Response of 'Rhode Red Valencia' orange (*Citrus sinensis*) to microirrigation in Adjuntas, Puerto Rico[1,2]

Elvin Román-Paoli[3], Rebecca Tirado-Corbalá[4] and Félix Román-Pérez[5]

J. Agric. Univ. P.R. 104(2):129-138 (2020)

ABSTRACT

Orange [*Citrus sinensis* (L.) Osb.] is a crop of great economic importance in the world and in Puerto Rico despite the negative impact caused by the presence of Huanglongbing disease. To maintain profitability, growers must optimize management practices. Important practices include proper use of supplemental irrigation, using improved rootstocks and cultivars, and effective disease control. To assess the response of 'Rhode Red Valencia' trees to supplemental microirrigation, an experiment was conducted in Adjuntas, Puerto Rico, at an orchard originally established in 2007 under microirrigation. From 2011 to 2013, the adult orange trees were submitted to three treatments. In two of the treatments, microirrigation was scheduled using tensiometers at soil water tension between 10 and 15 kPa and between 30 and 35 kPa. A third treatment, without microirrigation (rainfed), was included as a check. Water stress periods were evident from January through June during the years 2008 to 2014. Microirrigation treatments did not have a significant effect on number of fruits, fruit weight and canopy volume during 2011 to 2013. Hence, under the conditions of this experiment, supplemental irrigation was not necessary for an adequate production of 'Rhode Red Valencia'.

Key words: oranges, yield, soil-water tension, canopy volume

RESUMEN

Respuesta de la china (*Citrus sinensis*) cv. 'Rhode Red Valencia' a microrriego en Adjuntas, Puerto Rico

La china [*Citrus sinensis* (L.) Osb.] es un cultivo de gran importancia económica en el mundo y en Puerto Rico a pesar del impacto negativo causado por la presencia de la enfermedad Huanglongbing. Para mantener

[1]Manuscript submitted to Editorial Board 4 June 2020.

[2]The authors thank Jennifer Pagán, Leonides Román and Edwin Monroig for helping to conduct field research and data entry. This research was funded by USDA-National Institute of Food and Agriculture (W-3128:H-402).

[3]Professor, Department of Agroenvironmental Sciences, College of Agricultural Sciences, University of Puerto Rico, Mayagüez Campus. Mayagüez, PR. 00681. Author for correspondence Email: elvin.roman@upr.edu

[4]Associate Researcher, Department of Agroenvironmental Sciences, College of Agricultural Sciences, University of Puerto Rico, Mayagüez Campus. Mayagüez, PR. 00681.

[5]Retired Professor, Department of Agroenvironmental Sciences, College of Agricultural Sciences, University of Puerto Rico, Isabela Substation. Isabela, PR. 00662.

este cultivo rentable, los productores deben optimizar las prácticas de manejo. Entre las prácticas se encuentra el uso adecuado de riego suplementario, uso de patrones y cultivares mejorados y control efectivo de enfermedades. Para evaluar la respuesta del cv. 'Rhode Red Valencia' a microrriego suplementario, se estableció un experimento en Adjuntas, Puerto Rico, en un huerto que se había establecido en 2007 bajo microrriego. Del 2011 al 2013 los árboles de china se sometieron a tres tratamientos. En dos de los tratamientos, el microrriego se programó utilizando tensiómetros a una tensión hídrica entre 10 y 15 kPa y entre 30 y 35 kPa. Se incluyó un tercer tratamiento sin microrriego como testigo. Se evaluó el crecimiento y productividad de los árboles durante los años 2011 al 2013. El estrés hídrico fue evidente desde enero hasta junio durante los años 2008 al 2014. Los tratamientos de microrriego no tuvieron un efecto significativo en el número de frutas por árbol, peso de frutas y volumen del dosel foliar durante los años 2011 al 2013. Por consiguiente, bajo las condiciones de este experimento, el uso de riego suplementario no fue necesario para una producción adecuada de la china 'Rhode Red Valencia' .

