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A new approach to induce mango shoot maturation in Brazilian semi-arid environment

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Summary

The shoot maturation phase is important for growing mangoes because it precedes the floral induction, when plants are under stress caused by high temperatures and low water availability. Abiotic stress could be alleviated by using plant biostimulant which alters the phytohormone and carbohydrates biosynthesis. Thus, an experiment was conducted to evaluate the use a plant biostimulant containing *Ascophyllum nodosum* to induce shoot maturation of mango cv. Palmer grown in semi-arid environment. The experimental design consisted of randomized blocks with four treatments, ten replications and five plants per parcel. Treatments consisted of: T1) biostimulant foliar spray + K fertilizer; T2) foliar spray with biostimulant alternating with K fertilizer; T3) individual foliar sprays with magnesium sulfate, potassium sulfate, sulfur and calcium fertilizers, potassium fertilizer and Ethrel®; and T4) Control treatment. The total soluble carbohydrates in leaves, buds and shoots, N, K and S leaf concentrations and fruit production were recorded. The carbohydrate concentrations, nitrogen, sulphur and potassium leaf concentrations and fruit production of mango depend on shoot maturation strategy. Shoot maturation strategy using biostimulant containing *Ascophyllum nodosum* alternating with K fertilizer from 30 days after PBZ could be recommended for the production of mango cv. Palmer.

Key words: *Mangifera indica* L., biostimulant, fruit production, carbohydrate, algae extract.

Introduction

Mango (*Mangifera indica*) is a very important fruit crop for Brazil, which is the seventh most producing country and one of the largest mango exporter countries (FAO, 2017). In Brazil, mango is especially grown in São Francisco Valley, where more than 90% of Brazilian exported mango is produced (ALICEWEB, 2017).

Mango flowering has been demonstrated in field and in the scientific literature to be a complex event dependent of many factors concerning to climate conditions detaching that temperature is the most influential climatic factor (LAXMAN et al., 2016), nutritional status (CAVALCANTE et al., 2016; CARNEIRO et al., 2017), pruning (ASREY et al., 2013), hormone balance (RAMÍREZ et al., 2014), carbohydrate concentration (PRASAD et al., 2014; KUMAR et al., 2014) and shoot maturation of the last vegetative flush, which has been measured as age of the last flush of vegetative stems, and it appears to be the primary factor regulating floral induction in warm climates (RAMÍREZ et al., 2010).

Mango shoot suitable for flowering induction was studied by DAVENPORT et al. (2006) who concluded that terminal stems (terminal intercalary units) must have attained a dark green color and achieved a minimum age of 4 months since the previous limp, red-leaf stage in easily induced cultivars and 5 months for the more recalcitrant cultivars to obtain a reproductive shoot response in the low-latitude tropics; and RAMÍREZ et al. (2010) that stem age was the key factor correlated with flowering in the tropical conditions.

In addition, it is necessary to stablish the physiological characteristics of a mango shoot suitable for flowering, which is defined as a 'mature shoot'. Shoot maturation does not occur uniformly throughout the tree´s canopy and it is affected by shoot age, climate conditions and orchard management (non-published data), that could present crucial importance, especially for mango trees grown under adverse climate as occurs in São Francisco Valley. In this region mango has been grown under very high temperature and low air humidity averages, reaching 36.8 °C and 25.6% especially from September to December months (LABMET, 2016). This is a critical phase because it coincides with the pre-flowering-induction stage of those mango trees planned to produce fruits in April-May of the next year. In addition, during pre-flowering-induction phase mango is irrigated with lower water amounts, which is necessary to stimulate ethylene production and improve mango flowering (RAMÍREZ and DAVENPORT, 2016).

Under adverse climate conditions, the use of biostimulants could be an option to improve shoot maturation, especially those containing algae extracts such as *Ascophyllum nodosum*, that promotes benefic effects on plant physiology but the more substantial improvements are associated with improving tolerance toward abiotic stresses, including drought stress (SPANN and LITTLE, 2011), ion toxicity (MANCUSO et al., 2006) and high temperature (ZHANG and ERVIN, 2008). Indeed, according to WALLY et al. (2013) *A. nodosum* leaf sprays enhanced total concentration of cytokinins, abscisic acid (ABA) and ABA catabolite levels, whereas auxin levels reduction.

The plant nutritional status also affects mango flowering (GENÚ and PINTO, 2002), then the fertilizing management, especially for potassium, sulphur and nitrogen is crucial during the phase that precedes flowering induction, i.e., the shoot maturation. The key effect of potassium in plants is related to photosynthesis, plant respiration and solute translocations (MARSCHNER, 2012); and sulphur is used on Yang cycle for ethylene biosynthesis (PESSARAKLI, 2014). On the other hand, at the time of flowering induction nitrogen concentrations should be in the lower average limit of adequate supply in order to avoid new vegetative flushes instead of reproductive phase (DAVENPORT et al., 2003).

