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PRODUCTIVITY AND MORTALITY, OF *Fusarium oxysporum f. sp. passiflorae* IN PASSIONFRUIT VINES BRS RUBI DO CERRADO, GRAFTED ONTO DIFFERENT ROOTSTOCKS

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Abstract

The use of scions grafted onto passionfruit vines has become an alternative to their cultivation in areas with a history of fusariosis. However, the combinations between the graft and rootstock can influence on the productivity and longevity of the passionfruit farm. The objective was to evaluate the productivity and mortality of the passionfruit cv BRS Rubi do Cerrado grafted onto three species of rootstock in Terra Nova do Norte-MT. The design was a randomized block with 4 treatments BRS Rubi do Cerrado (BRS-RC) seedling plant along with those grafted onto three species of rootstock: *Passiflora gibertii*, *Passiflora alata*; *Passiflora nitida*. The scions were grafted through a cleft graft and the planting performed after 70 days. The evaluation was made of the total number and weight of the fruits, along with productivity and mortality of plants. Results showed that the BRS-RC, grafted onto *P. gibertii* and *P. nitida,* presented the best performance for weight of fruits, number of fruits and productivity. The cultivar that was grafted onto different rootstocks presented higher productivity in regards to the seedling plant. The BRS-RC, grafted onto *P. nitida,* presented a zero-mortality rate over the 16.5 months of cultivation. The rootstocks *P. nitida* and *P. gibertii* were superior to those of *P. alata* in reducing mortality in the passionfruit vine by *Fusarium oxysporum* f. sp. *passiflorae*. The confirmation was made of the pathogen *Fusarium oxysporum* f. *passiflorae* isolated in the experimental area in scions of the BRS-RC inoculated at 70 days of age.

Keywords: Agronomic performance. Grafting. *Passiflora edulis* Sims.

1. Introduction

Brazil is the largest producer in the world of passionfruit with production, in 2020, of 690,364 tons, with a planted area of 46,436 hectares and a productivity mean of 14,867 kg ha^{-1}. In the state of Mato Grosso, in 2020, the area cultivated with passionfruit was 272 ha, with a production of 4,411 tons and productivity at 16.217 kg ha^{-1} (IBGE 2020). Despite productivity being above the national average, it still has not reached the production potential of the crop due to phytosanitary issues such as fusariosis

(Preisigke et al. 2014). This disease is caused by the fungus *Fusarium oxysporum* Schlecht. f. sp. *passiflorae* Purss and necrosis of the vascular system occurs, which causes wilting of branches, collapse and death of plants at any stage of development (Bueno et al. 2014).

Among the five yellow passionfruit cultivars tested in three municipalities of the state of Mato Grosso, the FB 200 and BRS Rubi do Cerrado reached a yield greater than 40 t ha^{-1}, thus expressing a high production potential. However, these production results were achieved by only one of the three evaluated municipalities, due to the attack from fusariosis on the others (Roncatto et al. 2019).

In regards to the passionfruit (*Passiflora edulis* Sims), the adoption of grafting allows the producer to cultivate passionfruit in areas that present a history of the fusariosis disease, since other techniques, until the current moment, have not shown satisfactory results (Silva et al. 2017). Over recent years, some results obtained through research were validated through commercial production. Highlighted here is the use of a selection of *P. alata* as a rootstock in commercial crops in Rio de Janeiro, *P. nitida* and *P. alata* in Mato Grosso, *P. gibertii* in Bahia and *P. foetida* in Rio Grande do Norte (Machado et al. 2015).

Despite the benefits in using scions grafted onto passionfruit vines, the practice is relatively recent, and still has not been incorporated as normal practice on this particular cultivation, the reasons for such are found in the oscillations concerning graft-take, along with little information regarding the development of plants in the field (Ambrosio et al. 2018). Worthy of note here is that there exists a genetic variation within the interaction between species of *Passiflora* and *Fusarium*. Adherence to the *Passiflora* species will not be completely effective in all areas with a history of fusariosis. Therefore, the use of a rootstock will depend on the validation of this technology under commercial conditions (Faleiros et al. 2019).

New technology and alternative methods for production systems of passionfruit vines should be offered to producers, the use of cultivars that are productive, resistant or tolerant to drought, as well as to pests, nematodes and diseases, such as fusariosis (*F. oxysporum* f. *passiflorae*), avoiding in this way the premature death of plants (Roncatto et al. 2019). Studies performed with genotypic evaluations, when faced with the pathogen population in the soil and in the passionfruit vine, under the different edaphoclimatic conditions of Mato Grosso, are fundamental to the advance of this crop in the state (Roncatto et al. 2019).

The objective of this study was to evaluate the productivity and mortality of passionfruit vines of the cultivar BRS Rubi do Cerrado, grafted onto three species of rootstock in the municipalities of Terra Nova do Norte, in the state of Mato Grosso.

2. Material and Methods

Localization and experimental conditions

The experiment was conducted from May 2018 to June 2019 in an area with a known history of fusariosis on the property Sepé Tiaraju, located on the geographical coordinates 10º31’680”S latitude and 55º05’840”W longitude. The altitude of the location is 250 m, in the eighth Agro-villa in Terra Nova do Norte, Mato Grosso. The climate type is Aw (humid subtropical), according to the classification by Köppen, with an average annual temperature of 25.2 ºC, annual precipitation of 1,348.3 mm and a rainy season that extends from November to March. Under this condition, one finds relative soil humidity estimates of around 80%. The soil around the experimental area is classified as Red-Yellow Podzolic, non-hydromorphic, with textural B horizons, yellowish-red in color, and undulating topography (EMBRAPA 2006).

