Research, Society and Development, v. 9, n. 9, e888997948, 2020
(CC BY 4.0) | ISSN 2525-3409 | DOI: http://dx.doi.org/10.33448/rsd-v9i9.7948

Effect of carbohydrate content on shoot maturation and yield of Palmer mango submitted to potassium fertilization and biostimulant

Conteúdo de carboidratos na maturação da parte aérea e produtividade em mangueira Palmer submetidas a fertilização potássica e bioestimulante

Contenido de carbohidratos en la maduración y productividad de los brotes en manguera Palmer sometida a fertilización con potasio y bioestimulante

Received: 08/27/2020 | Reviewed: 09/06/2020 | Accept: 09/10/2020 | Published: 09/11/2020

Mariela Medeiros Lopes Silva
ORCID: https://orcid.org/0000-0002-5916-4099
Universidade Federal de São João del-Rei, Brasil
E-mail: mariela.medeiros@gmail.com
José Carlos Moraes Rufini
ORCID: https://orcid.org/0000-0001-9399-0872
Universidade Federal de São João del-Rei, Brasil
E-mail: rufini@ufsj.edu.br
Miriã Cristina Pereira Fagundes
ORCID: https://orcid.org/0000-0003-4682-1317
Universidade Estadual de Santa Cruz, Brasil
E-mail: miria.agro@yahoo.com.br
Victor Martins Maia
ORCID: https://orcid.org/0000-0002-6624-8805
Universidade Estadual de Montes Claros, Brasil
E-mail: victor.maia@unimontes.br
Ana Clara Pimenta Pereira
ORCID: https://orcid.org/0000-0003-4996-3644
Universidade Federal de São João del-Rei, Brasil
E-mail: claraapimenta@gmail.com
Paulo Antônio Santana Júnior
ORCID: https://orcid.org/0000-0003-4034-4433
Universidade Federal de Viçosa
santana.psj@gmail.com

Willian Gonçalves Souza
ORCID: https://orcid.org/0000-0002-8528-4692
Universidade Federal de São João del-Rei, Brasil
E-mail: wgs0710@gmail.com

Abstract

Mango production in the Brazilian semiarid region has gained prominence in the national scenario due to the high yield and long production period using techniques that help in the main culture stages. The aim of this work was to evaluate the use of two alternative techniques in the production of ‘Palmer’ mango in the vegetative phase. It was evaluated whether commercial potassium-based Multipotássio® fertilizer could be used as an alternative source of potassium nutrient in the maturation process of mango branches, and whether *Ascophyllum nodosum* algae extract MultiTurbo® biostimulant would be good alternative for fruit production. Two experiments were conducted in the same area, the first experiment with factors represented by four Multipotássio® concentrations (0; 1; 2 and 3 L ha^{-1}) and two assessment periods in the maturation of mango branches and leaves. In the second experiment, conducted in the same area, factors Multipotássio® concentration (0; 1; 2 and 3 L ha^{-1}) and four MultiTurbo® concentrations (0; 0.625 ml ha^{-1}; 1. 25 ml ha^{-1} and 2.50 ml ha^{-1}) were evaluated. Number and length of panicles, carbohydrate content in branches and leaves, fruiting rate, fruit mass, length and diameter and yield were evaluated. The use of potassium-based fertilizer helps to increase sugar content in 'Palmer' mango branches, which has been increasing in relation to the doses used. Biostimulants result in positive effects on the number of panicles, fruits and yield of 'Palmer' mango.

Keywords: *Ascophyllum nodosum*; Floral induction; *Mangifera indica* L.; Production.

Resumo

A produção da manga na região do semiárido brasileiro, tem ganhado destaque no cenário nacional em função do alto rendimento e amplo período de produção com o uso de técnicas que auxiliam nas principais fases da cultura. O objetivo deste trabalho foi avaliar o uso de duas técnicas alternativas na produção de mangueiras Palmer na fase vegetativa. Foi avaliado se o uso do fertilizante comercial a base de potássio Multipotássio®, poderia ser utilizado como alternativa de fonte do nutriente potássio no processo de maturação dos ramos da mangueira, e se o bioestimulante contendo o extrato de algas *Ascophyllum nodosum* MultiTurbo®, seria uma boa alternativa para a produção de frutas. Foram conduzidos dois experimentos em uma mesma área, sendo o primeiro experimento com os fatores representados por quatro concentrações de Multipotássio® (0; 1; 2 e 3 L ha^{-1}) e duas épocas de avaliação na maturação dos ramos e folhas da mangueira, já o segundo experimento, conduzido na mesma área, utilizou-se os fatores concentração de Multipotássio® (0; 1; 2 e 3 L ha^{-1}) e quatro concentrações de MultiTurbo®, (0; 0,625 ml ha^{-1}; 1,25ml ml ha^{-1} e 2,50 ml ha^{-1}). Foram avaliados comprimento e número de panículas, teores de carboidratos nos ramos e folhas, taxa de frutificação, massa, comprimento e diâmetro dos frutos e produtividade. O uso do fertilizante a base de potássio auxilia no incremento do teor de açúcar no ramo da mangueira 'Palmer' que foi crescente em relação às doses utilizadas. Os bioestimulantes resultam em efeitos positivos no número de panículas, número de frutos e produtividade da mangueira 'Palmer'.

Palavras-chave: *Ascophyllum nodosum*; Indução floral; *Mangifera indica* L.; Produção.

Resumen

La producción de mango en el semiárido brasileño ha ganado protagonismo en el escenario nacional debido al alto rendimiento y amplio período de producción con el uso de técnicas que ayudan en las principales fases del cultivo. El objetivo de este trabajo fue evaluar el uso de dos técnicas alternativas en la producción de mangueras Palmer en la fase vegetativa. Se evaluó si el uso del fertilizante comercial a base de potasio Multipotássio®, podría utilizarse como fuente alternativa del nutriente potasio en el proceso de maduración de las ramas del mango, y si el bioestimulante que contiene el extracto de algas *Ascophyllum nodosum* MultiTurbo®, sería un buena alternativa para la producción de frutas. Se realizaron dos experimentos en la misma zona, el primero con los factores representados por cuatro concentraciones de Multipotássio® (0; 1; 2 y 3 L ha^{-1}) y dos periodos de evaluación en la maduración de las ramas y hojas del árbol de mango, el segundo experimento, realizado en la misma zona, utilizó los factores de concentración de Multipotássio® (0; 1; 2 y 3 L ha^{-1}) y cuatro concentraciones de MultiTurbo®, (0; 0,625 ml ha^{-1}; 1, 25 ml ml ha^{-1} y 2,50 ml ha^{-1}). Se evaluó la longitud y número de panículas, el contenido de carbohidratos en ramas y hojas, tasa de fructificación, masa, longitud y diámetro de frutos y productividad. El uso de fertilizantes a base de potasio ayuda a incrementar el contenido de azúcar en la rama del mango 'Palmer', que ha crecido en relación a las dosis utilizadas. Los bioestimulantes tienen efectos positivos sobre el número de panículas, el número de frutos y la productividad de la manguera 'Palmer'.