Hence, the present study aimed to use a plant biostimulant containing *Ascophyllum nodosum* extract to induce shoot maturation of mango cv. Palmer grown in Brazilian semi-arid environment.

Material and methods

Plant material and growth conditions

'Palmer' mango (*Mangifera indica* L.) plants with uniform size and vigor, that were four years old thus in the first production cycle, were used in this study.

The study was conducted from 2016 to 2017 in two experimental orchards located in Sebastião da manga farm in Casa Nova County

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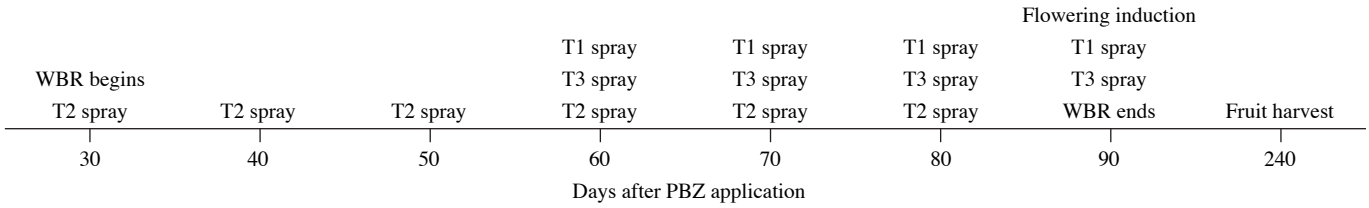
Fig. 1: Time scale of the main events during the experiments.



WBR begins = Water blade reduction begins; WBR ends = Water blade reduction ends

(09°11' S and 41º59' W; at an altitude of 400.3 m above sea level), Bahia State, Brazil. The climate of this region is classified as Bswh (Köeppen), which corresponds to a semi-arid region. The average air temperature and air humidity ranged from 20.7 ºC to 35.4 ºC and from 61.4% and 88.7%, respectively, with accumulated precipitation of 194.8 mm.

The plants, spaced with 5.0 m between the rows and 2.3 m between the plants, were daily drip-irrigated with one emitter at each 0.5 m, for a flow of 2.5 L h^{-1} each. All management practices such as pruning, control of weeds, pests and diseases, plant growth regulators for gibberellin inhibition (Cultar®) and break dormancy (calcium nitrate) were performed following the instructions of Genú and Pinto (2002). The nutrient management was performed through a fertirrigation system, according to plant demand (Genú and Pinto, 2002).

Treatments and experimental design

The experimental design consisted of randomized blocks with four treatments, ten replications and five plants in each parcel, reaching 50 plants per treatment. Treatments consisted of four strategies for shoot maturation of mango, as follows: T1) biostimulant foliar spray (2.5 ml L) + K fertilizer (2.5 mL L, 30% K_2O); T2) foliar spray with biostimulant (2.5 ml L) alternating with K fertilizer (2.5 mL L, 30% K_2O); T3) individual foliar sprays [magnesium sulfate (20 g L, 14% S and 10% Mg), potassium sulfate (25 g L, 17% S, 48% of K_2O and 1.2% Mg), sulfur and calcium fertilizers (8 g L, 50% S and 5% Ca), potassium fertilizer (25 mL L, 55% K_2O), and Ethrel® (3mL L)]; and T4) Control treatment. The biostimulant used contains N (1.3%), K_2O (1.0%), Ca (3.0%), Mg (3.0%), S (3.56%), Mo (0.5%), organic carbon (2.69%), *Ascophyllum nodosum* extract (1.5%), amino acids (5.0%) and fulvic acids (2.0%).

The treatments were applied according to the number of the days after the gibberellin inhibitor was applied, paclobutrazol (PBZ) ([(2RS, 3RS)-1-(4-clorofenil)-4,4-dimetil-2-(1H-1,2,4-triazol-1-il) pentan-3-ol]), in a ten days interval, beginning at 30 days after PBZ (T2) and 60 days after PBZ (T1 and T3), based on the traditional shoot maturation sprays (T3) used commercially.

Data gathered and statistical analysis

According to recommendations of Silva (2009) leaf samples were collected in shoots from the middle part of the canopy to perform the potassium, sulphur [K and S at the beginning, middle and end of shoot maturation (flower induction)] and nitrogen (at the end of shoot maturation, which coincides with flowering induction) leaf concentrations. Leaves were chemically analyzed after they were washed and rinsed with distilled water and dried at 65 ºC until reach constant weight following methodology described by Silva (2009). The K concentrations were determined by flame photometry, the N concentrations by Kjeldahl method and the S contents were measured by turbidometry.

The total soluble carbohydrates (TSC) concentrations were quantified in leaves, buds and shoots from the beginning of shoot maturation until flowering induction, reaching five evaluation dates, following the methodology described by Dubois et al. (1956).

