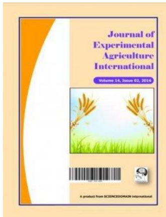

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Effects of Fruit Thinning and Main Stem Pruning in Melon Crops

Gleyce Lacerda da Silva[1], Roberto Cleiton Fernandes Queiroga[2], Francisco Hevilásio Freire Pereira[2], Francimalba Francilda de Sousa[3], Zaqueu Lopes da Silva[4], Rayana Pereira Ferreira[5] and Odair Honorato de Oliveira[1*]

[1]Postgraduate Program in Tropical Horticulture, Agro-Food Science and Technology Center, Campina Grande Federal University, Paraíba, Brazil.
[2]Agro-Food Science and Technology Center, Campina Grande Federal University, Paraíba, Brazil.
[3]Postgraduate Program in Agriculture, Department of Production and Plant Breeding, Faculty of Agronomic Sciences, Paulista State University "Júlio de Mesquita Filho", São Paulo, Brazil.
[4]Postgraduate Program in Agricultural Engineering, Department of Engineering, Federal University of Lavras, Minas Gerais, Brazil.
[5]Department of Agronomy, Federal University of Campina Grande, Paraíba, Brazil.

Authors' contributions

This work was carried out in collaboration among all authors. Author GLS elaborated the project and carried out the research, which was the subject of his Master&#39's dissertation in the graduate program in tropical horticulture of UFCG, Brazil, elaborating the first manuscript. Author RCFQ advised author GLS on his research in the field phase and performed the statistical analyses, charts, and tables. Author FHFP advised and performed the laboratory analyzes. Authors FS, ZLS, RPF and OHS carried out the field cultural practices, assisting in the conduction of the culture and the physical-chemical analyzes in laboratory. All authors read and approved the final manuscript.

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**Corresponding author: E-mail: odairhonorato2020@gmail.com;*

ABSTRACT

Objective: This study aimed to assess the productivity and quality of a melon crop treated with fruit thinning and main stem pruning under field conditions.
Experimental Design: The treatments comprised the amount of fruit thinning in the plant (one, two and without thinning) and the period of main stem pruning (35, 40, 45 and 50 days after transplanting - DAT). The crop was set up in a randomized block design factorial of type 3x4, with five replications.
Location and Duration of the Study: The experiment carried out at the Center for Agrifood Science and Technology (CCTA) of the Federal University of Campina Grande (UFCG), Campus Pombal - PB, Brazil, from December 2016 to February 2017.
Methodology: The Hopey King hybrid of the Cantaloupe group was cultivated at a spacing of 2.0 x 0.4 m.
Results: The plants without thinning of fruits provided lower values of leaf area and fruits of lower mass. However, due to their higher quantity per hectare, the crop total productivity was high. On the other hand, plants with fewer fruits had the highest values of soluble solids, total and non-reducing soluble sugars. The leaf area, fruit mass, total productivity, and the concentration of reducing and non-reducing soluble sugars were higher when the plants were pruned at 35 DAT.
Conclusion: The fruit thinning and main stem pruning affected the production and quality of melon fruits significantly. For more demanding markets, we recommend to treat the plants with one or two fruits and prune at 35 days after transplantation, aiming to enhance the quality variables.

Keywords: Cucumis melo; competition; physiology; yield.

1. INTRODUCTION

The vegetables contain carbohydrates, proteins, and an excellent supply of vitamins and minerals, which makes them essential nutritional sources in the human diet [1].

The cultivation of melon in the Brazilian Northeast has been outstanding in recent years, due to the edaphoclimatic conditions of the semi-arid environment and the easy management of the crop, thus, plants that grow in these environments, have their growth and adequate development to obtain fruits with excellent quality [2]. In this context, the state of Paraíba presents conditions favorable to the cultivation of these vegetables, such as high temperature and lightness, and low rainfall and relative humidity. However, the production of the fruits is still unexpressive due to problems in the management of the plants.

The study of carbon assimilation dynamics is essential to improve crop performance, which is functionally controlled by a source-sink relationship [3]. The sources are the tissues where the net CO_2 assimilation takes place, whereas the sinks are tissues where the photoassimilates are destined for growth or storage [4].

