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Original Article

Biostimulants on the occurrence of stenoespermocarpy in 'Palmer' mango[1]

Bioestimulantes na ocorrência de estenoespermocarpia em frutos de manga 'Palmer'

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HIGHLIGHTS:

Plant hormones exert distinct influences on the stenospermocarpy of mango 'Palmer'.
Exogenous applications of cytokinin (benzyladenine) at 20 g L^{-1} reduce stenospermocarpy indices.
Leaf boron levels of up to 55.71 g kg^{-1} do not reduce the incidence of stenospermocarpy.

ABSTRACT: Stenospermocarpy in mango trees is associated with hormonal regulation and boron fertilization. However, the mode of action of plant growth regulators and boron in mango trees of the Palmer cultivar affected by this physiological disorder needs to be elucidated. In this scenario, this study aimed to evaluate the association of plant growth regulators (auxin, cytokinin, and gibberellin) and boron with the incidence of stenospermocarpic fruits in 'Palmer' mango. Two experiments were conducted in two consecutive crop years (2018 and 2019) in a commercial orchard. The experiment was set up in a randomized block design, with six treatments and four replicates. The treatments consisted of: T1 = water application (control); T2 = gibberellin (25 ppm, GA_3); T3 = auxin (25 ppm, naphthaleneacetic acid); T4 = cytokinin (25 ppm, 6-BA); T5 = boron (2 ppm); and T6 = boron (2 ppm) + gibberellin (25 ppm). The application of gibberellic acid during the flowering phase resulted in higher mean values for the number of stenospermocarpic fruits. The cytokinin treatment reduced the incidence of stenospermocarpic fruits and led to higher mean values for the number of productive branches. Boron, auxin, and the combination of gibberellin and boron did not reduce the stenospermocarpy indices. Hormonal balance plays a crucial role in the manifestation of stenospermocarpic fruits, with gibberellin being associated with the expression of this disorder, while cytokinin exerts an antagonistic effect. The application of boron and auxin did not have a predominant effect on the increase or reduction of stenospermy.

Key words: *Mangifera indica* L., physiological disorder, auxin, gibberellin, cytokinin

RESUMO: A estenospermocarpia em mangueiras está associada à regulação hormonal e à fertilização com boro. No entanto, o modo de ação de reguladores de crescimento de plantas e boro em mangueiras da cultivar Palmer afetadas por esse distúrbio fisiológico precisa ser elucidado. Nesse contexto, o objetivo deste estudo foi avaliar a associação de reguladores de crescimento de plantas (auxina, citocinina e giberelina) e boro com a incidência de frutos estenospermocárpicos em mangas 'Palmer'. Dois experimentos foram conduzidos em anos consecutivos (2018 e 2019) em um pomar comercial. O experimento foi organizado em delineamento de blocos ao acaso, com seis tratamentos e quatro repetições. Os tratamentos consistiram em: T1 = aplicação de água (controle absoluto); T2 = giberelina (25 ppm, GA_3); T3 = auxina (25 ppm, ácido naftalenoacético); T4 = citocininas (25 ppm, 6-BA); T5 = boro (2 ppm); e T6 = boro (2 ppm) + giberelina (25 ppm). A aplicação de ácido giberélico durante a fase de floração resultou em médias mais altas para o número de frutos estenospermocárpicos. As citocininas reduziram a incidência de frutos estenospermocárpicos e levaram às médias mais altas para o número de ramos produtivos. Boro, auxina e a combinação de giberelina e boro não reduziram os índices de estenospermocarpia. O equilíbrio hormonal desempenha papel crucial na manifestação dos frutos estenospermocárpicos, estando a giberelina associada à expressão deste distúrbio, enquanto a citocinina exerce efeito antagônico. A aplicação de boro e auxina não teve efeito preponderante no aumento ou redução da estenocarpia.

Palavras-chave: *Mangifera indica* L., desordem fisiológica, auxina, giberelina, citocinina

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Introduction

Mango (*Mangifera indica* L.) cultivation holds significant economic importance in the agricultural scenario of Brazil, with the São Francisco Valley region in the northeast part of the country standing out with high yields favored by advanced agricultural practices that include irrigation, pruning, and plant growth regulators that enable year-round harvesting regardless of weather and environmental conditions (Genú & Pinto, 2002; Cavalcante et al., 2018). The productive calendar in this region is primarily determined by commercial opportunities (Cavalcante et al., 2018), with the local mango yield reaching about 28 t ha^{-1} (IBGE, 2024).