At harvest the number of fruits per plant, fruit production and fruit yield (t ha^{-1}) was calculated. Only commercial fruits were manually harvested in a single day when they reached the physiological maturity which was characterized through pulp color (yellow cream), following the fruit selection parameter recommended by the Brazilian Program For Horticulture Modernization (2004) for commercial farms.

Statistical analyses included analysis of variance (ANOVA) using combined data from the two experimental areas. All calculations were performed using the Assistat 7.7 software, and terms were considered significant at $p < 0.01$.

Results and discussion

All variables studied were affected by shoot maturation strategies, including those variables evaluated with time elapsing.

Total soluble carbohydrates depended on shoot maturation strategy independently of the plant part (shoot, leaf or bud) (Fig. 2). As can be seen in Fig. 2A, leaf carbohydrate concentrations of all treatments increased from the first to the second evaluation date but only T4 presented a peak at the third date. A similar data distribution presented in Fig. 2 was also recorded by Urban et al. (2006) in study about season effects on leaf nitrogen partitioning and photosynthetic water use efficiency in mango.

Indeed, from the third to the forth date It was registered a huge decrease in this variable especially for T4 (346%), T1 (250%) and T3 (154%), followed by stabilization at the end of shoot maturation (flower induction), when T2 was statistically higher than other treatments. The higher leaf carbohydrate concentration of T2 at the end of shoot maturation stage (flower induction) could be explained by the positive effects of *Ascophyllum nodosum* extract applied. According to Wally et al. (2013) such products contain growth regulators (auxins, cytokinins and gibberellins), betain, amino acids and low concentrations of inorganic elements that influence cell growth and division cycle, expansion, nutrition and maturity. On the other hand, Khan et al. (2009) explained that the mechanism(s) of actions of seaweed extract-elicited physiological responses are largely unknown and the algae extract effect on plants depends on plant species, soil, climate and crop management at all.

The leaf carbohydrate concentration of Fig. 2A are close to that recorded by Urban et al. (2006) and higher than average value quoted by Prasad et al. (2014) for the same phenological phase of the present study.

In shoots (stem of the last vegetative flush) total soluble carbohydrates concentration also presented the same tendency for T2 and T4, i.e., average enhancement until the third evaluation and stabilization for the last evaluation date (Fig. 2B). Carbohydrate concentrations in shoots were lower than those registered in leaves, independently of the evaluation date, but at the end of shoot maturation phase T2 also presented significantly higher carbohydrate concentration that

