Production and Quality of *Physalis ixocarpa* Brot. Fruit under Colored Shade Netting

Isidro Morales, Gabino Alberto Martínez-Gutiérrez, and Cirenio Escamirrosa-Tinoco

Instituto Politécnico Nacional (CIIDIR-IPN-Oaxaca), Xoxocotlán, Oaxaca 71230, Mexico

Cinthia Nájera

Centro de Investigación en Biotecnología Agroalimentaria (CIAIMBITAL), Universidad de Almería, Almería, Spain

Tatiana Pagan Loeiro da Cunha-Chiamolera

Faculdade Campo Real, Guarapuava, Paraná 85015-230, Brasil

Miguel Urrestarazu¹

Departamento de Agronomía, Universidad de Almería, Almería, Spain

Additional index words. radiation, protection covers, spectrum, commercial yield, husk tomato

Abstract. The use of colored shade nets is a method to protect plants from direct solar radiation and optimize the light spectra they transmit. The purpose of this work was to evaluate the photosynthetically active radiation (PAR), the photosynthetically active integrated radiation (IPAR), temperature, relative humidity, growth, production, and fruit quality of *Physalis ixocarpa* variety *Tecozautila*, cultivated under nets generating 60% shade in the colors beige, blue, green, red, and black and under a treatment without netting (control group). Different variables were observed: climatic variables, such as radiation, temperature, and relative humidity; growth variables, such as plant height and stem diameter; production variables, such as number, weight, and caliber of the fruit; and quality variables of the fruit, such as pH and total soluble solids. The highest PAR, IPAR, and temperature and lowest relative humidity were obtained in the absence of netting. The white net resulted in the highest PAR and IPAR but no difference in temperature or relative humidity. In addition, an increase in the height, stem diameter, number of branches, and weight, number, and size of the fruit was observed. The white net resulted in the highest yield: 88% higher than in the control group. The pH of the fruit was significantly higher under the white netting, and no differences among the treatments in terms of the content of total soluble solids were found.

In Mexico, the use of shade nets in protected agriculture has increased. In 2010, 9000 ha were cultivated under shade nets, and in 2016, 38,484 ha were cultivated under shade nets (SAGARPA, 2016). This increase was mainly due to the advantages these nets have compared with plastic, acrylic, and glass covers. These advantages are lower cost, increased durability, and versatility in their use and placement (Valera et al., 2014). They have been successfully used worldwide on tomatoes (Ayala-Tafoya et al., 2011; Valera et al., 2014), cherry tomatoes (Márquez-Quiroz et al., 2014), peppers (Ayala-Tafoya et al., 2014), cranberries (Rodríguez and Morales, 2015), and basil (Martínez-Gutiérrez et al., 2016).

The main objective of shade netting is to modify the radiation that reaches the crop in terms of both quantity and quality. Its placement on the crop decreases the amount of light radiation that strikes the plants during the day, and it also reduces the loss of long-wave radiation emitted by the crop during the night (Valera et al., 2014). As a result of these modifications, there is variation in other climatic parameters, such as temperature and the relative humidity of the environment, modifying transpiration, photosynthesis, respiration and other processes in the plants (Shahak and Gussakovsky, 2004; Valera et al., 2014), and decreasing stress to the plants due to biotic and abiotic factors as well as excluding phytopathogenic insects (Ilicì et al., 2014).

Husk tomato (*P. ixocarpa* Brot. ex Hornem.) is a vegetable native to Mesoamerica whose fruit has been used since the pre-Hispanic era in Mexican gastronomy and traditional medicine (Santiaguillo et al., 2012). Currently, nutraceutical, antibacterial, anticancer, and hypoglycemic properties have been found in the plant. These qualities

have caused an increase in demand in Mexico, the United States and Canada (Vargas-Ponce et al., 2015).

