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Phenology and production of guava cultivars, using two methods of vegetative propagation, subjected to fruiting pruning times in the Brazilian Semiarid

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A B S T R A C T

Guava (*Psidium guajava* L.) is known for its wide adaptation to different soil and climate conditions. However, the climatic seasonality of the growing regions exposes the plants to different environmental conditions, capable of influencing their phenology and production. Therefore, determining the behavior of cultivars at different fruiting pruning times is an important tool for crop planning. Thus, the present study aims to evaluate the phenological and productive behavior of guava cultivars, propagated vegetatively at different fruiting pruning times in the semiarid region. The experiment was conducted in randomized blocks, during the period from 2022 to 2023, in a 3 x 6 double factorial arrangement, the factors corresponded to: i) pruning season (rainy-dry, dry-rainy and dry) and, ii) cultivar + propagation method ('Paluma' grafted, 'Paluma' cutting, 'Tailandesa Vermelha' grafted, 'Tailandesa Vermelha' cutting, 'Tailandesa Branca' grafted and 'Tailandesa Branca' cutting). The phenological cycle and productive attributes were evaluated. The results revealed that the propagation methods do not alter the phenological cycle of the cultivars, which was 184 to 196 days. The grafting method provided better productive indices (number of fruits, production, average fruit weight) in the 'Paluma' and 'Tailandesa Branca' cultivars, in the 3 pruning seasons. The cultivars showed a reduced cycle between pruning and harvesting in the dry season. The productive potential of guava is greater in the dry-rainy season. The cultivar 'Tailandesa Branca' propagated by grafting with pruning in the dry-rainy season proved to be more promising in the semiarid region.

Keywords: productive attributes, BRS guaraçá, cultivars, propagation, *Psidium guajava* L.

Fenologia e produção de cultivares de goiabeira, em dois métodos de propagação vegetativa, submetidas a épocas de poda de frutificação no Semiárido Brasileiro

R E S U M O

A goiabeira (*Psidium guajava* L.) é conhecida por sua ampla adaptação a diferentes condições edafoclimáticas. No entanto, a sazonalidade climática das regiões de cultivo, expõe as plantas a diferentes condições ambientais, capazes de influenciar na sua fenologia e produção. Logo, a determinação do comportamento das cultivares em diferentes épocas de poda de frutificação são ferramentas importantes para o planejamento do cultivo. Desse modo, o presente estudo tem por objetivo avaliar o comportamento fenológico e produtivo de cultivares de goiabeiras, propagadas vegetativamente em diferentes épocas de poda de frutificação no semiárido. O experimento foi conduzido em blocos casualizados, durante o período de 2022 a 2023, em arranjo fatorial duplo 3 x 6, os fatores corresponderam a: i) época de poda (chuvosa-seca,

seca-chuvosa e seca) e, ii) cultivar + forma de propagação ('Paluma' enxertada, 'Paluma' estaca, 'Tailandesa Vermelha' enxertada, 'Tailandesa Vermelha' estaca, 'Tailandesa Branca' enxertada e 'Tailandesa Branca' estaca). Foi avaliado o ciclo fenológico e atributos produtivos. Os resultados revelaram que os métodos de propagação não alteram o ciclo fenológico das cultivares que foi de 184 a 196 dias. O método de enxertia, proporcionou melhores índices produtivos (número de fruto, produção, peso médio do fruto) nas cultivares 'Paluma' e 'Tailandesa branca', nas 3 épocas de poda. As cultivares apresentaram ciclo reduzido entre a poda e a colheita na poda de época seca. O potencial produtivo da goiabeira é maior na época seca-chuvosa. A cultivar 'Tailandesa Branca' propagada por enxertia com poda na época seca chuvosa, demonstrou ser mais promissora na região Semiárido.
Palavras-chave: atributos produtivos, BRS Guaraçá, cultivares, propagação, *Psidium guajava* L.

Introduction

The guava tree (*Psidium guajava* L.) is a prominent fruit plant from the Myrtaceae family, originally native to Central America (Sujeeun & Thomas, 2022). It shows remarkable adaptability to various soil and climate conditions, making it cultivable in different regions (Vitti et al., 2020), and is grown in tropical and subtropical areas (Santos et al., 2023). In Brazil, it is found throughout the national territory (Martins et al., 2020).

Guava is known for its delightful aroma, flavor, and nutritional value, holding a prominent position among cultivated fruits (Sarkar & Sarkar, 2022). It has several cultivars, each with its intrinsic characteristics, influencing aspects such as productivity, early production, fruit size and shape, number of fruits per plant, pulp color, canopy shape, phenological cycle, and fruit quality (Flori & Deon, 2022).

Among the main commercial cultivars, 'Paluma' is one of the most popular and widely cultivated. It has stood out for being highly productive (19 t ha^{-1}) and produces medium-sized fruits with red pulp (Santos et al., 2023), being the preferred choice among consumers and producers (Arruda et al., 2023).

However, the introduction and cultivation of new guava cultivars, such as the 'Tailandesa', originating from Thailand, has been gaining increasing market space due to its high productive potential (22 t ha^{-1}), as well as large fruits with white or red pulp (Martins et al., 2020).

The production of cultivars is determined by their intrinsic characteristics and management practices, such as vegetative propagation (Lourenço et al., 2022) and the timing of fruiting pruning (Santos et al., 2023). Vegetative propagation ensures greater uniformity and early production in orchards (Ribeiro et al., 2021). Fruiting pruning emerges as a vital practice, allowing better control and distribution of the plant's vegetative growth (Pineda et al., 2020).

In propagative management, cutting, a widely used method, consists of rooting a herbaceous cutting from the guava tree to produce a new plant (Santos, 2020). This method has been increasingly replaced by grafting, which is also used as a phytosanitary measure to control the spread of pests and diseases in orchards (Spano et al., 2020).

The use of the rootstock BRS Guaraçá, which is resistant to root-knot nematode (*Meloidogyne enterolobii*), is the only effective method for controlling nematodes in guava trees (Oliveira et al., 2019). The pest has been considered the main threat to guava cultivation, causing changes in the phenological cycle, from pruning to harvesting, contributing to a decrease in production (Cavalcanti Junior et al., 2020).

Regarding the management of fruiting pruning, which is a vital practice for inducing the phenological cycle, stimulating sprouting and the formation of reproductive structures (Santos et al., 2023), it is essential to emphasize that the timing of fruiting pruning can induce varied responses in the development of branches and fruits, in fruit set rate, and in guava production (Srivastava et al., 2022), as well as in the duration of its phenological cycle (Monteiro et al., 2021). Therefore, the agronomic characterization of guava cultivars should be observed in each growing region to establish productive and profitable practices (Martins et al., 2020), according to the climatic conditions during the plant's development period.