Palabras clave: *Ascophyllum nodosum*; Inducción floral; *Mangifera indica* L.; Producción.

1. Introduction

Mango (*Mangifera indica* L.) is a very important fruit species for the Brazilian economy, which is the sixth largest producer and one of the largest exporters (FAO, 2019). In 2018, the main mango producing states were Pernambuco, Bahia, São Paulo and Minas Gerais (semiarid region), representing 38%, 29%, 15% and 6% respectively (IBGE, 2019).

In all these regions, the use of techniques to manipulate mango flowering has become a common practice with the aim of staggering the production of this fruit tree (Ripardo et al., 2009). The reason for this practice is the complexity of this step that requires caution since it involves a multiplicity of factors (Kulkarni, 2004), highlighting climatic: temperature factor (Laxman et al., 2016), nutritional status (Cavalcante et al., 2016; Carneiro et al., 2017), pruning (Asrey et al., 2013), hormonal balance (Ramírez et al., 2014), carbohydrate concentration (Kumar et al., 2014; Moreira et al., 2014) and maturation of the vegetative flow (Cavalcante et al., 2018).

The phase preceding floral induction is called maturation of vegetative mango tree branches, which is of paramount importance for production, as it is at this time that plants most feel stress caused by high temperatures and low water availability (Ramírez & Davenport, 2016). At this stage, understanding the allocation of photoassimilates between mango leaves and branches may be important to identify the periods of greatest demand for photoassimilates during the reproductive stage. The energy requirement at this stage is high, with high carbohydrate demand (Prasad et al., 2014; Cavalcante et al., 2018). In this sense, management techniques are necessary to maintain carbohydrate reserves.

Among the techniques used to regulate the vegetative growth of mango aiming at floral induction, the combined use of paclobutrazol, potassium sulfate and ethephon is common (Silva & Neves, 2011; Ferreira et al.,2020).

Potassium ion interferes with the potassium / nitrogen ratio, contributing to the maturation of branches, thus improving bud fertility (Silva & Vilela, 2004). Under field conditions, specifically in the region of Janaúba, northern Minas Gerais, the use of potassium-based commercial product, named Multipotássio®, as alternative to potassium, sulfate has been observed to achieve higher quality in maturation and uniformity of branches.

Together with Multipotássio®, the use of natural products has become a viable alternative to minimize environmental impacts, also acting as a biostimulant in flower induction processes.

(CC BY 4.0) | ISSN 2525-3409 | DOI: http://dx.doi.org/10.33448/rsd-v9i9.7948

Bioetinulants are defined as products containing active components or biological agents capable of acting, directly or indirectly, on all or part of cultivated plants, improving the performance of the production system, and free from substances prohibited by organic regulation (Calvo et al., 2014), often containing seaweed extracts, representing one of the options for alleviating the consequences of abiotic stress on crops (Santaniello et al., 2017).

Seaweed synthesizes plant hormones and its extract is commercially used as biostimulants to increase agricultural production, being a natural source of cytokines, a class of plant hormones that promote cell division and delay senescence (Stirk et al., 2003). In Brazil, the use of seaweed extract in agriculture is regulated by Decree 4,954, which is a complexing agent used in fertilizer formulations for foliar application and fertigation.

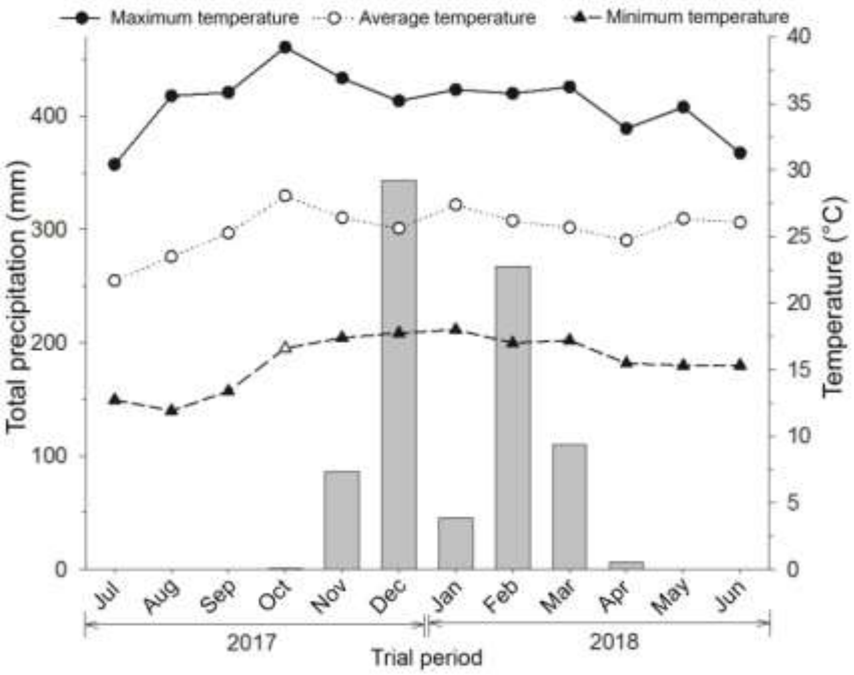
Seaweed extract has been used under field conditions in the floral induction of mango in order to give a stimulus to the plant for the moment of floral induction. Mangoes treated with seaweed extract have improved physical and chemical characteristics of 'Hindy Bisinnara' mango fruits in terms of increased fruit weight, sugars, and vitamin C content (Mohamed & El- Sehrawy, 2013).

Given the above, the aim of this work was to evaluate the efficiency of the use of potassium-based foliar fertilizer in the maturation process of mango tree branches and *Ascophyllum nodosun* extract-based foliar fertilizer on crop yield.

2. Methodology

The study used a quantitative experimental research in the field (Pereira et al., 2018) that was conducted conducted in a commercial 'Palmer' mango orchard located in the municipality of Janaúba, California Farm, northern state of Minas Gerais from June 2017 to June 2018. The municipality is located at 516 m a.s.l. at coordinates 15º47'50 "S and 43º18'31 "W. According to the Kopen classification, the local climate is characterized as tropical with dry winters and rainy summers. The maximum, average and minimum temperatures during the phase of experiment conduction are described in Figure 1. The climatic data used were obtained from weather station number 1034 - Uvale - Nova Porteirinha, provided by ABANORTE (Central Association of Fruit Growers of Northern Minas Gerais).

Figure 1. Monthly average temperatures: average, maximum, minimum and monthly accumulated precipitation during the development of 'Palmer' mango.



Source: Uvale Experimental Farm Weather Station, Nova Porteirinha.

The orchard was three years old and approximately 2 m of canopy, planted in a 4 m x 2 m spacing, which corresponds to 1,250 plants per hectare.

During the conduction of the work, application of pacoblutrazol (PBZ) was performed in the experimental area on July 2017. Commercial product Cultar® (2.0% i.a.) was used at dose of 7.5 ml L^{-1} in the soil. After 60 days, irrigation depth was gradually reduced to reach on the thirtieth day the value of 50% of the total irrigation required to stop the vegetative growth.

