Vol. 14, No. 1, pp. 30-36 (2014)
Journal of Agricultural Physics
ISSN 0973-032X
http://www.agrophysics.in

Research Article

Leaf and Fruit Turgor Potential in Passion Fruit Plants using Wiltmeter and Turgormeter

ANTONIO HÉLDER RODRIGUES SAMPAIO[1], MAURÍCIO ANTONIO COELHO FILHO[2]*, ADONAI GIMENEZ CALBO[3], TONI COSTA E SILVA[1], DAYSE BATISTA DOS SANTOS[1], AND MATEUS SANTOS MACHADO[1]

[1]*Federal Institute of Education, Science and Technology of Piauí– Highway PI 247, km 07– 4860-000– Uruçuí, PI-Brazil*

[2]*Embrapa Cassava and Fruits, C.P. 07–44380-000–Cruz das Almas, BA-Brazil*

[3]*Embrapa Instrumentation, 1452 Quinze de Novembro Street, C.P. 740–13560-970–São Carlos, SP-Brazil*

ABSTRACT

Turgor pressure (pp) is a component of total water potential (pw) associated with cellular expansion and plant structural maintenance. In this paper, leaf and fruit pp of passion fruit were monitored using the Wiltmeter® and Turgormeter, respectively. Results are discussed considering environmental variations in savannas of Piauí, Brazil. A completely randomized factorial design was used with three measurement times a day (6, 13 and 16 h), in 3 periods of the year (mean relative humidity varying from 33 to 84%) and 18 replicates. Fruit pp was evaluated on the day of harvest and during post-harvest period (6, 12 and 18 days after harvest). The measurements in different times of the year affected the leaf pp. The lowest pp values were observed when relative air humidity (RH) dropped to 33% (high vapor pressure deficit). Higher leaf pp values were found at 6 h and when RH was 66%. The highest fruit pp values occurred on the day of harvest, with a reduction of 74% associated with a decrease of 23% in fruit weight after 18 days. The Wiltmeter® and Turgormeter are efficient at measuring and monitoring leaf/fruit turgor pressure and could be valuable alternative for post-harvest and plant water relation studies.

Key words: Passiflora, Water potential, Vapour pressure deficit

Introduction

The total water potential (pw) is considered as the sum of turgor (pp) and osmotic potential (ps), while other components like gravitational and electric potentials are negligible (Kramer 1988, Kramer and Boyer 1995). Its greatness is influenced by the interaction with soil and atmosphere, and the existence of potential difference is taken as the cause of water transport in this system (Nonami and Boyer, 1993).

Many studies on plant water relations have investigated pw and the ps, while pp is estimated presumably as a residue. The pressure probe method proposed by Husken *et al*. (1978) to measure turgor pressure, on the other hand, involves a thorough monitoring through microscope and therefore, has small applicability for ecophysiology studies in the field (Calbo and Ferreira, 2011).

*Corresponding author,
Email: mauricio-antonio.coelho@embrapa.br

The knowledge of pp in plant cells allows one to establish relations between hydration level and growth rate of plant tissues. According to Hsiao and Acevedo (1974), after the cell division when the cell is metabolically prepared to expand, a hydrostatic pressure, turgor pressure is needed for the leaf expansion process. The reduction in this pressure affects morphological and physiological processes like leaf expansion, stomatal opening, photosynthesis and N assimilation (Hsiao 1973; Hsiao *et al*., 1976, Kramer 1983, Turner and Jones 1980).

Information on pp variations may be useful to determine the elasticity of cell walls (Calbo and Ferreira, 2011). Many researchers report in some species, as a tolerance mechanism to drying, there is increase in wall elasticity, together with the cellular osmotic adjustment. There are reports that the maintenance or delay of pp reduction is possible, even with the pw reduction (Saliendra and Meinzer, 1991). Studies involving water relations of passion fruit specially pp are rare, although the plant has high sensitivity to even mild soil moisture stress that can severely limit vegetative growth and potential yields (Menzel *et al*., 1986). At field conditions, the excess irrigation also reduces the plant productivity when cultivated in an Ultisol (Sousa *et al*., 2003).

Given the importance of the pp component in plant water relations and current low availability of equipment for its monitoring, this study aimed to evaluate the variations of pp in leaves and fruits of passion fruit plants, at different times of the day and periods of the year, using Wiltmeter® and Turgormeter, verifying the consistency and the applicability of the results.