Palabras clave: china, rendimiento, tensión hídrica en el suelo, volumen del dosel foliar

INTRODUCTION

Citrus trees can easily fall into water stress, especially during active growth. When a tree loses water faster than the soil can provide it, the tree becomes stressed due to drought and wind. Excessive irrigation or rain can also cause stress. This stress may happen because lack of oxygen in the tree root system increases hydrogen ions that can damage the root and therefore impede the absorption of water from the soil (Parsons and Wheaton, 1995). Several days of water stress can reduce stem and leaf enlargement and result in a lighter green color of the leaf. Longer periods of stress can cause leaves to dry, starting from the apex, and the abscission of flowers and fruits. Exposure of trees to stress during several years can reduce their size while reducing their long-term performance potential.

The value of production and the cost of irrigation determines if citrus tree irrigation is justified (Schumann et al., 2003). If fruit prices are high, accurate microirrigation applications can increase yield and income. Having a notion of the amount of water retained in the soil is very important in deciding when to irrigate. There are several instruments that may be used to measure soil moisture to schedule microirrigation (Morgan et al., 2020). Some instruments measure soil moisture content, others measure the tension with which that moisture is retained in the soil. As soil moisture decreases, the soil tension increases. Measuring soil water tension provides an idea of the amount of water in the soil, allowing us to determine the amount of water needed to irrigate the crop. Irrigation amount depends on many factors such as age, type of citrus, tree size, climate and soil. As trees undergo the processes of evapotranspiration, soil moisture is reduced since it is retained with greater force (greater soil water tension). The tensiometer is an instrument that can be used to estimate the amount of water in the soil, measuring soil water tension (Goyal, 2013). This instrument consists of a tube filled with water, sealed with a ceramic tip on one end, and on the other a vacuum meter that records the tension of the water in the soil. As the soil dries the water moves from the tube, through the ceramic tip into the ground. This creates a vacuum in the tube that is recorded by the meter. When irrigated, the water returns to the tensiometer, registering on the meter (Morgan et al., 2020; Shirgure, 2013).

The largest citrus production area in Puerto Rico is the humid central region (Lares, Adjuntas, Utuado). In Puerto Rico, total gross income from citrus at farm gate increased from $5.9 to $8.6 million from 2013/14 to 2016/17 despite yield reductions caused by Huanglongbing (HLB) disease (Department of Agriculture of Puerto Rico, 2019). This disease has significantly destroyed citrus production globally (Bove, 2006; Ghosh et al., 2013). Citrus trees infected with HLB show characteristic leaf mottling, chlorosis, deformed fruit, low yields, branch dieback, and tree death (Marroquín-Guzmán and Estévez de Jensen, 2013). The causal agent is the bacterium Candidatus *Liberibacter* asiaticus, vectored by the Asian citrus psyllid (ACP), *Diaphorina citri* Kuwayama (Hemiptera: Liviidae) (Jenkins et al., 2015).

Although rainfall is high and fairly well distributed in the humid central region throughout the year, there is the possibility of an occurrence of approximately three months of drought that would reduce growth and therefore production. The application of supplemental microirrigation is suitable to prevent tree stress. To be effective, the application of irrigation has to be systematic and at adequate levels and frequency since water stress may cause citrus bud dormancy, but also induce flowering (Guardiola, 1984).

For some farmers investing in a drip irrigation system is not economically justified since the rainfall registered in the citrus production region satisfies water requirements. An experiment was conducted from 2011 to 2013 in Adjuntas, Puerto Rico, to determine the effectiveness of using tensiometers to schedule microirrigation in adult orange trees (cv. 'Rhode Red Valencia' grafted onto 'Swingle citrumelo' rootstock). 'Rhode Red Valencia', an orange cultivar found in 1955 in Florida, U.S.A., is a tall and vigorous tree that produces sweeter fruit than traditional Valencia cultivars (Huallparimachi-Suárez, 2009). Swingle citrumelo is a citrus rootstock released by USDA-ARS in 1974. It is an interspecific hybrid (*Poncirus* x *Citrus*) tolerant to several diseases. In 2013, the Agricultural Experiment Station (AES) of the University of Puerto Rico (UPR) recommended the use of 'Swingle citrumelo' as a rootstock after having studied the cultivar for several years and in several locations (Román-Pérez and González, 2013).

