DOI: 10.5433/1679-0359.2021v42n3Supl1p1579

# Management of clonal mini-garden with gibberellic acid in guava rootstock propagation

# Manejo de minijardim clonal com ácido giberélico na propagação de porta-enxerto para goiabeira

Mariana Barreto de Souza Arantes[1]*; Claudia Sales Marinho[2]; Raudielle Ferreira dos Santos[1]; Sydney Pereira Galvão[3]; Giuliana Pulitini Vaz[4]

## Highlights

The guava propagation method is strategic for new crops.
The new 'BRS Guaraçá' rootstock can be propagated by mini-cuttings.
The management of mini-stumps with gibberellic acid increases propagule production.
The season of the year defines the concentration of gibberellic acid to be used.
The greatest rooting potential through mini-cuttings was 95% in the summer.

## Abstract

The viability of the mini-cutting technique requires seedling regrowth ability and continuous propagule production. It is hypothesized that the application of gibberellic acid (GA) can stimulate vegetation and increase the production of mini-cuttings. The aim of this study was to increase the mini-cutting yield of *Psidium guajava* (L.) × *Psidium guineense* (Sw.) ('BRS Guaraçá') as a function of foliar application of GA and season of the year. The experiment was laid out in a randomized-block design with split-plots in time, in which the plots consisted of different GA concentrations applied (0, 50, 100, 150 and 200 mg $L^{-1}$) and the subplots were represented by two application periods or seasons (summer and winter). Four replicates were used, with two plants per plot. After the seedlings were topped, GA was applied at different concentrations and the emerged shoots were evaluated over 30 days. Mini-stump yield was assessed by collecting and evaluating the potential number of mini-cuttings. Shoot length and mini-stump yield increased linearly with the increasing GA concentrations during the summer. In the winter, this response was quadratic, with optimal concentrations estimated at 65.3 mg $L^{-1}$ for shoot length and 76 mg $L^{-1}$ for mini-stump yield. The GA concentration of 200 mg $L^{-1}$ provided shorter internodes in the summer, whereas in the winter the use

[1] Doctoral Students in the Graduate Plant Production Program, North Fluminense State University, UENF, Campos dos Goytacazes, RJ, Brazil. E-mail: mariana.arant@yahoo.com.br; raudielle@outlook.com
[2] Professor, DSc. North Fluminense State University, UENF, Campos dos Goytacazes, RJ, Brazil. E-mail: claudia.marinho@uenf.br
[3] Master's Degree Student in the Graduate Plant Production Program, North Fluminense State University, UENF, Campos dos Goytacazes, RJ, Brazil. E-mail: sydneygalvaoagro@gmail.com
[4] Agronomy Student, North Fluminense State University, UENF, Campos dos Goytacazes, RJ, Brazil. E-mail: giuliana_vaz@hotmail.com
* Author for correspondence

Received: Nov. 09, 2020 - Approved: Jan. 12, 2021

of GA did not interfere with this trait. The increasing applications of GA induced a linear increase in stem diameter at both seasons of the year. Gibberellic acid did not interfere with the rooting of the mini-cuttings. The highest rooting percentage occurred in the summer, with an average of 95%. In the winter, this value was 77.2%, demonstrating that mini-cuttings are a promising technique for 'BRS Guaraçá'. Foliar spraying of GA promoted an increase in mini-cutting production, without interfering with their rooting.
**Key words:** *Psidium guajava* (L.) × *Psidium guineense* (Sw). 'BRS Guaraçá'. $GA_3$.

## Resumo

A viabilidade da mini-estaquia requer capacidade de rebrota das mudas e produção contínua de propágulos. A aplicação de ácido giberélico pode estimular a vegetação e proporcionar aumento na produção de mini-estacas, como hipótese. O objetivo deste trabalho foi aumentar a produtividade de minijardins de *Psidium guajava* (L.) × *Psidium guineense* (Sw.) ('BRS Guaraçá'), em função da aplicação foliar de ácido giberélico (AG) e da época do ano. O delineamento empregado foi em DBC, em parcelas subdivididas no tempo, sendo as parcelas constituídas por plantas submetidas a diferentes concentrações de AG (0, 50, 100, 150 e 200 mg $L^{-1}$) e as subparcelas constituídas por duas épocas de aplicação (verão e inverno), com quatro repetições e duas plantas por parcela. Após desponte das mudas, o AG foi aplicado em diferentes concentrações e as brotações emitidas foram avaliadas ao longo de trinta dias. A produtividade das minitouceiras foi avaliada por coleta e avaliação do número potencial de mini-estacas. O comprimento da brotação e a produtividade das minitouceiras aumentaram linearmente em função do aumento das concentrações de AG durante o verão enquanto que no inverno, essa resposta foi quadrática com as concentrações ótimas estimadas em 65,3 mg $L^{-1}$ para comprimento de brotações e 76 mg $L^{-1}$ para produtividade das minitouceiras. A concentração de 200 mg $L^{-1}$ possibilitou o menor comprimento de internódio no verão, no inverno, a utilização do AG não interferiu nessa característica. As aplicações crescentes de AG aumentaram linearmente o diâmetro do caule nas duas épocas do ano. O AG não interferiu no enraizamento das mini-estacas. O maior percentual de enraizamento ocorreu no verão, com média de 95% e no inverno este valor foi de 77,2%, evidenciando a mini-estaquia como técnica promissora para 'BRS Guaraçá'. A pulverização do AG via foliar promoveu aumento da produção de mini-estacas, não interferindo no seu enraizamento.
**Palavras-chave:** *Psidium guajava* (L.) × *Psidium guineense* (Sw). 'BRS Guaraçá'. $AG_3$.

## Introduction

Brazil is the fourth largest guava producer in the world (Altendorf, 2018). In the 2018 harvest, the country produced 578,000 t of the fruit from a cultivated area of 21,000 ha, with the most representative states being Pernambuco and São Paulo (Instituto Brasileiro de Estatística e Geografia [IBGE], 2020). Guava farming is important for Brazilian agriculture, as it meets the demands of the fresh fruit consumption market and the agribusiness. The fruit is used as main raw material for the manufacture of juices, jams, jellies and enriched flours (Velasco-Arango, Bernal-Martínez, Ordóñez-Santos, & Hleap-Zapata,2020; Kadam, Kaushik, Kumar, 2012). In view of the importance of this fruit crop for national agriculture, the renovation and implantation of new orchards have a critical point in the success of commercial exploitation.

