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Photosynthetic profiles and nutrimental characterization of yellow mango in Mexico

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Worldwide, Mexico represents the first exporter of mango. However, in recent years mango exports have decreased by 29 points due to a change in the preference of the American market; hence, it is essential to diversify the supply of mangoes exports. Measurement of the net photosynthesis response and internal CO_2 concentrations can provide data on important parameters of the physiology of a variety; these have been widely used in ecophysiological studies and allow the early evaluation of germplasm. The objective of the study is to do a physiological evaluation of 8 mango varieties (Nam Doc Mai, Rosigold, Mallika, Ivory, Alphonse, Neelum, Fairchild and Kesar) recently introduced to Mexico and 2 recently registered by INIFAP (Ataúlfo "Diamante" and Ataúlfo "Zafiro"), all with export potential. The work was carried out under 2 conditions (laboratory and greenhouse). For the photosynthesis registry, nursery plants approximately 18 months old were used (net photosynthesis, stomatal conductance, internal CO_2 concentration and evapotranspiration, SPAD units and nutrients (NO^{3-}, K^+, Ca^{2+} y Na^+). In both conditions (laboratory and nursery), it was found that the cultivars with the highest levels of the physiological variables, photosynthesis, concentration of chlorophyll and nutrients in the leaf were Fairchild, Mallika and Kesar. The cultivars such as Rosygold and Nam Doc Mai and Ivory, in contrast, those with the lowest levels were Ataulfo Zafiro, Ataulfo Diamante, Alphonse and Neelum. The evapotranspiration (Evap), net photosynthesis (PN) and concentration of Intercellular CO_2 (Cint) kinetics were used to describe that all the cultivars presented a similar behavior and evidenced differences in the intensity of the same.

Key words: *Mangifera indica* L., chlorophyll, photosynthesis, nutrients.

INTRODUCTION

There are approximately 150 commercial mango cultivars in the world (Galán, 2009). Mexico is the main exporter; however, out of the total volume produced (1.4 million tons per year), only 10% is exported. The main cultivars

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for the international market are: Tommy Atkins, Kent, Haden, Keitt, and Ataúlfo, which is the only polyembryonic cultivar (Ayala-Garay, 2009, Ledin, 1957). Mexico has favorable physical and climatic conditions for the optimum development of the crop (SENASICA, 2009).

To establish an adequate management strategy for different mango cultivars, it is necessary to understand fundamental aspects of their physiology, such as photosynthesis. During this process, CO_2 moves from the atmosphere to the internal sub-stomata cavities through the stomata, and from there to the carboxylation site inside the stroma. This last component of CO_2 diffusion is called mesophyll conductance (gm) (Taiz and Zeiger, 2002; Long and Bernacchi, 2003; Flexas et al., 2008).

González et al. (2011) reported a contrasting varietal comparison of the environmental effects in some commercial orchards of Guerrero and Chiapas. Manila mango in Guerrero was the variety that photosynthesized faster, while in Chiapas the highest rate was observed in Tommy Atkins and Haden, followed by Ataulfo. These biophysical and biochemical processes, as well as environmental variables such as light intensity and temperature, can have different effects on the net rate of CO_2 assimilation (Sharkey et al., 2007). In red varieties, the carbon increases as there is more CO_2 in the environment, followed by the Ataúlfo variety (González et al., 2011). Mango is characterized by relatively high nutrient requirements (Mora et al., 2017); the N content is the most important factor in the determination of the photosynthetic rate per foliar surface unit (Agustí and Fonfría, 2010). In the cv. Kent, the contents of N and K decrease in flowering, which is explained by its greater content in the productive stage. P behaves homogeneously during the crop cycle. In the case of Ca, the levels increase as the productive cycle starts. This is explained by the age of the leaf because as it increases, the Ca and Mg contents also increase (Mora et al., 2017).

N forms a structural part of the chlorophyll molecule, which is the main pigment that gives green coloration to plants and is responsible for absorbing the light energy necessary to initiate the process of photosynthesis. The use of portable chlorophyll meters has been validated in countries such as the United States since 1994. In our country, thanks to the MPM Project, it is used since 1998, with very promising results for crops such as rice, wheat, beet and corn among others (Díaz et al., 2002). A review of the literature on the measurement of chlorophyll content with portable meters shows that there are no reports employed in mango foliage.

Therefore, in the present work the objective of evaluating the following physiological parameters was proposed: chlorophyll content for the determination of total chlorophylls of the biomass; net photosynthesis (A $\mu mol.m^{-2}.s^{-1}$); stomatal conductance (gs $\mu mol.m^{-2}.s^{-1}$); internal concentration of CO_2 (Ci $\mu mol.m^{-2}.s^{-1}$); among others. In the nutritional analysis of the samples, portable ionometers were used to estimate the content of NO_3^-, K^+, Ca_2^+ and Na^+ $\mu mol.m^{-2}.s^{-1}$, in mature mango leaves with 50 days of development (dod) of Nam Doc Mai, Rosigold, Mallika varieties, Ivory, Alphonse, Neelum, Fairchild, Kesar and selections Ataúlfo "Diamante" and Ataúlfo "Zafiro". The expected results will help identify differences among materials in order to select those with the best characteristics. The registration of these parameters will allow one to have more elements to make decisions about the selection of cultivars in the establishment of new commercial orchards.