Two experiments were conducted, the first with 4 x 2 factorial in randomized blocks with factors dose of potassium-based commercial leaf fertilizer (Multipotássio®) (0; 1; 2 and 3 L ha^{-1}) and two assessment times (15 days and 30 days after the first fertilizer application), with three blocks and three plants per experimental unit. The first fertilizer application was carried out on September 2017 (60 days after PBZ application) in the soil.

In the second experiment, a 4x4 factorial was used, totaling four doses of potassium-based foliar fertilizer (Multipotássio®) (0; 1; 2 and 3 L ha^{-1}) and four doses of *Ascophyllum nodosum*-based leaf fertilizer (MultiTurbo®) (0.625 ml ha $^{-1}$, 1.25 ml ha $^{-1}$ and 2.50 ml ha $^{-1}$), with three blocks and three plants per experimental unit. In November 2017, pruning of 100% of branches was performed and then calcium nitrate applications were performed (once a week for three weeks) to stimulate growth initiation and assist in the breaking of dormancy of floral buds. Foliar application of seaweed extract fertilizer was performed shortly after the pruning of mango branches associated with the 2nd and 3rd foliar application of calcium nitrate and fruits were harvested on May 2018.

2.1 Evaluations

For the evaluation of experiments, plants were divided into four quadrants, marking four branches / quadrant with homogeneous characteristics for use in non destructive analysis.

For experiment one, the following vegetative characteristics were evaluated: a) carbohydrate content of leaves and branches: starch and total soluble sugars contents were evaluated at two times between 15 and 30 days after the first application of potassium-based foliar fertilizer, where branches and mature leaves were collected from each quadrant, dried in forced air oven at 65ºC for 72 hours until constant weight was obtained. Subsequently, samples were ground in Willey mill and placed in flasks for later chemical analysis. Extracts were obtained and starch and total soluble sugars concentrations were determined according to method described by McCready et al. (1950).

In experiment two, the following reproductive characteristics were evaluated: a) panicle length: after flowering, length was evaluated with the aid of graduated ruler, and the length of the largest panicle among the four previously marked branches was measured; b) number of panicles: at the time of flowering, with flowers fully open, the number of panicles emitted on branches marked in the quadrants was counted; c) fruiting rate: in full bloom, the fruiting rate (%) of each treatment (number of established fruits * 100 / number of flowers) was counted in branches marked in each quadrant; d) number of fruits per plant and yield: during harvest, all fruits of each treatment were stored in boxes and weighed to determine the weight of boxes and consequently yield. To determine the number of fruits per plant, fruits that were later weighed in digital scale to determine the number of fruits per plant were sampled; e) post-harvest characteristics: three fruits from the total harvested per experimental plot randomly selected, and the following variables were evaluated: fruit mass using precision analytical scale and values expressed in grams; fruit length and diameter using a digital caliper and expressed in mm.

Statistical analysis was performed with the aid of the System for Analysis of Variance - SISVAR computer software (Ferreira, 2011), and the means of treatment of qualitative data were compared by the Tukey test at 5% probability. Quantitative data were submitted to regression analysis, according to recommendations by Gomes (1990).

3. Results and Discussion

3.1 Vegetative characteristics

Interaction was observed between doses of potassium-based foliar fertilizer and evaluation times for the sugar content in the branch. In relation to starch, significant differences were observed for leaf and branch content at different times and different doses only for leaf starch. No statistical difference was observed for any of the factors regarding leaf sugar.

The starch content in the branch was higher in time 1 with value of 28.83 mg g^{-1}, with reduction of 23.7% compared to time 2 (Table 1). Similar results were found by Cavalcante et al. (2018), who observed reduction in carbohydrate content in 'Palmer' mango branches using different branch maturation strategies, especially in the period before anthesis. These results show that, for the beginning of a new mango cycle, it was necessary to mobilize starch reserves contained in branches.

Table 1. Starch content of 'Palmer' mango branches and leaves at different evaluation times.

Time	Starch (mg g^{-1})	
	Branch	Leaf
1	28.83 a	24.62 a
2	22.00 b	21.17 b
Coefficient of variation(%)	13.19	10.35

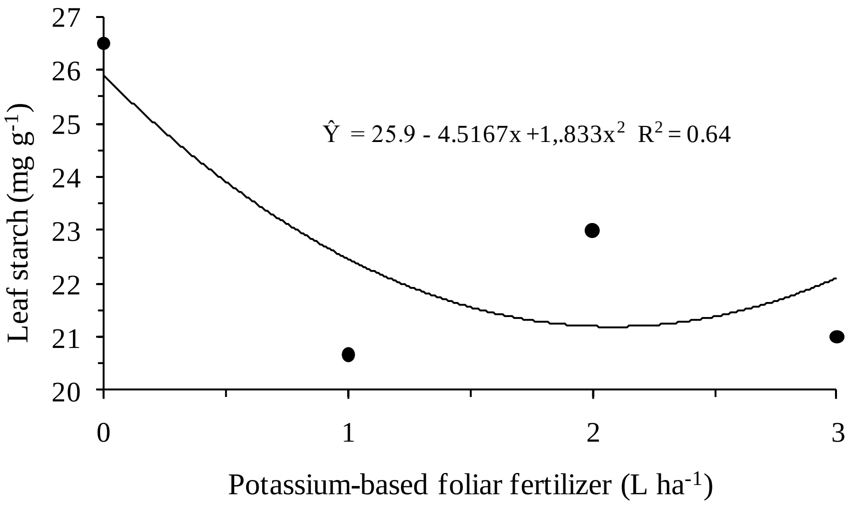
Means followed by the same lower case letter in the column do not differ from each other by the F test. Source: Authors

Leaf starch presented the same behavior, with the highest value of 24.67 mg g^{-1} showing reduction of 13.12% in time 2. These results corroborate results observed by Cruz et al. (2007) working with 'Tahiti' sour lime and 'Ponkan' mandarin. However, results differed from those found by Oliveira et al. (2018) in 'Ubá' mangos, in which starch remained stable throughout the bud swelling period. Leaf carbohydrate levels are involved in panicle development and flowering induction intensity (Davenport, 2007). Therefore, the reduction in starch levels may have occurred due to the energy demand for inflorescence formation.

The change in starch content of mature leaves and branches over time indicates that it accumulates reserve during winter rest. In spring, starch reserves decrease as a result of transport to growing vegetative and flowering shoots, beginning at this moment, strong competition among developing organs (Guardiola et al., 1984).

The highest leaf starch contents (25.9 mg g^{-1}) were found in the absence of potassium-based foliar fertilizer, decreasing to 21.19 mg g $^{-1}$ with dose of 2.08 L ha $^{-1}$. After this dose, levels increased again to reach 22.09 mg g $^{-1}$ starch in leaves (Figure 2).

Figure 2. Leaf starch content (mg g^{-1}) in 'Palmer' mango submitted to different doses of potassium-based foliar fertilizer.