The propagation of guava has become a strategic process for establishing new crops in areas already contaminated or with the possibility of contamination by the nematode *Meloidogyne enterolobii.* A possible approach to solve this problem is the use of resistant rootstocks, which would allow the continued use of the same cultivars in established markets. A rootstock with this characteristic has been developed from the cross between *Psidium guajava* (L.) and *Psidium guineense* (Sw.), called 'BRS Guaraçá'. However, it does not bear viable seeds (Costa, Santos, & Castro 2012), making vegetative propagation essential for its use. Therefore, propagation techniques that allow an optimized multiplication process for this rootstock must be employed.

The mini-cutting technique consists of cultivating parents of tree plants in containers installed in protected-environment conditions. The parents are topped for the emergence of lateral shoots, forming mini-stumps, whose herbaceous shoots are used in the production of mini-cuttings to be rooted in an environment with high moisture saturation. This approach, first applied in the propagation of forest species (Dias, Oliveira, Xavier, & Wendling, 2012; Ferriani, Zuffellato-Ribas, & Wendling, 2010), has also been successfully used in the propagation of guava and Cattley guava (*Psidium cattleyanum*) species. As such, it has even been indicated for seedling production (Altoé, Marinho, & Freitas, 2013; Altoé, Marinho, Terra, & Carvalho, 2011a) as well as for the multiplication of accessions for use in breeding or in the recovery of degraded areas (Biazatti, Marinho, Arantes, & Guilherme, 2018; Altoé, Marinho, Terra, & Barroso, 2011b).

Advantages of using clonal mini-gardens include the possibility of a higher frequency of material collection and the use of less space for the establishment of plants, which facilitates management (Ferriani et al., 2010). However, important differences exist in the production of lateral shoots due to topping, which vary according to genotype and environmental factors (Pimentel et al., 2019; Silva, Reiniger, Rabaiolli, Stefanel, & Ziegler, 2019; Altoé et al 2011a). In this respect, continuous production of mini-cuttings is important for the viability of use of this technique.

In this scenario, substances that can promote such behavior may be employed, e.g., certain growth regulators that promote the emergence and growth of new shoots. The use of some of these substances may favor shoot emergence and elongation. Gibberellic acid (GA), for instance, has been researched in some crops. Porto et al. (2018) found that a species of yellow cattley guava showed increased height, leaf area and survival when subjected to treatment with GA. In sapodilla plants (*Manilkara achras*), treatment with GA provided maximum shoot growth (Malshe, Desai, & Palshetkar, 2016). The time of year also interferes with the propagation and quality of propagules (Pimentel et al., 2019), which can influence the performance of GA on these characteristics.

The analogues have favored an increase in shoot length, since this regulator plays a role in induces cell stretching (Parween, Mishra, Adil, Pal, & Jha, 2019).

The greater number of mini-cuttings produced in response to the GA application management on 'BRS Guaraçá' mini-stumps can optimize the mini-cutting strategy for the multiplication of this hybrid. To this end, it is important to test it at different times of the year.

This study proposes to increase the mini-garden yield of 'BRS Guaraçá' through foliar application of a GA solution as well as examine the effect of the time of the year or season on its effectiveness.

## Material and Methods

The experiment was carried out in a greenhouse shaded with 50% shade cloth (Sombrite®), at the State University of Northern Rio de Janeiro. The temperature and relative humidity (RH) means during the experiment were recorded by a digital thermo-hygrometer. Figure 1A describes the temperatures and RH inside the mist chamber. The average maximum and minimum temperatures were 31.5 and 20 °C, respectively. The highest and lowest RH were 91.6 and 55.6%, respectively. During the experiment, in the summer, the average maximum temperature in the greenhouse was 31 °C, while the average minimum was 24 °C. The highest RH was 87.6% and the lowest 54.8%. In the winter, the highest temperature was 26.3 °C and the lowest 17.9 °C; for RH, 87.4% was the highest recorded mean and 48% the lowest (Figure 1B).

'BRS Guaraçá' originated from the Active Germplasm Bank of Embrapa Semiarid. The seedlings were used to establish a clonal mini-garden (first cultivation) in 7-L pyramidal pots. The pots were filled with the Basaplant® commercial substrate and with single superphosphate fertilizer (6 g $L^{-1}$), limestone (30 g $L^{-1}$) and Osmocote® (6.6 g $L^{-1}$) in the 14-14-14 formulation. Throughout the experiment, the plants were fertilized with 7.6 g urea, 24.7 g single superphosphate and 2.8 g potassium chloride per pot, which were split into three applications at 14-day intervals (Biazatti et al., 2018). Foliar fertilization with Bordeaxu mixture was performed every two weeks. The seedlings from the mini-garden were initially trained on a single stem. The first pruning was performed on lignified tissue, leaving approximately four pairs of mature leaves. New shoots formed the mini-stump, which was trained in a three-main-branch system. With each new pruning, the main branches were pruned on lignified tissue. This mini-garden was pruned in the fall for the first time, to produce new shoots, which were used to produce the mini-cuttings, with two pairs of apical leaves and with the blade cut in half. The base of the mini-cuttings was dipped for 10 s in an indolebutyric acid solution (1500 mg $L^{-1}$), as recommended by Ferreira et al. (2013) for 'BRS Guaraçá'.