Experimental design

The randomized blocks with four treatments were used with the cultivar BRS Rubi do Cerrado as a seedling plant and the combination of this cultivar as a passionfruit crown grafted onto three species of rootstock *Passiflora gibertii*, *Passiflora alata* and *Passiflora nitida*. Six repetitions were used totaling 24 plots, constituted of 8 plants each with a spacing of 3 x 3 m (3 m between plants and 3 m between planting lines).

Scion production

Obtainment of seeds and sowing

The scions were produced in a screened nursery (with 50% shade) from COOPERNOVA of Terra Nova do Norte-MT, using seeds that came from the germplasm bank of EMBRAPA CERRADOS. The seeds of the rootstocks *P. alata, P. nitida,* were obtained by means of fruits collected through the fruit collection realized by Coopernova. The seeds of *P. gibertii* were obtained from the germplasm bank of Embrapa Cassava & Fruits (Embrapa Mandioca e Fruticultura) and the seeds of the cultivar BRS Rubi do Cerrado came from Embrapa Agrossilvopastoril.

For each rootstock specie, 22 trays containing 54 tubes were used, totaling 1,188 seeds for each rootstock. The seeds were previously soaked in water at a temperature of 50 ° C, maintained in this environment for 1 hour until reaching room temperature. Following this, the sowing of the seeds was performed for the rootstocks (45 days prior to cultivation) in tubes (288 ml/tube), containing substrate composed of a commercial substrate mixture Plantmax® (peat, pine bark and vermiculite), sawdust and sieved soil from the nursery woodland surface at a proportion of 1:1:1, where these are left until germination and emergence until the point of grafting. In the same way, the seedlings were produced for the yellow passionfruit for the production of the cleft-grafts and for the cultivar BRS Rubi for the supplying the graft.

Performing the graft

Grafting was performed at 220 days after sowing, when the rootstocks and scions reached a height of 15 to 20 cm, with an average of three true leaves, by use of the full cleft-graft method on the hypocotyl top. The rootstocks were severed at 10cm, a height at which a longitudinal cleft was made of 1 to 2 cm, into which a graft was introduced and tape was then wound around the graft site. The scions were maintained in the nursery for 70 days and watered daily through a micro-sprinkler, sub-canopy irrigation system, of the nursery.

Implanting the experiment in the field

Preparation of the soil - lime and fertilizer

Holes were prepared at 0.30m x 0.30m x 0.30m and the spacing used was 3.0m between rows and 3.0m between holes. Liming and fertilization of the planting area and the covering of the passionfruit were carried out according to the soil analysis. The chemical analysis of the soil, at a depth of 0 to 20 cm, showed the following characteristics: pH in $CaCl^2$, 4.3; H + Al, 3.8 cmolc dm^{-3}; Ca, 0.6 cmolc dm^{-3}; Mg, 0.3 cmolc dm^{-3}; K, 58,53 mg dm^{-3}; P (resin), 21,7 mg dm^{-3}; base saturation, 20.7%. The clay content was 37.7 %. The fertilization of the planting area MAP was used at a dose of 200g/hole and limestone filler 300g/hole.

Planting and guides

The trellis (espalier) was made from a wire at 1.80m from the ground for guiding the plants. Planting was performed on 02 April 2018 (70 days after grafting), and the plants were fixed to the wire with the aid of string.

During the development, light or formation pruning was performed, along with pinning and guiding the plants to the wire through a single stem (primary branch) with pruning of the lateral branches. Upon reaching the wire, the primary branch was conducted to one side until reaching the next plant, i.e., 3.0 linear meters at which point it was pruned, thus removing the apical dominance of the branch, favoring in this way the formation of a curtain through the secondary branches, which were “combed” allowing for free growth in direction of the soil. This management is necessary, as the characteristic of the passionfruit vine being a climber still has a branch leader, and when pruned on both sides, dominance prevails on only one side. The last pruning was that of the formation of the crown, pruning out the branches at 30.0cm from the soil. As of the second year, pruning constituted of only eliminating branching, while maintaining the top at 30.0 com from the ground.

Cultural characteristics

Irrigation and fertilizing

Irrigation was performed using drip tape with spacing of 30 cm between drips, for 3 hours a day. As the plant occupies 3.0 linear meters and the drip tape irrigates 5 liters of water per meter per hora, each plant received 15L/day of water.

The fertilizer top dressings were performed via weekly fertigation from the second month after planting with differentiated doses over the formation period (from the first to the sixth month after planting) and the production period (from the seventh to the thirtieth month of cultivation). Calcium nitrate, potassium nitrate, purified MAP, urea, ammonium sulfate, potassium chloride, magnesium sulfate, zinc sulfate and boric acid were used, according to the soil analysis (annex) and culture recommendation (table annexed) (Brunker 2001).

