through the direct effect on the pathogen, since phosphites were applied after harvest after *C. musae* inoculation.

Analyzing anthracnose incidence (Table 1), it could be verified that no treatment reduced the disease incidence when compared to control with water; only the concentration of 2 mg. FK L^{-1} showed higher anthracnose incidence compared to Imazalil. Working with 'Prata anã' banana fruits, Rodrigues et al. (2020) found that the use of potassium phosphite was not efficient in controlling anthracnose incidence, since the results obtained did not differ statistically from control. Different results were obtained by Spolti et al. (2015), who worked with apples and observed a 35% reduction in bull's eye rot by the application of potassium phosphites in the final ripening period.

For AUSPC (Figure 1) and AUIPC (Figure 2), no interaction was observed between phosphite sources and concentrations used. Significance was found only for the different concentrations ($p<0.05$).

Decrease in disease severity and incidence was observed in both variables, followed by increase after the use of higher concentrations. This behavior can be explained by the fact that the content of soluble solids of fruits in all phosphite sources used increased with the increase of the applied dose (Figure 3). As *Colletotrichum musae* is a quiescent fungus, its infection mechanism is characterized by waiting for the host to present morphological, biochemical and physiological changes that allow its development, as the fungus needs soluble sugars to develop (BARKAI-GOLAN, 2001).

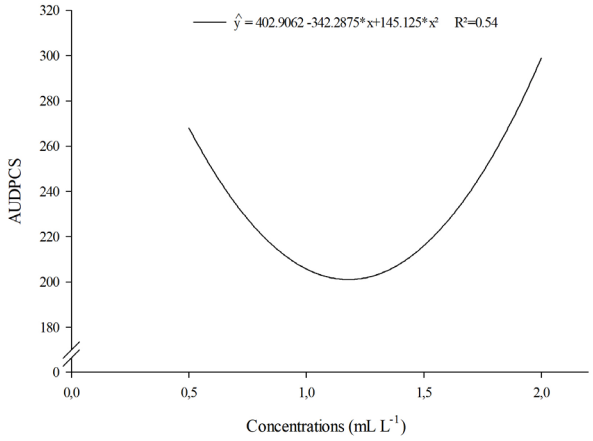

Figure 1. Area under the severity progress curve (AUSPC) of anthracnose in 'Prata-anã' banana submitted to different phosphite concentrations (* significant at 5% and ** significant at 1% by the t test).

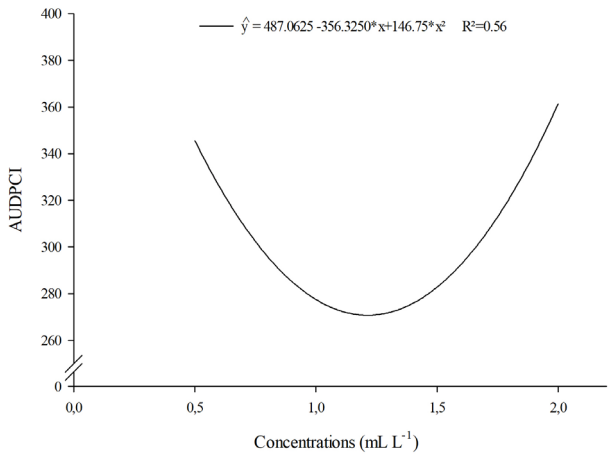

Figure 2. Area under the incidence progress curve (AUIPC) of anthracnose in 'Prata-anã' banana submitted to different phosphite concentrations (* significant at 5% and ** significant at 1% by the t test).

In AUSPC, the concentration at which the lowest severity was obtained was 1.18 mL. L^{-1}, showing AUSPC of 201 (Figure 1). For AUIPC, the lowest value found was 270 in fruits submitted to concentration of 1.21 mL. L^{-1} (Figure 2).

The results obtained in this study were different from others reported in literature, since greater control of phytopathogens with increasing doses of phosphites was verified in other pathosystems. Amaral et al. (2017) found that when increasing doses of calcium, potassium, ammonium phosphites and the association of calcium phosphite with boron phosphite, greater reduction in anthracnose severity was observed in papaya 'Sunrise Solo' cultivar. The same result was observed by Pereira et al. (2012) when working with two potassium phosphite formulations on vine downy mildew.