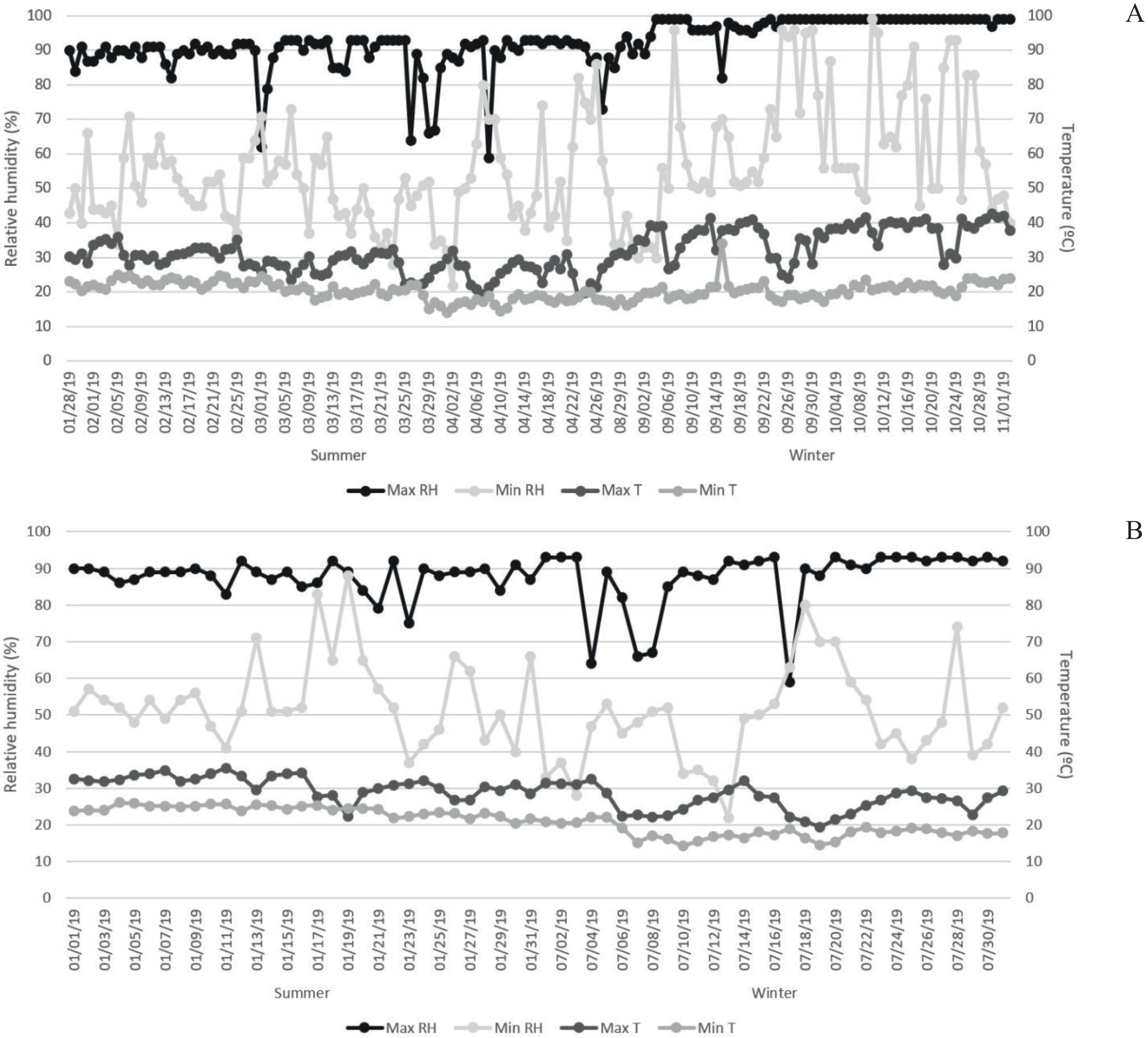



**Figure 1.** Maximum and minimum relative humidity and temperature recorded inside the mist chamber and measured in the greenhouse during the two evaluation periods: inside the mist chamber (A) and greenhouse (B).

The mini-cuttings were then placed in 280-cm$^3$ tubes containing Basaplant® as substrate and subsequently taken to the mist chamber in a regime of 15-s spraying time, 10-min intervals, 7-L h$^{-1}$ flow and 4.0 kgf cm$^{-2}$ pressure, where they remained for 60 days (Altoé et al., 2011a). After this period, the mini-cuttings were taken to acclimatization, during which time newly rooted seedlings were removed from the mist chamber and transferred to a more shaded place (70% shade cloth). Seedlings were irrigated twice a day with a fine-sieve watering can and remained in these conditions for 30 days.

After the previously mentioned period, the new seedlings were transplanted into 3.8-L pots. These pots were filled with the same substrate and fertilized in the same way as in the first cultivation. The plants were irrigated with a water volume of 250 mL twice a day during the summer and once a day during the winter. Seedlings were arranged on a workbench (1.15 m wide × 5 m long), at a height of 1 m from the ground, with 0.70-m spacing between rows and 0.27 m between pots in the same row. The clonal mini-garden of 'BRS Guaraçá' was trained on a single stem with the support of stakes, and when all the plants reached a woody aspect in the region of the fifth pair of leaves, at 240 days after transplanting, pruning was performed for the first time (summer).

The experiment was laid out in a randomized-block design with split-plots in time, in which the plots consisted of five concentrations of GA (0, 50, 100, 150 and 200 mg $L^{-1}$) and the subplots were represented by the application times (summer and winter). Four replicates were used, with two plants per plot.

After the first pruning, performed in the morning, the GA solutions were applied in the same period, according to each treatment. The plants were sprayed foliarly with 25 mL of Progibb® per plot. Progibb® is a commercial product containing 40% w/w gibberellic acid ($GA_3$) and (3S,3aS,4S,4aS,7S,9aR,9bR,12S)-7,12-dihydroxy-3-methyl-6-methylene-2-oxoperhydro-4a,7-methano-9b,3-propenoazuleno[1,2-b]furan-4-carboxylic acid.

Applications were performed in the morning. In the second season (winter), with the mini-stumps already formed, a new pruning procedure was carried out to bring the plants back into a single stem. Immediately after this new pruning, GA application was repeated.

The number of shoots emerged and shoot diameter (mm) were evaluated using a digital caliper. These evaluations were carried out 30 days after the application of GA in January and July of the same year. To determine shoot length and diameter, the shoot was marked with a tape on each mini-stump and measured weekly, over 28 days. Mini-stump yield, internode length and mini-cutting production were evaluated after the other shoots reached the point indicated for the production of mini-cuttings (leaves fully expanded and branch with herbaceous aspect). Each shoot originated more than one mini-cutting, which was made with two nodes and two pairs of leaves.

To evaluate the rooting potential of the mini-cuttings, shoots were collected in both seasons (summer and winter) 30 days after GA application. The mini-cuttings were made with two pairs of leaves, one of which was removed and the other kept, but with the blade cut in half, using the same methodology described for establishing the second clonal mini-garden. The mini-cuttings were placed in 280-cm3 tubes containing the commercial substrate Basaplant® and taken to a mist chamber with the same spraying regime used in the establishment of the second clonal mini-garden, where they remained around 60 days.

After 60 days in the mist chamber, the seedlings were evaluated for the distance between internodes, using a digital caliper, and for rooting percentage.