MATERIALS AND METHODS

Location description and orchard management

The study was conducted at Adjuntas-AES-UPR (18°10'21"N and 66°47'45"W) from 2011 to 2013. The soil at the experimental site is classified as Alonso clay [Very-fine, parasesquic, isohyperthermic Typic Humudepts (Muñoz et al., 2018)]. Long-term data indicate a mean annual rainfall of 2,270 mm, class A pan evaporation of 1,280 mm and an average annual temperature of 22.3° C (Chao de Báez and Goyal, 1990). Citrus cv. 'Rhode Red Valencia' grafted onto Swingle rootstock was planted on 4 April 2007 at a distance of 4.5 m x 6.0 m. From 2007 to 2011 the orchard was under microirrigation.

During the first two years of the experiment, irrigation was applied with two button drippers (7.57 L/h) per tree installed on polytubing lines with a diameter of 1.3 cm. After two years, button drippers were replaced by one micro-sprinkler with a discharge capacity of 29.07 L/h installed on plastic stakes under the canopy and raised about 20 cm from the soil surface. The actual water discharge was measured in five micro-sprinklers selected at random, at a system pressure of 138 kPa (20 PSI) at water intake.

Each tree received 0.45 kg of 12-6-6 controlled release fertilizer four times (every three months). Even though during 2011, HLB was reported in a 'Tahiti' lime orchard at the UPR Adjuntas-AES, no symptoms were detected at the 'Rhode Red Valencia' orchard (Marroquín-Guzmán and Estévez de Jensen, 2011). All other management practices were performed according to AES recommendations (Agricultural Experiment Station, 1987).

Treatments and Microirrigation Scheduling by Tensiometers

Microirrigation was scheduled using tensiometers. Orange trees were submitted to three treatments. In two of the treatments, trees were micro irrigated when tensiometers reached a low depletion level (10 to 15 kPa) and a high depletion level (30 to 35 kPa). A third treatment, without microirrigation (rainfed), was included as a check. Irrigation was applied based on average tensiometer readings taken two times per week per plot. These instruments were installed at 30-cm and 45-cm depths and one meter from the main stem. Soil water tension at both depths was averaged to obtain an average soil water tension per plot (consisting of three orange trees). To avoid continuous water replenishment, tensiometers were not installed in trees without microirrigation treatments because soil water tension often gets above 80 kPa producing a collapse of the water column inside the instrument causing erroneous readings. Microirrigation treatments were applied as needed, according to averaged tensiometers readings. Rainfall data was taken daily from a weather station located at the AES.

Experimental Design and Data Analysis

The experimental design was a randomized complete block design with four replications. Annual yield and growth data were statistically analyzed by analysis of variance and mean separation using Fisher's LSD at the 5% probability level (SAS Institute, 2013).

Variables Measured

The response variables measured were tree canopy volume, fruit number, fruit weight, soil water tension, and number of irrigation events. Tree canopy volume (CV) was estimated by using the same approach as Fallahi and Mousavi (1991), Román et al. (1997), Tirado-Corbalá et al. (2020) and Turrell (1961) by using the following equation:

CV= (0.524) x [tree height (m)] x [tree diameter square (m^2)]

where tree height was measured from soil surface to the tallest branch; and tree diameter was measured by averaging the canopy width within-row and across-row. Both variables, tree diameter and height were measured using a telescoping-measuring pole. Yield efficiency was calculated using the total average fruit number divided by CV. Fruit yield variables (i.e., number and weight) were totaled for each year. Fruits were harvested from January to February during 2011 to 2013.

RESULTS AND DISCUSSION

Microirrigation and water requirements

Soil water tension was recorded from 2012 to 2014 (Figure 1). Most of the time, soil water tension remained lower than 15 kPa (near field capacity) and lower than 35 kPa for the maximum threshold for each microirrigation treatment (Figure 1). However, during winter 2013 and summer 2014, due to a rainfall shortage, orange trees required more microirrigation events to maintain soil tension lower than the maximum threshold for each microirrigation treatment. Figure 2 represents the rainfall recorded at the experimental site. For instance, average tensiometers readings for the 10 to 15 kPa treatment (maintaining soil water