Materials and Methods

Characterization of experimental area and environmental monitoring

The experiment was carried out at the experimental area of the Federal Institute of Education, Science and Technology of Piauí-IFPI, located in the Cerrado biome, Uruçuí-PI, Brazil, in an orchard of yellow passion fruit (*Passiflora edulis* Sims f. *flavicarpa* Deg.) installed in February, 2012. The experimental area is 600 m^2 with plant spacing of 4x3 m; plants were conducted with vertical espalier with 1 wire at 2 m from the soil surface.

The plants were irrigated only during the dry period of the year, applying 10 L $plant^{-1}$ three times a week. At the time of pp determination, soil water content was measured through gravimetry in 0-0.25 m layer, 0.25 m distant from the stem. Environmental conditions were monitored through meteorological data of temperature and relative air humidity, obtained from the National Institute of Meteorology–INMET, located in the city of Uruçuí-PI, Brazil, and were used to estimate vapor pressure deficit (VPD), according to the following equations:

$$VPD = e_a - e_s \qquad \text{...(1)}$$

$$e_a = \frac{RH \times e_s}{100} \qquad \text{...(2)}$$

$$e_s = 0.6108^{\frac{17.3 \times t}{237.3+t}} \qquad \text{...(3)}$$

Where VPD is vapor pressure deficit, e_a is actual vapor pressure, e_s is saturated vapor pressure, RH is relative air humidity and t is the temperature.

Turgor potential (pp) determination in leaves

Turgor potential (pp) in the leaves was estimated using the equipment Wiltmeter® (Fig. 1), developed by Embrapa Instrumentation, based on the method of applanation of plant organs as its operating principle. For the pressure reading, the fast method was used, which is described by Calbo *et al*. (2010), Spricigo *et al*. (2009, 2012), Silva *et al*. (2012). The evaluated leaf was pressed by a flexible membrane against a porous applanation plate until the deformation became equal to the cellular turgor pressure and obstructed the air passage, supplied by a pressure gradient of 6.5 kPa, condition in which the pressure was recorded at the device's manometer.

The experimental design was completely randomized with a 3x3 factorial (3 treatments, 3 evaluation periods and 18 replicates). Experimental sample comprised of 3 physiologically mature and totally expanded

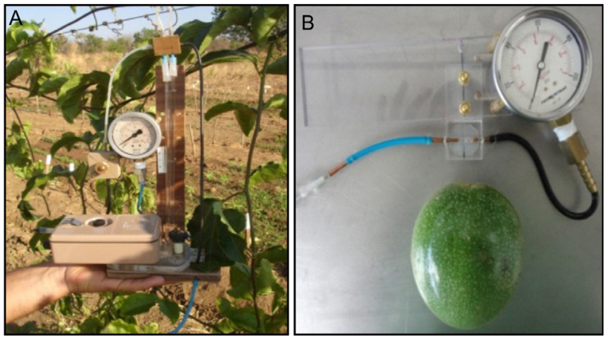

Fig. 1. Turgor potential meter for leaves (A – Wiltmeter®) and fruits (B–Open portable Turgormeter)

leaves plant^{-1}, selected from different tertiary branches. Turgor potential at 6, 13 and 16 h were determined. These treatments were evaluated in three periods with daily average relative air humidity of 33, 66 and 84%.

Turgor potential (pp) determination in fruits

Turgor potential (pp) in fruits was determined using the open, potable Turgormeter (Fig. 1), developed by CNPDIA (Calbo *et al*., 2011, Aroca *et al*., 2013). The equipment's applanation plate was placed in the fruit equatorial zone, avoiding sampling in areas with either mechanical or pathological injuries. The measurement started by pressing the turgormeter on the fruit, forming a flat elliptical area with diameter <4 mm. An external pressure was applied using a syringe with water attached to the equipment, which was enough to applanate cells and drain out the water through the lateral membrane of the equipment. At this moment, the pressure was read in the manometer, being it equivalent to the fruit pp.

The analyzed fruits were harvested on March 1, 2013, following the standardization for the size and color of the green peel. The completely randomized design was used, with 4 treatments and 6 replicates. Evaluation periods after harvest were: T1 – 1st day (harvest); T2 – 6th day; T3 – 12th day; and T4 – 18th day. The experimental plot consisted of five replicates, 30 fruits analyzed per treatment. The maximum fruit weight at the time of the harvest was considered and the percentage of weight reduction was determined. During analyses, fruits remained on the lab bench, with an average temperature of 25 ºC ± 3.