Number of shoots and rooting percentage data were $(x + 0.5)^{\wedge 0.5}$ and arcsine $(x + 0.5)^{\wedge 0.5}$ transformed, respectively, to meet the assumptions of normal distribution. The data were subjected to analysis of variance. Statistical analysis followed the model of split-plots in time. When there was a significant effect of GA concentrations, the means of the concentrations were subjected to regression analysis and the best-fitting curves were chosen, whereas the means of the two seasons were compared by the F test at 5%. In the case of a significant interaction between the two factors, the concentrations were decomposed within each season. Shoot length evaluated weekly at each time of the year was also subjected to analyses in a split-plot-in-time arrangement, adjusting the best fitting curves in case of significance.

## Results and Discussion

There was a significant interaction effect between the GA concentrations and the evaluated seasons (winter and summer) for shoot length (Figures 2 and 3). Shoots were longer in the summer than in the winter ($p<0.05$). In the summer, this variable increased linearly in response to the GA concentrations, whereas in winter, the GA concentration that provided the greatest growth was estimated at 65.3 mg $L^{-1}$, at 28 days after spraying (Figure 2).

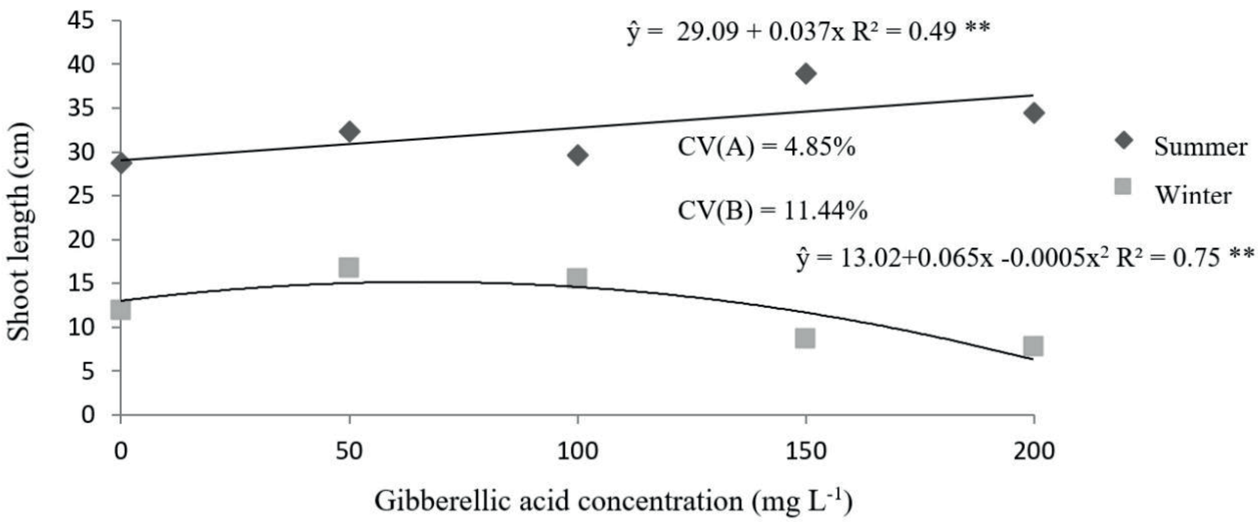



**Figure 2.** Shoot length of BRS-Guaraçá seedlings maintained in a mini-stump system and treated with increasing concentrations of gibberellic acid in the winter and summer, at 28 days of evaluation, at 1% probability. CV (A) = coefficient of variation in the plot and CV (B) = coefficient of variation in the subplot.

The differences observed for the length of seedlings treated in the summer and winter may be related to the fact that vegetative growth is normally stimulated by higher temperatures. Peña, Zanette and Biasi (2015) found, in mini-gardens of surinam cherry (*Eugenia uniflora* L.), another Myrtaceae, that shoots had greater growth in the summer than in the winter. In the present study, the natural stimulus for greater growth seen in the summer was influenced by an additive effect from of the GA applications.

The greater branch length observed in 'BRS Guaraçá' treated with gibberellin may be related to the application of GA in a period of higher temperature (Figure 2). In the winter, the shoots were shorter, and the use of GA doses contributed to increasing their growth up to the maximum effective concentration, causing a detrimental effect at higher concentrations. During the winter, shoots usually grow less, in which case applications of higher GA concentrations can accumulate in the smaller shoot mass, causing a phytotoxic effect. In the present study, the plants treated with GA showed a less vigorous aspect, with reduced height during this season; however, there were no phytotoxicity effects such as etiolation, yellowing, chlorosis or necrosis. The phytotoxicity of GA was observed by Oliveira et al. (2014) in micro-cuttings of 'Tainung 01' papaya under the treatment consisting of the highest dose used (2.0 mg $L^{-1}$), which caused damage to leaf development, with symptoms of yellowing.

Figures 3A and 3B illustrate shoot growth at seven-day intervals after the application of GA, for the summer and winter, respectively. At 28 days after application, the concentration of 150 mg $L^{-1}$ provided the highest average shoot length in the summer (Figure 3A), which was achieved with 50 mg $L^{-1}$ in the winter (Figure 3B). Lower effective concentrations were also found in other species, as in 'Tiger Flame' gladiolus, which responded to the GA concentration of 50 mg $L^{-1}$, which stimulated greater plant height and leaf width after 20 days of application (Padhi, Sisodia, Pal, Kapri, & Singh, 2018). However, in cattley guava grown in pots, Porto et al. (2018) found that foliar spraying of GA at the concentrations of 100, 200 and 300 mg $L^{-1}$ provided greater height growth in cattley guava seedlings. Thus, the effective concentrations found in this study are in agreement with the range of effective concentrations of GA observed in other studies. Nonetheless, we found that lower concentrations can be used in the winter.