Considering the main mango cultivars grown in the region, the leading factor that affects the yield of the mango cultivar Palmer is the occurrence of stenospermocarpy (Barbosa et al., 2016). In stenospermocarpy, the fruits produced are small, with a characteristic shape, and seedless. The fruit resembles a cashew nut (*Anacardium occidentale*) in shape and features a pronounced depression in its structure. This depression eventually ruptures, exposing the pulp layer and often leading to fruit drop (Cavalcante et al., 2023). Stenospermocarpy can result in production losses of up to 100% (Barbosa et al., 2016).

Factors associated with this disorder include high temperatures, nutritional deficiencies, and hormonal imbalances, which are potential contributors to embryo abortion following flower fertilization during the early stages of fruit development, leading to endosperm degeneration (Subbaraya et al., 2020; Navarro et al., 2023). As a strategy to mitigate this disorder, the application of plant growth regulators positively influences fruit growth (Bons et al., 2020), as also noted by Barbosa et al. (2016) with boron supplementation. From this perspective, this study aimed to evaluate the association of plant growth regulators (auxin, cytokinin, and gibberellin) and boron with the incidence of stenospermocarpic fruits in the mango cv. Palmer.

Material and Methods

The experiment was conducted over two consecutive crop years, from November 2017 to April 2018 (2018 season) and from November 2018 to March 2019 (2019 season), in a commercial mango orchard located at the Sebastião da Manga Farm (9° 16’ 52” S 40° 30’ 52” W) in the municipality of Petrolina, Pernambuco state, Brazil.

The local climate is classified as Bswh, according to the Köppen climate classification, corresponding to a hot, semi-arid region. Throughout the experiments, meteorological data related to rainfall, temperature, and relative air humidity were recorded by an automatic weather station (Figure 1).

Ten-year-old ‘Palmer’ mango trees spaced at 6.0 × 3.5 m and irrigated by a localized drip system at a flow rate of 2 L h^{-1} were used in the experiment. Soil samples were collected for the initial characterization of the area, and soil fertility was determined in both crop years (Table 1).

The plants were subjected to the recommended crop management practices for mango farming in the region, according to the guidelines of Genú & Pinto et al. (2002). To stimulate the emission of new shoots from axillary buds,

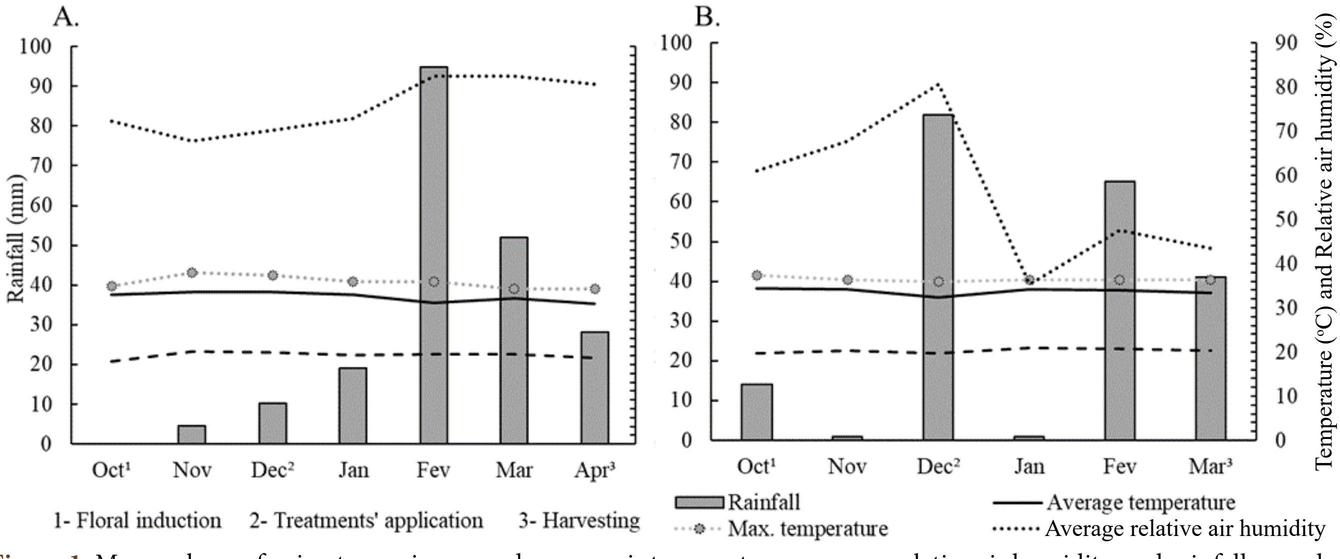


Figure 1. Mean values referring to maximum and average air temperatures, average relative air humidity, and rainfall recorded during the 2018 (A) and 2019 (B) crop years in Petrolina, PE, Brazil