MATERIALS AND METHODS

Experimental site

The research was conducted during the spring-autumn productive cycle (2016) at the Headquarters of the Master in Agricultural Sciences and Local Management of the Autonomous University of Guerrero, Tuxpan Unit (18º 20 '39' 'N, 99º 29' 53 '' O), in Iguala de la Independencia, Guerrero, Mexico, at 757 masl; its average annual temperature is 25.8°C and has approximate average rainfall of 1, 015 mm (García, 1988). Grafted plants were used with the cultivars Nam Doc Mai, Rosigold, Mallika, Ivory, Alphonse, Neelum, Fairchild and Kesar, recently introduced by the Fairchild Tropical Botanic Garden, as well as the national Ataulfo "Diamante" and Ataúlfo "Zafiro" selections, all of approximately 18 months age. The plants were planted in black polyethylene bags with a capacity of 5 L; they were fertilized weekly with a nutrient solution Steiner (1.0 L per plant poured into the soil and 1.0 mL L-1 sprinkled on the foliage) and watered until field capacity every third day.

Determination of physiological profiles in laboratory and nursery

Vegetative shoots were marked and when the leaves had 50 days of development (dod), the photosynthesis evaluations and SPAD units started. At the end of this phase, the leaves were cut to determine NO_3^-, K^+, Ca_2^+, Na^+ and chlorophyll. Each determination was made using the same leaves.

Laboratory

The plants were left for a seven-day adaptation period at the Plant Physiology Laboratory of the Autonomous University of Guerrero (UAGro). The temperature (26 ± 3°C) and relative humidity (70 ± 10%) were controlled using a LG® humidifier and the photoperiod (12:12h and 450 ± 50 lm) using PAR lamps. After the adaptation period, a randomized complete block design was used, and the experimental units consisted of 4 leaves attached to each plant, and a total of 4 plants (repetitions) per treatment. Every 2 h, the temperature, relative humidity and photoperiod in the laboratory were recorded with a Hobo® data logger, model U12.

Nursery

The plants were left for a seven-day adaptation period at the UAGro Fruit Tree Nursery, with polypropylene mesh (50% shade); the plants were established in black polyethylene bags of 27 cm by 27 cm of 5 l of capacity. After the adaptation period, the experiment was established using a randomized complete block design, with 4 leaves attached to each plant as an experimental unit and a total of 4 plants (repetitions) per treatment. The temperature (29 ± 3ºC), relative humidity (60 ± 10%) and photoperiod (12±1 h and 800-1009 lm) were recorded every 2 h with a Hobo® data logger, model U12.

Either at laboratory and nursery conditions, measurements were taken every 48 h at 10:00 am for 18 and 24 days on: photosynthesis, SPAD units, nutrients (NO_3^-, K^+, Ca_2^+ and Na^+). Foliage was also collected for total chlorophyll determination.

Determination of photosynthesis

This was quantified based on net photosynthesis (*A*), stomatal conductance (*gs*), internal concentration of CO_2 (*Ci*) and evapotranspiration (*Evap* $mmol.m^{-2}.s^{-1}$) with a TPS-2 (portable photosynthesis system) and PP system® software. Measurements were made on the anterior, middle and posterior part of mature leaves of 50 dod (4 per plant), based on the aforementioned variables; the area under the photosynthetic progress curve (AUPPC) was estimated with the method of trapezoidal integration (Campbell and Madden, 1990).

SPAD units

These were calculated with a Minolta SPAD® 502 (Soil Plant Analysis Development, Minolta Co. Ltd., Osaka, Japan); measurements were made on the front, middle and back of four mature leaves per plant of 50 dod. The SPAD units (chlorophyll content) were calculated by variety, based on the measurements made, the area under the progress curve (AUPPC) estimated with the trapezoidal integration method was calculated (Campbell and Madden, 1990).

Determination of total chlorophylls

The spectrophotometric method proposed by Hansmann (1973) was applied on 25 g of foliar samples chosen at random; those were crushed and suspended in 700 ml of acetone-water at 80% (v/v) as extractive solvent of the pigments. This was done several times to extract all the pigmentation. Subsequently, the extracted samples were transferred to plastic tubes and centrifuged at 15,000 rpm for 20 min. The samples were removed and decanted in glass tubes and flat bottomed, adjusted to 10 ml, allowing standing for 10 min. The optical density of the supernatant was determined by the AOAC method (1980), based on the following formula: Total chlorophyll = 8.2 (A663) + 20.2 (A645); where A663 and A645 correspond to the absorbance at 663 and 645 µm wavelength, measured with a spectrophotometer. The equation proposed by Parsons and Strickland (1963) was used for quantification**.**

Nutritional analysis

For estimating NO_3^-, K^+, Ca_2^+ and Na^+, portable LAQUAtwin Horiba Scientific® ionometers were used. The equipment was calibrated at 2 points with solutions at 200 and 2000 ppm according to the operations manual. For the measurement, ripe mango leaves of 50 dod were cut (4 per plant) and 1 ml of sap was extracted; finally the sample was placed in the equipment and after 3 and a half min where the results were obtained. Based on the results, the nutrient content was obtained by variety.