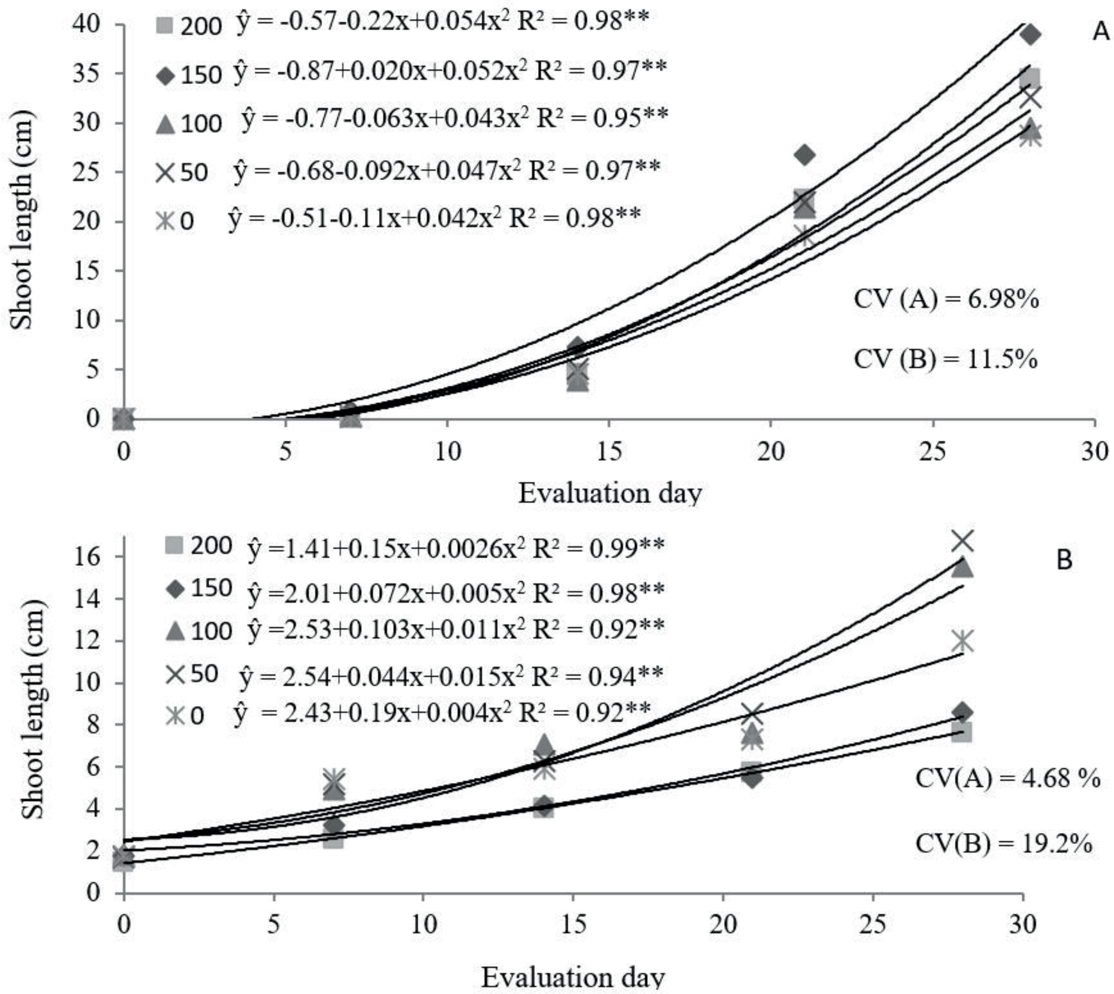



**Figure 3.** Shoot length of 'BRS Guaraçá' seedlings maintained in a mini-stump system treated with increasing concentrations of gibberellic acid in the summer (A) and winter (B), at 28 days of evaluation, at 1% probability. CV (A) = coefficient of variation in the plot and CV (B) = coefficient of variation in the subplot.

Plants have less vegetative development in periods of lower temperatures. The time when shoots are collected from the parental plant for making mini-cuttings interfered with shoot growth, and the period of higher temperatures was the best contributor to this gain (Peña et al., 2015).

The number of shoots per mini-stump was not significantly affected by the GA concentrations or their interaction with the evaluated seasons. However, there was an isolated effect of the application period, with the number of shoots in the summer being almost twice as high as in the winter (Table 1).

In general, mini-stumps are more prone to producing shoots during the period of higher temperatures. Silva et al. (2019) found a lower number of shoots in a clonal mini-garden of *Luehea divaricata* in the lower-temperature months. Low temperatures reduce shoot emergence, and vegetative development then occurs in a less pronounced manner, which results in shorter branches and lower mini-stump yields. However, deleterious effects of higher temperatures can also reduce the yield of guava mini-cuttings, as observed by Altoé et al. (2011).

**Table 1**

**Number of shoots per mini-stump of *P. guajava* (L.) × *P. guineense* (Sw.) treated with gibberellic acid concentrations in two evaluation periods (January and July)**

| GA concentration | January (Summer) | July (Winter) | Mean |
|---|---|---|---|
| 0 mg $L^{-1}$ | 5.37 | 3.5 | 4.43 $^{ns}$ |
| 50 mg $L^{-1}$ | 5.5 | 2.87 | 4.18 |
| 100 mg $L^{-1}$ | 6.0 | 2.62 | 4.31 |
| 150 mg $L^{-1}$ | 5.87 | 2.37 | 4.12 |
| 200 mg $L^{-1}$ | 4.87 | 2.5 | 3.68 |
| Mean | 5.52 A* | 2.77 B | |
| CV (A) | 4.4 % | | |
| CV(B) | 7.2 % | | |

$^{ns}$ = not significant by the F test.
*Means followed by the same uppercase letters in the row do not differ by the F test (5%).
Analysis performed after the data were $(x + 0.5)^{\wedge 0.5}$ transformed.
The displayed means are the original ones.