Table 1. Soil chemical analysis of samples (0-30 cm depth) from the experimental area cultivated with ‘Palmer’ mango trees before the application of treatments during the 2018 and 2019 crop years

pH	OM	B	P	K^+	Na^+	Ca^{2+}	Mg^{2+}	Al^{3+}	$H^+ + Al^{3+}$	SB
KCl	(g kg^{-1})	(mg dm^{-3})		(cmol dm^{-3})						
Season 2018										
5.54	8.90	1.58	44.87	0.26	0.01	5.29	0.24	0.03	1.76	5.80
Season 2019										
6.00	10.00	1.68	50.00	0.30	0.02	5.41	0.26	0.03	1.82	5.97

OM - Organic matter; SB - Sum of bases

production pruning was conducted after harvest by cutting the shoots above the internodes.

After the emergence of the second vegetative flush during both crop seasons, Paclobutrazol (PBZ) was applied at an average dose of 18 mL of Cultar 250 SC® per plant, corresponding to 4.5 ml of PBZ, applied to the soil within the canopy projection.

Five sprays of potassium sulfate (2%) and sulfur (0.75%) were applied for branch maturation one month after PBZ application, whereas weekly applications of KNO_3 (3%) were performed for floral induction, totaling seven applications.

The experiment was set up in a randomized block design, with six treatments, four replicates, and four plants per plot. The treatments included were: T1 = water application (control); T2 = gibberellin (25 ppm, GA_3); T3 = auxin (25 ppm, naphthaleneacetic acid); T4 = cytokinin (25 ppm, 6-BA); T5 = boron (2 ppm); T6 = boron (2 ppm) + gibberellin (25 ppm).

The commercial products used had the following composition: gibberellin: PROGIBB® - gibberellic acid 400 g kg^{-1} (40% w/w); auxin: naphthaleneacetic acid® - 99% p.a.; cytokinin: MAXCEL® - N6-benzyladenine (benzyladenine) 20 g L^{-1} (2% w/v); boron: Bortrac® - Nitrogen 4.7% w/w (655 g L^{-1}), urea, boron 10.9% w/w, boric acid (150 g L^{-1}). The treatments were applied at the full flowering stage using a tractor-mounted Jacto Arbus® sprayer with 2 L of spray mixture per plant, totaling four applications at weekly intervals.

Composite leaf samples consisting of twelve leaves from the last vegetative flush in all four quadrants and at mid-canopy height were collected one day before the treatments were applied and again eight and fifteen days after the applications. These samples were placed in plastic bags and transported to the Soil Chemistry and Fertility Laboratory at the Federal University of Vale do São Francisco (UNIVASF).

The criteria for leaf collection followed the recommendations of Malavolta et al. (1997), by washing the leaves in distilled water and then packing them in paper bags for drying to constant weight in a forced-air oven at 60 °C. Subsequently, the samples were ground using a stainless-steel knife mill (Willey-type) to determine the boron content, following the guidelines of Silva (2009).

Readings were conducted to determine net photosynthesis (A - μmol CO_2 m^{-2} s^{-1}), stomatal conductance (gs - mol H_2O m^{-2} s^{-1}), and transpiration (E - mmol H_2O m^{-2} s^{-1}) using an infrared gas analyzer (IRGA, Model Li-COR® 6400 XT) coupled to a portable modulated light fluorimeter. The water use efficiency (WUE - μmol $mmol^{-1}$) was also calculated by the ratio of A to E. The readings were taken one day after the second application of treatments on mature leaves from the last vegetative flush, at mid-canopy height, from 9:00 to 11:00 a.m., under an artificial light source providing 1500 μmol photons m^{-2} s^{-1}.

After the second physiological fruit drop, fallen fruits were collected from the ground beneath the tree canopy. During the 2018 crop year, fruits that underwent natural abscission and those removed during thinning were collected. In contrast, during the 2019 season, only fruits that underwent natural abscission were counted since no manual thinning was performed (Figure 2).