Leaf and fruit p_P data were subjected to analysis of variance and Tukey test at 5% of probability. Regression and correlation analysis were performed, between leaf p_P and air VPD data, as well as for the fruit p_P and percentage of weight reduction.

Results and Discussion

On the days of leaf p_P determination (August 30, 2012; February 22 and March 1, 2013), the daily average temperetures were 29, 27 and 25 °C and relative air humidity (RH) values were 33, 66 and 84%, respectively. These differences affected the VPD, of which daily average values were 2.9, 1.4 and 0.5 hPa, respectively (Fig. 2 A, B & C). Average air temperatures were within the optimum range for the plants. Passion fruit plants develop well in a thermic amplitude between 20 and 32 ºC; with the optimal interval being between 26 and 27 ºC (Piza Júnior, 1991). As for soil water content, differences were observed between the evaluated periods with averages of 0.10; 0.07 and 0.12 g g^{-1}, for the periods 1, 2 and 3, respectively (Fig. 2 D).

There were differences ($p<0.05$) in leaf p_P as a function of the evaluation periods (Fig. 3). The lowest leaf p_P values were registered on August 30 of 2012 and the highest ones on February 22 of 2013, with an increase in daily means of 96% between the periods. Intermediate values were observed on March 1 of 2013. The effect of environment on plant water balance is essential for the leaf p_P variation (Taiz and Zeiger, 2006), corroborates with our observation that there was no correlation between this variable and soil water content. The daily average values of RH of 66% and temperature of 27 ºC, with a VPD of 1.4 kPa, were ideal to the maintenance of a greater leaf turgescence in passion fruit plants. It is possible that VPD values, to a greater or lesser extent, have reduced leaf p_P, due to a smaller transpiration, either through water loss control or lower atmospheric demand.

There were also differences in p_P ($p<0.05$) for all the measurement times (Fig. 4). It was

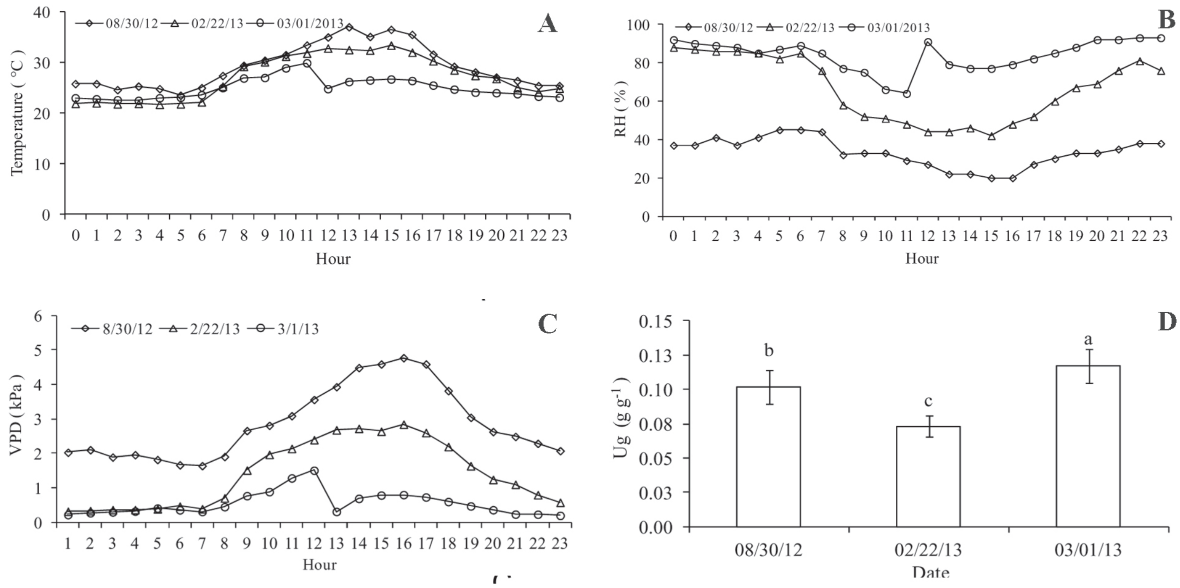

Fig. 2. A - Air temperature (°C); B – Relative air humidity (RH); C – Daily vapor pressure deficit (VPD); and D – soil water content for three periods of leaf turgor potential evaluation. Means represented by different letters statistically differ by Tukey test at 5% of probability