Phytosanitary control

Pest control was carried out aimed at the control of stinkbug (Leptoglossus gonagra) by use of the insecticide Provado 200 SC (Imidacloprid – neonicotinoid) at a dose of 0.5 mL/L water at application intervals of 15 days. The control of caterpillars was also carried out using the insecticide Pirate (Chlorfenapyr) at 0.5 mL/L water. During the dry season, control of the two-spotted spider mite (Tetranychus urticae) and red spider mite (*Tetranychus marianae*) is performed using Vertimec (Abamectin) 1 mL/L water, alternating with Pirate (Chlorfenapyr) 0.5 mL/L water, where the latter is used also for the control of leaf-eating caterpillars (Dione juno juno), juno Longwing with spraying carried out at 10-day intervals. Control of the following diseases is performed during cultivation: anthracnose (*Colletotrichum gloeosporioides*), wart (*Cladosporium herbarum*) and septoriosis (*Septoria passiflorae*). In order to control these diseases, the fungicide Recop (Copper Oxychloride) was sprayed at a dosage of 3g/L, alternating with the fungicide Nativo trifloxystrobin and tebuconazol at a dose of 1 ml/L water, weekly during the rainy period and every 15 days during the dry period. Applications were always carried out in the morning to avoid spraying the bumblebees of the genus *Xilocopa*.

Weed control

Weed control was performed in the first 90 days after planting by manual weeding along the line, maintaining the vegetation mowed short. After this period, an application of Roundup WG (Glyphosate; granulated) was applied at 5g/L water, along the line after 90 days of planting.

Pollination

To complement natural pollination, the manual transference of pollen was performed every day during the afternoon between 14.00 and 17.00hrs.

Data collection and analysis of agronomic characteristics

The evaluation of the harvest was carried out from November 2018 to June 2019. The harvest was initiated on 04 November 2018 (212 days after planting), on a weekly basis, by collecting commercial fruits with weight equal or superior to 50 g without damage, from which point these were counted and weighed.

The number of fruits per plant was determined through the counting of all fruits that could be commercialized.

During the harvest period, the following characteristics (variables) were also registered on a monthly basis: total weight of fruits per plot, number of fruits per plot and also the number of live plants over this period per plot. The average weight of the fruits was calculated by dividing the total weight of the fruits for each plot by the total number of fruits on each plot. The following variables were measured and calculated on each experimental plot, productivity (kg ha^{-1}), number of fruits per plant, average weight per fruit (g). In order to estimate productivity, a population of 1,111 plants ha^{-1} was considered.

For all data and estimations of the variables analyzed, the analysis of variance, test of comparison of means (Scott-Knott at 5%) and contrast tests by the F test at 5% were performed. The means were grouped considering the three grafted varieties and compared to seedling plants. These analyses were performed through use of the program Sisvar 3.7 (Ferreira 2011).

Phytopathological analyzes and percentage of dead plants in the field

Evaluation of plant mortality in the field

The assessment of mortality of plants was initiated at 214 days after planting and data were collected during eight different periods during the interval between 214 and 484 days from each experimental plot. The direct counting of dead plants was performed, from which the percentage of plants in each plot was established. The data were transformed into arc sine $\sqrt{x}/100$ (Pimentel-Gomes 2000).

The data obtained from each plot were submitted to the Shapiro-Wilk and O'Neil Matthews tests for evaluating the assumptions of the analysis of variance (normality and homogeneity). After concordance, the data were submitted to analysis of variance by the F test. The differences between the means of treatments and the test statistic were analyzed according to the Scott-Knott test at 5% significance, using the software R software (R Core Team, 2017) and ExpDes packages. In order to calculate efficiency percentages, the Abbot`s formula (1925) was employed, where the treatments with a rootstock were calculated regarding the test statistic BRS Rubi do Cerrado. For corrections, the statistical program Genes (Cruz 2001) was adopted, where simple Pearson correlations were made (Sopher et al. 1917) between the variables and the coefficient of determination, which quantifies the magnitude of variance. The test of averages was performed using the Scott-Knott at 5% significance for the comparison between treatments.

The progress curves of the disease were plotted, which considered the mortality data of plants from eight different periods over the interval between 214 and 484 days after planting, for each experimental plot.

With these data at hand, estimates were made as to the area under the disease progress curve (AUDPC), which is used to observe an epidemic. In the calculation of the area under the disease progress curve, the equation proposed by Shaner and Finley (1977) was employed.

The AUDPC was standardized by dividing the value of the area under the progression curve for the total time duration (tn - t1) of the epidemic (2), for comparing epidemics of different durations. The AUDPC data were submitted for statistical analysis, where the means were compared using the Scott Knott test, at a 5% level of probability. Where:

$$AUDPC = \sum_{i-1}^{n-1} (Yi + 1)/2x\ (Ti + 1-T1)$$

In which:

Yi = proportion of the disease in the ith observation
Ti = Time (days) in the ith observation
n = total number of observations

Detection of *Fusarium oxysporum* f. sp. *passiforae* in the soil and in infected plants from the cultivar Rubi

Soil collection from the experimental area of plants with symptoms from the cultivarBRS Rubi for laboratory isolation

The collecting of samples from the experimental area was performed across all plots with the different genotypes. Samples composed of 500 grams of soil were taken from each of the four treatments, which came from individual subsamples of 300 grams, in the six repetitions of each treatment (Ghini et al. 2006).

A separate sampling was performed on a single plant (stem, roots and aerial part) of the cultivar Rubi with visual symptoms of fusariosis. The samples of the soil and infected plant were sent to the Mycology and Plant Protection Laboratory of the Federal University of Uberlândia for identification.