Correlation analysis

Pearson correlation coefficient (r) of the SPAD units against total chlorophylls and photosynthetic kinetics by variety was calculated.

Statistical analysis

A normality analysis was performed using the MinitabR statistical software. In addition to analysis of variance and separation of means SMD ($p \leq 0.05$) with statistical analysis software SAS, v.9.1.3 (SAS Institute Inc, 2003) for the variables: A, gs, Ci, Evap, Chlorophyll SPAD, total chlorophylls and content of NO_3^-, K^+, Ca_2^+ and Na^+.

RESULTS AND DISCUSSION

Physiological characterization in laboratory and nursery

Photosynthesis

The net photosynthesis (*A*), a main indicator of physiological activity, as measured in laboratory showed that Ivory, Alphonse, Rosygold, Neelum and Nam Doc Mai had the highest photosynthetic capacity ($p \leq 0.05$). According to Damián et al. (2009) *Ci*, shows the internal concentration of CO_2 available for photosynthesis in chloroplasts. In this sense the largest amount of interior carbon was recorded in A. Diamante, Ivory, Fairchild, Alphonse, Rosigold, Nam Doc Mai and A Zafiro; and referring to the group with the highest rate of evaporation, it could be observed that the varieties that transpired most were Kesar, Mallika, A. Diamante, Ivory, Fairchild, Alphonse, Neelum, A. Zafiro, regarding *gs.* There were no differences between cultivars (Table 1).

In the nursery trial it was found that Fairchild, Rosygold, Neelum, Alphonse and Nam Doc Mai had the highest rate *A* ($p \leq 0.05$), whilst Ivory, Fairchild, Alphonse Rosygold, Nam Doc Mai and A. Zafiro recorded the highest amount of carbon interior and Kesar, Mallika, Rosygold, Neelum and A. Zafiro recorded the highest levels of evaporation. Ivory and Fairchild recorded the lowest levels of gs, the rest presented the highest levels (Table 2).

González et al. (2011) report that the varieties Rosigold, Nam Doc Mai, Ivory and Mallika photosynthesize at similar speeds than Ataúlfo Diamante, Haden and the improved selections of Ataúlfo 4, 8 and Manila Cotaxtla selection. It is noteworthy that, although there was variability in the significances between each variable, there was, generally, similar behavior of cultivars in the laboratory and nursery.

There is a direct relationship between the availability of carbohydrates in leaves and the harvest; therefore, photosynthetic rate can be a limiting factor for this. A severe defoliation of the tree by the attack of insects or a disease, during the phase of linear growth, the low rate of photosynthesis can limit the development of the fruits and the total harvest (Agustí and Fonfría, 2010). Urban and Alphonsout (2007) reported that ringing reduces net

Table 1. Net photosynthesis, stomatal conductance, internal concentration of CO_2 and evapotranspiration in mature leaves (50 dod) of ten mango cultivars under laboratory conditions.

Cultivar	*A*	*gs*	*Ci*	*E*
Kesar	18.85^{c}	203.6^{a}	666.79^{c}	2.21^{a}
Mallika	18.65^{c}	223.3^{a}	693.60^{bc}	2.17^{ab}
A. Diamante	19.01^{c}	222.3^{a}	734.45^{abc}	1.95^{abc}
Ivory	20.06^{abc}	183.46^{a}	778.34^{abc}	1.98^{abc}
Fairchild	19.45^{bc}	185.48^{a}	788.23^{ab}	1.99^{abc}
Alphonse	22.66^{ab}	190.24^{a}	776.00^{abc}	2.06^{abc}
Rosigold	22.99^{a}	206.40^{a}	807.34^{a}	1.90^{bc}
Neelum	22.78^{a}	248.30^{a}	668.10^{c}	2.20^{a}
Nam Doc Mai	22.95^{a}	216.36^{a}	730.55^{abc}	1.86^{c}
A. Zafiro	18.28^{c}	192.49^{a}	719.65^{abc}	1.95^{abc}

*Means followed by same letters in the columns are not significantly different, SMD test ($p \leq 0.05$). Net photosynthesis (*A*), stomatal conductance (*gs*), internal concentration of CO_2 (*Ci*) and evapotranspiration (*EVAP*).

Table 2. Net photosynthesis, stomatal conductance, internal concentration of CO_2 and evapotranspiration in mature leaves (50 dod) of ten mangoes cultivars under nursery conditions.