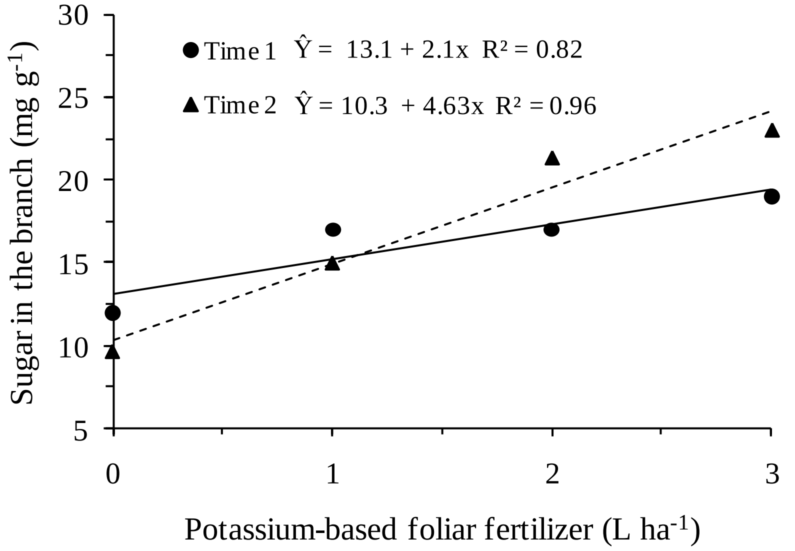
Source: Authors.

The reduction in leaf starch contents after increasing fertilizer doses occurs because high-dose potassium reduces starch content due to increased absorption and accumulation of this nutrient in the plant, resulting in reduced osmotic potential and increased water absorption, which causes dilution of starch contents in structures (Reis Junior & Fontes, 1996).

For the sugar content in branches, there was significant interaction between potassium-based foliar fertilizer doses and the different application times (Figure 3). There was positive linear trend regardless of application time.

(CC BY 4.0) | ISSN 2525-3409 | DOI: http://dx.doi.org/10.33448/rsd-v9i9.7948

Figure 3. Sugar in the branch content (mg g^{-1}) of 'Palmer' mango submitted to different doses of potassium-based foliar fertilizer.



Source: Authors.

In relation to time 1, there was a 48.09% increase in branch sugar content with maximum dose (3 L ha^{-1}) of potassium-based foliar fertilizer. The same behavior was observed for time 2, when there was an increase of 134.85% in the maximum fertilizer dose in relation to the absence of the product. Similar results were found by Corsato et al. (2008), in 'Rama Forte' persimmon plants, which also showed increase in sugar content in the period before flowering.

In the present work, greater increase in branch sugar content is still observed in the second time compared to the first. This result shows that the closer to the anthesis, the greater the accumulation of branch sugars from starch mobilization (Table 1).

The leaf sugar contents of ‘Palmer’ mango were not affected by potassium-based leaf fertilizer doses (0, 1, 2 and 3 L ha^{-1}) in both evaluation times. The average values of both evaluation times of ‘Palmer’ mango ranged from 26.34 to 33.00 mg g^{-1}, with average value of 28.76 mg g^{-1}. Similar results were found by Oliveira et al. (2018), evaluating ‘Ubá’ mango and Upreti et al. (2014), with 'Toupari' mango, both in the bud swelling period.

According to Koch (2004), total soluble sugars are very important substrates for plant metabolism, helping plants in physiological events and development, regulating carbon importation for the metabolically active drain. These sugars accumulated during the bud swelling and panicle emergence probably play a key role in reducing osmotic potential, which promotes the process of bud breakage (Benkeblia et al., 2005).

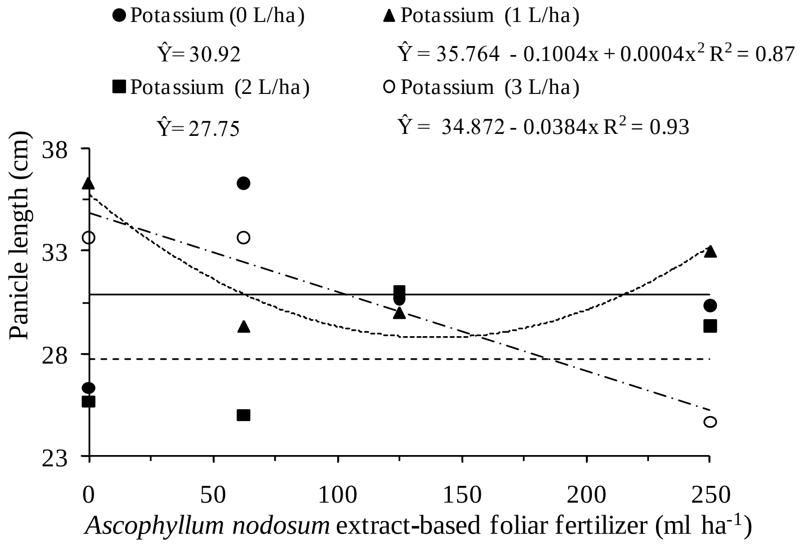
3.2 Reproductive characteristics

Significant interaction was observed between doses of potassium-based foliar fertilizer and *Ascophyllum nodosum* extract-based foliar fertilizer for panicle length. The number of panicles and the fruiting rate were not influenced by any of the factors alone or by their interaction.

The number of panicles per branch ranged from 3.33 to 5.0. These values were higher than those found by Lima et al. (2016) for 'Palmer' mango using different doses of flowering inducer, where averages ranged from 0.5 to 2.0 panicles per branch. Although no influence on this variable of any of the factors or their interaction was found, *Ascophyllum nodosum* has obtained positive responses in several crops.

Panicle length was influenced by the interaction between factors (*Ascophyllum nodosum* extract-based leaf fertilizer x potassium-based leaf fertilizer) (Figure 4).

Figure 4. Panicle length (cm) in 'Palmer' mango submitted to different doses of *Ascophyllum nodosum* extract-based foliar fertilizer and potassium-based foliar fertilizer.



Source: Authors.

In the absence of potassium-based fertilizer and at dose of 2 L ha^{-1}, panicle length was not influenced by *Ascophyllum nodosum* extract, reaching averages of 30.92 and 27.95 cm, respectively. On the other hand, when dose of 1 L ha^{-1} of potassium-based foliar fertilizer was tested, it presented a quadratic behavior, and the shortest length (28.84 cm) was reached in the dose of 125.5 ml ha^{-1} of *Ascophyllum nodosum* extract, increasing again and resulting in a

13.19% increase in panicle length. In the dose of 3 L ha^{-1} of potassium fertilizer, a negative linear trend was observed, which resulted in a 27.53% reduction in panicle length compared to the absence of the extract. Behavior contrary to the present study was found by Lobo et al. (2019), who observed increase in panicle length with the use of biostimulants in 'Kent' mango.

A possible explanation for the effect presented in this study may be the residual effect of PBZ. According to Husen et al. (2012), high doses of PBZ used in mango culture tend to compact panicles. This feature is undesirable and avoided, since more compacted panicles favor the proliferation of microorganism.