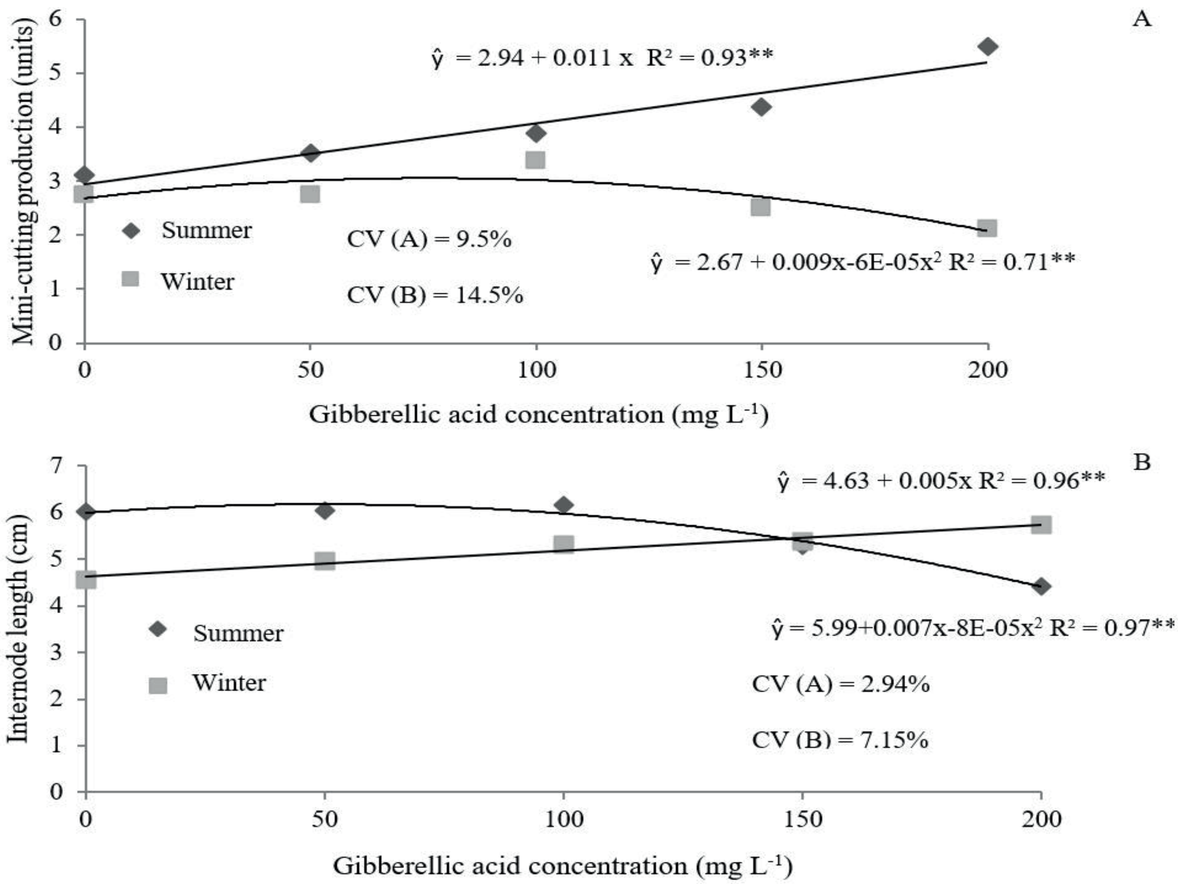
Mini-cutting production from the mini-stumps increased linearly in the summer and showed a quadratic response in the winter, whose estimated GA concentration for optimal production was 76 mg $L^{-1}$ (Figure 4 A). On the other hand, internode length exhibited the inverse response, having a quadratic effect in the summer, with the use of 200 mg $L^{-1}$ GA providing the lowest values, and a linear increase in the winter (Figure 4B).

The application of higher concentrations of GA favored the increase in vegetative propagules of 'BRS Guaraçá' during the summer. Peña et al. (2015) observed that surinam cherry seedlings produced more shoots during the summer season and concluded that the temperature helped bud development and shoot growth. In the winter, tropical plants such as guava trees tend to have their budding stimulus slowed (Ramos et al., 2011). In the current study, not even the use of GA was able to improve the effects related to the production characteristic of mini-cuttings in the winter, since there was less vegetative development at this time.

Overall, the time of year was found to influence mini-cutting production, and the use of GA provided an increase in this production in hotter or colder periods, although different concentrations were needed for each of these.

A shorter internode length is important to obtain a higher number of propagules.

In the present study, at the time of higher temperatures when the experiment took place, the internodes shortened at the highest GA concentration used. This effect is opposite to that reported in the literature for most crops (Zhang et al., 2020; Davies, 2010). The internode elongation observed in the mini-stumps treated in July is the typical action expected when GA is applied, since the use of this regulator tends to favor internode elongation (Davies, 2010). From the treatment with GA, epidermal cells initiate elongation processes provided by divisions in cortex and epidermal cells. Thus, genes that express gibberellin 2-oxidase are highly found among tissues. Elongation is also due to the synergy between gibberellins and auxins, which promotes cell wall growth and expansion (Davies, 2010). In the present study, the shortening of internodes due to the increasing GA concentrations, observed in the summer, did not result in a shorter shoot length, that is, it did not interfere with vigor in general, allowing the production of a greater number of cuttings. Another important result is that shoot diameter responded linearly to the GA concentration applied in both evaluated seasons (Figure 4C).



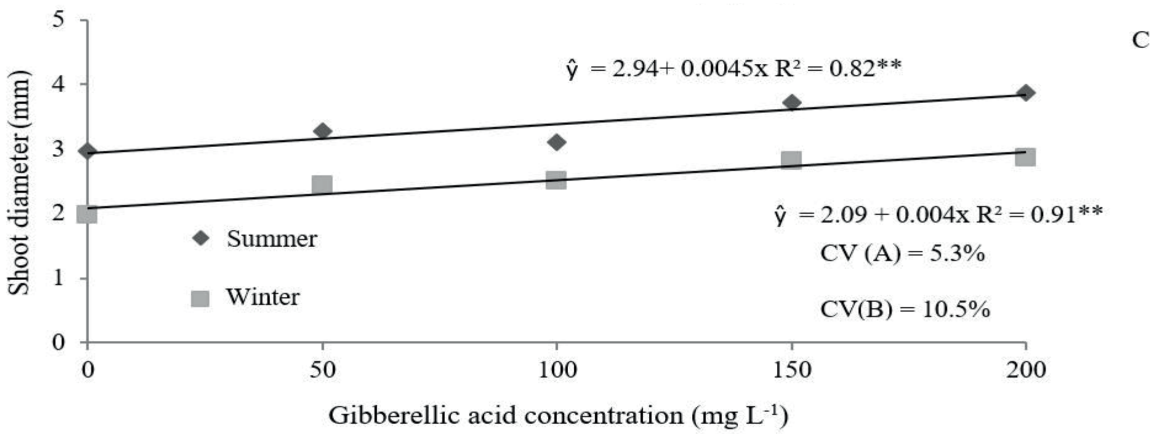



**Figure 4.** Mini-cutting production, internode length and shoot diameter of 'BRS Guaraçá' seedlings maintained in a mini-stump system and treated with increasing concentrations of gibberellic acid, in the summer (A) and winter (B), ** Significant at 1%. CV (A) = coefficient of variation in the plot and CV (B) = coefficient of variation in the subplot.

Shoot diameter is important for making herbaceous mini-cuttings, since, after rooting, if these seedlings are used as rootstocks, this step can occur more quickly according to stem thickness (Gomes et al., 2010; Campos, Marinho, Portella, Amaral, & Carvalho, 2017), as it allows for faster grafting.