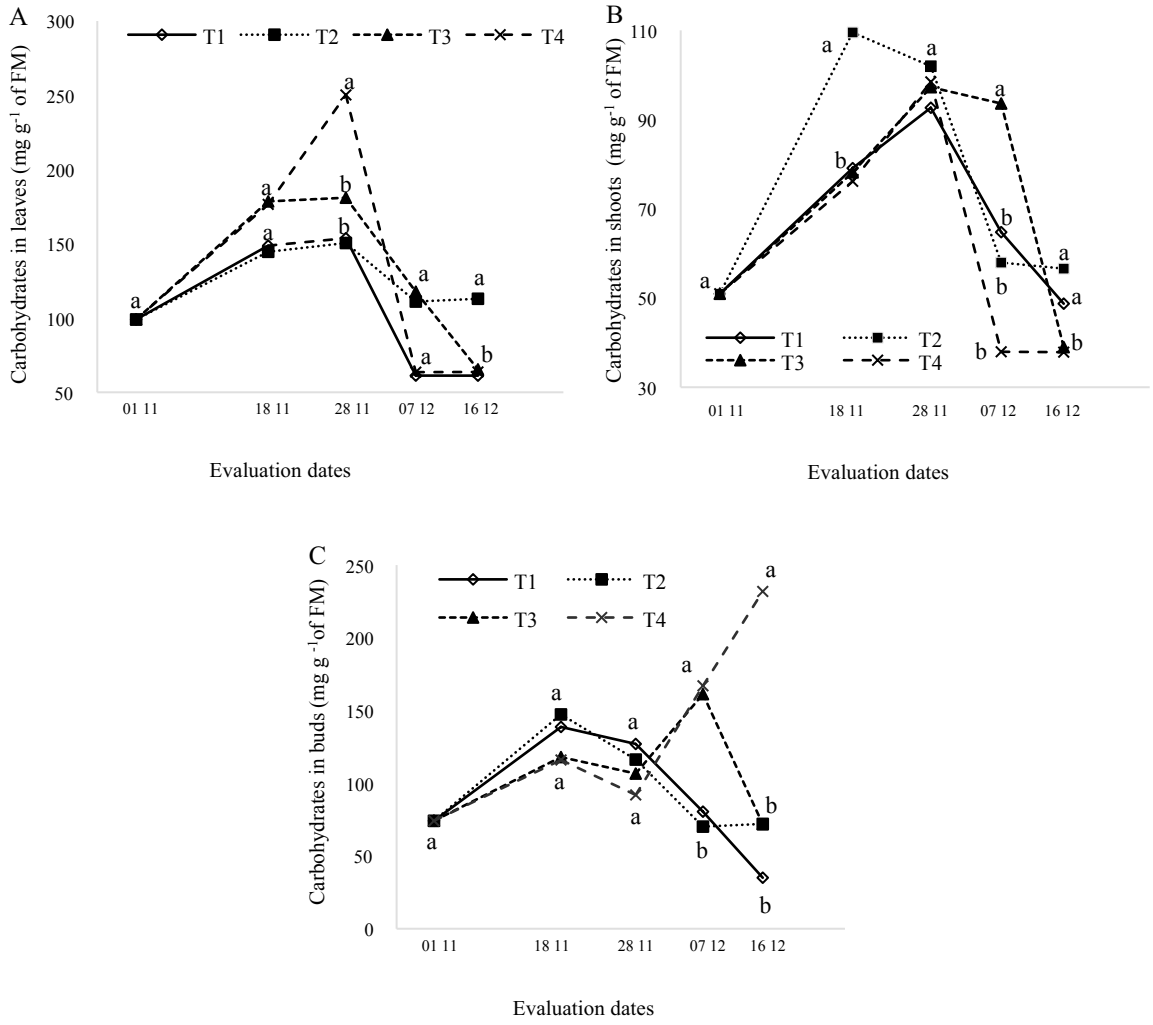


Fig. 2: Total soluble carbohydrates concentrations in leaves (A), shoots (B) and buds (C) of mango cv. Palmer as a function of branch maturation strategy in five evaluation dates.
Points with the same letters do not differ in among themselves by Tukey's test at 1% probability in each evaluation date. T1) biostimulant foliar spray + K fertilizer; T2) foliar spray with biostimulant alternating with K fertilizer; T3) individual foliar sprays (magnesium sulfate, potassium sulfate, sulfur and calcium fertilizers, potassium fertilizer, and Ethrel®; and T4) Control treatment. FM = fresh mass.

is a positive scenario since source-to-sink transport of sugar is one of the major determinants of plant growth and relies on the efficient and controlled distribution of sucrose (and some other sugars such as raffinose and polyols) across plant organs through the phloem. However, sugar transport through the phloem can be affected by many environmental factors that alter source sink relationships (LEMOINE et al., 2013).

It is important to note the lower carbohydrate concentrations decrease recorded for T2 in both leaves and shoots from the middle to the end of shoot maturation phase, showing that plants of this treatment at the flowering induction (end of the shoot maturation) presented higher soluble carbohydrate concentrations.

The other hand, soluble carbohydrates in buds (Fig. 2C) presented a different data distribution as a function of the dates during shoot maturation, except for T2. It is relevant to point the extremely higher average recorded to the non-treated plants at the end of shoot maturation, because these plants presented very poor or no flowers, showing that for mango high carbohydrate concentration in buds is not a key for good flowering and fruit production. Whether compared to PRASAD et al. (2014) data it is verified that average value recoded for T4 (control treatment) is extremely higher.

Leaf concentrations for potassium, sulphur and nitrogen depended on shoot maturation strategy (Fig. 3). Independently of the treatment, K leaf concentrations enhanced with time elapsing until reach a peak at the end of shoot maturation when T2 and T3 were above the other treatments. During shoot maturation phase the key effect of potassium in plants is related to photosynthesis, plant respiration and solute translocations (MARSCHNER, 2012).

Whether compared with MALAVOLTA et al. (1997) adequate range of supply (4.0-6.0 g kg^{-1}), it verifies that at the end of shoot maturation (flower induction) plants of all treatments presented higher averages. The other way, for the adequate range of supply reported by PIMPLASKER and BHARGAVA (2003), i.e. 1.02-2.01% (or 10.2-20.1 g kg^{-1}), plants of all treatments had adequate K leaf concentrations. Comparatively, the average foliar potassium values presented in Fig. 3A were higher than those recorded by CAVALCANTE et al. (2016) in study about K fertilizing of 'Palmer' mango under semi-arid environment.

Sulphur leaf concentrations of T1, T2 and T4 were similar among them and presented a soft variation during shoot maturation phase (Fig. 3B), but, T3 promoted a S leaf concentration peak at the middle of shoot maturation, followed by a huge decay of 300% until the end of this phase. This data distribution could be caused by the foliar spray with sulphates performed in T3 followed by Ethrel® leaf