Isolation of the fungus in soil, plant and inoculation samples

For isolation of the specie *Fusarium oxysporum* f. sp. *passiflorae,* two procedures were used (Alfenas et al. 2007):

a) Isolation of the soil: the soil samples for each cultivated genotype, in the experimental area, were sprinkled (5 grams) onto the surface of the medium PDA (Potato - dextrose - agar) in a laminar airflow chamber under aseptic conditions for obtaining individual *Fusarium* colonies. Five petri dishes were used all containing culture medium for soil sampling. After the sprinkling of the soil onto the surface of the dishes, these were incubated at 25ºC for 6 days. After the growth of the colonies, these went on to be divided into test tubes that contained the same medium culture. Following this, these were stored in a refrigerator at 5ºC for subsequent identification of the *Fusarium* specie.

b) Direct isolation of stem tissue with suspicion of *Fusarium* in PDA medium: fragments of 2 to 3mm taken from the internal part of the stem, without saprophytic fungi, were transferred in lots of five to the surface of the petri dishes with PDA, and following this were incubated at 25ºC for 6 days. After confirming the growth of the pathogen as Fusarium, the medium culture was divided into test tubes. After this procedure and growth of the cultures, the tubes were stored in a refrigerator at 5ºC for the subsequent identification of the specie.

c) Identification of the specie: from all the obtained cultures, be they from soil isolation or the plant of the cultivar Rubi, fragments of mycelium and conidia of the fungus were retrieved and placed on microscopic slides with visual presence in Lactophenol Cotton Blue Stain, aimed at confirming the phytopathogenic specie *Fusarium oxysporum* f. sp. *passiflorae*.

d) Inoculation from *Fusarium oxysporum* f. sp. *passiflorae* in BRS Rubi do Cerrado seedlings and *P. nítida*: BRS Rubi seedlings at 70 days of age and *P. nitida* seedlings at 210 days of age received mycelium culture disks of 10 days of age of the phytopathogen grown in PDA. The mycelium disks of 1cm containing mycelium and conidia were inoculated at the median height of the stem of each seedling, with 2 seedlings showing signs of damage and without damage. After 15 days of inoculation the seedlings, preserved in chambers at 25ºC, will have subsequent vascular necrosis from the pathogen analyzed, both in plants with and without damage (Menezes and Silva 1997).

3. Results

Evaluation of agronomic characteristics in an area infested with *Fusarium oxysporum* f. passiflorae

The mean data are presented for the variables of total number of fruits per plot, total weight and average weight of fruits. One notes that the plants grafted onto *P. nitida* and *P. gibertii* present the highest total weight of fruits (Table 1).

Furthermore, in regards to the total weight of fruits, the results demonstrate that on average the grafted plants produced more than 187.73 Kg, while the seedling plant only 120.95 Kg, thus indicating that the grafted plants possess higher production potential over those of seedlings.

The same behavior was noted for the production in number of fruits. The grafted plants present on average more than 783 fruits, while the seedling plants only 555 fruits. Among the grafted plants, there was no significant difference in terms of number of fruits. This result demonstrates that the evaluated rootstocks do not differ concerning the number of fruits produced on the passionfruit vine.

In regards to average weight of fruits, the best performance was obtained with *P. gibertii,* and there was no significant difference between *P. alata, P. nitida* and the seedling plant. The grafted plants also present higher means for fruits when compared to seedling plants, using the F contrast test.

The plants grafted onto *P. gibertii* present higher weight for fresh fruits when compared to the other treatments, however, there was no difference in productivity with *P. nitida* (Table 2). There was negative correlation of the area under the progress curve of incidence (AUPCI) in regards to fresh fruit weight in grams and productivity (Table 3). One notes from Table 3, the negative correlation and significance of the number of dead plants to the reduction of average fruit weight and reduction in productivity.

Table 1. Total weight of fruits from sour passionfruit cultivar BRS Rubi do Cerrado, seedling plant along with those grafted onto *Passiflora gibertii, Passiflora nitida* and *Passiflora alata,* over the period from November 2018 to June 2019, in Terra Nova do Norte-MT. UFMT, Cuiabá, MT, 2020.

Treatments	Total weight of fruits / plot (Kg)	Total number of fruits (Unit)	Average weight of fruits (g)
BRS Rubi do Cerrado	120.95^{b}*	555^{b*}	218.54^{b}
BRS Rubi x *P. gibertii*	204.00^{a}	741^{a}	273.46^{a}
BRS Rubi x *P. nitida*	199.21^{a}	889^{a}	224.23^{b}
BRS Rubi x *P. alata*	160.00 ^{b}	721^{a}	220.76^{b}
Test F (P-value)	0.0041	0.0109	0.0018
CV	21.32	20.07	9.59
Contrast test F at 5% (seedling x graft)	0.0015 (120.95x 187.73)**	0.0046 (555 x 783.66)	0.0668 (218.54 x 239.48)

*Means followed by the same letter in the column do not differ among themselves statistically by the Scott-Knott test at 5% probability. **Contrasts analyzed by the F test at 5% (Mean values of plants seedling x grafted).

Table 2. Agronomic characteristics fresh weight (g), productivity (kg ha^{-1}) and increment of passion fruit cultivar BRS Rubi do Cerrado, seedling and grafted on *Passiflora gibertii, Passiflora nitida* and *Passiflora alata,* during the period from November 2018 to June 2019, in Terra Nova do Norte-MT. UFMT, Cuiabá, MT, 2020.