Studies on the 'Paluma' cultivar regarding propagation by cuttings are well established, while research on its phenology and productive attributes when grafted onto BRS Guaraçá rootstock, as well as for the 'Tailandesa Vermelha' and 'Tailandesa Branca' cultivars, is lacking. The BRS Guaraçá rootstock shows potential to increase the orchard lifespan, providing an increase in productivity, making studies of this nature particularly necessary.

Therefore, guava cultivars may undergo changes in their phenological phases and productive attributes, modulated by the timing of fruiting pruning with interactions with the propagation method. Thus, the present study aims to evaluate the phenological and productive behavior of guava cultivars, vegetatively propagated at different times of fruiting pruning in the Semi-arid region.

Material and methods

The experiment was conducted at the experimental guava orchard of the Department of Horticulture at the Federal University of Piauí (UFPI/FEAG), located in Alvorada do Gurguéia, Piauí, Brazil (8°22'30" S, 43°51'06" W).

The climate of the region is classified as tropical (Aw) according to the Köppen system, with a hot and dry season (winter) from April to October and a hot and rainy season (summer) from November to March. The average annual precipitation is 1,400 mm, and the average annual temperature is 30 °C, ranging from 15 to 42 °C. The climatic conditions during the experiment are represented in Figure 1.

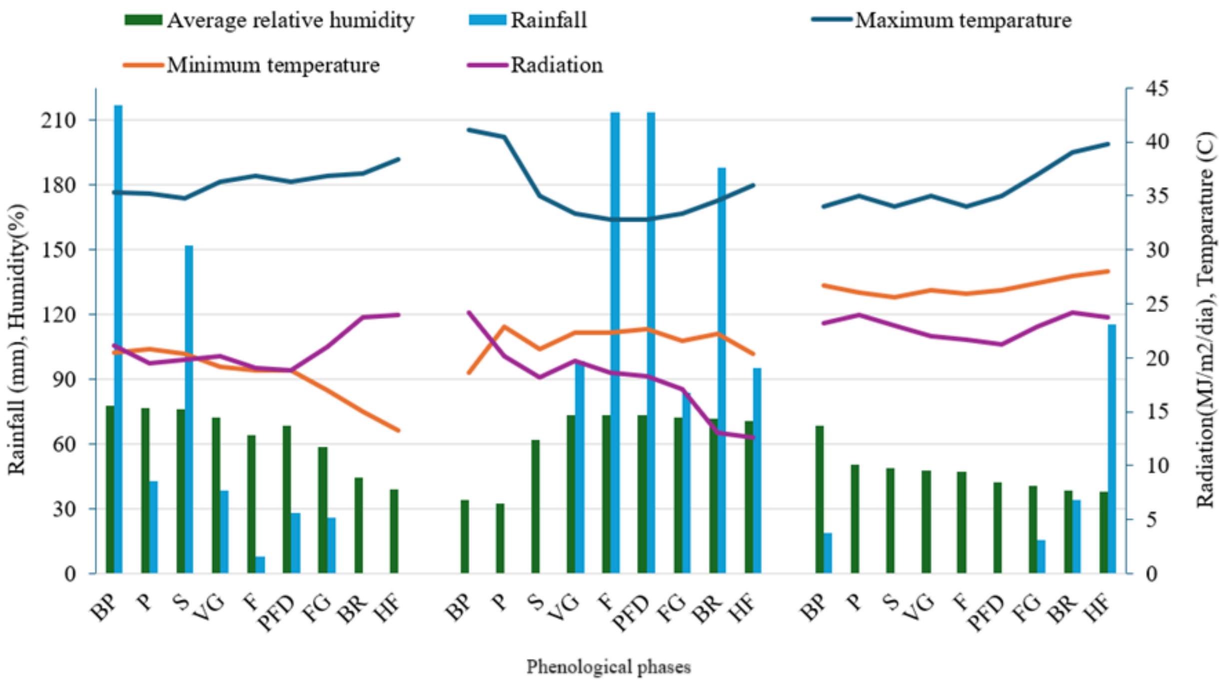

Figure 1. Meteorological data recorded during three pruning seasons for fruiting and development of the phenological phases of guava trees, from January 2022 to November 2023 in the semiarid region of Brazil. BP: Before pruning; P: Pruning; S: Sprouting; VG: Vegetative growth; F: Flowering; PFD: Physiological fruit drop; FG: Fruit growth; BR: Beginning of maturation; HF: Harvesting of fruits.

The orchard was planted in April 2021, with a planting spacing of 5 × 5 meters, in soil classified as Dystrophic Yellow Latosol according to the classification of the Brazilian Agricultural Research Corporation (EMBRAPA, 2018).

Three guava cultivars were used: 'Paluma', 'Tailandesa Vermelha', and 'Tailandesa Branca', propagated by grafting onto the BRS Guaraçá rootstock. These same cultivars were also propagated by cuttings as a control.

Before each fruiting pruning, soil samples were collected to a depth of 0.40 m to characterize the soil's physical-chemical properties. The experimental area of the guava orchard has sandy soil (11% clay, 2% silt, and 87% sand) with low natural fertility. The main results of the soil chemical analysis are presented in Table 1.

Table 1. Chemical properties of the soil in the 0.0–0.40 m layer before pruning for fruiting of guava trees, during the rainy-dry, dry-rainy, and dry seasons, in Alvorada do Gurguéia, Piauí, Brazil.

Fruiting pruning	pH	OM	P	K	Ca	Mg	H+Al	CEC	V	Cu	Fe	Mn	Zn
season	H_2O	g kg^{-1}	mg dm^{-3}	----------$cmol_c$ dm^{-3}-----------					%	----------mg dm^{-3}-----			
Drainy-dry	5.0	7.4	7.7	0.05	0.43	0.02	1.55	1.20	23.6	0.08	39.2	11.6	0.03
Dry-drainy	4.9	6.0	29.1	0.15	0.71	0.10	1.22	1.74	42.4	0.04	61.0	11.8	1.23
Dry	5.9	7.0	31.7	0.16	1.00	0.70	1.30	1.56	48.3	0.07	67.1	15.3	1.35

OM: organic matter; CEC: cation exchange capacity; V: Soil base saturation

The experiment was arranged in a randomized block design with 4 replications, each replication consisting of 3 plants in a 3×6 factorial arrangement. The factors corresponded to: i) pruning time (rainy-dry, dry-rainy, and dry), and ii) cultivar + propagation method ('Paluma' grafted, 'Paluma' cutting, 'Tailandesa Vermelha' grafted, 'Tailandesa Vermelha' cutting, 'Tailandesa Branca' grafted, and 'Tailandesa Branca' cutting), starting the phenological cycle with fruiting pruning and ending with harvest.

The medium intensity pruning were carried out in three periods:

1st> 02/05/2022, rainy-dry season, with pruning in the rainy period and harvest in the dry period.

2nd> 08/10/2022, dry-rainy season, with pruning in the dry period and harvest in the rainy period.