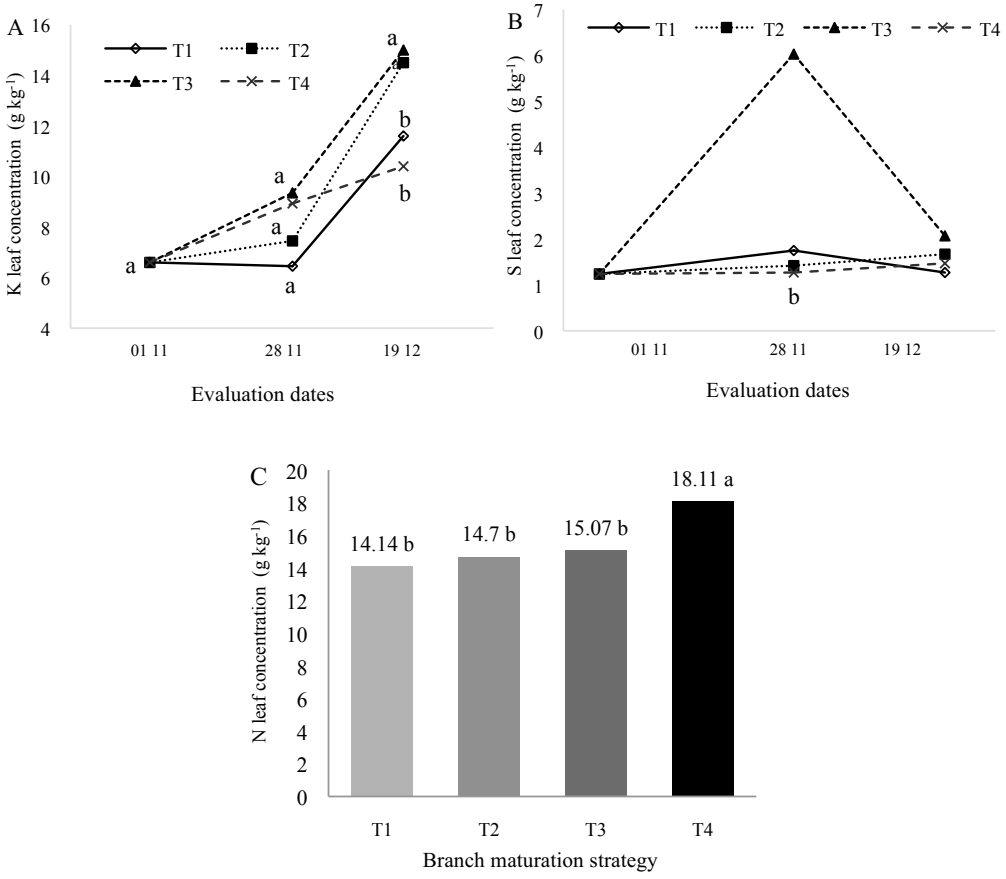


Fig. 3: Leaf concentrations of potassium (A), sulphur (B) at the beginning, middle and end of shoot maturation; and nitrogen (C) at the end of shoot maturation of mango cv. Palmer as a function of shoot maturation strategy.
Points or bars with the same letters do not differ in among themselves by Tukey's test at 1% probability in each evaluation date. T1) biostimulant foliar spray + K fertilizer; T2) foliar spray with biostimulant alternating with K fertilizer; T3) individual foliar sprays (magnesium sulfate, potassium sulfate, sulfur and calcium fertilizers, potassium fertilizer, and Ethrel®; and T4) Control treatment.

spray, an ethylene precursor, in which production cycle uses S for Yang cycle (Pessarakli, 2014). Independently of the shoot maturation strategy studied, all treatments were within the stated adequate range of supply 1.1-1.7 g kg^{-1} properly described by Pimplasker and Bhargava (2003).

As can be seen in Fig. 4C, N leaf concentrations at the end of shoot maturation (flower induction) also depended on shoot maturation strategies, with statistically high average recorded for T4 (control treatment). According to Pimplasker and Bhargava (2003) the N leaf concentration considered as adequate for mangoes range from 8.9 to 19.3 g kg^{-1}, but there is controversy because according to Davenport et al. (2003) the leaf N levels for mango should be at 11 to 14 g kg^{-1} at the time of flowering induction in order to avoid new vegetative flushes instead of reproductive phase, i.e., N leaf concentration should be in maximum 14 g kg^{-1}. On the other hand, in the present study T1, T2 and T3 presented commercial fruit yields with leaf N concentrations of 14.4, 14.7 and 15.1 g kg^{-1} respectively, while T4 presented no fruit production with N leaf concentration of 18.1 g kg^{-1} showing that adequate maximum N leaf concentration at flowering induction depends on mango cultivar and the production system used.

Fruit production variables depended on treatments studied (Fig. 4), and that plants of control treatment presented a very poor fruit production, including lots of parcels presented no fruit production making not possible to perform statistical analysis for this treatment. Fruit production variables presented the same data tendency, i.e., T2 promoted the higher number of fruits per plant, fruit production and fruit yield (Fig. 4). For number of fruits per plant T2 presented an average almost 46% higher than T3, the second higher average, and it reached 94.8 commercial fruits per plants. Cavalcante et al. (2016) recorded a maximum number of commercial fruits per plant of 294, but in eleven years old plants, that's different from the current study which used four years old plants, in the first production cycle.