Treatments	Agronomic Characteristics		
	Fresh weight (g)	Productivity (kg.ha^{-1})	Increment (kg.ha^{-1})
	Mean¹	Mean¹	
BRS Rubi do Cerrado	218.67^{b}	16,797.00^{c}	-
BRS Rubi x *P. gibertii*	273.67^{a}	28,330.50^{a}	11533
BRS Rubi x *P. nitida*	224.17^{b}	27,666.33^{a}	10869
BRS Rubi x *P. alata*	220.67^{b}	22,220.00^{b}	5423
Coefficient of variation (%)	9.57	21.32	
S-W^{3}	0.12	0.78	
O-M^{4}	0.03	0.80	

Means followed by the same letter do not differ statistically by the Scott-Knott test at 5% significance; 1-Original means in red are retrospective to the treatments and not the test statistic (without application); 2-%E. Percentage of efficiency (Abbot) - n.s: not significant; 3-Values of S-W in bold indicate normal distribution of residuals by the Shapiro-Wilk test at 0.05 significance; 4- Values of O-M in bold indicate homogeneity of variances by the O'Neil Mathews test at 0.05 significance.

Table 3. Correlation of the Pearson coefficients among the studied variables.

Characters	ρ
AUPCI x Weight of fresh fruit	-0.37*
AUCPI x Productivity	-0.86**

**, *Significant at 1 and 5% probability by the t-test, respectively. ns, not significant.

In the evaluation for mortality, it was observed that there was planta death 214 days after planting in tehe treatments with free-standing and grafted on Passiflora alata (Figure 1).

In regards to the AUPCI (area under the progress curve of incidence) that considered all the evaluations over the period of 214 to 494 days, substantiated through Figure 2 that the rootstock *P. nitida* presented an efficiency of 100% in the reduction of plant mortality in relation to the seedling plant, followed by the rootstock *P. gibertii* at 77.33% and *P. alata* at 50%. This is the first study that analyzed the time related progress of fusariosis in the field, through a comparison with seedling and grafted plants.

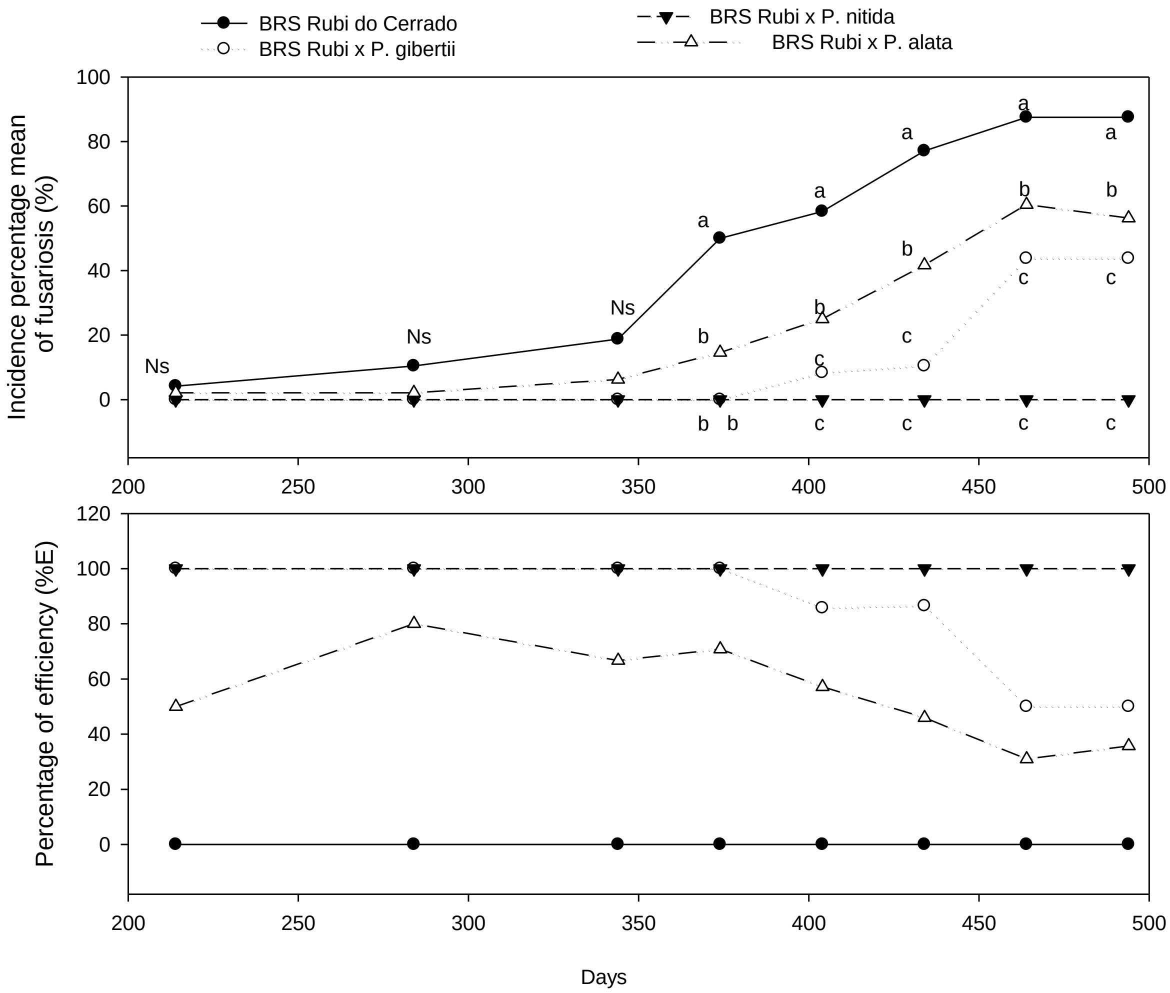

Figure 1. Incidence percentage mean of fusariosis (*Fusarium oxysporum* f. sp. *passiflorae*) in the passionfruit crop for the cultivar BRS Rubi do Cerrado seedling plant and grafted onto *Passiflora gibertii, Passiflora nitida* and *Passiflora alata* over the period from November 2018 to June 2019, in Terra Nova do Norte-MT. UFMT, Cuiabá-MT, 2021. Means followed by the same letter in day do not differ statistically by the Scott-Knott test at 5% significance. %E. Percentage of efficiency (Abbot) - n.s: not significant.