Effect similar to that obtained in this experiment was observed by Ferraz et al., (2016) working with potassium phosphite to control anthracnose in guavas. The authors found that the doses of 1.0- and 1.5-mL L^{-1} of FK were more efficient in reducing the diameter of lesions caused by *Colletotrichum gloeosporioides* when compared to the dose of 2.0 mL L^{-1}.

By analyzing anthracnose incidence and comparing the results of this research with results found by Alexandre et al. (2014), it could be concluded that results are conflicting, as the authors found that increasing the concentration of calcium, potassium, magnesium, zinc and copper phosphites reduces anthracnose incidence from quiescent field infections in scarlet eggplants. Blum et al. (2007) reported that by increasing the doses of potassium and calcium phosphite, the incidence of blue mold in apples was reduced.

The incidence of pathogens varies according to fruit development stage and storage conditions, so it is important to identify the ideal time for control (SAUTTER, 2008). Thus, Araújo et al. (2008) recommends that phosphite application should be carried out throughout the plant cycle.

Spolti (2015) tested the association of potassium phosphite with fungicide to control the incidence of bull's eye rot in apples and found that when the treatment was applied 24 hours before harvest, there was no control at the time of harvest. However, after 3 months of conservation, 40% reduction in the disease incidence was verified, while control showed 30% reduction.

The results obtained in the physical and chemical characterization of fruits are shown in Table 1. It was verified that the fresh mass loss in treatments using FCu1 and FCu2 at concentration of 2.0 mL. L^{-1} and FK at concentration of 1.0 mg. L^{-1} showed difference from treatment in which Imazalil was applied, by the Dunnett's test ($p < 0.05$). This result indicates that in fruits treated with different phosphite formulations, fresh mass loss was superior to those treated with the fungicide. Phosphites are presented in the form of salt and, therefore, greater water loss may have occurred through the osmotic dehydration process in fruits treated with the different formulations when compared to control. In FCu1 at concentration of 0.5 mL.L^{-1}, difference from the absolute control was observed, indicating that PMF was reduced when applying this treatment.

An isolated effect of phosphite sources was verified (Table 2). Fruit PMF was higher in treatment in which FK was applied. This loss occurs due to the elimination of water in the transpiration process caused by the vapor difference between the fruit and the ambient air (SOUZA, 2000).

Table 2. Fresh mass loss (FML) of fruits submitted to different phosphite formulations.

Phosphite sources	PMF(%)
FCu1	5.22 a
FCu2	6.55 ab
FK	7.20 b

Means followed by the same letter in columns do not differ from each other by the Tukey's test at 5% significance level.

Ferraz et al., 2016 worked with guava fruits and reported lower fresh mass loss in fruits from conventional cultivation treated with calcium and magnesium phosphite. However, Lopes (2017) worked with papaya and found that there was no difference between phosphite sources (Mg, K, Ca, Zn) for fresh mass loss. Santos et al. (2006) reported that mass loss becomes an important factor to be taken into account, as it is directly linked to the commercial aspect of fruits, which are marketed according to weight.

The fresh mass loss of fruits also presented an isolated effect in the different phosphite concentrations applied (Figure 4, $p<0.05$). It was verified that when increasing phosphite concentrations, the fresh mass loss of fruits increases linearly. The water rate that can be lost without fruit deterioration is variable for each species; however, it should not exceed 10% (CHITARRA; CHITARRA, 2005). Considering the above, the values found in this study are within standards required to avoid fruit deterioration.

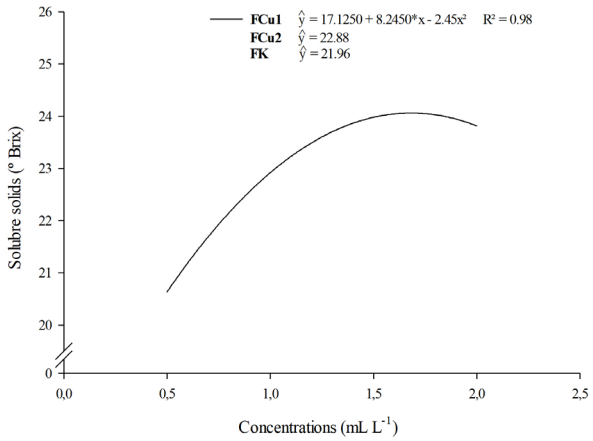

Figure 3. Content of soluble solids of 'Prata-anã' banana pulp submitted to different phosphite formulations at different concentrations (* significant at 5% and ** significant at 1% by the t test).