Cultivar	*A*	*gs*	*Ci*	*E*
Kesar	12.30^{b}	40.91^{abc}	926.14^{abc}	0.64^{a}
Mallika	13.23^{b}	49.71^{a}	791.66^{Bc}	0.62^{ab}
A.Diamante	13.92^{b}	43.02^{abc}	685.49	0.54^{bc}
Ivory	13.44^{b}	33.13^{c}	1109.60^{a}	0.39^{d}
Fairchild	17.03^{b}	36.14^{bc}	1079.80^{a}	0.49^{cd}
Alphonse	14.24^{ab}	38.84^{abc}	1008.65^{ab}	0.49^{cd}
Rosigold	14.80^{ab}	47.35^{ab}	846.81^{abc}	0.57^{abc}
Neelum	14.32^{ab}	40.58^{abc}	790.54^{bc}	0.59^{abc}
NamDocMai	15.04^{ab}	38.07^{abc}	1055.62^{ab}	0.53^{bc}
A.Zafiro	14.05^{b}	44.56^{abc}	865.27^{abc}	0.55^{zbc}

*Means followed by same letters in the columns are not significantly different, SMD test ($p \leq 0.05$). Net photosynthesis (A), stomatal conductance (gs), internal concentration of CO_2 (Ci) and evapotranspiration (*EVAP*).

photosynthesis and stomatal conductance to a similar extent, in 77 and 71%, respectively, within 20 days after banding, and both remained below 2.1 μm $CO2 \cdot m^{2} \cdot ^{s-1}$ and 0.06 μmol H_2O m^{-2} s^{-1}, respectively, until the beginning of flowering. An extensive literature review on mango plants to document the positive relationship of the highest photosynthetic rate with high fruit production shows that there is no literature available. Additionally, it has been reported that in fruits such as peach (*Prunus persica*), plum (*Prunus domestica*), cherry (*Prunus cerasus*) and almond (*Prunus dulcis*), a high photosynthetic capacity of the tree ensures an abundant harvest so that photosynthesis can become a limiting factor in cases such as competition between organs and/or when for various reasons there are major stress or defoliation phenomena (Agustí and Fonfría, 2010).

Photosynthetic kinetics

The cultivars showed a similar behavior for variables *A*, *gs*, *Ci* and *Evap*, during the period of laboratory study (Figure 1). A similar trend was observed for nursery evaluations (Figure 2); however, differences were found in their intensity ($p \leq 0.05$), where only the high, medium and low kinetics were represented (Figures 1 and 2).

Lu et al. (2012) reported that 5 cultivars of mango, Kensington Pride, Strawberry, Haden, Irwin and Tommy Atkins showed a significant seasonal variation in *A* and *gs*, with the maximum values being registered during the wet season and the minimum during the dry season. The values of *Evap* were not significantly different among the cultivars during the wet season; however, they were significantly different during the dry season. Among the

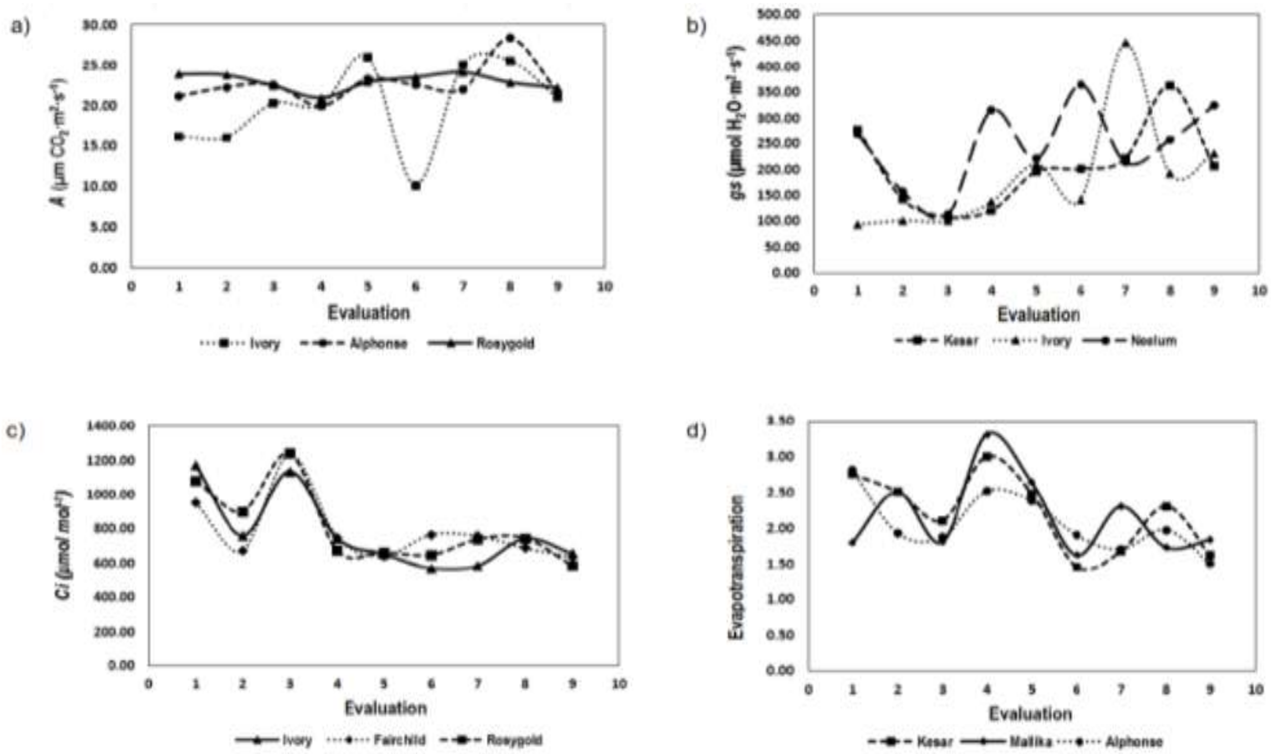

Figure 1. Kinetics of net photosynthesis (a), stomatal conductance (b), internal concentration of CO2 (c) and evaporation (d) of three mango cultivars (*Mangifera indica* L.) during nine sampling dates under laboratory conditions.