According to the statistical analysis for the AUPCI of fusariosis on passionfruit by the Scott-Knott test (Figure 2), the cultivar BRS Rubi do Cerrado seedling plant had a greater AUPCI, and as such presented greater susceptibility to death of plants caused by the referred to disease. On the contrary, those plants grafted onto *P. nitida* and *P. giberti* presented lower AUDPC, showing themselves as being more resistant to this disease.

Identification of the specie *Fusarium oxysporum* f. sp. passiflorae. in soil and plants of the cultivar BRS Rubi with vascular necrosis and mortality

Plants from the cultivar BRS Rubi do Cerrado that presented premature death had their etiology conformed as *F. oxysporum* f. sp. passiflorae by the Laboratory of Mycology and Plant Protection at UFU. In the samples collected from soil with grafted and seedling plants, the identification was also made for colonies pathogen in soil collected from where the susceptible cultivar (BRS Rubi) was situated (Figure 3).

Figure 3, presents colonies of the pathogen identified in the soil and plant. Pathogenicity tests in seedlings with and without damage developed symptoms from 15 days after inoculation in the susceptible BRS Rubi cultivar. This was not found in *P. nitida,* which led to the understanding that there exists a physiological resistance in the vascular tissues that prevents the colonization of the fungi.

Figure 4 confirms the pathogenicity of *Fusarium oxysporum,* which was isolated from the soil where the BRS Rubi seedling plant. Thus demonstrating the formation of the hyphae and spores of the fungus (Figure 4). After 15 days inoculation the six plants from *Passiflora edulis* (cultivar Rubi) showed symptoms from Fusarium wilt disease (*Fusarium oxysporum* f. *passiflorae*). Plants symptoms were vein discoloration end plants died (Figure 5).

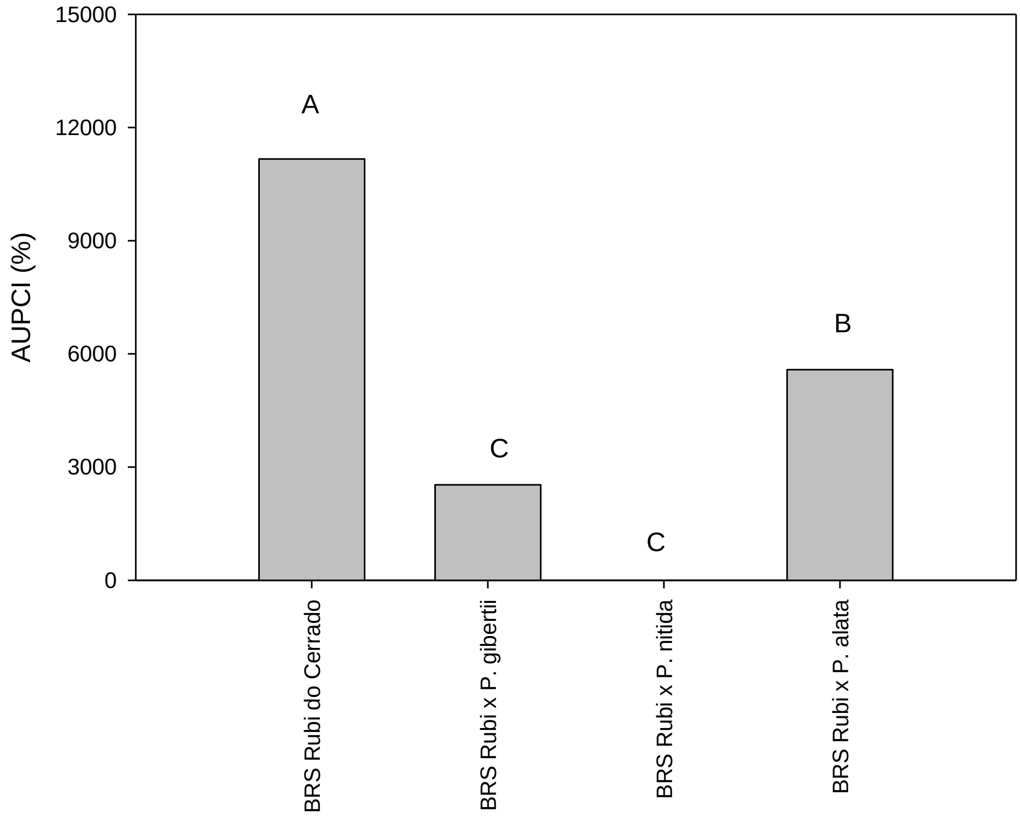

Figure 2. % of infection and area under the progress curve of incidence (AUPCI), for the cultivar BRS Rubi do Cerrado seedling plant and grafted onto *Passiflora gibertii, Passiflora nitida* and *Passiflora alata* over the period from November 2018 to June 2019, in Terra Nova do Norte-MT. UFMT, Cuiabá-MT, 2021. Means followed by the same letter in the bars do not differ statistically by the Scott-Knott test at 5% significance.