The results obtained by Dutra et al. (2018) demonstrated that phosphite concentration did not affect PMF in passion fruits treated with zinc and potassium phosphites, since no difference was found in treatments submitted to concentrations of 1.5 and 2.5 mL.L^{-1}.

Water is found in greater proportions in unripe fruits, which with ripening, tend to reduce with increased transpiration (LUCENA, 2004). Post-harvest evaluations were carried out on the last day of storage, so fruits were already at maximum ripeness. Mass loss is common during the storage of fruits and vegetables, which occurs due to the consumption of nutrients through the metabolism and mainly due to water loss caused by the transpiration process and to the difference in vapor pressure between the product and the environment (SARMENTO et al, 2015).

For variable pH, only FK at concentration of 0.5 mL. L^{-1} showed difference from fruits treated with Imazalil (Table 1). An isolated effect of phosphite sources (Table 3) and applied concentrations (Figure 5) was verified. No interaction was observed between factors tested ($p<0.05$). In this experiment, variation from 4.97 to 5.26 in the pH of fruits was observed (Table 3).

Table 3. pH values of fruits submitted to different phosphite formulations.

Phosphite sources	pH
FCu1	4.97 a
FCu2	4.99 a
FK	5.26 b

Means followed by the same letter in columns do not differ from each other by the Tukey's test at 5% significance level.

Results observed by Pereira et al. (2012), working with 'Merlot' grapes are different from those obtained in this experiment since the authors reported that the potassium phosphite sources used did not influence the pH of fruits in two analyzed harvests. Ferraz et al. (2016) reported that among phosphites tested (calcium, zinc, magnesium and potassium) only zinc phosphite increased the pH of guavas from 4.3 to 4.6.

Analyzing Figure 5, it is possible to verify a decrease in pH with subsequent increase when increasing the concentrations of phosphite formulations applied. At concentration of 1.39, the lowest pH value of 4.95 was obtained, and when applying concentration of 2 mL.L^{-1}, the pH increased to 5.1.

The pH values obtained in this study are different from those reported by different authors. The pH obtained for ripe bananas ranges from 4.13 to 4.98 (SANTOS et al., 2018; SOUSA, 2018; SIQUEIRA et al., 2017, SIQUEIRA et al., 2010).

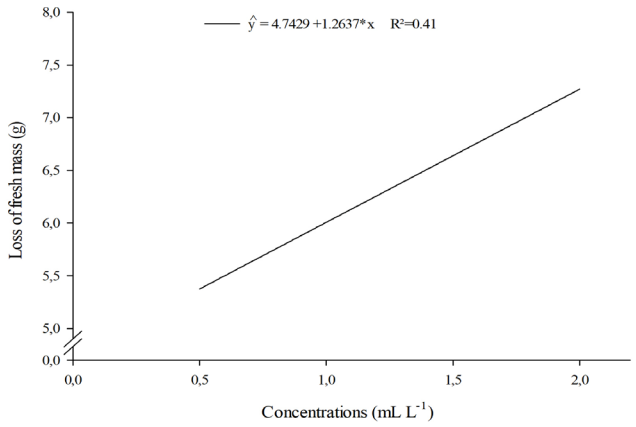

Figure 4. Fresh mass loss (%) of 'Prata-anã' banana submitted to different phosphite concentrations (* significant at 5% and ** significant at 1% by the t test).

The pH behavior of bananas is different from other fruits, and in most of them during ripening, the acid concentration decreases as a result of its use as a substrate in the respiratory process or its conversion into sugar (KADER et al. 2002). As bananas are rich in starch and carbohydrate reserves, which are used in the metabolic processes of respiration, these compounds are not used during ripening (CHITARRA; CHITARRA, 2005). When evaluating titratable acidity, treatments FCu2 at concentration of 2.0 mL. L^{-1} and FK at concentration of 1.5 mg L^{-1} showed difference from control in which pure water was applied, indicating that treatments increased the malic acid content in the fruit pulp (Table 1).

Figure 6 shows interaction between phosphite concentrations and sources tested. Increase in titratable acidity is observed with subsequent reduction when the FK concentration is increased. For the other phosphite sources (FCu1 and FCu2), there was no significant regression model for these treatments.