The use of new cultivation practices requires the knowledge of the crops and choose of the most appropriate management for production. Additionally, the source and drain relationship results from the balance between the number of fruits and the leaf area and can be manipulated through agronomic practices such as manual or chemical thinning of the fruits, irrigation or pruning, that directly influence fruit quality [5].

Studies on carbohydrate economics are relevant for agricultural production due to its potential for modification in carbon allocation in the plant, which reflects on the increase or decrease in commercial fruit production. These changes are directly influenced by cultural practices, affecting translocation and carbon allocation fixed during the photosynthetic process [6]. Therefore, a balanced source-sink relationship allows carbon allocation to be primarily directed to the fruit, favoring its growth [7].

In melons, fruit thinning can improve the distribution of photoassimilates in the plant, allowing the production of larger or smaller fruits, depending on the demand of consumers [8]. Therefore, crop management through the thinning of flowers or fruits may result in increased fruit production and size, as well as, raise the quality of these fruits.

In a study evaluating the effect of the period of fruit thinning on the post-harvest quality of melon, in the municipality of Mossoró-RN, the fruits had the greatest length (134 mm) and pulp firmness (40 N) when the thinning was performed at six days after the removal of the row cover. Also, the soluble solids, soluble solids/acidity ratio, and pH decreased as thinning was retarded [9].

On the other hand, pruning of the main stem promotes rapid growth of lateral branches and subsequent increase in the photosynthetic area of the plant, which allows the production of larger fruits with high soluble solids content [10].

In pumpkin crop without pruning, and with pruning in the sixth, eighth and tenth node of the main stem, it was verified that there was a significant difference only for the number of secondary branches per plant and mass of thousand seeds. Thus, apical pruning does not influence fruit and pumpkin seed production nor the physiological quality of seeds [11].

With the fruit thinning and the pruning of the main stem, one expects to stimulate the emission of more lateral shoots, with larger leaf area per fruit and higher contribution of photoassimilates used in growth and sweetening of fruits in the harvest period.

Thus, this research aimed to evaluate the productivity and quality of melon fruits as a function of fruit thinning and pruning of the main stem under field conditions in the semiarid region of Paraíba.

2. MATERIALS AND METHODS

The experiment was carried out at the Center for Agrifood Sciences and Technology, Campus Pombal - PB, geographical coordinates (6°46'59.6"S 37°48'05.7"W) from December 2015 to February 2016. The soil of the experimental area was classified as Fluvisol. According to the Koppen climate classification, the climate of the region is the BSh type, i.e. hot and dry semi-arid region, showing a period of irregular rainfall between the months of February to June, and a dry spell between the months of July to January with average rainfall of 750 mm $year^{-1}$.

The experimental crop was cultivated in a randomized block design with a 3 x 4 factorial scheme in five replications. The first factor comprised the number of fruits set per plant (one fruit, two fruits, and plants without fruit thinning) and the second factor consisted of different periods of main stem pruning (35, 40, 45, and 50 days after transplanting - DAT).

In the preparation of the soil, we perform plowing, harrowing, and turning over the upper layer of the land. Fertilization with N and K was done as follows: 10% of both nutrients were applied in planting, and the remaining (90%) in cover, via fertigation. The P fertilization with P_2O_5 at the rate of 40 kg ha^{-1} was 100% applied fifteen days before planting.

The sowing occurred in polystyrene trays of 128 cells filled with a commercial agricultural substrate on December 9, 2015. Thirteen days after planting, we transplanted the seedlings, when the second leaf was expanded entirely on December 22, 2015. The Hopey King melon hybrid of the Cantaloupe group have a yellow to greenish netted peel and a salmon-colored pulp, their aroma is intense, and the average cycle is 65 to 70 days. The spacing for cultivation was 2.0 x 0.4 m.

After transplanting, the plants were covered with a white polypropylene row cover, 1.38 m wide and 15 g cm^{-2} in weight. After twenty-five days after transplanting, the row cover was removed and performed the manual removal of weeds.