Fruit production (kg per plant) ranged from 28.14 kg plant (T1) to 38.62 kg plant, which is lower than other scientific results in the literature such as Cavalcante et al. (2016), Wahdan et al. (2011) in Egypt, 82.71-88.86 kg plant reported by Yeshitela et al. (2005) in South Africa, Quijada et al. (2009) in Venezuela and Saran and Kumar (2011) in India. On the other hand, except for Cavalcante et al. (2016), all authors quote the total fruit production per plant and not a commercial fruit production, in orchards with wide spaces between plants were, naturally, the plants are higher and produce more fruits, so the crucial comparison must refer to fruit yield.

Following the same tendency of the number of fruits per plant and fruit production (kg plant), the commercial fruit yield (t ha) was significantly higher to T2 which promoted an average of 33.6 t ha (Fig. 4C), thus 20% and 27% higher than those quoted to T3 (26.89 t ha) and T1 (24.48 t ha) respectively. The fruit yield promoted by T2 is compatible to average value recorded by Barbosa et al. (2016) (36.6 t ha) for 'Palmer' and higher than 27 t ha of Cavalcante et al. (2016) for 'Palmer', 10.5 ton ha^{-1} of Pleguezuelo et al. (2012) in Spain as well as higher than in the main worldwide producer countries such as Brazil (16.1 t ha), China (8.2 t ha), India (7.3 t ha) and Mexico (8.9 t ha) (Fao, 2017).

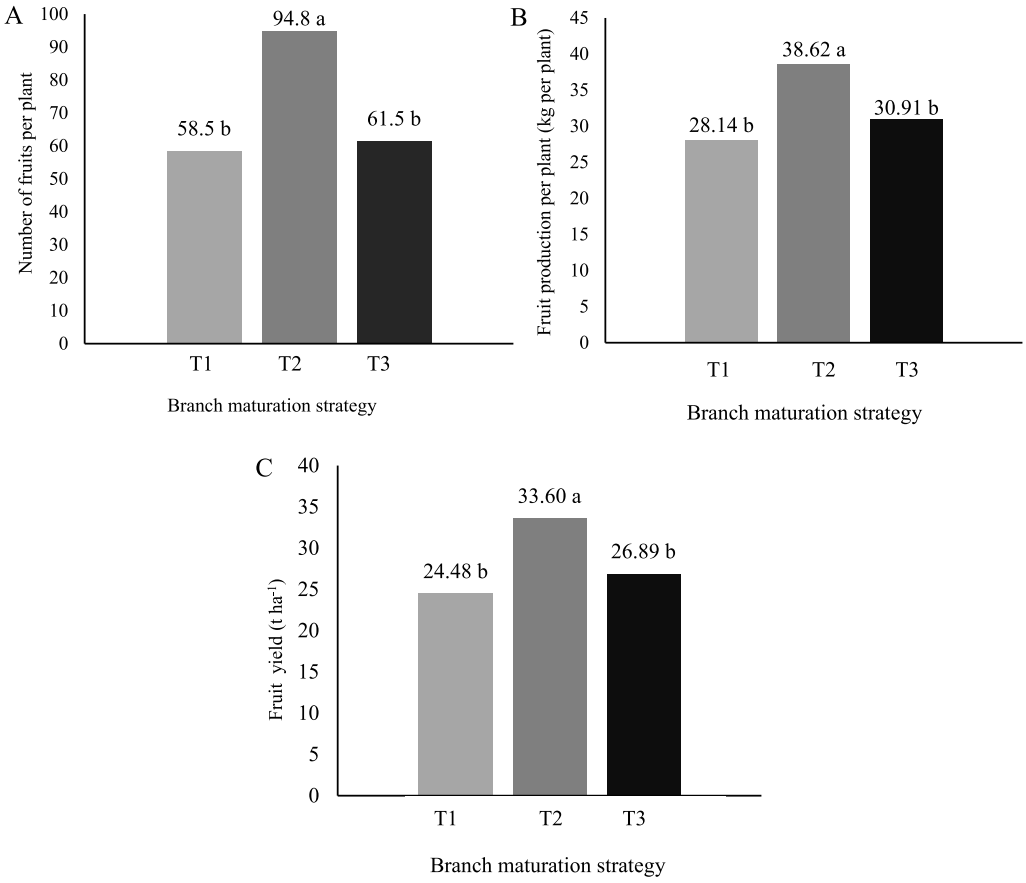


Fig. 4: Number of fruits per plant (A), (B) and commercial fruit yield (C) of mango cv. Palmer as a function of shoot maturation strategy. Bars with the same letters do not differ in among themselves by Tukey's test at 1% probability in each evaluation date. T1) biostimulant foliar spray + K fertilizer; T2) foliar spray with biostimulant alternating with K fertilizer; T3) individual foliar sprays (magnesium sulfate, potassium sulfate, sulfur and calcium fertilizers, potassium fertilizer, and Ethrel®; and T4) Control treatment.