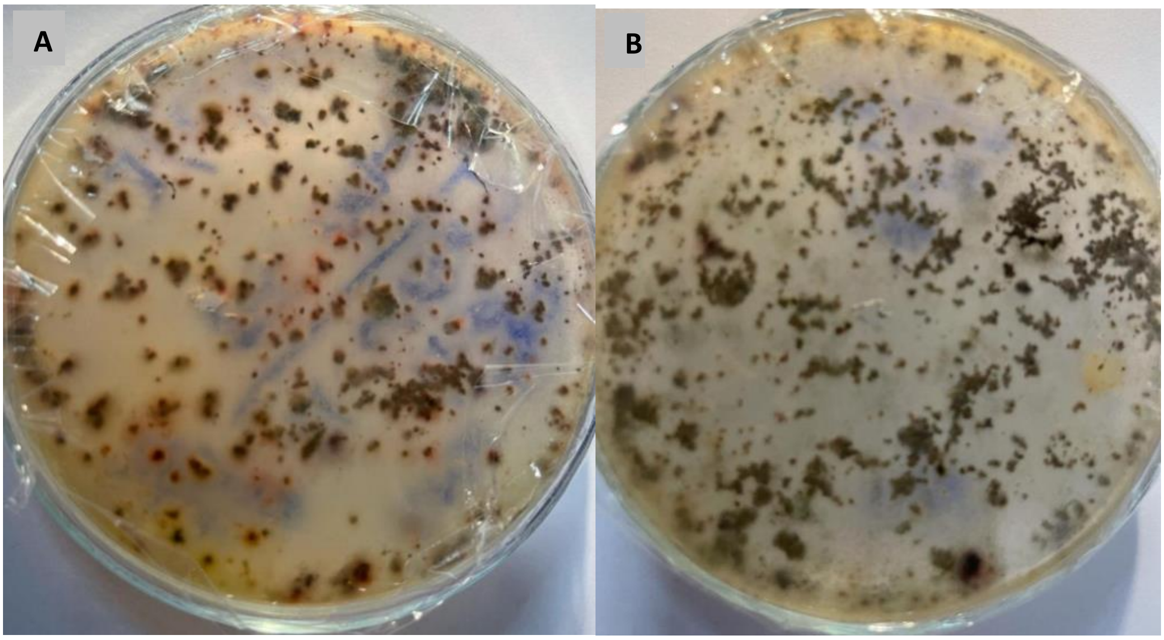

Figure 3. Isolation and identification of *Fusarium oxysporum:* (A) presence of fusarium in the soil of the BRS Rubi seedling. B) absence of Fusarium isolated from the soil where *P. nítida* is situated. Phot F.C. Juliatti, LAMIP, UFU, 15/02/2020.

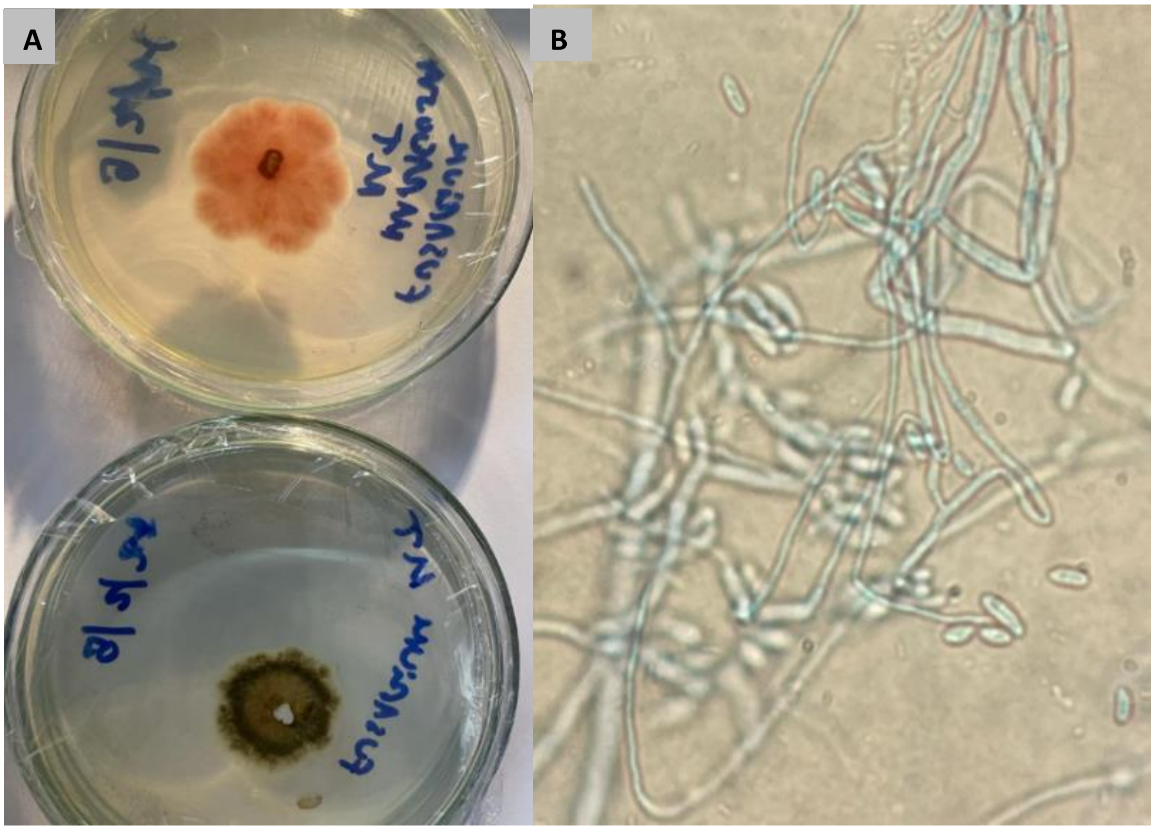

Figure 4. Development of *Fusarium oxysporum:* (A) with *Fusarium*; (B) Another fungus from isolation in PDA (C) Growth and formation of *Fusarium* spores. Photo F.C. Juliatti, LAMIP, UFU, 15/02/2020.