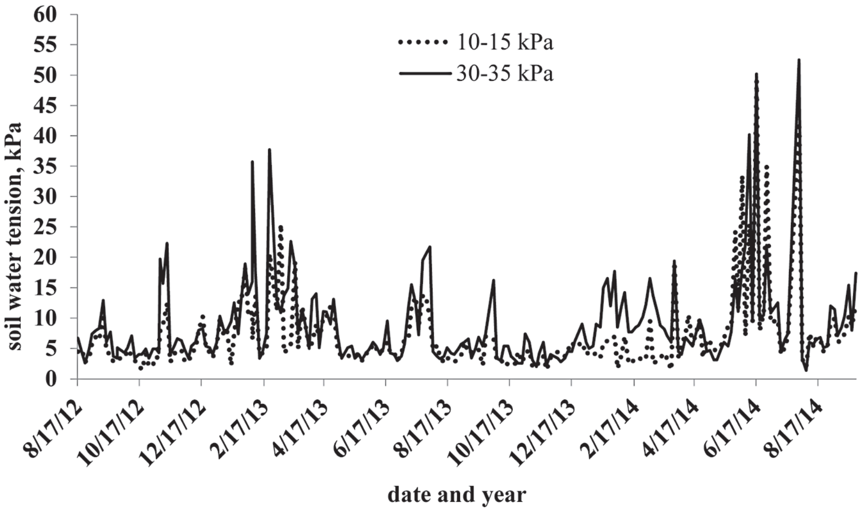

FIGURE 1. Soil tension per microirrigation treatment scheduled by tensiometers in an Alonso clay (in 'Rhode Red Valencia' grafted onto 'Swingle' rootstock) at Adjuntas, Puerto Rico.

content near field capacity) exceeded 11 times the 15 kPa soil water tension threshold requiring microirrigation to lower the tension below 15 kPa. For the 30 to 35 kPa treatment (allowing the soil to dry, but without reaching permanent wilting point) readings exceeded the threshold on

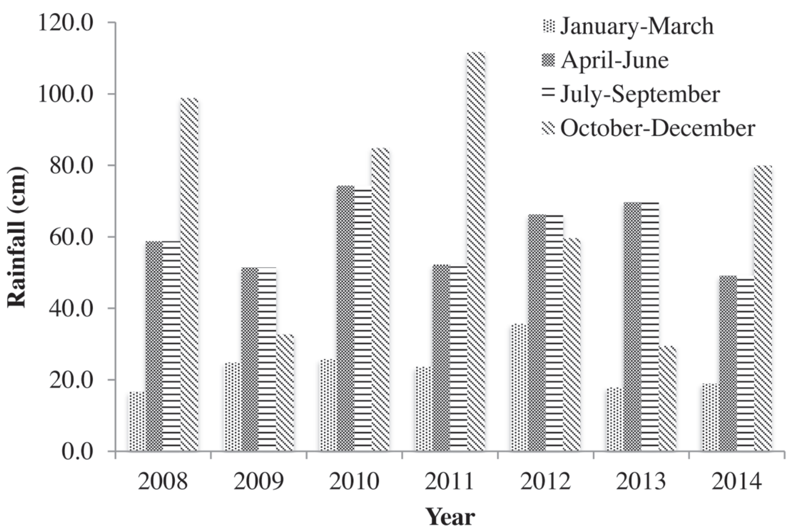

FIGURE 2. Rainfall registered during three-month periods from 2008 to 2014 at Adjuntas, Puerto Rico.

only three occasions. Rainfall pattern at the experimental site was evaluated from 2008 (one year after planting) until 2014, however yield and growth response data was recorded from 2011 to 2013. Data registered during those seven years indicate that January to March was the driest three-month period with a rainfall variation between 16.7 and 35.7 cm; while the period of greatest rainfall is July to September with an average rainfall of 71 cm. An estimate of citrus water requirements per growing cycle (which in a tropical climate, such as Puerto Rico, is considered the entire year) is 90 to 120 cm of water (FAO, 2020). According to calculations, registered rainfall varied between 1.8 and 4.0 cm per day during the driest period (January to March) and water requirement estimates varied between 0.24 and 0.32 cm per day. Therefore, most of the time rainfall surpassed tree water requirements. Tensiometers readings were reflecting a low need for irrigation events required by trees under the climatic conditions registered at Adjuntas, Puerto Rico.