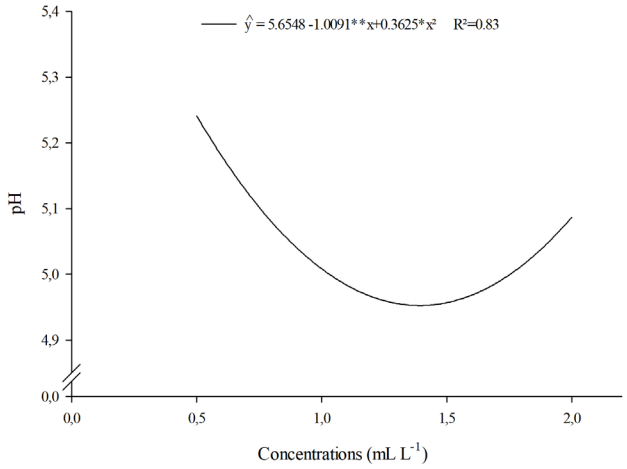

Figure 5. pH values of 'Prata anã' banana pulp submitted to different phosphite concentrations (* significant at 5% and ** significant at 1% by the t test).

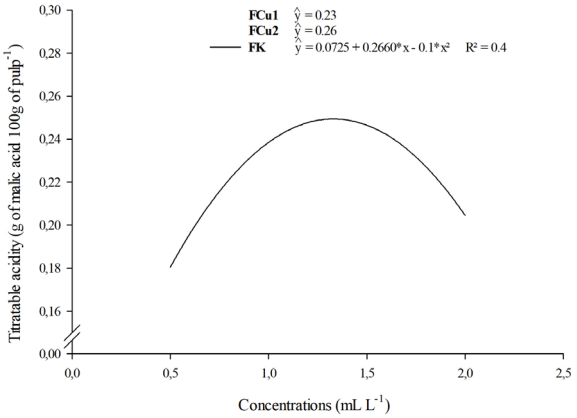

Figure 6. Titratable acidity (g of malic acid 100g of pulp-1) of 'Prata-anã' banana submitted to different phosphite formulations at different concentrations (* significant at 5% and ** significant at 1% by the t test).

According to Pimentel et al. (2010), the acidity of fruits can decrease or increase, depending on the species and the organic acids that are used in respiration for the production of ATP. This results in decrease in the acidity of fruits, as well as the respiratory process itself, which produces organic acids that can accumulate in fruits, causing a slight increase in their acidity. The decline in TA observed in this experiment may be associated with the maturation stage of fruits, since they were already at stage 7 when analyses were performed.

In bananas, unlike most fruits, titratable acidity increases during fruit storage and ripening (ALENCAR et al., 2010).

The acceptance of bananas by consumers is significantly influenced by their chemical composition, mainly by acids, sugars and phenolic compounds (BOLFARINI, 2018). According to Souza et al. (2013), the consumer market showed lower preference for fruits that presented the highest acidity.

Analyzing variables firmness and soluble solids, there was no statistical difference between treatments when compared to controls. Firmness also showed no statistical difference between phosphite sources as well as their concentrations ($p<0.05$).

For soluble solids, significant interaction between phosphite doses and formulations was observed (Figure 3, $p<0.05$). Increase with subsequent decline was observed when increasing the phosphite concentration.

Soluble solids indicate the amount of solids that are dissolved in the fruit pulp, which are mainly composed of sugars. Its content varies according to the species, cultivar, maturation stage and climate (CHITARRA; CHITARRA, 2005).

During ripening, there is increase in SS as a result of the transformation of insoluble polysaccharides into soluble sugars (BLEINROTH, 1995; CHITARRA; CHITARRA 2005). When unripe, banana is a fruit with high starch content and as it ripens, the starch is broken down into sugars to be used in the respiration process, increasing the content of soluble solids (PIMENTEL et al., 2010).

A different effect was found by Lopes et al. (2017), applying Mg, K, Ca, Zn phosphites to papaya, in which the authors found that the content of soluble solids was not influenced by phosphites. Fontana et al. (2018) found that the application of 2.0 ml L^{-1} of potassium phosphite in peach did not influence the SS content.

Conclusions

The phosphite sources and concentrations tested were not effective in controlling anthracnose.

Fresh mass loss is proportional to the applied phosphite concentration.

The physical and chemical characteristics of fruits were influenced by the different phosphite sources and concentrations applied.

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