3rd> 06/05/2023, dry season, the cycle from pruning to harvest occurred in the dry period.

Soil correction and fertilization of the guava orchard were carried out based on soil analysis (Table 1) and the crop's nutritional needs, as proposed by Natale et al. (2009). The mineral fertilizer doses were divided into three application stages: fruiting pruning, flowering, and the beginning of fruit growth (Phase I). Supplemental irrigation was used through a micro-sprinkler system, with one micro-sprinkler per plant, with a flow rate of 80 L h^{-1}, as needed.

After fruiting pruning, four branches were selected and marked, one in each quadrant, to characterize the phenological phases. This was done through nine distinct phases, following a methodology adapted from Serrano et al. (2008).

The analysis of the phenological phases was carried out every 7 days during the production cycle, which starts with fruiting pruning and ends at the harvest. The following phenological phases were evaluated:

1. Beginning of sprouting and branch establishment.
2. Vegetative growth;
3. Flowering (anthesis);
4. Physiological fruit drop;
5. Period of rapid fruit growth (Phase I);
6. Period of slow fruit growth (Phase II);
7. Period of exponential fruit growth and color change (Phase III);
8. Beginning of fruit maturation;
9. Harvest of the fruits.

Based on the determination of the phenology of the cultivars, a descriptive (Figure 2) and illustrative (Supplementary Figure 1) phenological scale was created.

After the physiological fruit drop, four fruits were marked per plant, one in each quadrant, to measure the longitudinal diameter (axis parallel to the peduncle) and the transverse diameter (axis perpendicular to the peduncle) every 15 days. The fruits were measured with a digital caliper to characterize and define the three phases of fruit growth (Phenophases 5, 6, and 7).

After the physiological fruit drop, the number of productive branches (PB) (with fruit) and vegetative branches (VB) per guava tree were counted to define the productive branch index (PBI) (equation 1). Based on the number of fruits harvested (NFH) and the fruits that fell to the ground (FFG), the total number of fruits per guava tree was determined, and the fruit set index (FSI) was calculated (equation 2). All harvested fruits were weighed on a digital scale to determine the fruit production per plant (FPP) in kilograms. The production was divided by the number of fruits and converted into grams to determine the average fruit weight (AFW). The rates (PBI and FSI) were calculated by dividing the analyzed part by the total sum found and multiplying by 100, expressed as a percentage.

Equation 1

$$IRP = \left(\frac{RP}{RP + RV}\right) * 100$$

Equation 2

$$IPF = \left(\frac{NFC}{NFC + FCS}\right) * 100$$

The data were subjected to analysis of variance, and the means were compared using Tukey's test with a 5% probability level. Principal component analysis was used to relate the variation in the characteristics of each treatment with the variables. All statistical analyses were performed using R software version 3.5.2 (R Core Team, Vienna, AUT, 2020).

Results

The phenological phases of the three guava cultivars were studied to assess the impact of vegetative propagation methods. The results revealed that grafting or cutting did not induce significant changes in the phenological phases.

The duration of the nine phenological phases was presented as relatively uniform for each cultivar propagated by both propagation methods (grafting and cuttings) in each fruiting pruning period (rainy-dry, dry-rainy, and dry). The phenological phases of the guava tree show overlap from one phase to the next, with the guava tree potentially producing shoots while already having defined branches with floral buds. This explains the extended harvest period, which starts and ends with few fruits, reaching its peak 15 to 20 days after the start of harvesting. Figure 2 shows the illustration of the 9 phenophases

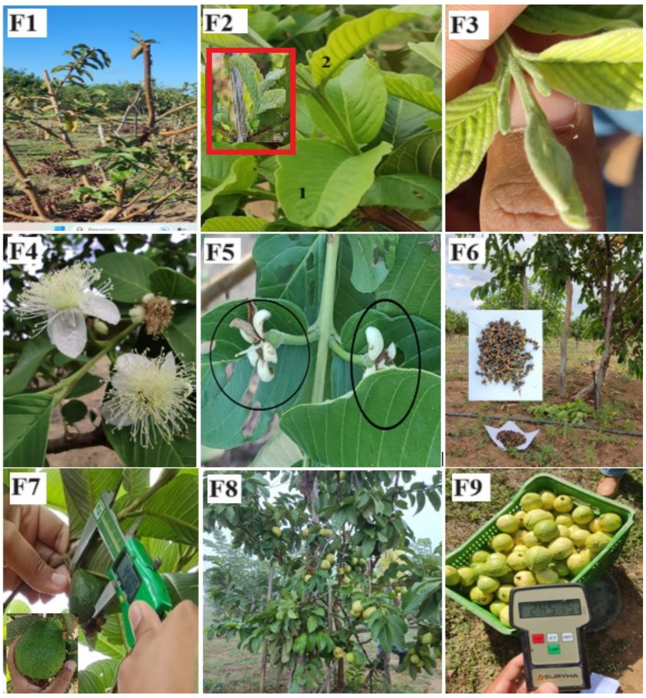

Figure 2. Illustration of the phenological phases of guava trees grown in the semiarid region of Brazil, propagated by cuttings or grafting. F1 - pruning of guava trees; F2 - beginning of budding; F3 - vegetative growth; F4 - flowering (anthesis); F5 - fruiting; F6 - physiological fruit drop; F7 - fruit growth (Phase I); F8 - beginning of fruit ripening; F9 - fruit harvesting

The cultivars showed differences in the phenological cycle, revealing specific variations among them. The timing of the fruiting pruning directly influenced the phenological cycle of each cultivar, resulting in changes in the duration of the phenological period (Figure 3).

In general, the complete cycle of the guava cultivars, from pruning to fruit harvest, ranges from 189 to 206 days. The longest cycle occurred in the dry-rainy period for the 'Tailandesa Branca' and 'Tailandesa Vermelha' cultivars, while the longest cycle for 'Paluma' occurred in the rainy-dry period (Figure 3). On the other hand, the shortest cycle showed synchronization with the pruning period, where the dry period resulted in the shortest cycle for the studied cultivars. Furthermore, all phenophases of the cultivars developed during the dry period (dry season) had a shorter cycle compared to the other periods (Figure 3).