In the top side dressing fertilization, we used an amount of 126 kg ha^{-1} of N and 135 kg ha^{-1} of K_2O, which were applied in seven subsequent weeks after transplanting. In each week, the following percentages of each nutrient were applied: 1st week = 5.0% N and 7.0% K_2O; 2nd week = 8.0% N and 8.0% K_2O; 3nd week = 10.0% N and 15.0% K_2O; 4th week 15.0% N and 18.0% K_2O; 5th week 20.0% N and 18.0% K_2O; 6th week = 20.0% N and 18.0% K_2O; 7th week = 12.0% N and 6.0% K_2O.

Drip irrigation was performed daily, using 0.4 m spaced drippers with a flow rate of 2.7 L h^{-1}.

Two applications with registered crop protection products were carried out, one at the time of the row cover removal and the other 15 days after the first application, on January 29, 2016.

The harvest was carried out on February 23-28, 2016. The fruits were harvested when the peduncle was cracked and peel with a uniform netting, which are reliable indications for harvest moment of this cultivar. The crop cycle lasted 82 days, from sowing until the end of harvest.

One week before the fruit harvest, the leaf area of plants (cm^2 $plant^{-1}$) was estimated using leave samples with more than 3.0 cm in length. The measurement was performed with the aid of a Li-3000 apparatus.

During the harvest, the following variables were evaluated: number of fruits per plant, counted only in the treatment without fruit thinning; average fruit mass (g fruit^{-1}), calculated by the ratio of total fruit weight to number of plants in the useful area; the total productivity (mg ha^{-1}), estimated at 1.0 ha at the experimental level. Twenty fruits per treatment were analyzed for soluble solids (%) and titratable acidity (% citric acid) according to the methodology of the Adolfo Lutz Institute [12]. Subsequently, the total soluble sugars were evaluated by the reaction with Antrona according to Yemn and Willis [13], the reducing sugars by DNS method [14], and non-reducing sugars by the difference between total and reducing sugars.

The significance of the effect of fruit thinning and main stem pruning on the response variables was investigated using an analysis of variance at the SAEG 9.0 software. The data were submitted to the normal pre-test of Shapiro-Wilk. As post-hoc tests, we used the Tukey test at 5% probability for fruit thinning, and regression analyses for the pruning period of the main stem at the Table Curve 2D software.

3. RESULTS AND DISCUSSION

Fruit thinning had a significant effect on leaf area (0,007), fruit mass (0,000), and yield of melon (0,000) (p < 0,05). The period of main stem pruning affected only the fruit mass by test significant ANOVA at 0.024 (p < 0.05). There was no significant effect of the interaction between the fruit thinning and the pruning season of the main stem on the leaf area and the production characteristics of the melon.

Plants with one and two fruits, because of the control exerted by the treatment, kept the number of fruits constant. However, plants without fruit thinning produced an average of 3.5 fruits per plant (data not shown).

The leaf area of the melon is an important measure to estimate the photosynthetic potential and, consequently, the final production and quality of the fruits at harvest [15]. Regarding fruit thinning, plants with only one fruit had higher values of leaf area than plants without fruit thinning (Table 1). According to Shi et al. [7], the allocation of carbon in the vegetative part of plants is favored by the reduction of sinks (fruits), which increase leaf production, raising the leaf area.

Regarding the mass of the fruits, the highest values occurred in plants submitted to thinning, leaving one and two fruits, which provided a greater mass compared to plants without fruit thinning. However, these conditions resulted in lower productivity due to the smaller number of fruits per hectare (Table 1).

The number of fruits in the plant directly influences the fruit mass, because the sinks also compete with each other for photoassimilates, which leads to the development of fruits with lower mass [15]. Thus, the largest leaf area available per fruit, when only one fruit set per plant, provide more assimilates from the source (leaf) to the sink (fruit), contributing to the increase of fruit mass.

Pathirana et al. [16], studying the tomato crop to determine the appropriate management of shoot and fruit thinning, verified that fruit thinning between 2 and 5 fruits per bunch per plant increased the fruit masses. Thus, the higher the number, the lower the mass of fruits, demonstrating that the plant has production capacity limited by the source.

Plants cultivated without fruit thinning showed higher total productivity (Table 1). In these plants, the fruits had lower mass but, due to the higher number of fruits per plant and area, there was a compensation of the loss of its mass concerning the plants with one and two fruits.