In 2015, in Mexico, 43,817 ha were cultivated, with an average yield of 17.34 t·ha⁻¹ under irrigation and 11.73 t·ha⁻¹ under rainfed conditions (SIAP, 2015). These statistics are considered low because of the scarce research on new technologies, such as the use of protection covers for macro tunnels and greenhouses (Martínez-Gutiérrez et al., 2014), fertirrigation, drip irrigation (López-López et al., 2008), and the lack of commercial cultivars (Fischer et al., 2014). Soldevilla-Canales et al. (2002) obtained 83 t·ha⁻¹ with padding and the injection of CO₂ into the soil, whereas Peña-Lomelí et al. (2014) indicated that to produce greenhouse husk tomato, the problem of pollination must first be solved because of its gametophytic self-incompatibility (Jiménez-Durán and Cruz-García, 2011; Santiaguillo-Hernández et al., 2004).

Because of the socioeconomic importance that the fruit of *P. ixocarpa* has acquired and with the purpose of generating information for their protected cultivation, the objective of this work was to evaluate the effects of shade nets of different colors covering wooden structures on the environmental microclimatic variation, growth, yield, and quality of the fruit of the *Tecozautila* variety compared with conventional crops.

Materials and Methods

The research was carried out in Cuilapam de Guerrero, Oaxaca, located at 16°57'N; 96°45'W and an elevation of 1560 m. The crop cycle was from Aug. to Dec. 2015. The *Tecozautila* variety, which was provided by the National System of Plant Genetic Resources of Mexico (*Sistema Nacional de Recursos Fitogenéticos de México*), was evaluated. The seeds were sown in 200-well polystyrene trays with a mixture of 80% sphagnum moss and 20% perlite. The seedbed was irrigated daily by incorporating 75, 20, and 75 mg·L⁻¹ of N, P, and K, respectively, into the water. The experiment was performed in soil in plots 5 m in width and 10 m long (50 m²) that contained four rows that were 1 m wide and 9 m long. The crop density was two plants/m². In each plot, wooden structures 2.0 × 5.0 × 10 m in height, width, and length, respectively, were built; they were covered with shade nets (Fig. 1) of Rashell type and made with high-density polyethylene allowing 60% shading (*Plastimalla Sombra*, Mexico) in beige, blue, white, red, and black colors under which the spectrum was also measured (Fig. 2), resulting in an average of three measurements made under the net at a 20-cm distance with a UPRtek MK350S LED Meter (Miaoli, Taiwan). A HD 2302.0 photometer (Delta OHM®, Veneto, Italy) was used to quantitatively measure the light (Urrestarazu et al., 2016). LP 471 PAR and quantum LP 471 PHOT radiometric probes were used to measure the intensity density of the photon flux (μmol·m⁻²·s⁻¹) and

Received for publication 27 Mar. 2018. Accepted for publication 18 Apr. 2018.

We thank the Instituto Politécnico Nacional and CONACyT, Mexico, for the projects SIP/2015-RE/123 and 248261. We also thank Abraham Gerardo Sánchez-Velasco and José Antonio Maldonado-Patolzin for the field work.

¹Corresponding author. E-mail: mgavilan@ual.es.

Fig. 1. Wooden structure and area covered with different *netting* colors used for the cultivation of *Physalis ixocarpa* Brot. *Tecozautla* variety.

illuminance (Lux), respectively. These data are shown in Table 1. To allow the entrance and exit of pollinating insects, the lower part of each structure was left uncovered (Fig. 1). Each color corresponded to a treatment, and the control group had no netting (in the field). The experiment was established under a randomized complete block design with three replications. The experimental unit consisted of eight plants.

Drip irrigation was carried out, and the nutrient solution was designed to apply ($\text{mg}\cdot\text{L}^{-1}$) N (250), P (60), K (300), S (200), Mg (75), Fe (3), Mn (0.5), B (0.5), Cu (0.1), and Zn (0.1). The pH values and electrical conductivity (EC) were measured once a week to adjust them to between 5.5 and 6.5 with the addition of nitric acid and between 2.0 and 2.6 $\text{dS}\cdot\text{m}^{-1}$, respectively. The pH was measured with a potentiometer, model 211R (Hanna Instruments®), and the EC was measured with an EC meter, model 407303 (Extech Instruments®).