Regarding fruit emission, the fruiting rate showed no difference between treatments. The average ranged from 39.33% (with the use of potassium-based fertilizer at dose of 1 L ha^{-1} and in the absence of *Ascophyllum nodosum* extract-based fertilizer) to 66.67% (with potassium-based fertilizer at dose of 3 L ha^{-1} and *Ascophyllum nodosum* extract-based fertilizer at dose of 250 ml L^{-1}). The behavior observed in the present work can probably be attributed to higher potassium absorption, with the presence of *Ascophyllum nodosum* extract. Carvalho et al. (2019), researching the effect of seaweed extracts on nutrition, yield, and quality of 'Niagara Rosada' grape cultivar and foind that with 6% of *Ascophyllum nodosum* extract, there was an increase in K absorption.

Potassium acts directly on stomata opening and closing, and photosynthesis production (Moutinho - Pereira et al., 2010; Hernández - Herrera et al., 2014), which positively reflects the fruiting of fruit plants.

Fruit mass, length and diameter were not influenced by any factor alone or by their interaction.

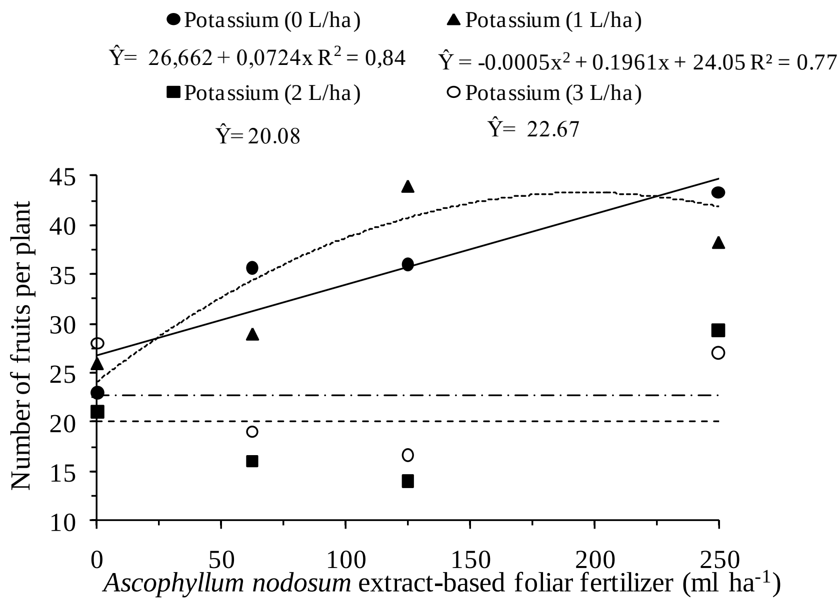
Fruit mass ranged from 642.67 to 880.87g, with general average of 746.23g. Similar behavior was observed by Hafle et al. (2003) and Mouco & Albuquerque (2005), where floral induction treatments did not influence the mass of 'Tommy Atkins' mango fruits. According to the authors, such behavior can be explained by the fact that the number of established fruits in each panicle, between treatments, also did not vary. Although fruit mass does not differ significantly between treatments, they are in accordance with the mango quality control standard established by the FFV-45 of the United Nations Economic Commission for Europe (UNECE, 2017), the main fruit exporter, where fruits for export must be at least 100g, and are classified by weight: Type A (100-350 g), Type B (351-550 g), Type C (551-800 g) and Type D (> 800g). For fruits obtained in this work, all treatments produced Type C fruits.

(CC BY 4.0) | ISSN 2525-3409 | DOI: http://dx.doi.org/10.33448/rsd-v9i9.7948

The length and mean cross-sectional diameter of fruits were 14.1 cm and 9.4 cm, respectively. These results were similar to those found by Santos (2009) in Janaúba-MG, with 13.8 cm length and 8.6 cm diameter for ‘Palmer’ mango. Carvalho et al. (2004) observed different values for the same cultivar, with average length of 11.9 cm and diameter of 7.7 cm. According to Modesto et al. (2016), the same cultivar may present variability in fruit diameter, mainly due to crop seasonality, factors inherent to the plant, water availability and temperature changes.

Regarding the number of fruits plant^{-1}, significant interaction was observed for treatments potassium-based foliar fertilizer and *Ascophyllum nodosum* extract-based foliar fertilizer (Figure 5).

Figure 5. Number of fruits per plant in 'Palmer' mango submitted to different doses of *Ascophyllum nodosum* extract-based foliar fertilizer and potassium-based foliar fertilizer.



Source: Authors.

In the absence of potassium-based foliar fertilizer, an increasing linear trend was observed, i.e., as the dose of *Ascophyllum nodosum* extract-based foliar fertilizer increased, an increase in fruit yield per plant was observed, and the highest average observed was 43.33 fruits per plant with 250 ml ha^{-1} of *Ascophyllum nodosum* extract-based foliar fertilizer, which resulted in an increase of 88% compared to the absence of algae. Similar results were found by Koyama et al. (2012), who observed increase of 14.7% and 45.7% in the number of fruits plant^{-1} in tomato trees cultivated in protected environment and in the field, respectively, using 0.3% and 0.5% of *Ascophyllum nodosum* extract biweekly applied.

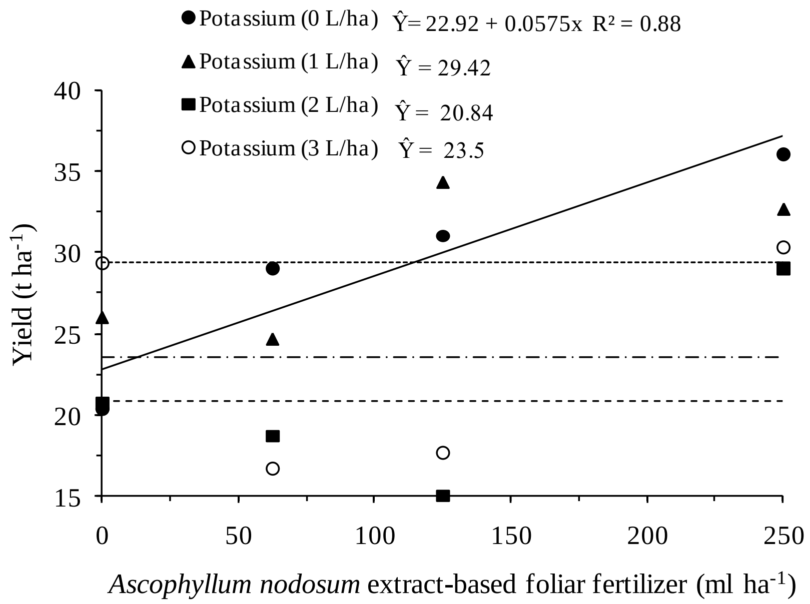
For treatment with 1 L ha^{-1} of potassium-based fertilizer as a function of *Ascophyllum nodosum* fertilizer doses, quadratic adjustment was observed, where the highest estimated average was 42 fruits plant^{-1} with dose of 179.6 ml ha^{-1} of *Ascophyllum nodosum* extract foliar fertilizer. The increase in the number of fruits in the present work can be explained by the presence of substances that either induce plants to metabolize plant growth regulators, or behave similarly to growth regulators (Khan et al., 2009; Spinelli et al., 2010; Khan et al., 2011; Wally et al., 2013). Zhang & Ervin (2004) identified by the ELISA test on *Ascophyllum nodosum* extract Zeatin-riboside (ZR) and Isopentenyl adenine (iPA) concentrations of 66 μg g^{-1} and 4 μg g^{-1}, respectively. In addition, the presence of potassium acts to improve carbohydrate translocation and protein synthesis (Moutinho - Pereira et al., 2010; Hernández - Herrera et al., 2014).