Fruit Production

No significant differences were detected in fruit number and weight or tree canopy volume, during 2011-2013 (Figures 3A, B and C). In 2011, the number of fruits per tree varied from 45 to 90. During 2012 trees showed a considerable increase in fruit number producing close to 120 fruits per tree under the three treatments. A reduction observed during 2013 could be explained by the biennial production of trees. Estimated average fruit weight over three years varied from 247 to 295 g for all irrigation treatments (data not shown). Huallparimachi-Suárez, (2009) reported an average fruit weight of 236.2 g for 'Rhode Red Valencia' grafted onto 'Swingle' at Adjuntas. No other yield data has been published on 'Rhode Red Valencia' grafted onto 'Swingle' in an Alonso clay in Puerto Rico. However, Román-Pérez et al. (2011) reported a six-year average of 136 fruits per tree of sweet orange cv. 'Hamlin' planted at Adjuntas in an Alonso clay. 'Rhode Red Valencia', grafted onto 'Cleopatra', was not affected by microirrigation treatments (without microirrigation, 10 to 15 kPa, and 30 to 35 kPa) scheduled by tensiometers in a Coto clay at Isabela, Puerto Rico (Román and Román, 2006).

Tree Growth

The microirrigation treatments did not affect sweet orange 'Rhode Red Valencia' growth expressed by canopy volume during 2011 and 2013 (Figure 3C). Unfortunately, 2012 data is unavailable. Average canopy volume varied from 2 to 10 cubic meter per tree for 4- to 6-year-old trees. The average canopy volume of 10-year-old trees of six Valencia clones was 5.75 cubic meters per tree evaluated in an Alonso clay without irrigation (Cedeño-Maldonado et al., 1994). Meanwhile, sweet

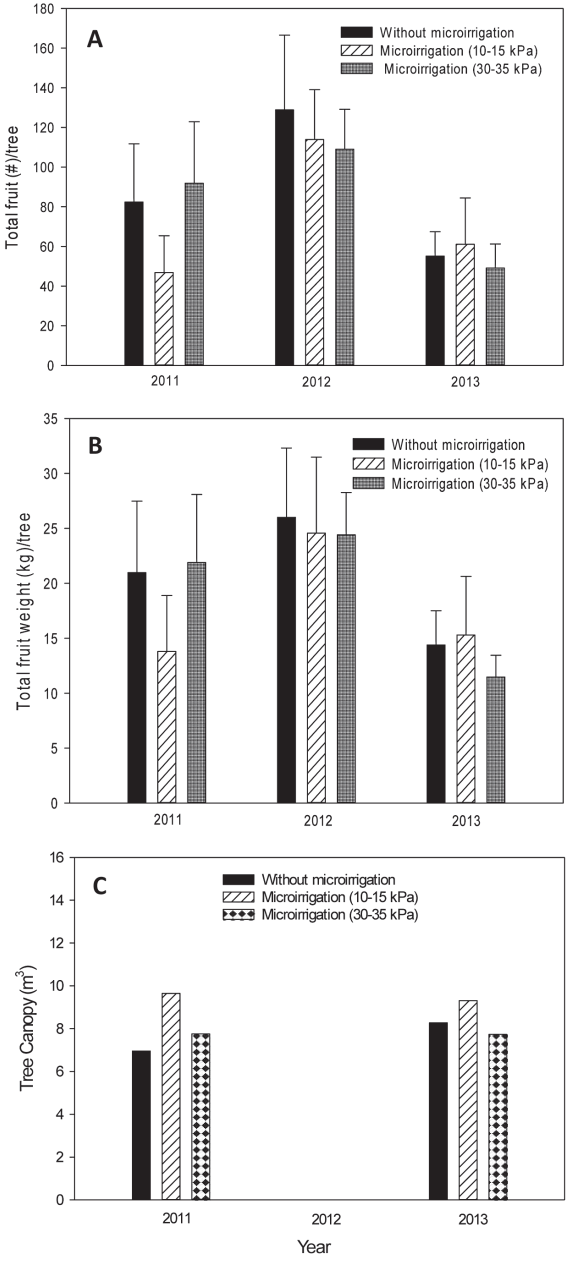

FIGURE 3. Effect of three microirrigation levels on A) total fruit number per tree; B) total fruit weight per tree; and C) tree canopy volume of 'Rhode Red Valencia' grafted on 'Swingle citrumelo' rootstock growing in an Alonso clay over three years in Adjuntas, Puerto Rico.