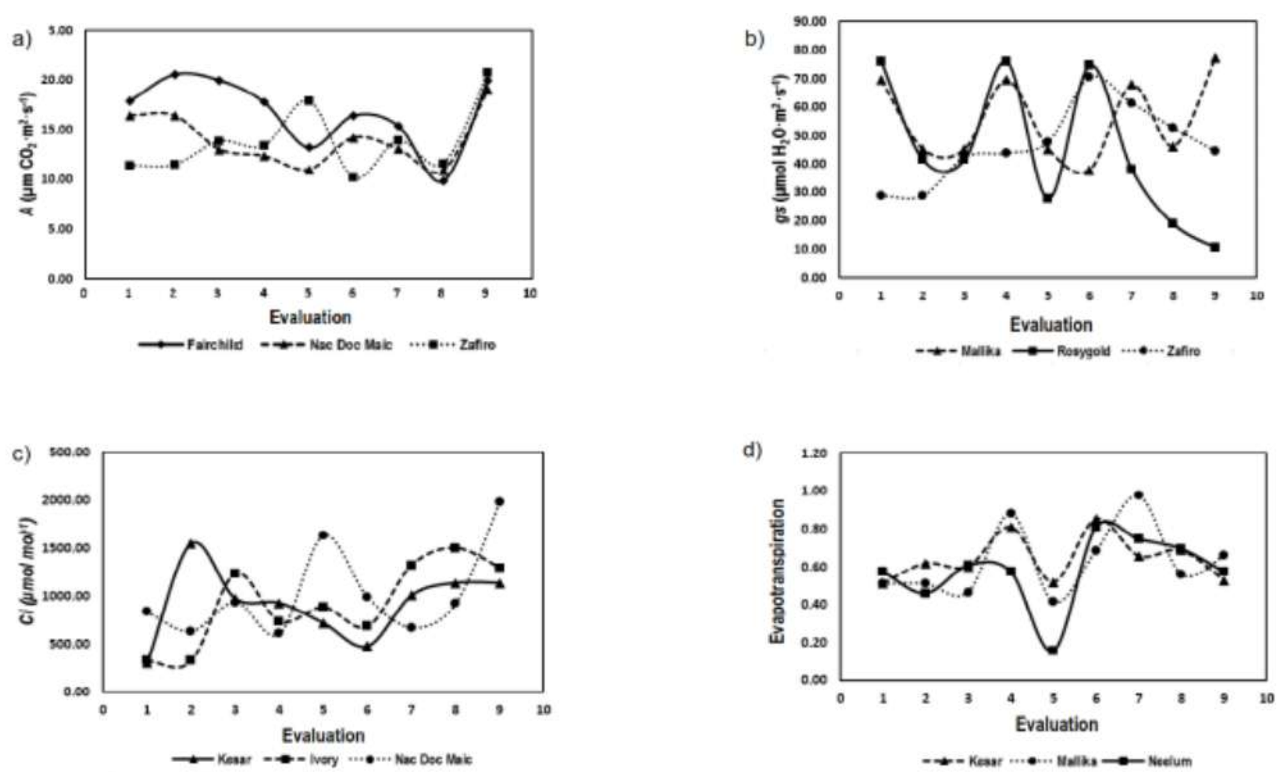

Figure 2. Kinetics of net photosynthesis (a), stomatal conductance (b), internal concentration of CO_2 (c) and evaporation (d) of three mango cultivars (*Mangifera indica* L.) during nine sampling dates under nursery conditions.

Table 3. SPAD units and area under the curve of photosynthetic progress (AUPPC) in mature leaves (50 dod) of ten mango cultivars under laboratory conditions.

Cultivar	SPAD502	AUPPC
Kesar	44.24[d]	1761.14[c]
Mallika	52.65[ab]	2136.73[a]
A.Diamante	48.93[c]	1974.56[b]
Ivory	52.50[ab]	2098.96[a]
Fairchild	53.50[a]	2157.97[a]
Alphonse	49.42[c]	1958.61[b]
Rosigold	47.60[c]	1918.06[b]
Neelum	44.73[d]	1789.70[c]
NamDocMai	52.29[ab]	2104.41[a]
A.Zafiro	50.07[bc]	1976.87[b]

Table 4. SPAD units and area under the curve of photosynthetic progress (AUPPC) in mature leaves (50 dod) of ten mango cultivars under nursery conditions.