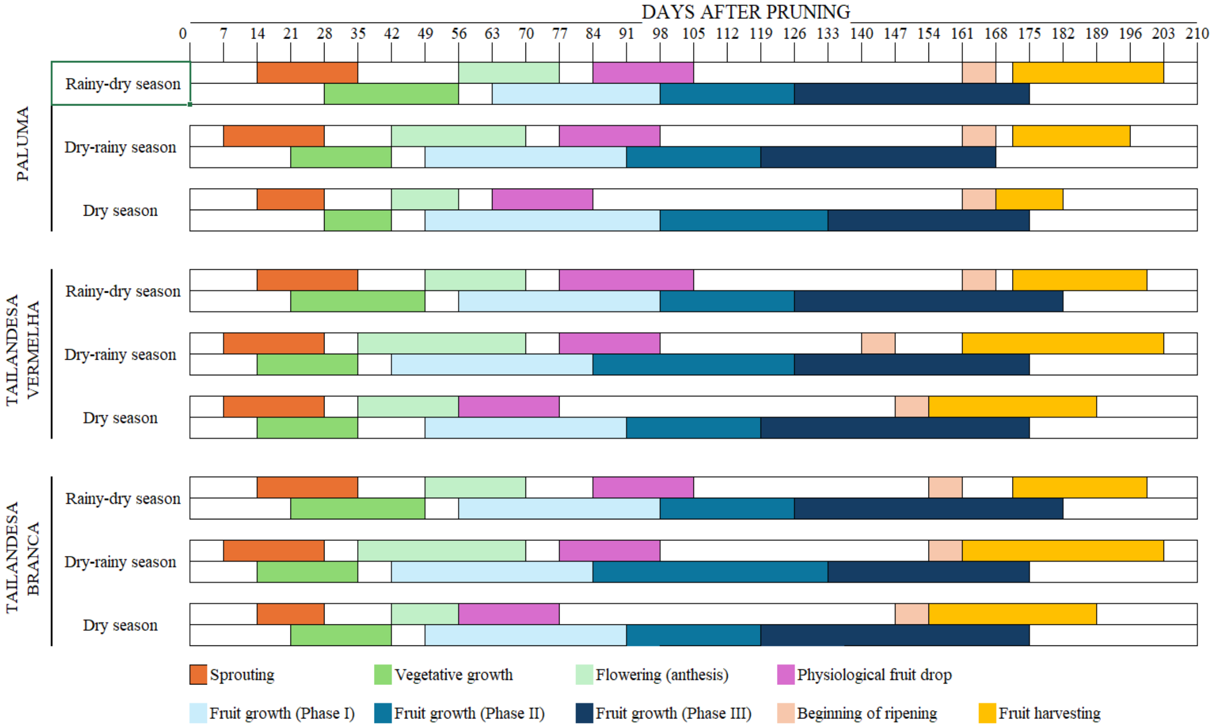

Figure 3. Duration of phenological phases of three guava cultivars ('Paluma', 'Tailandesa Vermelha' and 'Tailandesa Branca') propagated by cuttings or grafting and subjected to fruiting pruning seasons [rainy-dry period, dry-rainy period and dry period] in the semiarid region of Brazil.

The sprouting of the studied cultivars occurred 14 and 7 days after pruning in the rainy-dry and dry-rainy periods, respectively. During the dry period, the 'Tailandesa Vermelha' cultivar sprouted in 7 days, while the 'Paluma' and 'Tailandesa Branca' cultivars began the process in 14 days (Figure 3). The interval between the start of sprouting and the completion of flowering was approximately 70 days for all three cultivars during the rainy-dry and dry-rainy periods (Figure 3).

However, during the dry period, there was synchronization between the cultivars for the start of sprouting and the completion of flowering, with the process being completed in 56 days. Nevertheless, regarding the onset of flowering, the 'Tailandesa Vermelha' and 'Tailandesa Branca' guava cultivars showed earlier flowering (35 days after pruning) compared to the 'Paluma' cultivar (42 days after pruning), especially in the dry season.

The duration of physiological fruit drop for the 'Paluma' and 'Tailandesa Branca' cultivars lasted 21 days in all three periods, while for the 'Tailandesa Vermelha' cultivar, this period was extended to 28 days when subjected to pruning in the rainy-dry period (Figure 3). The period between the start of flowering and the beginning of harvest was shorter in the dry period for the 'Tailandesa Branca' (112 days) and 'Tailandesa Vermelha' (119 days) cultivars, while for the 'Paluma' cultivar, it was in the rainy-dry period, with 114 days. The longest interval occurred in the dry-rainy period, where all cultivars took 126 days from the start of flowering to the beginning of harvest.

During fruit development, covering phases I, II, and III of growth, the 'Paluma' cultivar showed a shorter duration (112-119 days) in the rainy-dry and dry-rainy periods, while the 'Tailandesa Vermelha' and 'Tailandesa Branca' cultivars had a period of 124-133 days in the same periods. In the dry period, all cultivars had a uniform period of 126 days, which was the longest for 'Paluma' compared to the other periods.

The 'Paluma' cultivar showed consistency across the periods, with the first mature fruits appearing 98 days after fruiting. In 'Tailandesa Branca,' mature fruits appeared 112 days in the dry-rainy period. The 'Tailandesa Vermelha' and 'Tailandesa Branca' cultivars showed earlier harvests, occurring at 170, 161, and 154 days after pruning, with durations of 30, 42, and 35 days in the rainy-dry, dry-rainy, and dry periods, respectively. In contrast, 'Paluma' harvest began at 170 days, lasting 33, 26, and 14 days for the same pruning periods.

The interaction between cultivars propagated by grafting or cuttings and pruning times showed statistical significance in all productive characteristics of the guava trees, as identified by the analysis of variance in Table 2.

Table 2. Summary of the analysis of variance of the effects of cultivars and stages of development of phenological phases on the productive characteristics of fruits from guava trees propagated by cuttings and grafting.

Soures of Variation	**'F' value**				
	PBR	FSR	NFH	AFW	FY
Cultivar/propagation(C)	212.2*	654.7*	7035.0*	937.3*	383.7*
Pruning season (P)	117.4*	2279.3*	32582.0*	5740.5*	2224.9*
C x P	8.8*	168.8*	1026.0*	56.8*	55.5*
CV (%)	7.0	3,3	1.4	1.3	6.7

PBR: productive branch rate; FSR: fruit set rate; NFH: number of fruits harvested;
AFW: average fruit weight; FY: fruit yield. *: indicates a significance level of $p>0.001$ by the F test. CV: coefficient of variation.

The pruning in the rainy-dry period resulted in a significantly higher rate of productive branches ($p \leq 0.05$) compared to the other periods in the evaluated cultivars, with the exception of the grafted 'Tailandesa Branca' cultivar, where the pruning times had no impact on the productive branch rate (Figure 4). The 'Tailandesa Branca' and 'Tailandesa Vermelha' cultivars propagated by cuttings showed superior results, with productive branch rates of 89.54% and 93.52%, respectively.

The 'Paluma' cultivar propagated by cuttings exhibited the lowest productive branch rates (49%, 19%, and 31% in the rainy-dry, dry-rainy, and dry periods, respectively) (Figure 4). Regarding the propagation methods, 'Tailandesa Vermelha' propagated by cuttings performed better in all pruning periods compared to 'Tailandesa Vermelha' grafted, in terms of productive branch rates.