orange cv. 'Hamlin' grafted onto 'Swingle' showed an average canopy volume of 18.02 cubic meters per tree for five-year-old irrigated trees (Román-Pérez and González, 2013). Tirado-Corbalá et al. (2020) reported an average canopy volume of 7.74 and 8.01 cubic meter per tree for cv. 'Marr's Early' and 'Pera', respectively. Those cultivars were evaluated under microirrigation in the same soil and location, but grafted onto 'Carrizo', HRS 802 and HRS 812 rootstocks.

Since its establishment in 2007, the citrus orchard was under microirrigation, reducing water stress when young trees are more sensitive. At the beginning of the experiment in 2011, the orchard was already well established when supplemental microirrigation treatments and the rainfed treatment were implemented. From 2007 to the initiation of the experiment, there were no rainfed trees; therefore, there is no data indicating the response of 'Rhode Red Valencia' to rainfed treatment since planted.

CONCLUSION

Microirrigation treatments scheduled on tensiometers readings did not affect oranges' growth and yield when compared with rainfed trees (without microirrigation). Even though rainfall was relatively well distributed and abundant for most of the experimental period, we presented evidence showing that orange trees underwent water stress for short periods of time during the dry season.

In this study, the benefits of microirrigation on the six-year-old 'Rhode Red Valencia' trees were not apparent. Nevertheless, if a farmer decides to establish a microirrigation system to provide irrigation water during dry periods of the year, the system may also be used to apply soluble fertilizers and pesticides, thus reducing management costs, balancing out the initial investment for the establishment of the irrigation system.

Tensiometers are useful for scheduling microirrigation but require some maintenance. When used, microirrigation water must be applied as to maintain soil water tension lower than 35 kPa.

LITERATURE CITED

Agricultural Experiment Station, 1987. Conjunto Tecnológico para la Producción de Cítricas. Publicación 113 (Edición Revisada). Universidad de Puerto Rico, San Juan, PR.

Bove, J.M., 2006. Huanglongbing: A destructive, newly-emerging, century-old disease of Citrus. *Plant Pathol. J.* 88 (1): 7-37.

Cedeño-Maldonado, A., A. Pérez-López, E. Boneta and C. J. Torres, 1994. Effect of rootstocks on tree size and yield of six Valencia orange clones. *J. Agric. Univ. P.R.* 78(3-4): 123-129. https://doi.org/10.46429/jaupr.v78i3-4.4280

Chao de Báez, C. and M.R. Goyal, 1990. Class A Pan Evaporation versus Potential Evapotranspiration at seven locations in Puerto Rico. *J. Agric. Univ. P.R.* 74(3): 343-346. https://doi.org/10.46429/jaupr.v74i3.6673

Department of Agriculture of Puerto Rico, 2019. Ingreso Bruto de la Agricultura de Puerto Rico-cifras revisadas 2013/14 y preliminares 2014/15, 2015/16 y 2016/17. Oficina Estadísticas Agrícolas. Gobierno de Puerto Rico, San Juan.

Fallahi, E. and Z. Mousavi, 1991. Performance of Orlando tangelo trees on ten rootstocks in Arizona. *J. Amer. Soc. Hort. Sci.* 116(1): 2-5.

FAO, 2020. Water requirements. http://www.fao.org/land-water/databases-and-software/crop-information/citrus/en/

Ghosh, D., S. Bhose, K. Mukherjee and V.K. Baranwal, 2013. Sequence and evolutionary analysis of ribosomal DNA from Huanglongbing (HLB) isolates of Western India. *Phytoparasitica* 41(1): 295-305.