In melon, the number of fruits per plant and the mass of the fruits are determinant characteristics in crop productivity. These factors may change due to the partitioning of assimilates in the plant. Thus, the high number of fruits per hectare contributed significantly to increase productivity in plants without thinning. According to Dalastra et al. [8], in the cultivation of melon with different cultivars ('Amarelo', 'Rendilhado, and 'Pele de Sapo') and number of fruits per plant (one and two), the system with two fruits per plant is the most productive and shows high quality for commercialization regardless cultivars.

As for the period of main stem pruning, we found a quadratic response of the leaf area over time and a linear response decreasing of the fruit mass and total productivity of crop (Fig.1).

During the pruning of the main stem at 35 DAT, the plant leaf area value was estimated in 35,062.3 cm^2 plant^{-1}. After this period the leaf area increased, reaching its maximum value of 48,423.6 cm^2 plant^{-1} at 42,1 DAT (an increase of 38,11%). With the pruning at 50 DAT, the leaf area decreased to 37,829 cm^2 $plant^{-1}$ (21,88%) was observed (Fig. 1).

When pruning of the main stem is carried out earlier, at 35 DAT, occurs the emission of a higher number of secondary and tertiary lateral branches, which contributed to increase the leaf area until approximately 42,1 DAT, when the plant was already in full fruiting phase. Thus, as the fruit is the preferential sink after anthesis, from 42,1 DAT, the plant invests photoassimilates from the photosynthesis process preferably in fruit growth to the detriment of vegetative growth, so the leaf area values decreased when the plants were pruned later, that is, at 50 DAT.

Table 1. Average values of leaf area (LA), fruit mass (FM), and total productivity (TP) of melon fruits as a function of the number of fruits in the plant. CCTA/UFCG. Pombal - PB, 2016

Number of fruits	LA(cm^2 $plant^{-1}$)	FM (g $fruit^{-1}$)	TP(t ha^{-1})
Plants with one fruit	47820.3 a	2578.68 a	25.78 c
Plants with two fruits	40480.3 ab	2430.59 a	48.61 b
Plants without fruit thinning	37006.2 b	2081.53 b	72.26 a
CV (%)	26.73	11.32	21.56

**Averages in the same column and followed by the same letters did not differ significantly according to the Tukey Test at 5% of probability level*

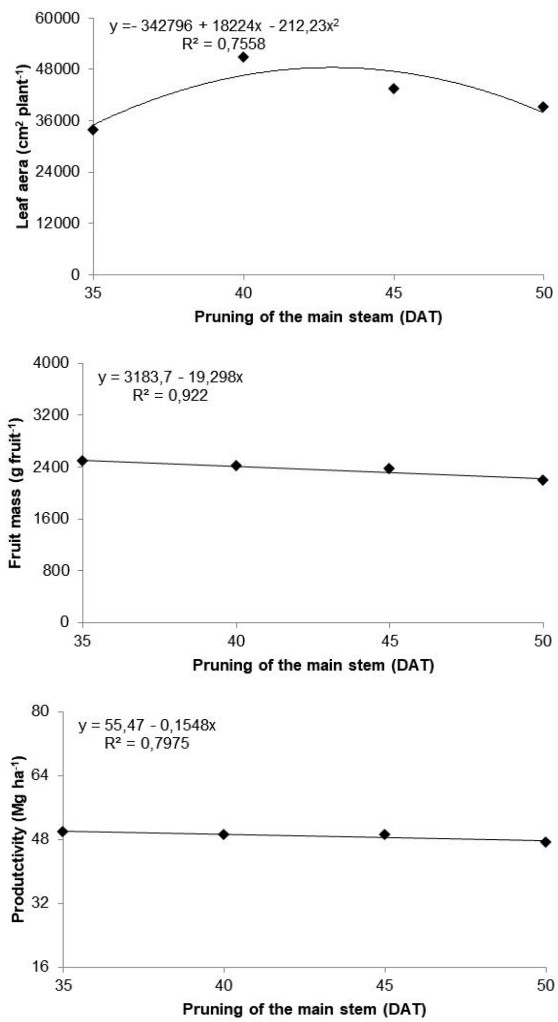

Fig. 1. Response functions adjusted for leaf area, fruit mass, and total productivity of melon fruits as a function of pruning period of the main stem. CCTA/UFCG, Pombal - PB, 2016

Campagnolo et al. [17] verified that plants with only one stem have lower leaf area than plants with two stems (3485.5 cm^2 $plant^{-1}$ and 4263.7 cm^2 $plant^{-1}$, respectively), suggesting that the more branches, the larger the leaf and the higher the leaf area of the plant.