With the increase of potassium-based fertilizer doses, no significant influence of *A. nodosun* extract fertilizer doses was observed, and the number of fruits per plant ranged from 20.08 to 22.67. According to Carneiro et al. (2018), the low production linked to the increase in potassium dose can be explained by the occurrence of 'luxury consumption', that is, increases in fertilization do not result in increase in crop production.

Yield had a significant effect on potassium-based and *Ascophyllum nodosun* extract fertilizer doses (Figure 6).

Linear behavior was observed in the absence of potassium-based foliar fertilizer, with the highest yield of 36 t ha^{-1}, with dose of 250 ml ha^{-1} of *Ascophyllum nodosum* extract, which is 16 t ha^{-1} higher than the average reached in the absence of the extract. This result corroborates results found by Lobo et al. (2019), who observed increases in 'Kent' mango yield with the use of different biostimulants. These results were also compatible with the average value found by Cavalcante et al. (2018), who observed average yield of 33.06 t ha^{-1} in four-year-old 'Palmer' mango. In the presence of potassium-based foliar fertilizer, no significant influence of *Ascophyllum nodosun* extract doses was observed, and the average ranged from 20.84 to 29.42 t ha^{-1}. However, regardless of treatment, they were above the national average in 2018 for this fruit (20.09 t ha^{-1}) and also higher than the main producing countries such as India (8.8 t ha^{-1}), China (8.2 t ha^{-1}), Thailand (8.6 t ha^{-1}) and Mexico (10.4 t ha^{-1}) (FAO, 2019). This shows that 'Palmer' mango performs well and adapts to semiarid conditions regardless of treatments tested.

Figure 6. Yield (t ha^{-1}) of 'Palmer' mango submitted to different doses of *Ascophyllum nodosum* extract-based foliar fertilizer and potassium-based foliar fertilizer.



Source: Authors.

Increases in seaweed treatment efficiency are associated with hormonal substances present in extracts, especially cytokines (Mohamed & El - Sehrawy, 2013). In reproductive organs, high levels of cytokines may be linked to nutrient mobilization. These results are in agreement with those obtained by El - Sharony et al. (2015), El - Sawy (2005) and Hegab et al. (2005).

The efficiency in the use of seaweed extract may be related to the anti-stress effect that is one of the characteristics of this product, since during the floral induction phase, temperatures were high (39.21ºC) and fruits were exposed to reduced water availability. Positive effects of *Ascophyllum nodosun*-based biostimulant have been reported in literature by Morales - Payan (2013) during the phase of seedling formation and by Mohamed and El - Sehrawy (2013), who reported better plant nutrition and retention of mango fruits.

4. Conclusions

The use of potassium-based leaf fertilizer (Multipotássio®) was satisfactory to increase sugar content in 'Palmer' mango branches, which was increasing in relation to the doses used. Biostimulants result in positive effects on the evaluated plant characteristics, and the leaf application of MultiTurbo® provided the highest increase in the number of panicles, number of fruits and yield of 'Palmer' mango.

For future work, experiments should be carried out to evaluate the physical-chemical characteristics of the fruits, showing the effect of the application of the biostimulant, combining potassium-based fertilizer on the quality of the fruits.

Acknowledgments

To Multitécnica®, Capes, CNPq and Fapemig for technical support.

References

Asrey, R., Patel, V. B., Barman, K., & Pal, R. K. (2013). Pruning affects fruit yield and postharvest quality in mango (*Mangifera indica* L.) cv. Amrapali. *Fruits, 68* (5), 367-380. https://doi.org/10.1051/fruits/2013082

Benkeblia, N., Onodera, S., & Shiomi, S. (2005). Variation in 1-fructoexohydrolase (1-FEH) and 1-kestose-hydrolysing (1-KH) activities and fructo-oligosaccharide (FOS) status in onion bulbs. Influence of temperature and storage time. *Journal of the Science of Food and Agriculture, 85*(2), 227-234. https://doi.org/10.1002/jsfa.1959

Calvo, P., Nelson, L., & Kloepper, J. W. (2014). Agricultural uses of plant biostimulants. *Plant and Soil*, *383* (1-2), 3-41. https://doi.org/10.1007/s11104-014-2131-8

Carneiro, M. A., Lima, A. M. N., Cavalcante, I. H. L., Cunha, J. C., Rodrigues, M. S., & Lessa, T. B. S. (2017). Soil salinity and yield of mango fertigated with potassium sources. *Revista Brasileira de Engenharia Agrícola e Ambiental*, *21*(5), 310-316. http://dx.doi.org/10.1590/1807-1929/agriambi.v21n5p310-316

Carneiro, M. A., Lima, A. M. N., Cavalcante, I. H. L., Sousa, K. D. S. M. D., Oldoni, F. C. A., & Barbosa, K. D. S. (2018). Production and quality of mango fruits cv. Tommy atkins fertigated with potassium in semi-arid region. *Revista Brasileira de Fruticultura*, *40*(5). https://doi.org/10.1590/0100-29452018034

Carvalho, C. R. L., Rossetto, C. J., Mantovani, D. M. B., Morgano, M. A., Castro, J. V., & Bortoletto, N. (2004). Avaliação de cultivares de mangueira selecionadas pelo Instituto Agronômico de Campinas comparadas a outras de importância comercial. *Revista Brasileira de Fruticultura*, *26*(2), 264-271. https://doi.org/10.1590/S0100-29452004000200021

Carvalho, R. P., Pasqual, M., de Oliveira Silveira, H. R., de Melo, P. C., Bispo, D. F. A., Laredo, R. R., & Lima, L. D. A. S. (2019). “Niágara Rosada” table grape cultivated with seaweed extracts: physiological, nutritional, and yielding behavior. *Journal of Applied Phycology*, *31*(3), 2053-2064. https://doi.org/10.1007/s10811-018-1724-7

Cavalcante, I. H. L., Lima, A. M. N., Carneiro, M. A., Rodrigues, M. S., & Silva, R. L. (2016). Potassium doses on fruit production and nutrition of mango (*Mangifera indica* L.) cv. Palmer. *Revista de la Facultad de Agronomia de la Universidad del Zulia*, *33*, 418-432.

Cavalcante, I. H. L., Santos, G. N. F., Silva, M. A., Martins, R. S., Lima, A. M. N., Modesto, P. I. R., Alcobia, A. M., Silva, T. R. S., Araújo e Amariz, R., & Beckmann-Cavalcante, M. Z. (2018). A new approach to induce mango shoot maturation in Brazilian semi-arid environment. *Journal of Applied Botany and Food Quality*, *91*, 281-286. DOI:10.5073/JABFQ.2018.091.036

Corsato, C. E., Scarpare Filho, J. A., & Sales, E. C. J. D. (2008). Teores de carboidratos em órgãos lenhosos do caquizeiro em clima tropical. *Revista Brasileira de Fruticultura*, *30*(2), 414-418. https://doi.org/10.1590/S0100-29452008000200025

Cruz, M. D. C. M., de Siqueira, D. L., Salomão, L. C. C., & Cecon, P. R. (2007). Teores de carboidratos em limeiras ácidas 'Tahiti' tratadas com paclobutrazol. *Revista Brasileira de Fruticultura*, *29*(2), 222-227. https://doi.org/10.1590/S0100-29452007000200007.