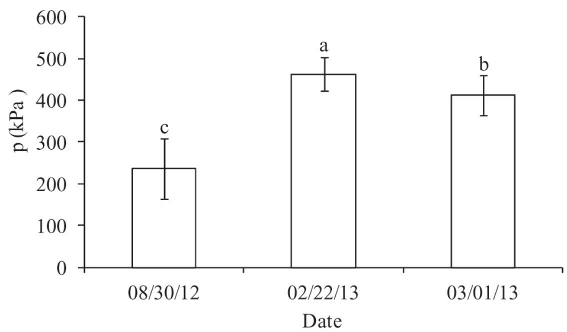

Fig. 3. Mean value of leaf turgor potential in passion fruit plants determined in different evaluation periods. Means represented by different letters differ statistically by Tukey test at 5% of probability

observed that the highest leaf p_P values occurred at 6 h, compared to 13 and 16h. In the first and second assessments, there were no statistical difference between the readings of 13 and 16 h, clearly indicating plant adjustment to atmospheric condition, because of higher values of air temperature and VPD in the first (35-36 °C, VPD 3.9-4.7 kPa, at 13 and 16h) and second evaluation (33-32 °C, VPD 2.6-2.8 kPa, at 13 and 16 h). When the assessment occurred in a more humid atmosphere and lower temperature (25-26 °C, VPD 0.3-0.8 kPa, at 13 and 16 h), lower potentials were observed (Fig. 4).

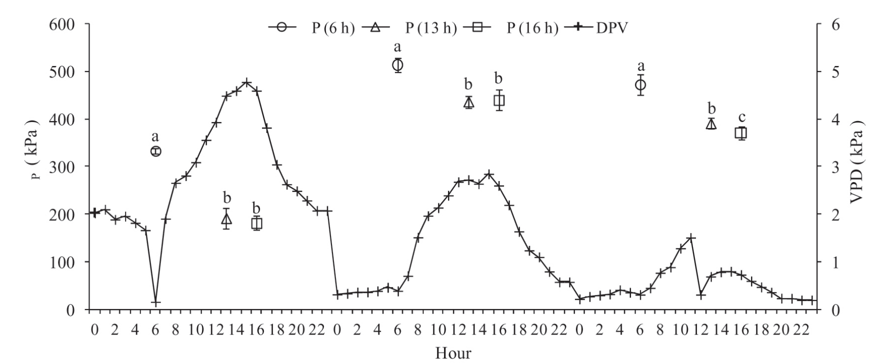

Fig. 4. Leaf turgor potential in passion fruit plants at 6, 13 and 16 h, for 30th Aug 2012, 22 Feb 2013 and 1 Mar 2013, with the respective daily vapor pressure deficit (VPD). Means followed by the same letters do not differ by Tukey test at 5% of probability. Bars represent mean standard deviation

This behavior can also be explained through leaf transpiration (not monitored in this study), and agrees with Shackel (1987), which reported that high VPD and transpiration values reduced the plant turgor potential in hourly scale. As observed in this study, the highest p_P at 6 h coincided with a still low VPD, and in the measurements at 13 and 16 h, the VPD reached the highest values of the day, influencing the p_P reduction. This shows that p_P changes due to the variation in atmospheric demand in yearly and daily periods, in which plant redistributes the water absorbed during the day to all of its tissues during night, reaching its maximum turgescence at night. Since early morning, water losses begin by transpiration, making leaves reduce turgescence at the time of more intense solar radiation until the end of the day (Taiz and Zeiger, 2006).

Regression analysis adjusted to a linear model for the p_P and VPD values with determination coefficient (R^2) of 0.75. There was high correlation between these variables, with Pearson's correlation coefficient of -0.86 (Fig. 5A). With the increase in VPD from 0.4 to 4.6 kPa, p_P reduced from 512 to 181 kPa. This shows that when soil water content is above the critical limit, it is the atmospheric water demand (VPD in this study) that regulates the variation in turgor potential. Regarding the fruit pp, maximum values were registered on the first day, right after harvesting. Means were significantly different ($p<0.5$) with values in decreasing order between the first and the 18th day after the harvest (Fig. 5B), thus turgor reduction occurred during fruit ripening. From the 12th day after the harvest, a threshold turgescence was observed, in which the external appearance of the peel, like smooth surface and brightness, started decreasing. This can reduce the market value. We also observed that in the last two evaluations, there were losses of 14 to 20%, respectively with the emergence of fungi on the outside of the fruit.