The fruit mass of the melon had maximum and minimum values of 2508.3 and 2218.9 g $fruit^{-1}$ with the pruning of main stem at 35 and 50 DAT, respectively (Fig. 1). In this sense, the delay of main stem pruning until 50 DAT reduces at 11.5% in the mass of fruits.

Therefore, when pruning of main stem of melon is performed up to 42,1 DAT, the plant increases the leaf area, contributing to the production and subsequent translocation of photoassimilates to the fruits. Besides, plants with no fruit thinning had a lower number of fruits (data not shown) when pruning was performed at 35 DAT, proving that the presence of fewer fruits per plant provides an increase in the average mass of these fruits.

Similar results were found in the watermelon cultivation, in which a reduction of fruit mass was observed with pruning delay from 25 to 40 DAT [2]. The pruning performed earlier, at 25 DAT, probably favored the investment in lateral branches due to the loss of apical dominance and, consequently, the formation of a larger leaf area per fruit set. With this, there was an increase in transport of photoassimilates for the growth of fruits in detriment of their higher set.

When pruning of main stem was performed at 35 and 50 DAT, we estimated maximum and minimum values in total melon productivity of 50.05 and 47.72 mg ha^{-1}, respectively. Thus, with the pruning delay, there was a 4.7% reduction in crop yield (Fig.1). This higher total productivity of the melon found in plants pruned at 35 DAT is a result of the higher mass of fruits regardless of the number of fruits per plant.

Freitas et al. [11] suggested that apical pruning in pumpkins could stimulate the emission of lateral shoots, leading to the development of more flowers and fruits and, consequently, increase the production per plant. However, these same authors, in their experiments, concluded that apical pruning did not influence fruit production in the pumpkins.

Regarding the quality of melon fruit, there was no interaction between fruit thinning and the period main stem pruning by test not significant ANOVA at 0,350 ($p > 0.05$) (Table 2). These results were similar to those obtained by Ferreira et al. [9]. However, when analyzed individually, fruit thinning affected soluble solids, non-reducing sugars, and total soluble sugars, whereas main stem pruning influenced only soluble solids by test significant ANOVA at 0,036 ($p \leq 0.05$). The factors studied pruning and pruning x fixing the fruit did not affect total acidity and reducing sugars by test not significant ANOVA at 0.052 and 0,427, and 0,270 and 0,08 respectively ($p > 0.05$).

The plant cultivated with one and two fruits increased the values of soluble solids, non-reducing sugars, and total soluble sugars compared to melons without thinning. This result was favored by the larger leaf area per fruit that increased the production and transport of photoassimilates, initially for the fruit growth and, after the beginning of the maturation phase, for the accumulation of sugars in the fruit pulp.

Barzegar et al. [18] observed that the removal of some melon fruits induces the plant to direct photoassimilates to the fruits setting or to the vegetative growth, being more efficient when the thinning is carried out in the early stages of development.

Table 2. Mean values of soluble solids (SS), total acidity (TA), reducing sugars (RS), non-reducing sugars (NRS) and total soluble sugars (TSS) of melon fruits as a function of the number of fruits in the plant. CCTA/UFCG. Pombal - PB, 2016

Number of fruits	SS(^{0}Brix)	TA(% citric acid)	SR(%)	NRS(%)	TSS(%)
Plants with one fruit	9.00 a	0.169 a	2.02 a	5.56 a	7.58 a
Plants with two fruits	8.85 a	0.179 a	2.22 a	4.97 a	7.19 a
Plants without fruit thinning	8.13 b	0.183 a	2.34 a	4.21 b	6.55 b
CV (%)	15.51	13.53	21.40	16.75	16.99

**Averages in the same column and followed by the same letters did not differ significantly according to the Tukey Test at 5% of probability level*

The melon requires an increase in the availability of carbohydrates near the harvest, after the fruit has gone through the phases of cell division and expansion, resulting in the increment of stored sugars. Zhang and Flottmann [19] report that yield of canola was limited by the availability of photoassimilate by the source during seed filling, while it may also be limited by the size of the drain that is established during flowering, thus, they found that both the source and drain need compatible in the distribution of assimilates and storage.