Matos et al. (2015) evaluated different concentrations of GA in eucalyptus clones and demonstrated that the treatment with 150 mg $L^{-1}$ provided a 29% increase in stem diameter in comparison to control. In the present study, the mini-stumps responded linearly, regardless of the time of year, when the GA treatment was performed. This finding suggests that the higher the GA concentration, the greater the stem diameter growth response of emerged shoots.

The GA treatments on the mini-stumps did not interfere with the rooting capacity of the mini-cuttings. However, the mini-cuttings exhibited greater rooting in the summer, with values higher than 95% (Table 2). The mini-cuttings strategy has provided high rooting rates in *Psidium* species (Altoé et al., 2013, 2011a,b), which was confirmed in the present study. According to Biazatti et al. (2018), the summer was the best time for rooting. Altoé et al. (2011) found that 'Cortibel 1' mini-cuttings had the lowest rooting percentages in the months of June and November. In the present study, the rooting percentages were considered high in both seasons, although higher in the summer, which is another positive characteristic for the propagation of this genotype through mini-cuttings.

Gibberellins usually inhibit the formation of adventitious roots, as they act in a way that impairs polar auxin transport (Mauriat, Petterle, Bellini, & Moritz, 2014). However, the spraying of GA 30 days before the collection of the shoots from the 'BRS Guaraçá' hybrids to make the mini-cuttings did not compromise the rooting of the plants during the two periods in which the evaluations took place.

**Table 2**
**Rooting of mini-cuttings after 60 days of rooting in the mist chamber, in plants treated with GA at two times of the year**

| GA concentration | January 2019 (Summer) | July 2019 (Winter) | Mean |
|---|---|---|---|
| 0 mg $L^{-1}$ | 85.00 | 80.00 | 82.5 $^{ns}$ |
| 50 mg $L^{-1}$ | 97.50 | 80.00 | 88.7 |
| 100 mg $L^{-1}$ | 97.50 | 80.00 | 88.7 |
| 150 mg $L^{-1}$ | 97.50 | 73.00 | 85.2 |
| 200 mg $L^{-1}$ | 97.50 | 73.00 | 85.2 |
| Mean | 95 A* | 77.2 B | |
| CV (A) | 3.5 % | | |
| CV(B) | 7.6 % | | |

$^{ns}$ = not significant by the F test.
*Means followed by the same uppercase letters in the row do not differ by the F test (5%).
Analysis performed after the data were arcsine (x + 0.5)$^{\wedge 0.5}$ transformed.
The displayed means are the original ones.

When stimulated for high gibberellin biosynthesis signaling, *Populus* and *Arabidopsis* plants exhibited fewer adventitious roots (Mauriat et al., 2014). However, treatment with 50 mg $L^{-1}$ GA did not prevent the rooting of the rhizomes of the Tiger Flame cultivar. In this way, the authors conclude that low GA levels are required for rooting to occur (Padhi et al., 2018). Niu et al. (2013) found that GA did not influence polar auxin transport, but high levels negatively regulate rooting, at least in the induction and initiation phase, which consists of biochemical, anatomical and cell multiplication stages.

## Conclusions

Foliar spraying of gibberellic acid at the concentrations of 76 and 200 mg $L^{-1}$ in the winter and summer, respectively, increases the production of mini-cuttings from 'BRS Guaraçá' rootstock and does not interfere with their rooting, allowing percentages greater than 95% in the summer.

## Acknowledgment

The authors would like to thank Embrapa Semiárido/Petrolina-PE for BRS-Guaraçá, a hybrid development in that instituition and used in that article. Thank to Rio de Janeiro State Research Support Foundation (FAPERJ) for the financial support and the Coordination for the Improvement of Higher Education Personnel (Capes) and CNPq for the scholarships granted to carry out this study.

## References

Altendorf, S. (2018). *Minor tropical fruits: mainstreaming a niche market.* Rome: Food and Agriculture Organization of the United Nations. Retrieved from http://www.fao.org/fileadmin/templates/est/ COMM_MARKETS_MONITORING/Tropical_Fruits/Documents/Minor_Tropical_Fruits_FoodOutlook_1_2018.pdf

Altoé, J. A., Marinho, C. S., & Freitas, I. L. J. (2013). Goiabeiras Paluma, Pedro Sato e Cortibel 6 propagadas por miniestaquia e miniestaquia seriada. *Ciência Rural, 43*(8), 1351-1356. doi: 10.1590/S0103-847820 13000800002

Altoé, J. A., Marinho, C. S., Terra, M. I. C., & Barroso, D. G. (2011b). Propagação de araçazeiro e goiabeira via miniestaquia de material juvenil. *Bragantia, 70*(2), 312-318. doi: 10.1590/S0006-87052011000200009

Altoé, J. A., Marinho, C. S., Terra, M. I. C., & Carvalho, A. J. C. (2011a). Multiplicação de cultivares de goiabeira por miniestaquia. *Bragantia, 70*(4), 801-809. doi: 10.1590/S0006-87052011000400011

Biazatti, M. A., Marinho, C. S., Arantes, M. B. S., & Guilherme, D. O. (2018). Multiplication of cattley guava by different techniques and variability among genotypes in vigor and rooting. *Cerne, 24*(4), 379-386. doi: 10.1590/01047760201824042571

Campos, G. S., Marinho, C. S., Portella, C. R., Amaral, B. D., & Carvalho, W. S. G. (2017). Production of guava mini-grafted on intra or interspecific rootstock. *Revista Brasileira de Fruticultura, 39*(1), e-635. doi: 10.1590/0100-29452017635

Costa, S. R., Santos, C. A. F., & Castro, J. M. C. (2012). Assessing *Psidium guajava* × *P. guineense* hybrids tolerance to *Meloidogyne enterolobii. Acta Horticulturae, 959,* 59-66. doi: 10.17660/ActaHortic.2012. 959.6

Davies, P. J. (2010). The plant hormones: their nature, occurrence, and functions. In P. J. Davies (Ed.), *Plant hormones* (pp. 1-15). Dordrecht: Springer.

Dias, P. C., Oliveira, L. S., Xavier, A., & Wendling, I. (2012). Estaquia e miniestaquia de espécies florestais lenhosas do Brasil. *Pesquisa Florestal Brasileira, 32*(72), 453. doi: 10.4336/2012.pfb.32.72.453

Ferreira, G. O., Nascimento, R. C., Costa, S. R., Nogueira, T. O., Santos, C. A. F., & Flori, J. E. (2013). Propagação vegetativa de plantas originadas do cruzamento entre *Psidium guajava* x *Psidium guineense,* resistentes a *Meloidogyne enterolobii. Anais da Jornada de Iniciação Científica da EMBRAPA Semiárido,* Petrolina, PE, Brasil.