Figure 2. Details of 'Palmer' mango fruits cut longitudinally for the identification and counting of seedless fruits (stenospermocarpic fruits) and normal fruits obtained after physiological drop and manual thinning. A regular fruit with seeds (A) and fruits considered seedless (B and C)

All fruits collected after physiological fruit drop or thinning (average of 70 and 97 fruits per plant in the 2018 and 2019 crop years, respectively) were taken to the Horticulture Laboratory of UNIVASF, where they were cut transversely using a knife, and the presence or absence of seeds was observed to confirm the presence of the physiological disorder (stenospermocarpy) or its absence (normal fruits). In both seasons, fruit length (average of ten fruits per plant) was assessed using digital calipers, and the number of branches with fruits was counted 15 days before harvest.

The data from each crop year were subjected to analysis of variance to evaluate significant effects using the F-test, and the means were compared using Tukey's test ($p \leq 0.05$) through the statistical software SISVAR 5.6® (Ferreira et al., 2014).

Results and Discussion

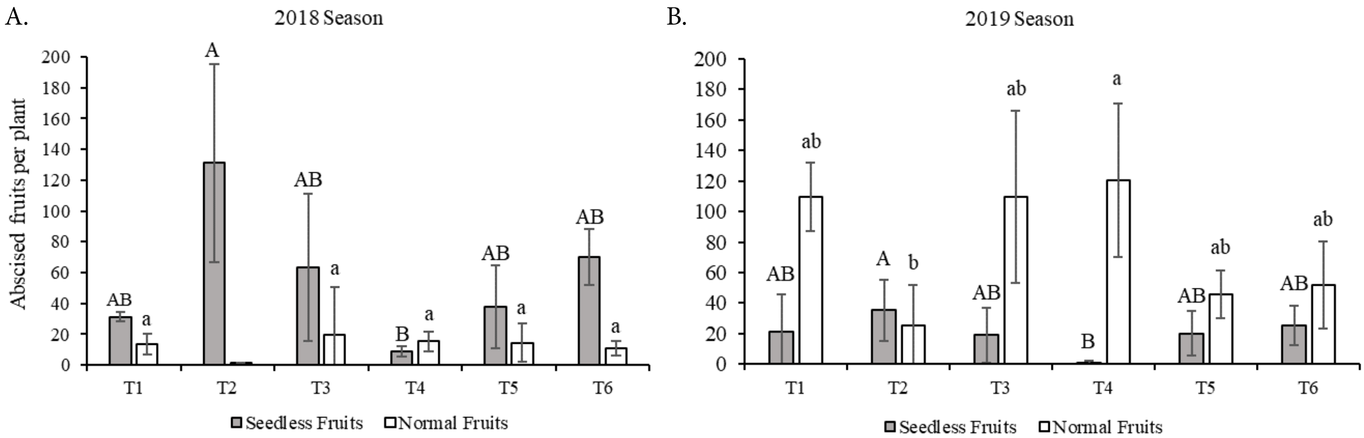
According to the summary of the analysis of variance (Table 2), there was a significant effect of the treatment on the number of stenospermocarpic/seedless fruits and normal fruits during the 2018 and 2019 crop years.

Statistical differences in the number of seedless fruits abscised per treatment were only observed between T2 (gibberellin) and T4 (cytokinin) in both crop seasons (Figure 3). The variation in the number of abscised fruits between the two seasons can be attributed to the absence of thinning practices during the 2019 crop year.

Table 2. Summary of the analysis of variance for the number of abscised fruits per plant with the presence of the physiological disorder (seedless fruits) and normal fruits in 'Palmer' mango trees as a function of the use of plant growth regulators and boron during the 2018 and 2019 crop years in Petrolina, PE, Brazil

Sources of variation	F value			
	Abscised fruits per plant			
	Seedless fruits	Normal	Seedless fruits	Normal
	2018 season		2019 season	
Treatment	0.033*	0.036*	0.042*	0.021*
Block	0.469^{ns}	0.086^{ns}	0.575^{ns}	0.987^{ns}
CV (%)	2.95	3.96	6.15	3.49

CV - Coefficient of variation; ns - Not significant; * - Significant at $p \leq 0.05$ by the F-test



Lowercase letters compare data for normal fruits and uppercase letters compare data for seedless fruits (fruits with stenospermocarpy). Bars with the same letters do not differ significantly according to Tukey's test ($p \leq 0.05$). T1 - Control; T2 - Gibberellin (GA_3); T3 - Auxin (naphthaleneacetic acid); T4 - Cytokinin (benzyladenine); T5 - Boron; T6 - Boron + gibberellin; Error bars represent the standard error