Davenport, T. L. (2007). Reproductive physiology of mango. *Brazilian Journal of Plant Physiology*, *19*(4), 363-376. https://doi.org/10.1590/S1677-04202007000400007

El-Sawy, Y. A. E. (2005). *Studies on the effect of some organic fertilizers, ammonium nitrate and the biofertilizer (Algae extract) on growth and productivity of Williams banana (Musa Cavendishii L.).* Thesis Fac. of Agric. Minia Univ. Egypt.

El-Sharony, T. F., El-Gioushy, S. F., & Amin, O. A. (2015). Effect of foliar application with algae and plant extracts on growth, yield and fruit quality of fruitful mango trees cv. Fagri Kalan. *Journal of Horticulture*, *2*(4). http://dx.doi.org/10.4172/2376-0354.1000162

FAO. Food and Agriculture Organization of the United Nations. (2019). *Faostat.* Retrieved October 29, 2019, from http://www.fao.org/faostat/en/#data/QC

Ferreira, K. M., Simões, W. L., Mouco, M. A. do C., Silva, J. L. da., Silva, J. S. da., & Mesquita, A. C. (2020). Efficient management of the application of paclobutrazol for the production and quality of ’Tommy Atkins’ mango. *Research, Society and Development*, *9*(8), e348984894. https://doi.org/10.33448/rsd-v9i8.4894

Ferreira, D. F. (2011). Sisvar: a computer statistical analysis system. *Ciência e Agrotecnologia*, *35*(6): 1039-1042. https://doi.org/10.1590/S1413-70542011000600001

Gomes, F. P. (1990). *Curso de estatística experimental*. Piracicaba: Nobel.

Guardiola, J. L., García-Mari, F., & Agustí, M. (1984). Competition and fruit set in Washington Navel orange. *Physiologia Plantarum*, *62*(3), 297–302. https://doi.org/10.1111/j.1399-3054.1984.tb04576.x

Hafle, O. M., Delfino, F. I., Mendonça, V., & Araujo Neto, S. E. (2003). Flowering and production of mango cv.Tommy Atkins using ethrel, potassium nitrate and calcium nitrate. *Revista Ciências Agrárias*, *39*, 145-152.

Hegab, M. Y., Shaarawy, A. M. A., & El-Saida, S. A. G. (2005). Effect of Algae extract and mono potassium phosphate on growth and fruiting of Balady orange trees. *Minia Journal of Agricultural Research and Development*, *25*, 50-72.

Hernández-Herrera, R. M., Santa Cruz-Ruvalcaba, F., Ruiz-López, M. A., Norrie, J., & Hernández-Carmona, G. (2014). Effect of liquid seaweed extracts on growth of tomato seedlings (*Solanum lycopersicum* L.). *Journal of applied phycology*, *26*(1), 619-628. DOI 10.1007/s10811-013-0078-4

Husen, S., Kuswanto, S. A., & Basuki, N. (2012). Induction of flowering and yield of mango hybrids using paclobutrazol. *Journal of Agriculture and Food Technology*, *2* (9), 153-158.

IBGE. Instituto Brasileiro de Geografia e Estatística. (2019). *Sistema IBGE de recuperação automática - SIDRA: levantamento sistemático da produção agrícola.* Retrieved October 28, 2019, from http://www.sidra.ibge.gov.br

Khan, W., Rayirath, U. P., Subramanian, S., Jithesh, M. N., Rayorath, P., Hodges, D. M., Critchley, A. T., Craigie, J. S., Norrie, J., & Prithiviraj, B. (2009). Seaweed extracts as biostimulants of plant growth and development. *Journal of Plant Growth Regulation*, *28*(4), 386-399. DOI 10.1007/s00344-009-9103-x

Khan, W., Hiltz, D., Critchley, A. T., & Prithiviraj, B. (2011). Bioassay to detect *Ascophyllum nodosum* extract-induced cytokinin-like activity in *Arabidopsis thaliana*. *Journal of Applied Phycology*, *23*(3), 409-414. DOI 10.1007/s10811-010-9583-x

Koch, K. (2004). Sucrose metabolism: regulatory mechanisms and pivotal roles in sugar sensing and plant development. *Current Opinion in Plant Biology*, *7*(3), 235-246. https://doi.org/10.1016/j.pbi.2004.03.014

Koyama, R., Bettoni, M. M., Roder, C., de Assis, A. M., & Roberto, S. R. (2012). Extrato da alga *Ascophyllum nodosum* (L.) Le Jolis no desenvolvimento vegetativo e na produção do tomateiro. *Revista de Ciências Agrárias*, *55*(4), 282-287. http://dx.doi.org/10.4322/rca.2012.067

Kulkarni, V. J. (2004). The tri-factor hypothesis of flowering in mango. *Acta Horticulturae: VII International Mango Symposium*, *645*, 61-70. 10.17660/ActaHortic.2004.645.3

Kumar, M. Ponnuswami, V. Kumar, P. J., & Saraswathy, S. (2014). Influence of season affecting flowering and physiological parameters in mango. *Scientific Research and Essays*, *9* (1), 1-6. https://doi.org/10.5897/SRE2013.5775.

Laxman, R. H., Annapoornamma, C. J., & Biradar, G. (2016). *Mango*. In: Rao, N. K. S., Shivashankara, K. S., & Laxman, R. H. Abiotic stress phisiology of horticultural crops. New Delhi: Springer India Publisher.

Lima, G. M. D. S., Pereira, M. C. T., Oliveira, M. B., Nietsche, S., Mizobutsi, G. P., Públio Filho, W. M., & Mendes, D. S. (2016). Floral induction management in 'Palmer' mango using uniconazole. Ciência Rural. *46*(8), 1350-1356. https://doi.org/10.1590/0103-8478cr20150940

Lobo, J. T., Cavalcante, I. H. L., Lima, A. M. N., Vieira, Y. A. C., Modesto, P. I. R., & da Cunha, J.G. (2019). Biostimulants on Nutritional Status and Fruit Production of Mango 'Kent'in the Brazilian Semiarid Region. *HortScience*, *54*(9), 1501-1508. https://doi.org/10.21273/HORTSCI13753-18

Mccready, R. M., Guggolz, J., Silviera, V., & Owens, H. S. (1950). Determination of starch and amylose in vegetables. *Analytical chemistry*, *22*(9), 1156-1158. https://doi.org/10.1021/ac60045a016

Modesto, J. H., Leonel, S., Segantini, D. M., Souza, J. M. A., & Ferraz, R. A. (2016). Qualitative attributes of some mango cultivars fruits. *Australian Journal of Crop Science*, *10*(4), 565-570. 10.21475/ajcs.2016.10.04.p7388x

Mohamed, A. Y., & El-Sehrawy, O. A. (2013). Effect of seaweed extract on fruiting of Hindy Bisinnara mango trees. *Journal of American Science*, *9*(6), 537-544.