Figure 5. A - Plants from *P.edulis* (Cultivar Rubi) with wilt and died after 15 days inoculation at 25° C temperature; B - Plants from *P. nitida* without symptoms. Photo F.C. Juliatti, LAMIP, UFU, 28/02/2020.

4. Discussion

The highest productivity was obtained with plants grafted with *P. nitida* and *P. gibertii.* The seedling cultivar presented a much lower productivity. This result contradicts those obtained by Ambrosio (2018), where seedling plants present higher productivity in relation to those grafted onto *P. nitida* and *P. alata*. These results can be justified by the absence of the quantification of mortality due to *Fusarium* in the study by Ambrosio (2018) or in the use by the author of a soil with a low index or absence of the disease. In this type of study based on the host pathogen interaction, the presence of the two is fundamental in order that the plant express its resistance and consequently higher productivity. Therefore, in the absence of the pathogen, the susceptible seedling plant can obtain a higher productivity than the resistant rootstock. The increase in productivity of the grafted plants in regards to productivity of seedling plants demonstrates that the use of seedling plants grafted at the planting of the passion fruit culture, can promote not only greater longevity of the farm due to resistance to fusariosis, but also more productive farms. Noted here is the negative correlation of the area under the progress curve of incidence (AUPCI) in regards to fresh fruit weight in grams and productivity. One notes from Table 3, the negative correlation and significance of the number of dead plants to the reduction of average fruit weight and reduction in productivity.

The cultivar BRS Rubi do Cerrado seedling plant had a greater AUPCI, and as such presented greater susceptibility to death of plants caused by the referred to disease. On the contrary, those plants grafted onto *P. nitida* and *P. giberti* presented lower AUDPC, showing themselves as being more resistant to this disease. Research by Junqueira et al. (2005), using a commercial passionfruit clone grafted onto *P. nitida* stocks, documented that 14 months from harvest, the grafted plants had similar productivity to those plants propagated from seed and were less affected by root or cervix rot (*Fusarium solani*).

The good performance attained from plants grafted onto *P. nitida*, was also obtained by Semprebom (2012) in an area contaminated with fusariosis in Terra Nova do Norte, where no mortality of plants grafted onto *P. nitida* was noted, even in areas with a documented occurrence of disease by *Fusarium* spp., while all plants grafted onto *Passiflora edulis* died after 2 years. A criticism of this study was the lack of identification for the predominant *Fusarium* specie. If one considers that the experiment was set up in plots of eight plants, it was not possible to differentiate statistically, by use of the test of means, the differences between *P. nitida* and *P. gibertii*. The suggestion is therefore made from such findings that future scientific studies increase the number of plants per plot to detect differences between *P. nitida* and *P. gibertii* in areas with a high occurrence of *Fusarium oxysporum* f. sp. passiflorae.

The seedling plants and those grafted onto *P. alata* were shown to be more susceptible to premature death when compared to the others, where death of the plants initiated around 284 days and intensified around 374 days after transplanting. In this study, higher longevity was noted for plants grafted onto *P. gibertii* in relation to the results obtained for Cavichioli et al. (2011b), which reported mortality of 9.0% in plants grafted onto *P. gibertii*, at 12 months of cultivation. These selfsame authors state the advantage of using *P. gibertii* as the rootstock, due to its low mortality rate in relation to plants of the specie *P. edulis* grafted onto this selfsame species, on which 91.4% of plants succumbed to premature death when cultivated in soil contaminated by the very fungus that caused the premature death of plants.

Over the whole period of analysis, i.e., 16.5 months, the best behavior regarding mortality of plants was noted in *P. nitida,* which presented zero mortality over the whole period, thus indicating greater longevity for this specie. Statistically speaking both rootstocks *P. nitida* and *P. giberti* present similar behavior for plant mortality and better than *P. alata*. Under the experimental conditions in Terra Nova do Norte, the worst behavior was of the seedling cultivar BRS Rubi do Cerrado.

5. Conclusions

The cultivar BRS Rubi do Cerrado grafted onto *P. nitida* presented 0% mortality. The BRS Rubi do Cerrado grafted onto *P. gibertii* and *P. nitida* presented a better performance for weight of fruits, number of fruits and productivity. The cultivar BRS Rubi do Cerrado grafted onto the different rootstocks presented higher productivity in relation to the seedling. The rootstocks *P. nitida* and *P. gibertii* were superior to *P. alata* in reducing passionfruit mortality caused by *Fusarium oxysporum* f. sp. passiflorae. The pathogenicity of *Fusarium oxysporum* f. sp. passiflorae isolated from the experimental area in scions of the cultivar Rubi inoculated at 70 days of age.

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