Figure 3. Number of abscised fruits per plant in the 2018 (A) and 2019 (B) crop years for 'Palmer' mango trees as a function of the use of plant growth regulators and boron in Petrolina, PE, Brazil

Despite the difference between crop years, it is noticeable that T2 (Figures 3A and B) led to the initial setting of stenospermocarpic fruits. However, this treatment alone was not sufficient to promote the growth of these fruits, resulting in their abscission and removal through manual thinning. These results contrast with those observed by Nkansah et al. (2012), where the same concentration of gibberellic acid at 25 ppm, applied at full flowering in 'Keitt' mango trees, was effective in retaining and promoting fruit growth.

According to Ogata et al. (2010), gibberellin application to promote fruit growth should be carried out from flowering until fruit establishment. However, in the present study, gibberellin application during flowering and early fruit development favored the initial setting of stenospermocarpic fruits but did not reduce stenospermocarpy.

Since stenospermocarpic fruits lack seeds for the production of endogenous gibberellin and exogenous gibberellin application was performed for a short period, it is likely that stenospermocarpic fruits had lower concentrations of gibberellin, resulting in reduced growth and fruit abscission, as also reported by Shaban & Ibrahim (2009).

The lowest means for the number of seedless fruits were observed with cytokinin (T4), with 8.75 stenospermocarpic fruits abscised per plant for the 2018 crop year and 1.25 stenospermocarpic fruits abscised per plant for the 2019 crop year. The low number of stenospermocarpic fruits abscised in both seasons (Figures 3A and B) highlights the potential of cytokinin treatment in reducing the occurrence of seedless fruits in 'Palmer' mango trees compared to gibberellin application (T2).

Cytokinin application promotes greater cell division and differentiation, increasing competition for carbohydrates among fruits (Yang et al., 2021). Nutrients are preferentially transported to tissues treated with cytokinins because they enhance the sink strength, promoting fruit growth (Sakakibara, 2021). Consequently, cytokinin application may have stimulated the growth of stenospermocarpic fruits by compensating for the absence of endogenous seed hormones responsible for cell differentiation and division.

Treatments T1, T3, T5, and T6 during the 2018 and 2019 crop years (Figures 3A and B) did not differ regarding the number of seedless and normal fruits. Despite the critical role of auxin throughout embryo development, the application of naphthaleneacetic acid (NAA) did not reduce the number of seedless fruits. These results differ from those observed by Nkansah et al. (2012), where NAA application resulted in maximum mango retention and weight.

According to Chacko & Singh (1969), in order for stenospermocarpic fruits to grow in size, an initial application of cell division factors such as cytokinin is required, followed by the application of factors that promote cell enlargement, e.g., auxin. Based on this, the behavior of the treatment in not reducing the incidence of seedless fruits is justified because the absence of an embryo likely disrupted the flow of hormones from the seed. Simultaneously, the absence of the application of an exogenous cell division factor to complement the effects of NAA in expanding fruit cells likely increased the sensitivity of the pedicel to ethylene, inducing detachment and interfering with fruit growth (Estornell et al., 2013).

In the 2018 and 2019 crop seasons, treatments 5 and 6 (Figures 3A and B), which consisted of boron sprays and the combination of boron and gibberellin, did not reduce the incidence of seedless fruits, showing similar means to the control. These results differ from those observed by Barbosa et al. (2016), where boron fertilization reduced the incidence of seedless fruits in 'Palmer' mango trees.

As for the number of normal fruits abscised per plant, the lowest means were observed for the use of gibberellin (T2), indicating that normal fruits grew at the expense of estenoespermocarpic fruits. During the 2019 crop year (Figure 3B), there was intense natural abscission of normal fruits, with the highest averages observed for T4 (cytokinin), with 120.5 abscised fruits per plant.