The superiority recorded for the treatment with algae extract leaf spray applied individually could also be explained by the anti-stress characteristics of this product since during maturation phase the temperatures were high (36.8 ºC) the air humidity was low (25.6%) and mango plants were exposed to water blade reduction. This way, LANE et al. (2006) argue that *Ascophyllum nodosum* contain the polysaccharides laminaran, fucoidan, and alginate and laminarin has been shown to stimulate natural defense responses in plants and is involved in the induction of genes encoding various pathogenesis-related proteins with antimicrobial properties.

In a general form, positive effects of *Ascophyllum nodosum* extracts were previously reported by MORALES-PAYAN (2013) during seedling formation phase and MOHAMED and EL-SEHRAWY (2013), who recorded better plant nutrition and fruit retention of mango.

Conclusion

Thus, the results of this study indicate that: i) carbohydrate concentrations, nitrogen, sulphur and potassium leaf concentrations and fruit production of mango 'Palmer' depend on shoot maturation strategy; ii) under the soil, climate and plant conditions of this study, shoot maturation strategy using foliar spray with biostimulant containing *Ascophyllum nodosum* alternating with K fertilizer from 30 days after PBZ use could be recommended for the production of mango 'Palmer' in the semi-arid environment; iii) the very poor fruit production of the control plants is a clear indication of the importance to induce shoot maturation for growing mangoes for commercial purposes in the semi-arid environment. On the other hand future research is demanded to study effects of shoot maturation in different mango cultivars and/or mango grown in warm climates or different seasons.

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References

ALICEWEB. Sistema de Análise das Informações de Comércio Exterior, 2016. Retrieved 20th October 2017, from http://aliceweb.desenvolvimento.gov.br

ASREY, R., PATEL, V., BARMAN, K., PAL, R., 2013: Pruning affects fruit yield and postharvest quality in mango (*Mangifera indica* L.) cv. Amrapali. Fruits. 68, 367-380. DOI: 10.1051/fruits/2013082

BARBOSA, L.F.S., CAVALCANTE, I.H.L., LIMA, A.M.N., 2016: Desordem fisiológica e produtividade de mangueira cv. Palmer associada à nutrição de boro. Rev. Bras. Frutic. 38, 1-10. DOI: 10.1590/0100-2945-273/14

BRAZILIAN PROGRAM FOR HORTICULTURE MODERNIZATION, 2004: Standards classification of mango. Quality Center on Horticulture (CEAGESP), São Paulo, Brazil.

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. Rev. Bras. Eng. Agr. Amb. 21, 310-316. DOI: 10.1590/1807-1929

Cavalcante, I.H.L., Lima, A.M.N., Carneiro, M.A., Rodriguez, M.S., Silva R.L., 2016: Potassium doses on fruit production and nutrition of mango (*Mangifera indica* L.) cv. Palmer. Rev. Fac. Agron. Luz. 34, 385-399.

Davenport, T.L., 2003: Management of flowering in three tropical and subtropical fruit tree species. HortScience. 38, 1331-1335.

Davenport, T.L., 2006: Pruning strategies to maximize tropical mango production from the time of planting to restoration of old orchards. HortScience. 41, 544-548.

Dubois, M., Gilles, K.A., Hamilton, J.K., Rebers, P.A., Smith, F., 1956: Colorimetric method for determination of sugars and related substances. Anal. Chem. 28, 350-356. DOI: 10.1021/ac60111a017

Fao. Food and Agriculture Organization of the United Nations, 2017: Retrieved 14th October 2017, from http://apps.fao.org.

Genú, P.J.C., Pinto, A.C.Q., 2002: A cultura da mangueira. 1ª ed. Embrapa Informação Tecnológica, Brasília, Brazil.

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. J. Plant Growth Regul. 28, 386-399. DOI: 10.1007/s00344-009-9103-x

Kumar, M., Ponnuswami, V., Kumar, P.J., Saraswathy, S., 2014: Influence of season affecting flowering and physiological parameters in mango. Sci. Res. Essays. 9, 1-6. DOI: 10.5897/SRE2013.5775

Labmet. Laboratorio de Meteorologia, 2016: Meteorology Laboratory of San Francisco Valley University. Retrieved 27th November 2017, from http://labmet.univasf.edu.br.

Lane, C.E., Mayes, C., Druehl, L.D., Saunders, G.W., 2006: A multi-gene molecular investigation of the kelp (Laminariales, haeophyceae) supports substantial taxonomic re-organization. J. Phycol. 42, 493-512. DOI: 10.1111/j.1529-8817.2006.00204.x

Laxman, R.H., Annapoornamma, C.J., Biradar, G., 2006: Mango. In: Rao, N.K.S., Shivashankara, K.S., Laxman, R.H. (eds.), Abiotic stress phisiology of horticultural crops. Springer India Publisher, India.