There was strong correlation between pp and fruit weight (Fig. 6). Fruit weight reduced by 26.5% between harvest and the 18th day, which led to a variation in pp of approximately 74%

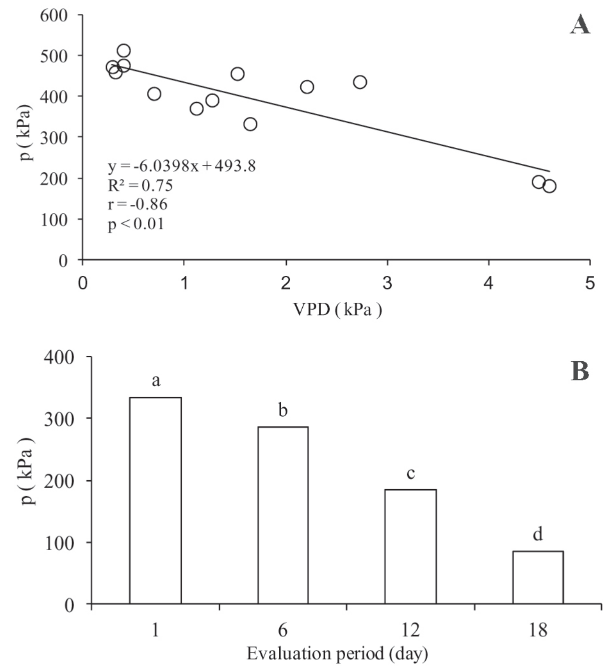

Fig. 5. A - Relation between leaf turgor potential (pp) of passion fruit plants and vapor pressure deficit (VPD). B - Turgor potential (pp) in fruits of passion fruit in different post-harvesting periods. Means followed by the same letter do not differ by Tukey test at 5% of probability

(values ranging from 334 to 87 kPa). Johnson *et al*. (1992) observed that the fast growth of tomatoes is related to the increase of solution flow to its interior due to the existence of water potential gradient and when the opposite occurs, the fruit may have its weight and its size reduced.

It is possible to have leaf pp lower than fruit pp, as observed on August 30 of 2012 (Fig. 4).

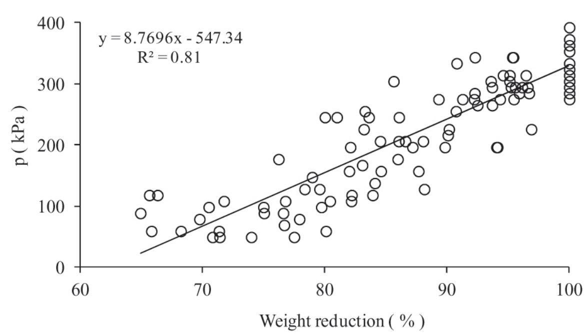

Fig. 6. Relation between turgor potential (pp) in fruits of passion fruit and their percentage of weight reduction during eighteen days

During this period, the potential gradient between these organs may hamper fruit growth. There have been reports claiming that leaf pp reduction is usually followed by reduction in osmotic potential (ps) and total potential (pw) (Saliendra and Meinzer, 1991), which might also influence the changes in these components in fruits (Yakushiji *et al*., 1996).

Conclusions

We have seen that the vapor pressure deficit (VPD) in the air influenced daily variation of leaf p_p of passion fruit plants, which was sharply reduced when VPD is >4 kPa. The fruit p_p was the maximum on the day of harvest and decreased by 74% on 18th day after harvest, which resulted in reduction of initial weight. The equipments Wiltmeter® and Turgormeter were efficient at determining and monitoring pp, hence could be recommended for water relation studies in fruit plants.

References

Aroca, R.V., Gomes, R.B., Dantas, R.R., Calbo, A.G. and Gonçalves, L.M.G. 2013. A wearable mobile sensor platform to assist fruit grading. *Sensors* **13**: 6109-6140.

Calbo, A.G. and Ferreira, M.D. 2011. Evaluation of hydration indexes in kale leaves. *Braz. J. Plant Physiol.* **23**: 141-149.

Calbo, A.G.A., Ferreira, M.D. and Pessoa, J.D.C. 2010. Leaf lamina compression method for estimating turgor pressure. *Hortscience* **45**: 418-423.