These results may have been influenced by the foliar boron levels observed in both crop seasons. According to Rezende et al. (2022), the appropriate range for foliar boron content in the 'Keitt', 'Kent', and 'Tommy Atkins' mango cultivars varies from 55 to 298 mg kg^{-1}, depending on the variety. However, the boron levels observed during the 2018 and 2019 crop years (Table 3) were lower than the appropriate levels, except for treatment 5 during the 2018 season eight days after the beginning of treatment applications. This suggests that the

Table 3. Foliar boron content in ‘Palmer’ mango trees as a function of the use of plant growth regulators and boron in two crop years (2018 and 2019) in Petrolina, PE, Brazil

Treatment	BAT	8 DAT	15 DAT	BAT	8 DAT	15 DAT
	(mg kg^{-1})					
	2018 season			2019 season		
T1	51.46 a	32.24 b	30.34 b	34.22 a	20.55 c	29.45 bc
T2	48.67 a	36.76 b	34.93 b	33.90 a	20.16 c	27.11 c
T3	49.97 a	34.55 b	37.64 b	33.97 a	25.53 b	24.31 c
T4	49.97 a	34.61 b	48.97 ab	32.90 a	19.17 c	30.06 bc
T5	48.10 a	55.71 a	51.21 a	29.91 a	48.97 a	46.91 a
T6	48.81 a	54.32 a	52.06 a	31.04 a	45.90 ab	39.48 ab
CV (%)	5.65	5.48	6.38	6.04	12.11	11.00

Means followed by equal letters do not differ significantly according to Tukey’s test ($p \leq 0.05$); BAT- Before the application of treatments; 8 DAT- Eight days after the beginning of treatment applications; 15 DAT- Fifteen days after the beginning of treatment applications; T1 - Control; T2 - Gibberellin (GA_3); T3 - Auxin (naphthaleneacetic acid); T4 - Cytokinin (benzyladenine); T5 - Boron; T6 - Boron + gibberellin; CV – Coefficient of variation

treatments were not sufficient to promote increases in boron sufficiency. According to Barbosa et al. (2016), the minimum foliar boron content required to affect the incidence of seedless fruits should be above 200 mg kg^{-1}, which is significantly higher than the values recorded in this study.

The leaf boron content prior to treatment application in the experimental orchard was consistent throughout both growing seasons, enhancing the credibility of subsequent results. In the 2018 season, at 8 and 15 DAT, only T5 and T6 surpassed the control (T1); however, in the 2019 season, T3 also exceeded the control at 8 DAT, whereas at 15 DAT, only T5 showed superiority over T1, with a difference of 45.76% (Table 3). Therefore, boron supplementation is more appropriate to increase the foliar boron content, showing consistent results based on the dates and crops seasons studied.

Another factor to consider is the timing of boron supply. Foliar boron supply over the course of the experiment occurred only during the flowering phase. However, due to its difficulty in being translocated by the plant, boron should be supplied earlier through either soil or foliar application (Marschner, 2012).

Similarly, the absence of boron fertilization for the 2018 and 2019 crop years, based on soil analysis results, where the boron levels observed were 1.58 and 1.68 mg dm^{-3}, respectively, may have influenced the low foliar boron levels. This suggests that the boron present in the soil was not fully available for plant uptake.

According to Barbosa et al. (2016), foliar boron levels in ‘Palmer’ mango trees play an important role in reducing seedless fruits. As the concentration of boron in the leaves increases, there is a reduction in the number of seedless fruits per plant. The authors observed that, for the Palmer cultivar, the sufficiency range for boron does not meet the nutritional demand of the crop, favoring the development of seedless fruits. Therefore, when the plant is subjected to boron levels below the crop’s requirement, there may occur metabolic, morphological, and anatomical changes in fruits (Liu et al., 2014).

Insufficient boron levels can result in reduced embryo vitality, compromising its growth and leading to its death, characterizing the formation of seedless fruits. This justifies the results observed and emphasizes the need for the supply of adequate amounts of boron during phases of higher demand to reduce this physiological disorder.

For the evaluation of net photosynthesis (A), stomatal conductance (E), water use efficiency (WUE), and transpiration (gs), there was no significant effect of the treatments in both seasons (Table 4).

The interaction of phytohormones such as gibberellin, auxin, and cytokinin influences gas exchange in plants, depending on the environmental conditions to which plants are subjected (Müller & Munné-Bosch, 2021). However, the exogenous application of these phytohormones in this study did result in observable effects.