Cultivar	SPAD502	AUPPC
Kesar	46.06[ef]	473.72[g]
Mallika	62.94[a]	676.61[a]
A.Diamante	48.56[de]	537.53[ef]
Ivory	54.32[bc]	599.81[bc]
Fairchild	57.12[b]	631.86[b]
Alphonse	49.52[cde]	551.12[def]
Rosigold	51.82[bcd]	570.51[cde]
Neelum	42.69[f]	470.00[g]
NamDocMai	53.40[bcd]	589.46[cd]
AZafiro	48.33d[e]	523.40[f]

*Means followed by the same letter in columns are not significantly different, SMD test ($p \leq 0.05$).

cultivars the difference of *A* is relevant to indicate the capacity of the cultivars for particular environments

SPAD (chlorophyll)

It is one of the most reliable, non-destructive devices focused on determining the level of chlorophyll in a plant. The cultivars with the highest concentration of chlorophyll in the laboratory per unit area were Fairchild, Mallika, Ivory and Nam Doc Mai (Table 3); the cultivar that presented the highest concentration of chlorophyll in the nursery was Mallika (Table 4), but the obtained results were like those found in the laboratory test. Ramírez et al. (2011) confirm the reliability of chlorophyll foliar content (µg per mg of leaf) from SPAD data, demonstrating the feasibility of using SPAD-502 (Minolta) reducing time, work and evaluation costs obtaining regression analysis that can be used in greenhouse and field. The use of portable chlorophyll meters is emerging as a technological opportunity, profitable, economical and feasible to be used, but it must be calibrated for each cultivar (Callejas et al., 2013).

Nutrients

Currently, it is required to obtain express information from chemical analyses, so the measurement of ions in the cellular extract of the foliage with specific portable ionometers is widely used in intensive production systems. A review of the literature on the concentration of nutrients shows that there are no literature reports on the use of portable ionometers brand Horiba Scientific® type LAQUAtwin in mango foliage. However, Tapia et al. (2003) refer to the existence in the market of technical equipment to determine *in situ* the nutritional status of the crop, like the specific ionometers for NO_3, P and K, etc.,

Table 5. Nutrients: (NO_3^-), (K^+), (Ca^{2+}) and (Na^+) in mature leaves (50 dod) on ten mango cultivars under laboratory conditions.

Cultivar	NO^{3-}	K^+	Ca^{2+}	Na^+
Kesar	490.00^{a}	236.17^{b}	19.00^{bc}	54.75^{a}
Mallika	430.00 ^{b}	280.50^{a}	5.75^{e}	31.95 ^{b}
A. Diamante	250.00^{d}	234.16^{b}	12.00^{de}	17.66^{def}
Ivory	208.83^{e}	172.66^{cd}	24.66^{ab}	19.83^{de}
Fairchild	267.50^{c}	213.83	15.16^{cd}	23.00^{cd}
Alphonse	116.16^{h}	134.11^{d}	15.50^{cd}	25.91^{c}
Rosigold	90.25 ^{i}	146.00^{d}	25.91^{a}	14.12^{efg}
Neelum	142.50^{f}	168.94^{d}	7.75^{e}	28.79^{bc}
Nam Doc Mai	128.75^{g}	152.50^{d}	22.91^{ab}	14.00f^{g}
A. Zafiro	86.00 ^{i}	172.47^{cd}	8.33^{e}	8.83 ^{g}

*Means followed by the same letter in columns are not significantly different, SMD test ($p \leq 0.05$).

Table 6. Nutrients: (NO_3^-), (K^+), (Ca_2^+) and (Na^+) in mature leaves (50 dod) on ten mango cultivars under nursery conditions.

Cultivar	NO_3^-	K^+	Ca^{2+}	Na^+
Kesar	192.25^{a}	303.83^{e}	14.00^{de}	20.37^{a}
Mallika	190.00^{a}	301.33^{e}	22.50^{bc}	20.12^{a}
A. Diamante	167.25^{b}	343.67^{d}	11.75^{e}	18.12^{a}
Ivory	134.50^{e}	334.67^{d}	34.75^{a}	21.62^{a}
Fairchild	149.12^{d}	304.33^{e}	17.87^{cd}	14.75^{a}
Alphonse	106.00^{f}	294.00^{f}	20.75^{c}	15.25^{a}
Rosigold	74.00^{g}	387.50^{a}	21.25^{bc}	19.00^{a}
Neelum	162.50^{bc}	304.33^{e}	12.12^{e}	20.50^{a}
Nam Doc Mai	155.00^{cd}	374.91^{d}	12.50^{e}	16.62^{a}
A. Zafiro	127.50^{e}	391.00^{a}	25.50^{b}	17.75^{a}