On the other hand, propagation by grafting provided the 'Paluma' cultivar with the best rates compared to the same cultivar propagated by cuttings. For 'Tailandesa Branca', cuttings were more efficient only during the rainy-dry period, and the grafted 'Tailandesa Branca' did not show any difference in productive branch rates across the three pruning periods. The productive branch rate decreased with each period (Figure 4) for the cultivars 'Tailandesa Vermelha' (both grafted and cuttings), 'Tailandesa Branca' cuttings, and 'Paluma' grafted.

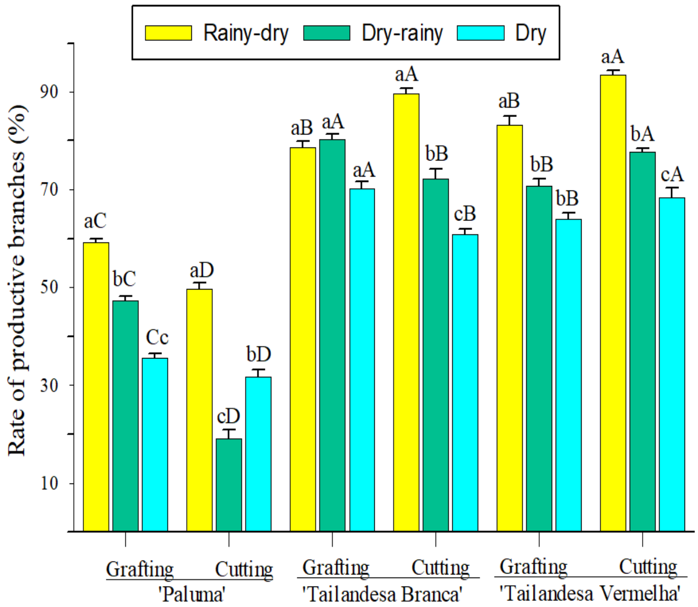

Figure 4. Rate of productive branching (PBR) of the three guava cultivars ('Paluma', 'Tailandesa Vermelha' and 'Tailandesa Branca') propagated by cuttings or grafting and subjected to fruiting pruning seasons [rainy-dry period, dry-rainy period and dry period] in the semiarid region of Brazil.

With the reduction in productive branches, consequently, the fruit set rate in the cultivar 'Paluma' (grafted and cuttings) and 'Tailandesa Branca' grafted was reduced. The cultivar 'Paluma' shows the lowest fruiting rates during the pruning periods, compared to the 'Tailandesa' guava cultivars (Figure 5A). In the rainy-dry pruning cycle, the fruiting rate for the 'Paluma' cultivar propagated by grafting and cuttings was 45% and 53%, respectively. This reduced to 31% and 22% in the dry-rainy period, reaching 15% for both propagation methods in the dry period (Figure 5A).

The 'Tailandesa' cultivars had their lowest fruit set rates in the dry period, while the highest rate occurred during the rainy-dry period for 'Tailandesa Branca' grafted and during the dry-rainy period for 'Tailandesa Vermelha' cuttings.

Despite the reduction in fruit set rate when comparing the rainy-dry pruning period to the dry-rainy pruning period, in the cultivars 'Paluma' grafted and 'Tailandesa Branca' (grafted and cuttings), there was a simultaneous increase in the variable of fruits harvested per plant. This increase ranged from 129 to 226 fruits in the 'Paluma' cultivars and from 211 to 360 fruits in the 'Tailandesa Branca' cultivar in the aforementioned pruning periods (Figure 5B).

For the following period (dry), there was a sharp reduction of 78% and 64% in the number of fruits harvested for the same cultivars, respectively. For the 'Tailandesa Vermelha' (grafted and cuttings) cultivar, the number of fruits harvested showed a similar increasing trend to the fruit set rate. The pruning performed in the dry-rainy period resulted in the highest number of fruits harvested. In contrast, as observed in the other cultivars, there was a sharp reduction in the number of fruits harvested during the dry period.

The 'Tailandesa Branca' cutting maintained the fruit set rate from the rainy-dry period to the dry-rainy period (Figure 5A), while the number of fruits increased by 66% from the first to the second period, with 171 and 285 fruits harvested per plant, respectively.

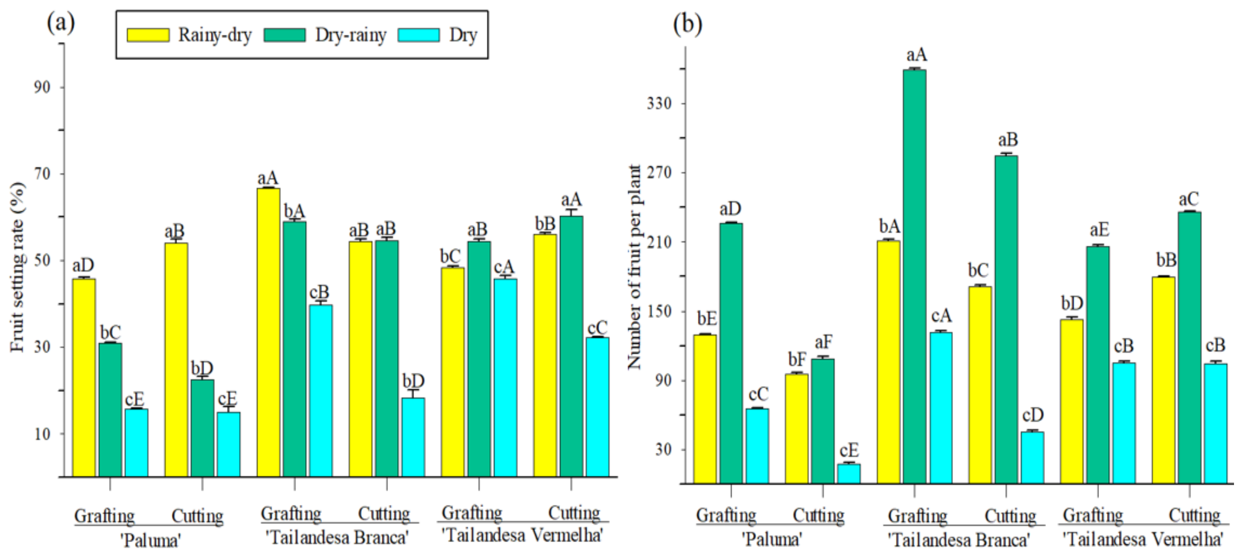

Figure 5. Fruit set index (A) and number of fruits per plant (B) of the three guava cultivars ('Paluma', 'Tailandesa Vermelha' and 'Tailandesa Branca') propagated by cuttings or grafting and subjected to fruiting pruning seasons [rainy-dry period, dry-rainy period and dry period] in the semiarid region of Brazil.

The propagation method significantly influenced the number of fruits harvested per plant.Grafting resulted in a higher increase in the number of fruits harvested from the rainy-dry season to the dry-rainy season compared to cultivars propagated by cuttings. Among the grafted cultivars, 'Paluma' showed the greatest increase, with a 74% increment, followed by 'Tailandesa Branca' (70%) and 'Tailandesa Vermelha' (44%) (Figure 5B).