These results indicate that the plants were grown under appropriate management conditions and the gas exchange rates were compatible with well-balanced crop management. According to Faria (2016) and Almeida et al. (2015), when subjected to adverse growing conditions, net photosynthesis

Table 4. Summary of the analysis of variance for net photosynthesis (A), stomatal conductance (E), water use efficiency (WUE), and transpiration (gs) of ‘Palmer’ mango as a function of plant growth regulators during two crop years (2018 and 2019) in Petrolina, PE, Brazil

Sources of variation	Value ‘F’			
	A (μmol CO_2 m^{-2} s^{-1})	E (mmol H_2O m^{-2} s^{-1})	WUE (μmol mmol^{-1})	Gs (mol H_2O m^{-2} s^{-1})
	Season 2018			
Treatment	0.635^{ns}	0.970^{ns}	0.997^{ns}	0.523^{ns}
Block	0.843^{ns}	0.890^{ns}	0.776^{ns}	0.819^{ns}
Mean	9.82	3.52	2.79	0.090
CV (%)	24.82	26.58	22.97	29.09
	Season 2019			
Treatment	0.212^{ns}	0.943^{ns}	0.13959^{ns}	0.257^{ns}
Block	0.076^{ns}	0.593^{ns}	0.48244^{ns}	0.248^{ns}
Mean	10.07	3.57	2.82	0.094
CV (%)	21.99	28.09	15.07	28.3

CV - Coefficient of variation; ns, **, * - Not significant, and significant at $p \leq 0.01$ and $p \leq 0.05$ by F test and transpiration rates can decrease, reaching averages of 2.65 μmol CO_2 m^{-2} s^{-1} and 1.23 mmol H_2O m^{-2} s^{-1}, respectively, which can negatively affect plant performance.

Compared to the literature from studies conducted in the same region as the present study (São Francisco Valley in northeastern Brazil), Carreiro et al. (2022) found lower values of net photosynthesis (7 μmol CO_2 m^{-2} s^{-1}) for the Tommy Atkins mango cultivar in an evaluation conducted at the beginning of branch maturation in the control group. Silva et al. (2022) found different values for 'Keitt' mango trees in their first productive cycle in two phases, approximately 4 μmol CO_2 m^{-2} s^{-1} during reduced water supply and 13 μmol CO_2 m^{-2} s^{-1} during floral induction. Faria (2016), studying in 'Tommy Atkins' mango trees evaluated at the flowering stage under full irrigation (100% ETc), reported the following mean values: net photosynthesis (8.23 μmol CO_2 m^{-2} s^{-1}), transpiration (2.87 mmol H_2O m^{-2} s^{-1}), and stomatal conductance (0.10 mol H_2O m^{-2} s^{-1}).

One of the factors that may have contributed to the results observed was the combination of the average relative air humidity of around 72 and 79% during the 2018 and 2019 growing years, respectively, along with high temperatures and the occurrence of rainfall during the evaluation periods (Figure 1).

The photosynthetic variables were very similar in the two seasons, which was particularly noticeable when observing the WUE, with a disparity of only 1.08%. It is worth noting that the evaluations conducted by the IRGA are specific and can vary depending on environmental conditions, climate, and soil moisture at the time of the assessment, not fully reflecting the conditions experienced by the plant (Calzadilla et al., 2022). According to the results of the analysis of variance (Table 5), there was an effect of the treatments on the number of productive branches (branches with fruit presence) and fruit length for both crop years (2018 and 2019).

During the 2018 crop year, the lowest mean values for the number of productive branches were observed for the use of gibberellin (T2, Figure 4A), compared to other treatments. These results were influenced by the number of seedless fruits shown by the treatment, with abscission and thinning practices reducing the number of remaining fruits, resulting in an average of 20 productive branches per plant. These results were similar to those observed by Cavalcante (2023) in an experiment conducted with the Palmer cultivar, where the high

Table 5. Summary of the analysis of variance for the number of productive branches and fruit length in 'Palmer' mango as a function of plant growth regulators and boron during two crop years (2018 and 2019) in Petrolina, PE, Brazil

Sources of variation	F-value			
	Productive branches	Fruit length (mm)	Productive branches	Fruit length (mm)
	2018 season		2019 season	
Treatment	0.002**	0.032*	0.037*	0.034*
Block	0.945^{ns}	0.547^{ns}	0.574^{ns}	0.621^{ns}
CV (%)	20.95	3.96	19.64	3.49

CV - Coefficient of variation; ns, **, * - Not significant, and significant at $p \leq 0.01$ and $p \leq 0.05$ by F test