Ferriani, A. P., Zuffellato-Ribas, K. C., & Wendling, I. (2010). Miniestaquia aplicada a espécies florestais. *Revista Agro@mbiente, 4*(2), 102-109. doi: 10.18227/1982-8470ragro.v4i2.363

Gomes, W. A., Mendonça, R. M. N., Souza, E. P., Estrela, M. A., Melo, V. S., Silva, S. M., & Souza, A. (2010). Garfagem e diâmetro de porta-enxerto na obtenção de mudas de umbuzeiro do acesso Laranja. *Revista Brasileira de Fruticultura, 32*(3), 952-959. doi: 10.1590/S0100-29452010000 300041

Instituto Brasileiro de Estatística e Geografia (2020). *Área destinada à colheita, área colhida, quantidade produzida e valor da produção da lavoura permanente.* Recuperado de https://sidra.ibge.gov.br/tabela/1613

Kadam, D. M., Kaushik, P., & Kumar, R. (2012). Evaluation of guava products quality. *International Journal of Food Science and Nutrition Engineering, 2*(1), 7-11. doi: 10.5923/j.food.20120201.02

Malshe, K. V., Desai, B. G., & Palshetkar, M. G. (2016). Effect of different growth regulators on growth of khirni (Manilkara hexandra L.) rootstock. *Annual Review of Plant Physiology, 30*(2), 15-17. Retrieved from http://www.researchgate.net

Matos, F. S., Silva, D. Z. D., Souza, B. R. D., Moura, D. R., Lopes, V. D. A., Carvalho, D. D. C., & Araujo, M. D. S. (2015). Análise de crescimento, incidência de *Rhizoctonia* sp. e efeito antixenose para a formiga-cortadeira *Atta sexdens rubropilosa* f. em clones de *Eucalyptus grandis* x *Eucalyptus urophylla* tratados com giberelina. *Revista Árvore, 39*(5), 915-922. doi: 10.1590/0100-67622015000500014

Mauriat, M., Petterle, A., Bellini, C., & Moritz, T. (2014). Gibberellins inhibit adventitious rooting in hybrid aspen and Arabidopsis by affecting auxin transport. *The Plant Journal, 78*(3), 372-384. doi: 10.1111/tpj.12478

Niu, S., Li, Z., Yuan, H., Fang, P., Chen, X., & Li, W. (2013). Proper gibberellin localization in vascular tissue is required to regulate adventitious root development in tobacco. *Journal of Experimental Botany, 64*(11), 3411-3424. doi: 10.1093/jxb/ert186

Oliveira, M. J. V. D., Schmildt, E. R., Amaral, J. A. T. D., Coelho, R. I., & Schmildt, O. (2014). Formas de esterilização do GA3 e reação morfogênica em microestacas de mamoeiro. *Revista Brasileira de Fruticultura, 36*(2), 467-471. doi: 10.1590/0100-2945-271/13

Padhi, M., Sisodia, A., Pal, S., Kapri, M., & Singh, A. K. (2018). Growing media, $GA_3$ and thiourea stimulates growth and rooting in gladiolus cormels cv. Tiger Flame. *Journal of Pharmacognosy and Phytochemistry, 7*(3), 1919-1922. doi: Retrieved from https://www.phytojournal.com/archives/2018/vol7issue3

Parween, N., Mishra, S., Adil, A., Pal, A., & Jha, K. K. (2019). Effect of GA3 on reproductive growth and cormel production of gladiolus. International *Journal of Current Microbiology and Applied Sciences, 8*(6), 1739-1750. doi: 10.20546/ijcmas.2019.806.208

Peña, M. L.P., Zanette, F., & Biasi, L. A. (2015). Época de coleta e ácido indolbutírico no enraizamento de miniestacas de pitangueira. Semina: *Ciências Agrárias, 36*(5), 3055-3068. doi: 10.5433/1679-0359.2015 v36n5p3055

Pimentel, N., Lencina, K. H., Kielse, P., Rodrigues, M. B., Somavilla, T. M., & Bisognin, D. A. (2019). Productivity of mini-stumps and rooting of mini-cuttings of erva mate (*Ilex paraguariensis* A. St.-Hil.) clones. *Ciência Florestal, 29*(2), 559-570. doi: 10.5902/1980509827009

Porto, A. H., Wagner, A., Jr., Kosera, C., Neto, Silva, M., Stefeni, A. R., & Fabiane, K. C. (2018). Giberelina e substratos na produção e qualidade de mudas de araçazeiros amarelo e vermelho (*Psidium cattleyanum* Sabine). *Colloquium Agrariae, 14*(1), 35-48. doi: 10.5747/ca.2018.v14.n1.a188

Ramos, D. P., Leonel, S., Silva, A. C., Souza, M. E., Souza, A. P., & Fragoso, A. M. (2011). Épocas de poda na sazonalidade, produção e qualidade dos frutos da goiabeira' Paluma'. *Semina: Ciências Agrárias, 32*(3), 909-918. doi: 10.5433/1679-0359.2011v32n3p909

Silva, K. B., Reiniger, L. R. S., Rabaiolli, S. D. S., Stefanel, C. M., & Ziegler, A. D. F. (2019). Productivity of minicepas and rooting of minicuttings of *Luehea divaricata* Mart. & Zucc. in the different seasons of the year. *Scientia Forestalis, 47*(122), 294-302. doi: 10.18671/scifor.v47n122.12

Velasco-Arango, V. A., Bernal-Martínez, A. A., Ordóñez-Santos, L. E., & Hleap-Zapata, J. I. (2020). Characterization of guyaba epicarp (*Psidium guajava* L.) as a natural alternative for use in processed food products. *Biotecnología en el Sector Agropecuario y Agroindustrial, 18*(2), 26-35. doi: 10.18684/bsaa(18)26-36

Zhang, Y., Wang, Y., Ye, D., Xing, J., Duan, L., Li, Z., & Zhang, M. (2020). Ethephon-regulated maize internode elongation associated with modulating auxin and gibberellin signal to alter cell wall biosynthesis and modification. *Plant Science, 290,* 110196. doi: 10.1016/j.plantsci.2019.110196