Lemoine, R., Camera, S., Atanassova, R., Dédaldéchamp, F., Allario, T., Pourtau, N., Bonnemain, J.L., Laloi, M., Coutos-Thévenot, P., Maurousset, L., Faucher, M., Girousse, C., Lemonnier, P., Parrilla, J., Durand, M., 2013: Source-to-sink transport of sugar and regulation by environmental factors. Front Plant Sci. 4, 1-21. DOI: 10.3389/fpls.2013.00272

Malavolta, E., Vitti, G.C., Oliveira, S.S., 1997: Avaliação do estado nutricional das plantas: princípios e aplicações. 2ª Ed. Potafós, Piracicaba, Brazil.

Mancuso, S., Azzarello, E., Mugnai, S., Briand, X., 2006: Marine bioactive substances (IPA extract) improve foliar ion uptake and water stress tolerance in potted *Vitis vinifera* plants. Adv. Hort. Sci. 20, 156-161.

Marschner, H., 2012: Mineral nutrition of higher plants. 3ª Ed. New York, USA. Academic Press.

Mohamed, A.Y., El-Sehrawy, O.A.M., 2013: Effect of seaweed extract on fruiting of hindy bisinnara mango trees. J. Am. Sci. 9, 537-544.

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

Pessarakli, M., 2014: Handbook of plant and crop physiology. 3ª Ed., New York, USA. Marcel Dekker.

Pimplasker, M., Bhargava, B.S., 2003: Leaf and soil nutrient norms in mango (*Mangifera indica* L.) grown in tribal belt of Southern Gujarat. J. Indian Soc. Soil Sci. 51, 268-272.

Pleguezuelo, C.R.R., Zuazo, V.H.D., Fernández, J.L.M., Tarifa, D.F., 2012: Physico-chemical quality parameters of mango (*Mangifera indica* L.) fruits grown in a mediterranean subtropical climate (SE Spain). J. Agr. Sci. Technol. 14, 365-374.

Prasad, S.R., 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. Int. J. Fruit Sci. 14, 437-459. DOI: 10.1080/15538362.2014.897891

Quijada, O., Herrero, B., González, R., Casanova, A., Camacho, R., 2009: Influencia de la poda y de la aplicación de nitrato potásico y tiossulfato potásico sobre el mango en Maracaibo, Venezuela. II. Producción e índices de eficiencia productiva. Agron. Trop. 59, 289-296.

Ramírez, F., Davenport, T.L., 2016: Mango (*Mangifera indica* L.) pollination: A review. Sci Hortic-Amsterdam. 203, 158-168. DOI: 10.1016/j.scienta.2016.03.011

Ramírez, F., Davenport, T.L., Fischer, G., Pinzón, J.C.A., 2010: The stem age required for floral induction of synchronized mango trees in the tropics. HortScience 45, 1453-1458.

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. Sci. Hortic-Amsterdam. 168, 258-266. DOI: 10.1016/j.scienta.2014.01.040

Saran, P.L., Kumar, R., 2011: Boron deficiency disorders in mango (*Mangifera indica* L.): field screening, nutrient composition and amelioration by boron application. Indian J. Agr. Sci. 81, 506-510.

Silva, F.C., 2009: Manual de Análises Químicas de Solos, Plantas e Fertilizantes. 2ª Ed. Embrapa Informação Tecnológica, Brasília, Brazil.

Spann, T.M., Little, H.A., 2011: Applications of a commercial extract of the brown seaweed *Ascophyllum nodosum* increases drought tolerance in container-grown 'Hamlin'sweet orange nursery trees. HortScience 46, 577-582.

Urban, L., Montpied, P., Normand, F., 2006: Season effects on leaf nitrogen partitioning and photosynthetic water use efficiency in mango. J. Plant Physiol. 163, 48-57. DOI: 10.1016/j.jplph.2005.02.005

Wahdan, M.T., Habib, S.E., Bassal, M.A., Qaoud, E.M., 2011: Effect of some chemicals on growth, fruiting, yield and fruit quality of "Succary Abiad" mango cv. J. Am. Sci. 7, 651-658.

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*. J. Plant Growth Regul. 32, 324-339. DOI: 10.1007/s00344-012-9301-9

Yeshitela, T., Robbertse, P.J., Stassen, P.J.C., 2005: Potassium nitrate and urea sprays affect flowering and yields of 'Tommy Atkins' (*Mangifera indica* L.) mango in Ethiopia. S. Afr. J. Plant Soil. 22, 28-32. DOI: 10.1080/02571862.2005.10634676

Zhang, X., Ervin, E.H., 2008: Impact of seaweed extract-based cytokinins and zeatin riboside on creeping bentgrass heat tolerance. Crop Sci. 48, 364-370. DOI:10.2135/cropsci2007.05.0262

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