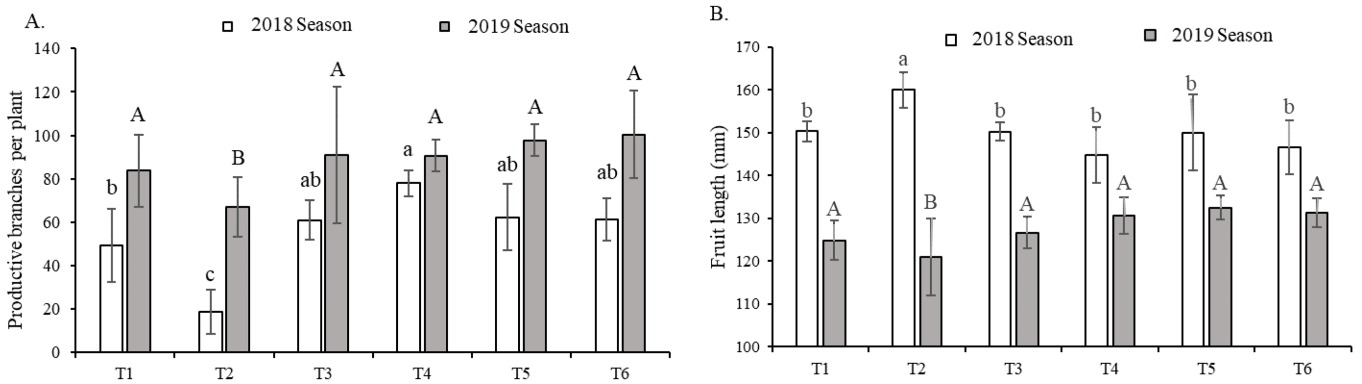
incidence of seedless fruits compromised crop productivity, causing losses of up to 90% in fruit production.

During the 2018 season, the highest mean values were observed for T4 compared to the control (T1), with 58.38%, and T2, with 316% more productive branches per plant. This indicates that cytokinin (T4), in addition to reducing the number of seedless fruits compared the gibberellin (T2) (Figure 3A), also resulted in better fruit retention, expressing its potential for higher yields.

For the 2019 season, the lowest averages for the number of productive branches were observed for T2, with 67.07 branches containing fruits. The other treatments did not differ significantly (Figure 4B).

The reduction in the number of fruits per productive branch favored increases in fruit length (Figure 4B), with T2 during the 2018 season showing the highest mean value, with 160 mm in length. However, in the 2019 season, T2 had the lowest mean fruit length, with only 120.94 mm. These results indicate the interference of thinning, which was not performed during the 2019 season, causing greater competition and resulting in a smaller average fruit growth due to competition for water and nutrients (Falchi et al., 2020). On the other hand, manual thinning and natural abscission in the 2018 season promoted greater fruit growth, justifying the thinning practice performed by producers, reducing the competition for assimilates among the remaining fruits.

Photoassimilates serve multiple purposes, with the majority during the plant's reproductive phase being allocated to fruit growth, i.e., by reducing the number of sinks, sources transport a greater amount of photoassimilates to the remaining fruits,



Lowercase letters compare data from the 2018 season, while uppercase letters compare data from the 2019 season; Bars with the same letters do not differ significantly according to Tukey's test at $p \leq 0.05$; T1 - Control; T2 - Gibberellin (GA_3); T3 - Auxin (naphthaleneacetic acid); T4 - Cytokinin (benzyladenine); T5 - Boron; T6 - Boron + gibberellin; Error bars represent the standard error

Figure 4. Number of productive branches per plant (A) and fruit length (B) of 'Palmer' mango trees as a function of plant growth regulators and boron in the 2018 and 2019 crop years

allowing for greater fruit growth (Silva et al., 2021). However, despite the approximately 20 mm difference in fruit length between the two seasons, they fall within the range of fruit lengths reported by Batista et al. (2015) for 'Palmer' in the São Francisco Valley region, where the authors observed fruit lengths of around 130.5 mm, also reporting occurrences of averages exceeding 150 mm for the cultivar. According to Modesto et al. (2016), the same mango cultivar can exhibit differences in fruit size in different agricultural years. These differences can arise due to the crop's natural seasonality, internal factors within the plant, water availability, and temperature variations.

The results of this research are promising, showing potential to provide insights for the effective management of the physiological disorder in mango trees. However, it is necessary to conduct additional research to investigate the mechanisms by which hormones can prevent stenospermocarpy.

Conclusions

1. Hormonal balance plays a crucial role in the occurrence of stenospermocarpic fruits, with gibberellin being associated with the expression of this disorder, while cytokinin exerts an antagonistic effect.

2. The application of boron and auxin did not have a predominant effect on the increase or reduction of stenospermy.

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