Morales-Payan, J. P. (2013). Effects of an agricultural extract of the brown alga, *Ascophyllum nodosum* (Phaeophyceae), on mango, *Mangifera indica* (Anacardiaceae), grown for transplants in the nursery. *Life: The Excitement of Biology*, *1*(2), 111-117. DOI: 10.9784/LEB1(2)Morales.03

Moreira, R. A., da Cruz, M. D. C. M., Fagundes, M. C. P., de Araújo Pantoja, L., & dos Santos, A. S. (2014). Carboidratos foliares durante a floração e estádios iniciais de crescimento de frutilhos em tagerineira 'Ponkan'. *Pesquisa Agropecuária Brasileira*, *49*(1), 34-39. https://doi.org/10.1590/S0100-204X2014000100005

Mouco, M. D. C., & Albuquerque, J. D. (2005). Efeito do paclobutrazol em duas épocas de produção da mangueira. *Bragantia*, *64*(2), 219-225. https://doi.org/10.1590/S0006-87052005000200008

Moutinho-Pereira, J. M., Bacelar, E. A., Gonçalves, B., Ferreira, H. F., Coutinho, J. F., & Correia, C. M. (2010). Effects of Open-Top Chambers on physiological and yield attributes of field grown grapevines. *Acta Physiologiae Plantarum*, *32*(2), 395-403. DOI 10.1007/s11738-009-0417-x

Oliveira, G. P., Siqueira, D. L. D., Cecon, P. R., & Salomão, L. C. C. (2018). Teores de carboidratos em mangueira Ubá submetida a diferentes doses de paclobutrazol. *Revista de Ciências Agrárias*, *41*(3), 171-180. http://dx.doi.org/10.19084/RCA18016

Pereira, A. S., Shitsuka, D. M., Parreira, F. J., & Shitsuka, R. (2018). *Metodologia da Pesquisa científica*. Universidade Federal de Santa Maria. Retrieved September 07, 2020, from https://repositorio.ufsm.br/bitstream/handle/1/15824/Lic_Computacao_Metodologia-Pesquisa-Cientifica.pdf?sequence=1.

Prasad, S. S., Reddy, Y. T. N., Upreti, K. K., & Rajeshwara, A. N. (2014). Studies on changes in carbohydrate metabolism in regular bearing and "off" season bearing cultivars of mango (*Mangifera indica* L.) during flowering. *International Journal of Fruit Science*, *14*(4), 437-459. https://doi.org/10.1080/15538362.2014.897891

Ramírez, F., Davenport, T. L., Fischer, G., Pinzón, J. C. A., & Ulrichs, C. (2014). Mango trees have no distinct phenology: the case of mangoes in the tropics. *Scientia Horticulturae*, *168*, 258-266. https://doi.org/10.1016/j.scienta.2014.01.040

Ramírez, F., & Davenport, T. L. (2016). Mango (*Mangifera indica* L.) pollination: A review. *Scientia Horticulturae*, *203*, 158-168. http://dx.doi.org/10.1016/j.scienta.2016.03.011 0304-4238

Reis Júnior, R. A., & Fontes, P. C. R. (1996). Qualidade de tubérculos de batata em função de doses da adubação potássica. *Horticultura Brasileira*, *14*(2), 170-174.

Ripardo, A. K. S., Sampaio, A. C., & Leonel, S. (2009). Viabilidade e métodos de indução artificial do florescimento da mangueira. *Toda Fruta*, 12p.

Santaniello, A., Scartazza, A., Gresta, F., Loreti, E., Biasone, A., Di Tommaso, D., Piaggesi, A., & Perata, P. (2017). *Ascophyllum nodosum* seaweed extract alleviates drought stress in Arabidopsis by affecting photosynthetic performance and related gene expression. *Front in Plant Science, 8*, 1362. doi: 10.3389/fpls.2017.01362. eCollection 2017

Santos, F. S. (2009). *Produção e monitoramento de pragas e doenças da mangueira no norte de Minas Gerais.* Tese Doutorado Universidade Federal de Viçosa.

Silva, G. J. N., & Villela, A. L. G. (2004). *Indução floral da mangueira e princípios do controle fitossanitário.* In: Rozane, D. E., Darezzo, R. J., Aguiar, R. L., Aguilera, G. H. A., & Zambolim, L. Manga: produção integrada, industrialização e comercialização. Viçosa: UFV, 233-302.

Silva, J. A. L. D., & Neves, J. A. (2011). Combinação do paclobutrazol, sulfato de potássio e etefon na indução floral da mangueira cv. Tommy Atkins. *Comunicata Scientiae*, *2*(1), 18-24.

Spinelli, F., Fiori, G., Noferini, M., Sprocatti, M., & Costa, G. (2010). A novel type of seaweed extract as a natural alternative to the use of iron chelates in strawberry production. *Scientia Horticulturae*, *125*(3), 263-269. https://doi.org/10.1016/j.scienta.2010.03.011

Stirk, W. A., Novák, O., Strnad, M., & Van Staden, J. (2003). Cytokinins in macroalgae. *Plant growth regulation*, *41*(1), 13-24.

UNECE. United Nations Economic Commission for Europe. (2017). *Standard FFV-45 concerning the marketing and commercial quality control of Mangoes.* Retrieved from https://www.unece.org/fileadmin/DAM/trade/agr/standard/standard/fresh/FFV-Std/English/45_Mangoes.pdf

Upreti, K. K., Prasad, S. S., Reddy, Y. T. N., & Rajeshwara, A. N. (2014). Paclobutrazol induced changes in carbohydrates and some associated enzymes during floral initiation in mango (*Mangifera indica* L.) cv. Totapuri. *Indian Journal of Plant Physiology*, *19*(4), 317-323. DOI 10.1007/s40502-014-0113-8

Wally, O. S. D., Critchley, A. T., Hiltz, D., Craigie, J. S., Han, X., Zaharia, L. I., Abrams, S. R., & Prithiviraj, B. (2013). Regulation of phytohormone biosynthesis and accumulation in Arabidopsis following treatment with commercial extract from the marine macroalga *Ascophyllum nodosum*. *Journal of Plant Growth Regulation*, *32*(2), 324-339. DOI 10.1007/s00344-012-9301-9

Zhang, X., & Ervin, E. H. (2004). Cytokinin containing seaweed and humic acid extracts associated with creeping bentgrass leaf cytokinin and drought resistance. *Crop science*, *44*(5), 1737-1745. https://doi.org/10.2135/cropsci2004.1737

Percentage of contribution of each author in the manuscript

Mariela Medeiros Lopes Silva – 25%

José Carlos Moraes Rufini – 20%

Miriã Cristina Pereira Fagundes – 20%

Victor Martins Maia – 15%

Ana Clara Pimenta Pereira – 5%

Paulo Antônio Santana Júnior – 10%

Willian Gonçalves Souza – 5%