According to Huang et al. [20] the main sugars found in melon fruits are: Sucrose (non-reducing), fructose and glucose (reducing), among these sugars, sucrose is the dominant sugar in the melon in full ripeness.

Although there was no significant effect on total acidity ($p > 0,05$), there was a tendency of increase of acidity values with the increase in number of fruits per plant. This increase in fruit pulp acidity may be related to the higher concentration of non-reducing sugars (sucrose) in plants cultivated with only one fruit that had a higher proportion of sugars compared to organic acids.

The number of fruits per plant potentially affect the quality of melons since it can change the leaf area per fruit ratio and modify the relation between the source and sink and the assimilated partition in the plant. Queiroga et al. [15], working with melon 'Rendilhado' verified that the number of fruits in the plant did not interfere in the total acidity, which corroborates with our results.

The soluble solids contents varied from 9.0 to 8.1 in plants with one fruit and plants without thinning, respectively (Table 2). The low values of soluble solids found in this research can be related to two factors: the incidence of melonworm moth that defoliated the plants and leaf senescence that is common in the final phase of the cycle, both of which led to a reduction in leaf area. In this sense, the decline of leaf area of the plant one week before the harvest may have affected the accumulation of sugars in the fruit due to the low production and transport of photoassimilates in the stage of maturation and sweetening.

The total acidity varied in a quadratic way as a function of the period of main stem pruning, with a maximum value of 0.22% of citric acid reached at 44,3 DAT. From this period, a minimum value of 0.16% was recorded, that is, occurred a decrease of 11.1% with the delay of pruning for 50 DAT (Fig. 2).

On the other hand, the soluble solids showed a linear decrease with the delay of the pruning period from 35 to 50 DAT, decreasing from 9.5 to 8.0°Brix, which led to a 15.8% reduction in soluble solids content (Fig. 2).

Higher value of soluble solids observed when pruning of the main stem at 35 compared to 50 DAT was probably influenced by the highest leaf area recorded when pruning was done earlier.

A study evaluating the influence of main stem pruning and the period of fruit thinning on post-harvest quality of melon 'Amaregal' and 'Banzai' showed that the titratable acidity (0.077%) were low while soluble solids were high in treatments with early pruning [9].

Total soluble sugars, reducing sugars, and non-reducing sugars had similar behaviors, presenting linear decreasing responses with estimated values of 7.6%, 2.3%, and 5.2%, and minimum values of 6.4%, 1.9%, and 4.5% at 35 and 50 DAT, respectively (Fig. 2). These decreases corresponded to a reduction of 15.8% in total soluble sugars, 17.4% in reducing sugars and 15.6% in non-reducing sugars with delay up to 50 DAT of the pruning.

It is possible that the higher concentration of sugars in the fruits of the plants pruned earlier occurred due to these fruits grew under suitable conditions, that is, when the plants had no signs of foliar senescence and no attacks of pests and diseases that arise at the end of the cycle.

In this way, under favorable conditions of growth at 35 DAT, the melon fruit accumulates monosaccharides in the cell wall, such as xylose, glucose, rhamnose, and mannose, which are solubilized during fruit ripening, which contributes to the increase of the content of sugars in fruits [21].

Besides, the early break of apical dominance increases the number of secondary and tertiary branches, raising the available leaf area with the successful production and translocation of photoassimilates in the final phase of fruit maturation. On the other hand, in plants pruned later, the photoassimilates that would be destined to fruits (preferential sinks) were redirected to new branches (source), reducing the accumulation of sugars in the fruit pulp [9].