based on the solution of soil and cell extract; the ionometers can provide information instantly about the nutritional status of the tree. Kesar and Mallika presented the highest levels of Nitrogen (NO_3^-); Mallika statistically surpassed the rest of the cultivars for (K^+); Kesar, Mallika and Neelum had the highest concentration of (Na^+); Rosygold, Ivory and Nam Doc Mai exceeded the rest of the cultivars with respect to Ca^{2+}), under laboratory conditions (Table 5). In nursery, the highest concentration of Nitrogen (NO_3^-) was recorded in the cultivars Kesar and Mallika, similar to the results in laboratory test; no statistical differences were found among cultivars for (Na^+); Ivory, A. Zafiro, Mallika and Rosigold registered the highest amount of (Ca_2^+); for the case of (K^+), Rosygold and Ataúlfo-Zafiro statistically surpassed the rest of the treatments (Table 6). The results are partially like those found in the laboratory test. These values are high to that reported in avocado (*Persea americana*) by Arellano et al. (2017), for NO_3^-, K^+ and Na^+ there were no statistical differences; Ca^{2+} reported statistical differences with low concentrations. N fertilization is one of the most important growth factors in the production of yield and quality in production. Adequate supply of this nutrient is associated with adequate levels of chlorophyll, vigorous vegetative growth, high photosynthetic activity and carbohydrate synthesis, on which the yield depends on (Castro et al., 2004).

Chlorophylls and SPAD units

Fairchild, Nam Doc Mai, A. Zafiro and Mallika had the highest concentrations of photosynthetic pigments, like those obtained by the SPAD method (Table 7). A positive relationship was found between the analysis by spectrophotometry ($mg*g^{-1}pf^{-1}$ of chlorophyll) with the SPAD units obtained in the laboratory ($r=0.78$) (Figure 3). Borres et al. (2017) report a correlation of a color sensor known as digital image analysis and SPAD 502 in Carabao mango shows that the two methods can detect the reading value of the specimen with almost uniform precision. The results indicate that the SPAD 502 device

Table 7. Concentration of total chlorophylls in mature leaves (50 dod) on ten mango cultivars using the method proposed by Hansmann (1973).

Cultivar	Mg*g^{-1}pf^{-1} de chlorophyll
Kesar	1.32^{cd}
Mallika	1.61^{abc}
A. Diamante	1.32 ^{cd}
Ivory	1.56^{abc}
Fairchild	1.91^{a}
Alphonse	1.25^{cd}
Rosigold	1.48^{bc}
Neelum	1.06^{d}
Nam Doc Mai	1.86^{ab}
A. Zafiro	1.62^{abc}

*Means followed by the same letter in columns are not significantly different, SMD test (p≤0.05).

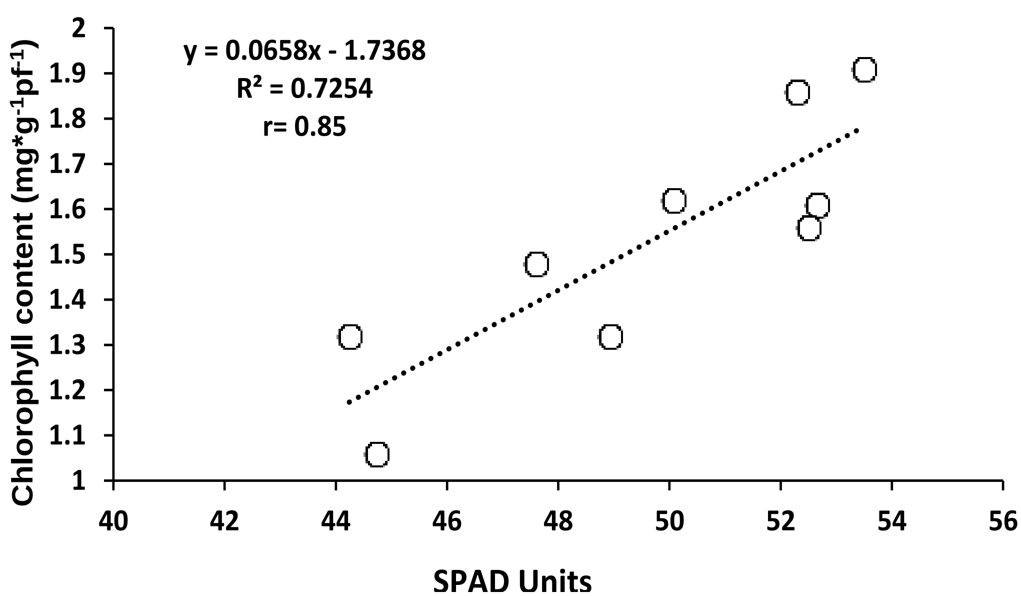

Figure 3. Correlation analysis (the correlation analyzes were made through a linear regression model) of the chlorophyll content (mg * g-1pf-1) with the method proposed by Hansmann (1973) and the SPAD units using a kit SPAD® 502 (Soil Plant Analysis Development, Minolta Co. Ltd., Osaka, Japan), in mature leaves (50 ddd) of 10 mango cultivars evaluated in laboratory.

can be a practical substitute for digital image analysis and spectrophotometric analysis (mg*g^{-1}pf^{-1} of chlorophyll) and it can be used for rapid, accurate, non-destructive usage and estimation of chlorophyll content in mango leaves.