On the other hand, cultivars propagated by cuttings showed a more pronounced reduction in the number of fruits harvested from the dry-rainy to the dry season. This reduction was 84% for 'Paluma' and 'Tailandesa Branca', while 'Tailandesa Vermelha' showed a 55% reduction. Despite the 'Tailandesa Branca' propagated by cuttings having the same fruit set rate in the rainy-dry and dry-rainy pruning periods (54%) (Figure 5A), the cultivar showed a significant 66% increase in the number of fruits harvested per plant, totaling 284 fruits harvested in the dry-rainy period (Figure 5B).

The pruning in the dry season resulted in a reduction in fruit set rate, number of fruits harvested per plant, and average fruit weight (Figure 6A) for the evaluated cultivars, compared to the two previous seasons (rainy-dry and dry-rainy). This directly reflected in the decrease in the production of the cultivars (Figure 6B).

For average fruit weight, the grafting propagation method resulted in better average fruit weight for the 'Paluma' and 'Tailandesa Branca' cultivars across all three pruning seasons, compared to those propagated by cuttings. Regarding the propagation method, the 'Tailandesa Vermelha' cultivar showed varying results depending on the pruning season. In the rainy-dry season, there was no significant difference in average fruit weight. However, in the dry-rainy season, the cutting propagation method resulted in the highest averages for fruit weight, while the 'Tailandesa Vermelha' cultivar grafted and pruned in the dry season showed the best performance for average fruit weight, outperforming the other cultivars in the study.

The variation in the number of fruits harvested per plant and average fruit weight directly impacted production. For example, the 'Tailandesa Branca' cultivar propagated by grafting showed a 91% increase in production during the dry-rainy season compared to the rainy-dry season (Figure 6B), despite a smaller increase in average fruit weight (20 g), reaching 196 g in the dry-rainy season. However, the number of fruits harvested per plant increased by 70%, totaling 359 fruits in the dry-rainy season pruning (Figure 5B).

The peak fruit production during the rainy-dry season pruning reached 37 kg per plant for the 'Tailandesa Branca' cultivar propagated by grafting. However, during pruning in the dry-rainy season, this same cultivar and propagation method showed a significant increase, producing 70.7 kg per plant (Figure 5B).

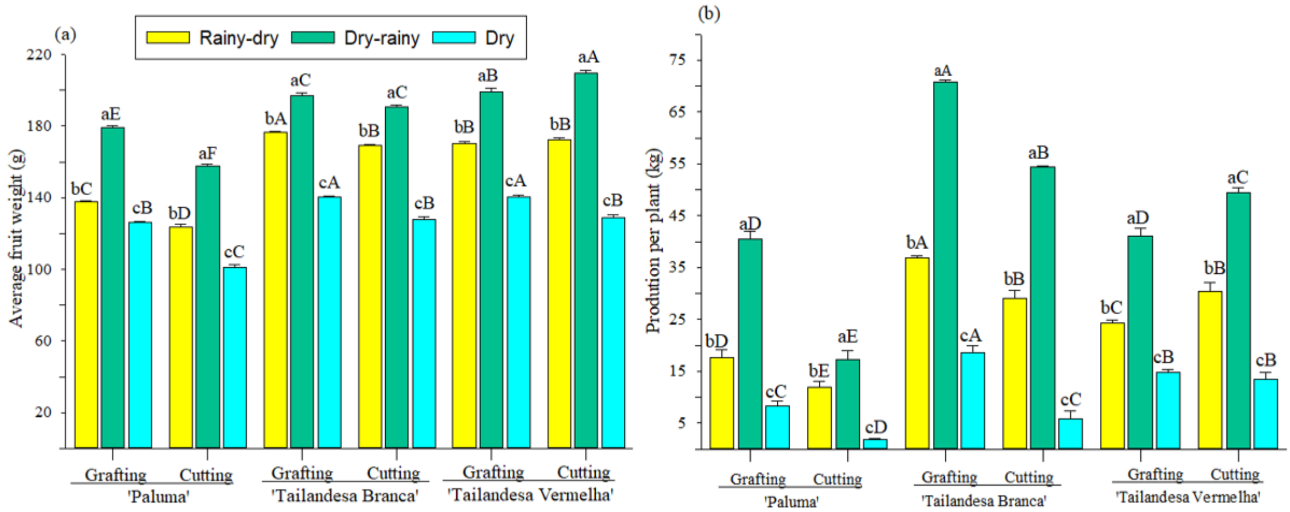

Figure 6. Production per plant (A) and Average Fruit Weight (B) of the three guava cultivars ('Paluma', 'Tailandesa Vermelha' and 'Tailandesa Branca') propagated by cuttings or grafting and subjected to fruiting pruning seasons [rainy-dry period, dry-rainy period and dry period] in the semiarid region of Brazil.

The guava cultivar 'Paluma', when propagated by cuttings, showed a fruit production of 11, 17, and 1.7 kg per plant during the rainy-dry, dry-rainy, and dry pruning periods, respectively. In contrast, the 'Tailandesa Branca' and 'Tailandesa Vermelha' cultivars, also propagated by cuttings, demonstrated higher fruit production, with 29 and 30 kg per plant in the rainy-dry period, and 54 and 49 kg per plant in the dry-rainy period. However, there was a significant decrease ($p \leq 0.05$) in the dry season, with production of 5 and 13 kg per plant, respectively. These cultivars significantly outperformed ($p \leq 0.05$) the fruit production of 'Paluma'.

The principal component analysis (PCA) explained 93.2% of the total data variation, with 78.47% in principal component 1 (PC1) and 14.73% in principal component 2 (PC2) (Figure 7). In this context, it is observed that the variables related to production, average fruit weight, and number of fruits were more closely associated with the 'Tailandesa Branca' and 'Tailandesa Vermelha' cultivars, regardless of the propagation method.