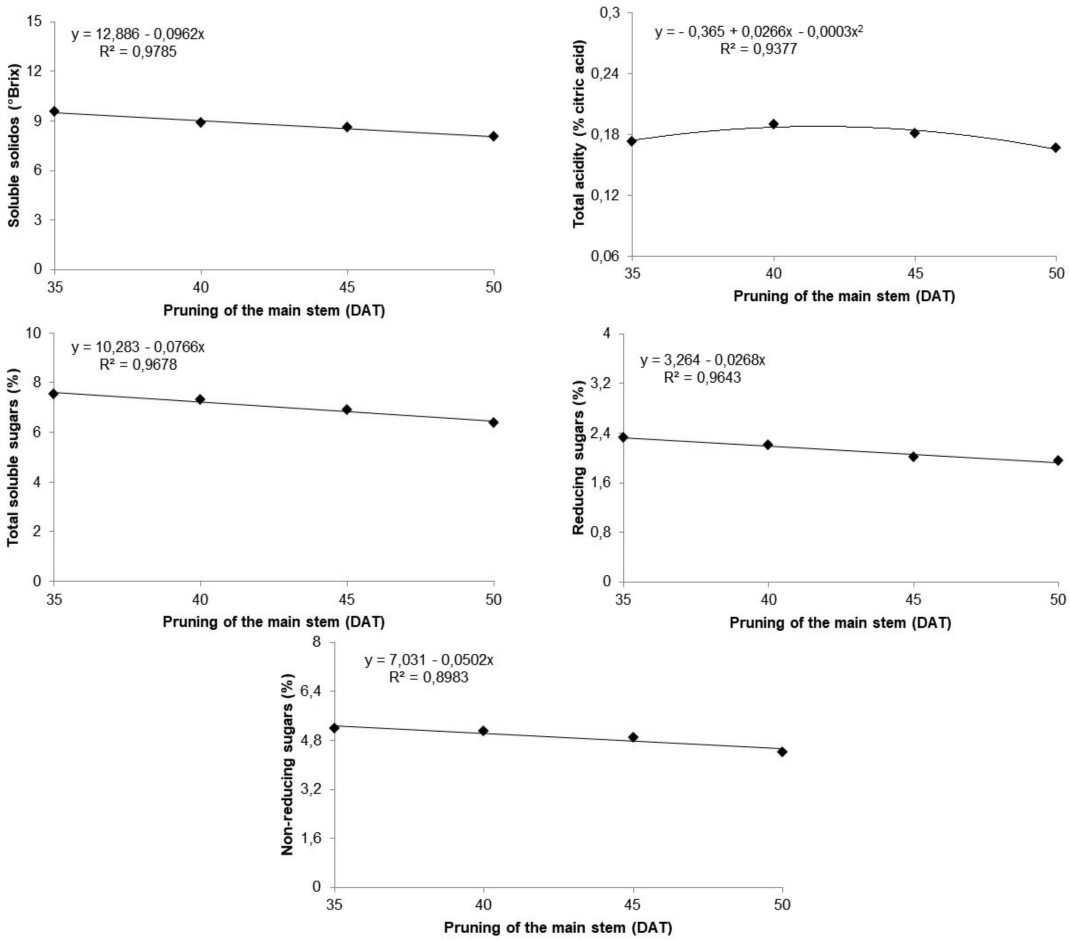

Fig. 2. Response functions adjusted for soluble solids, total acidity, total soluble sugars, reducing and non-reducing sugars in melon fruits as a function of pruning period of the main stem. CCTA/UFCG, Pombal - PB, 2016

A study evaluating the influence of main stem pruning and fruit thinning on quality and post-harvest conservation of Charentais 'Banzai' melon showed that the treatment without pruning increased the titratable acidity of the fruits, while the thinning at 51 days after sowing reduced soluble solids, pulp firmness, titratable acidity, and reducing sugars [22].

4. CONCLUSION

Melons submitted to fruit thinning produced fruits with high values of soluble solids, total soluble sugars, and non-reducing sugars. On the other hand, the cultivation without the thinning resulted in small leaf areas and fruits of low mass, however, due to their high number per hectare, there was an increase in total productivity. Plants pruned at 35 DAT had high values of leaf area, fruit mass, total productivity, total soluble sugars, reducing and non-reducing sugars.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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