Calbo, A.G., Pessoa, J.D.C., Ferreira, M.D. and Marouelli, W.A. 2011. Device measuring pressure and flow control. *Patent BR* 1107358-6. (Portuguese)

Hsiao T.C. 1973. Plant responses to water stress. *Annu. Rev. Plant Physiol.* **24**: 519-570.

Hsiao, T.C. and Acevedo, E. 1974. Plant responses to water deficits, water use efficiency, and drought resistance. *Ag. Meteorol.* **14**: 59-84.

Hsiao, T.C., Acervedo, F., Fereres, E. and Henderson, D.W. 1976. Stress metabolism, water stress, growth, and osmotic adjustment. *Phil. Trans. Royal Soc. London Ser. B.* **273**: 479-500.

Husken, D., Steudle, E. and Zimmermann, U. 1978. Pressure probe technique for measuring water relations of cells in higher plants. *Plant Physiol.* **61**: 158-163.

Johnson, R.W., Dixon, M.A. and Lee, D.R. 1992. Water relations of the tomato during fruit growth. *Plant Cell Environ*. **15**: 947-953.

Kramer, P.J. 1983. Water deficits and plant growth. In: Kramer P. J. (ed.): Water Relations of Plants. Academic Press, New York, 342-415.

Kramer, P.J. 1988. Changing concepts regarding plant water relations. *Plant Cell Environ*. **11**: 565-568.

Kramer, P.J. and Boyer, J.S. 1995. Water relations of plants and soils. Academic Press, New York.

Menzel, C.M., Simpson, D.R. and Dowling A.J. 1986. Water relations in passion fruit: Effect of moisture stress on growth, flowering and nutrient uptake. *Scientia Horticulturae* **29**: 239-249.

Nonami, H. and Boyer J.S. 1993. Origin of growth-induced water potential: Solute concentration is low in apoplast of enlarging tissues. *Plant Physiol.* **83**: 596-601.

Piza Júnior, C.T. 1991. The culture of passion. Campinas, CATI, 71. (Portuguese)

Saliendra, N.Z. and Meinzer, F.C. 1991. Symplastic volume, turgor, stomatal condutance and growth in relation to osmotic and elastic adjustment in droughted sugarcane. *J. Expt. Bot*. **42**: 1251-1259.

Silva, M.R., Silva, S. de O., Silveira, D.G., Calbo, A.G., Sampaio, A.H.R. and Santos-Serejo, J.A. 2012. Estimate of banana ploidy with evaluation of turgor leaf using the Wiltmeter®. In: XXII Brazilian Congress of Tropical Fruits, Bento Gonçalves, RS. (Portuguese).

Spricigo, P.C., Bertini, V.A., Ferreira, M.D., Calbo, A.G. and Tavares, M. 2009. Evaluation of post-harvest hydroponic lettuce, depending on the amount of roots, using equipment Wiltmeter®. *Horticultura Brasileira* 27: 3790-3796. (Portuguese).

Spricigo, P.C., Calbo, A.G.A. and Ferreira, M.D. 2012. Post-harvest turgidity of chrysanthemums using the equipment Wiltmeter®. *Ciência Rural* **42**: 255-260 (Portuguese).

Shackel K.A. 1987. Direct measurement of turgor and osmotic potential in individual epidermal cells. *Plant Physio.* **83**: 719-722.

Sousa, V.F., Folegatti, M.V., Frizzone, J.A., Correa, R.A. and Eloi, W.M. 2003. Produtividade do maracujazeiro amarelo sob diferentes níveis de irrigação e doses de potássio via fertirrigação. *Pesquisa Agropecuária Brasileira, Brasília* **38**: 497-504.

Taiz, L. and Zeiger, E. 2006. Plant Physiology 3ª edição. Massachusetts. Ed. Sinauer Associates, Inc., 792.

Turner, N.C. and Jones, M.M. 1980. Turgor maintenance by osmotic adjustment: A review and evaluation, In: Turner N.C., Kramer P.J. (eds.): Adaptation of plants to water and higher temperature stress. Wiley-Interscience, New York, pp 155-172.

Yakushiji, H., Nomami, H., Fukuyama, T., Ono, S., Takagi, N. and Hashimoto, Y. 1996. Sugar accumulation enhanced by osmoregulation in Satsuma mandarin fruit. *J. Amer. Soc. Hort. Sci.* **121**: 466-472.

Received: 16 May 2014; Accepted: 23 June 2014