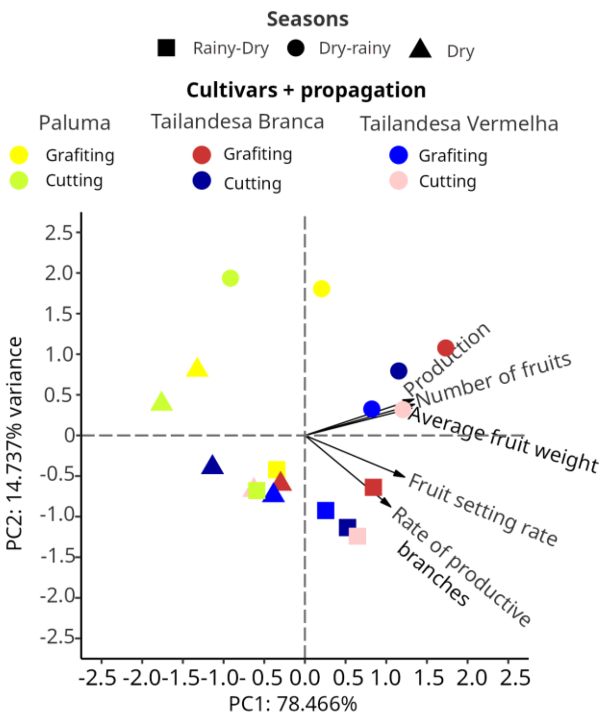

Figure 7. Principal Component Analysis (PCA) of the three guava cultivars ('Paluma', 'Tailandesa Vermelha' and 'Tailandesa Branca') propagated by cuttings or grafting and subjected to fruiting pruning seasons [rainy-dry period, dry-rainy period and dry period] in the semiarid region of Brazil.

These variables had a greater influence when the plants were pruned during the dry-rainy period. On the other hand, the fruit set rate and number of productive branches, although more related to the same cultivars, were more significantly influenced by pruning during the rainy-dry period, regardless of the propagation method.

The results obtained for productive branches (Figure 3), fruit set index (Figure 5A), number of fruits per plant (Figure 5B), average fruit weight (Figure 6A), and production (Figure 6B) highlight the negative influence of the *Meloidogyne enterolobii* root-knot nematode attack on cultivars propagated by cuttings. The diagnosis of this phytosanitary issue allowed for the identification of the problem that led to low productivity performance, associated with reduced vegetative development, as evidenced in Figure 8. The visual difference between plants propagated by grafting on the resistant BRS Guaraçá rootstock and those propagated by cuttings, which are susceptible to the nematode, reinforces the nematode's impact on plant vigor and productivity.

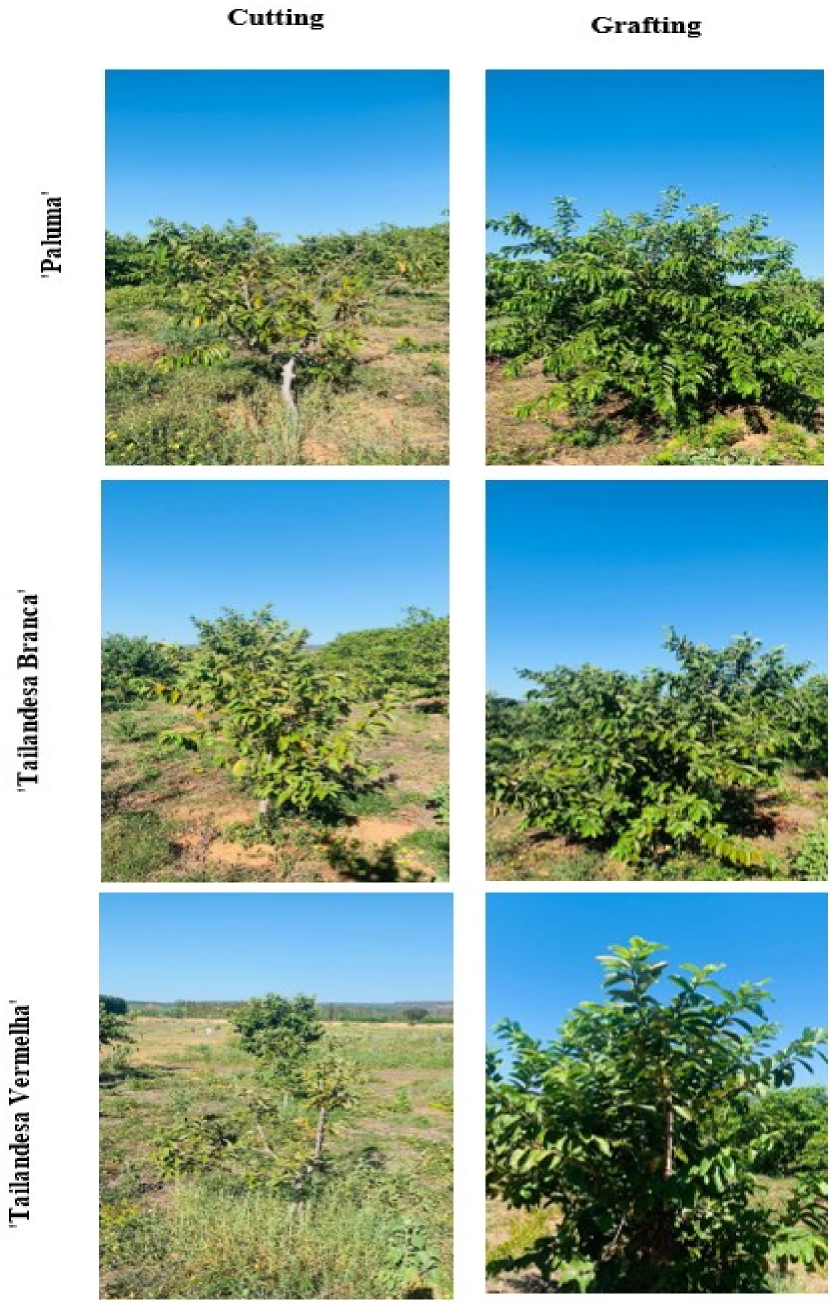

Figure 8. Representation of guava plants of three guava cultivars ('Paluma', 'Tailandesa Vermelha' and 'Tailandesa Branca') propagated by cuttings or grafting and subjected to fruiting pruning seasons [rainy-dry period, dry-rainy period and dry period] in the semiarid region of Brazil. The images show the plants after the third growing cycle.

Discussion

In the face of constant climate changes and frequent pest and disease attacks, especially those related to soil pests, there is an increasing push for studies aimed at the acclimatization of new plant cultivars of economic importance in non-traditional cultivation regions. This scenario underscores the importance of fruit tree propagation through grafting, a well-established and essential practice for plant adaptation and resistance.

In this regard, the present study provides evidence that the different guava cultivars

('Paluma', 'Tailandesa Branca', and 'Tailandesa Vermelha'), propagated through grafting and cutting, across three pruning seasons, exhibit their phenological phases in a similar manner. It should be noted that the specific responses of each cultivar and propagation method are closely tied to the management practices and specific environmental conditions.

Furthermore, Figure 8 allows for a visual comparison between the two propagation methods used and their responses to the semi-arid environment. It is observed that, despite the differences in propagation methods, the plants exhibit distinct phenotypic adaptation characteristics, influenced both by the climatic conditions of the region and by the interaction with the pruning cycle.