A close relationship was also determined between the SPAD units registered in nursery and laboratory (Figures 4 and 5). A literature review on the concentration of SPAD units and correlation of different environmental conditions showed that there are no literature reports for mango. Márquez et al. (2017) report a linear regression between SPAD units and total chlorophyll content of juvenile avocado plants 'Hass' under 3 treatments of solar radiation, no statistical differences were found between the chlorophyll contents estimated from SPAD units in these 3 treatments; those conditions are different to the partially found when comparing the laboratory and nursery tests (Tables 3 and 4); significant differences were observed, with higher content of total chlorophylls in laboratory conditions.

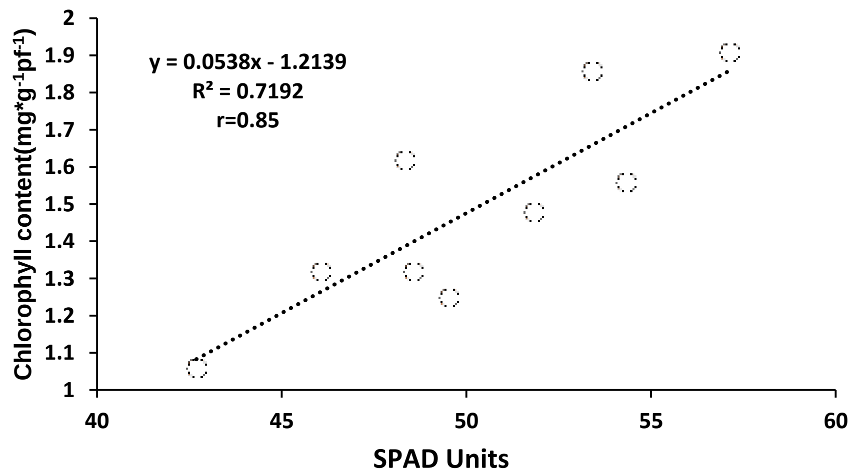

Figure 4. Correlation analysis (the correlation analyzes were made through a linear regression model) of the chlorophyll content (mg * g-1pf-1) with the method proposed by Hansmann (1973) and the SPAD units using a kit SPAD® 502 (Soil Plant Analysis Development, Minolta Co. Ltd., Osaka, Japan), in mature leaves (50 ddd) of 10 mango cultivars evaluated in nursery conditions.

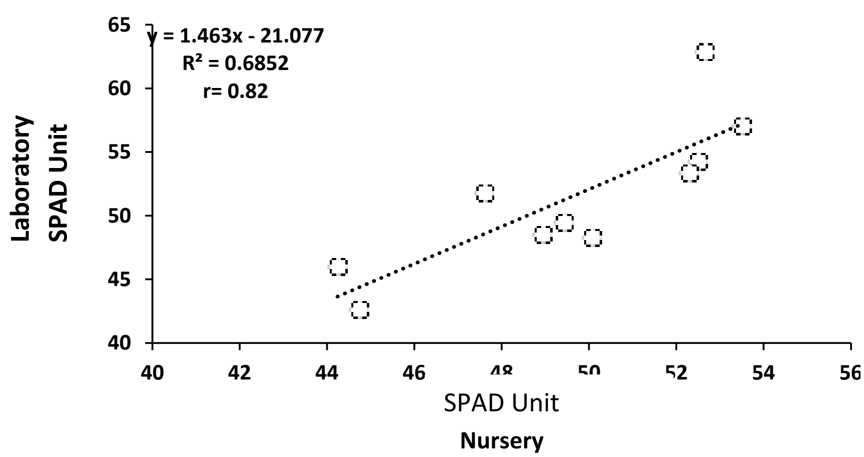

Figure 5. Correlation analysis and linear regression between the SPAD units registered using a SPAD® 502 (Soil Plant Analysis Development, Minolta Co. Ltd., Osaka, Japan), in mature leaves (50 ddd) of 10 mango cultivars evaluated in nursery and laboratory.

Conclusion

The cultivars with the highest levels of photosynthesis, chlorophyll concentration and nutrients were: Ivory, Alphonse, Rosygold, Neelum and Nam Doc Mai (Laboratory), Fairchild, Rosygold, Neelum, Alphonse and Nam Doc Mai (Nursery); Fairchild, Mallika, Ivory and Nam Doc Mai (Laboratory), Mallika (Nursery); Kesar, Mallika NO_3^-, Mallika K^+, Kesar, Mallika, Neelum Na^+, Rosygold, Ivory, Nam Doc Mai Ca^{2+} (Laboratory), Kesar, Mallika NO_3^-, Ivory, A. Zafiro, Mallika, Rosigold Ca^{2+}, Rosygold, Ataulfo-Zafiro K^+ (Nursery), respectively.

The values of *Evap, gs*, *A* and *Ci*, presented similar kinetics, with differences in their intensity among cultivars.

A creative relationship was found between the chlorophyll content ($mg*g^{-1}pf^{-1}$) with the method proposed by Hansmann (1973) and the SPAD units, so the use of SPADs is an alternative method to estimate chlorophyll, and it is a non-destructive method.

This type of work allows an early decision making for the establishment of mainly perennial crops, where the evaluation of yield, resistance to water stress, susceptibilit y to pests and diseases, etc. can take years.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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