Goyal, R.M. (Ed), 2013. The Tensiometer: Use, Installation and Maintenance. Management of Drip/Trickle or Micro Irrigation. Apple Academic Press, Inc. ISBN 978-1-926895-12-3.

Guardiola, J.L., 1984. Overview of flower bud induction, flowering and fruit set. http://www.fao.org/land-water/databases-and-software/crop-information/citrus/en/. Departamento de Biología Vegetal. Universidad Politécnica de Valencia, Valencia, Spain.

Huallparimachi-Suárez, M., 2009. Utilización de parámetros de calidad de jugo para determinar tiempo óptimo de cosecha en variedades de naranja 'Hamlin' y 'Rhode Red Valencia'. MS Thesis. College of Agricultural Sciences, Mayagüez Campus, University of Puerto Rico.

Jenkins, D.A., D.G. Hall and R. Goenaga, 2015, *Diaphorina citri* (Hemiptera: Liviidae) abundance in Puerto Rico declines with elevation. *J. Econ. Entomol.* 108: 252–258.

Marroquín-Guzmán, M.R. and C. Estévez de Jensen, 2013. Dissemination of Citrus Greening in Puerto Rico. *J. Agric. Univ. P.R.* 97(3-4): 119-134. https://doi.org/10.46429/jaupr.v97i3-4.2991

Morgan, K.T., L. Zotarelli and M.D. Dukes, 2020. Use of Irrigation Technologies for Citrus Trees in Florida. HORTTECH 20(1): 74-81.

Muñoz, M.A., W.I. Lugo, C. Santiago, M. Matos, S. Ríos and J. Lugo, 2018. Taxonomic classification of the soils of Puerto Rico, 2017. Bulletin 313. Agricultural Experiment Station, College of Agricultural Science, University of Puerto Rico, Mayagüez Campus.

Parsons, L. and T.A. Wheaton, 1995. Citrus Irrigation: Why is it important to you? *Citrus Industry Magazine* April 1995.

Román, F.M., C. Flores and G. Ruiz-Sifre, 1997. Evaluación de doce genotipos de china (*Citrus sinensis*) en dos patrones. *J. Agric. Univ. P.R.* 81(1-2): 79-82. https://doi.org/10.46429/jaupr.v81i1-2.3679

Román-Pérez, F.M. and A. González, 2013. Liberación de los patrones de cítricas 'Swingle Citrumelo', 'Carrizo' y 'HRS 812' para Puerto Rico. *J. Agric. Univ. P.R.* 97(1-2): 101-106. https://doi.org/10.46429/jaupr.v97i1-2.3044

Román-Pérez, F., A. González-Vélez and R. Macchiavelli, 2011. Producción y calidad de la china 'Hamlin' [*Citrus sinensis* (L.) Osb.] en cuatro patrones en tres localidades de Puerto Rico. *J. Agric. Univ. P.R.* 95(1-2): 25-34. https://doi.org/10.46429/jaupr.v95i1-2.2544

Román, E. and F. Román, 2006. Evaluation of soil moisture levels on growth and productivity of young citrus trees. Proceedings of the 42th Annual Meeting. Caribbean Food Crops Society, July 9-15, Carolina, Puerto Rico. Pp 380-386.

SAS Institute, 2013. SAS 9.4 Language reference: Concepts. Cary, NC.

Schumann, A.W., A. Fares, A. Alva and S. Paramasivam, 2003. Response of 'Hamlin' orange to fertilizer source, annual rate and irrigated area. Proc. Fla. State Hort. Soc. 116: 256-260.

Shirgure, P.S., 2013. Research review on irrigation scheduling and water requirement in citrus. *Scientific Journal of Review* 2(4): 113-121.

Tirado-Corbalá, R., A. Segarra-Carmona, M. Matos-Rodríguez, D. Rivera-Ocasio, C. Estévez de Jensen and J. Pagán, 2020. Assessment of two sweet oranges grafted on selected rootstocks in an Inceptisol in Puerto Rico. *Horticulturae* 6(2): 30. doi:10.3390/horticulturae6020030

Turrell, F.M., 1961. Growth of the photosynthetic area of citrus. *Botanical Gazette* 122(4): 284-298.