Our results indicated a greater response of the 'Tailandesa Branca' and 'Tailandesa Vermelha' cultivars to pruning, with an earlier bud break during the dry-rainy season. This behavior may be attributed to the increase in thermal intensity and solar radiation, combined with a reduction in relative humidity due to lower precipitation during this phenological phase (Figure 1). In contrast, higher precipitation during the vegetative growth phase delayed the start of flowering, prolonging it when the rains were more intense. On the other hand, low precipitation before and during flowering favored earlier and more uniform flowering (Figures 1 and 3). The variations in flowering of guava are influenced by both genetic and climatic factors, as noted by Medda et al. (2022).

Studies on different fruiting pruning times have shown variations in the phenological cycle of the main guava cultivars, ranging from 192 to 240 days (Monteiro et al., 2021). This is due to the influence of climate, which can accelerate (e.g., higher temperatures) or delay (e.g., milder temperatures and lower light intensity) the physiological metabolism of the plants, shortening or lengthening the phenological phases (Matsushita et al., 2022).

The data indicated that the earlier flowering in guava trees during the dry-rainy and dry pruning seasons was closely related to the climatic conditions recorded in this study (Figure 1). Thus, the subsequent phase is directly affected, with fruit set being reduced due to the high rates of physiological fruit drop (Farias et al., 2019). It was observed that from the beginning of flowering to harvest, despite the influence of pruning seasons, the cultivars showed an average of 170 days, which is a positive point, already noted in previous studies (Monteiro et al., 2021). This is especially relevant for planning the staggered production, which is crucial for generating supply during economically favorable periods.

In this sense, it is suggested that each season be carefully evaluated, but based on the results, it is possible to infer that pruning during the dry season and all subsequent phases may result in lower productive branch rates and a later harvest, particularly for the 'Paluma' cultivar (Figure 3), reaching up to 240 days after pruning (Monteiro et al., 2021). Another point to highlight is the low productive branch index of 'Paluma' propagated by cuttings during the dry-rainy season (Figure 4), which aligns with its susceptibility to nematode damage, resulting in a higher physiological fruit drop.

It is also important to highlight that all cultivars propagated by cuttings suffered from infestation by *Meloidogyne enterolobii*, resulting in lower fruit set, average fruit weight, and production, as observed during the dry season, when the plants already showed visual signs of infestation (Figure 8). The nematode is prevalent in soils cultivated with guava in Brazil, leading to reduced vegetative growth, inhibition of floral bud formation, and causing flower and fruit abortion (Thakre, 2020), significantly reducing production (Oliveira et al., 2024) (Figure 6A).

After diagnosing the presence of *Meloidogyne enterolobii* in the experimental areas, no phytosanitary control measures were adopted. This decision was intentionally made to assess the resilience of the cultivars to nematode attack, considering different propagation methods and pruning seasons. This approach allowed for a better understanding of the limitations and potential of the cultivars propagated by cuttings and grafting, especially regarding the use of resistant rootstocks, such as BRS Guaraçá.

Moreover, the fruit set rate is intrinsically connected to the characteristics of each cultivar and pruning season, as well as the nutritional demands of each cultivar. It was observed that there is no clear pattern in the fruit set rate across the different pruning seasons, suggesting that climatic factors can impact each cultivar and propagation method differently. As shown in Figure 6A, the 'Paluma' cultivar exhibited its best fruit set rate in the rainy-dry season, while 'Tailandesa Vermelha' performed best in the dry-rainy season, for both propagation methods. On the other hand, the 'Tailandesa Branca' cultivar propagated by cuttings did not show any difference between the rainy-dry and dry-rainy seasons.

Sarkar and Sarkar (2022) found variation in the fruit set rate across different cultivars. Likewise, Fischer and Melgarejo (2021) emphasized that temperature plays a crucial role in fruit set, with the optimal temperature for guava fruiting ranging from 23 to 28°C.

The better fruit development observed during the dry-rainy season can be attributed to the more favorable climatic conditions prevailing throughout the fruit growth period. Specifically, it is believed that higher temperatures and increased relative humidity (Figure 1) positively influenced the metabolic and photosynthetic processes in guava plants. This overall increase in plant development and photosynthetic metabolism during the dry-rainy season pruning led to a higher number of fruits per plant and an increase in the average fruit weight, contributing to higher overall fruit production compared to the rainy-dry and dry seasons. In these seasons, fruit development occurred under high light intensity, leading to elevated temperatures and consequently low humidity, falling outside the optimal range for fruit development (Fischer & Melgarejo, 2021).

In this investigation, the guava cultivar 'Paluma', when propagated by cuttings, exhibited relatively low fruit production compared to the other cultivars. This situation is associated with the infestation of root-knot nematodes (*Meloidogyne enterolobii*), which reside in the root system, blocking nutrient flow (Oliveira et al., 2024). In contrast, the 'Tailandesa Vermelha' cultivar showed higher production when propagated by cuttings, as it is tolerant to the nematode (Casagrande et al., 2020), while the 'Paluma' cultivar is susceptible to infestation.

Overall, the multivariate analysis clearly highlighted the close relationship between production variables (average fruit weight and number of fruits) and the cultivars 'Tailandesa Branca' and 'Tailandesa Vermelha' during the dry-rainy season. It is suggested that the relationships explored by the Principal Component Analysis (PCA) are linked to genetic factors, physiological characteristics, and other cultivar-specific traits. These genetic variations manifest depending on the environment and reflect characteristics such as disease resistance, flowering time, fruit size, and yield potential. Therefore, selecting cultivars with desirable genetic traits adapted to specific environmental conditions and production goals is a common strategy in agriculture (García-Gómez et al., 2020), and increasingly necessary. Furthermore, certain cultivars may exhibit compatibility with specific propagation methods, leading to enhanced production under those conditions (Cockerton et al., 2021).

A suggestion that production parameters are correlated with the cultivars used in the experiment indicates inherent differences in production between the cultivars, regardless of the propagation method. This can be attributed to genetic factors, physiological characteristics, or other cultivar-specific traits that influence production. These genetic variations can manifest in features such as disease resistance, flowering time, fruit size, and yield potential. Selecting cultivars with desirable genetic traits adapted to specific environmental conditions and production goals is a common strategy in agriculture (Zahid et al., 2022).

Conclusions

The fruiting pruning season has a significant effect on the phenology of the guava cultivars 'Paluma', 'Tailandesa Branca', and 'Tailandesa Vermelha', regardless of the propagation method, whether by grafting or cuttings. A shorter cycle was observed during the rainy-dry and dry-rainy seasons, with higher fruit set rate, number of fruits harvested, average fruit weight, and total fruit production.

Pruning during the dry season should be avoided, as it results in low productive yield across all cultivars studied, while pruning during the dry-rainy season is more suitable for semi-arid tropical regions.

The 'Tailandesa Branca' and 'Tailandesa Vermelha' cultivars exhibited desirable behavior for cultivation in the Brazilian Semi-Arid region, with excellent production and harvest uniformity. When associated with the grafting propagation method on the BRS Guaraçá cultivar, they are promising for soils contaminated with nematodes.

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