The assessed climatic variables included *PAR* ($\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$), which was recorded every other week on sunny days under each shade net and in the absence of netting. The readings were made every hour between 0800 and 1800 HR with a quantum sensor LI-191SA® (LI-COR). Using the average values per hour of *PAR*, the IPAR was measured according to Faust (2002) and

Chang et al. (2008). The temperature and relative humidity were recorded with LI-191SA and LI-1400-101 sensors connected to an LI-1400® Data Logger (LI-COR).

The plant variables measured were the height, stem diameter, number of branches, and equatorial and polar diameters of the fruits according to the Mexican Standard NMX-FF-54-1982 (SECOFI, 1982) for husk tomato, which considers the following sizes (cm): a) greater than 5.4, b) from 4.7 to 5.4, c) from 3.9 to 4.6, d) from 3.0 to 3.8, and e) less than 3.0.

The pH and the total soluble solids were obtained from the third harvest in a subsample of three fruits; this analysis was performed using an Oakton pH 700 potentiometer and a digital refractometer from Hanna® Instruments.

The data obtained were subjected to ANOVA using the statistical package SAS version 9.0 (SAS®, 2002) and comparison of the means as conducted using the Tukey test ($P \leq 0.05$).

Results and Discussion

Photosynthetically active radiation. The *PAR* was higher without netting than under the shade nets, with a maximum flux of $1599 \mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ at 1200 HR. Under the shade nets, the *PAR* had a flux of 725, 544, 584, 523, and

$494 \mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ in the colors white, beige, red, blue, and black, respectively, and as without netting. The highest *PAR* was obtained at noon (Fig. 3). The white net decreased the *PAR* by 50%, whereas the black net decreased the *PAR* by 68%. These data are similar to the results from the measurements of photon flux intensity performed in the laboratory. In addition, these values are consistent with those reported by Valera et al. (2014) for tomato and pepper crops under shade nets in southeast Spain. Moderate shading of the pepper crop (30% to 50%) protected the fruit from sunburn, improving its quality, and for the plant, it reduced the use of water and increased the yield, whereas shading greater than 50% decreased photosynthesis and productivity (Díaz-Pérez, 2013; Shahak et al., 2008). Ombodi et al. (2015), with the use of nets of different colors in a pepper crop, recorded a reduction of 32% to 46% of the *PAR*, decreasing the yield by 23% to 31%.

Photosynthetically active integrated radiation. During the day, the IPAR had the same tendency as the *PAR* during all months of cultivation of *P. ixocarpa* (Table 2). The values of the IPAR significantly differed among the colors of the shade nets and no netting. The largest IPAR occurred in October without a net ($48.98 \text{ mol}\cdot\text{m}^{-2}\cdot\text{d}^{-1}$) and was significantly higher than that obtained under the white shade net in the same month ($25.68 \text{ mol}\cdot\text{m}^{-2}\cdot\text{d}^{-1}$), and it was also under this shade net color that the largest IPAR of the evaluated nets was found during the four months of *P. ixocarpa* cultivation. The lowest IPAR values were found under the black-, blue-, red-, and beige-colored shade nets, and there were no significant differences among them.

Temperature and relative humidity. From October to December, significant differences ($P \leq 0.05$) in the environmental temperature and relative humidity were found among the colored shade nets and no netting (Table 2). In the absence of nets, the temperature was 2 °C higher on average and the relative humidity was 4% lower. The differences between the daytime temperature and relative humidity inside and outside the shade nets were influenced by the characteristics of the covering material, such as its shape and size of the pores and threads (Teitel et al., 2010), as well as the roof cover and the shape and area covered (Möller and Assouline, 2007). Tanny et al. (2009) recorded a lower temperature within shade nets placed horizontally without a vertical cover; this result was similar to that found in the present study.

In January, both the temperature and the relative humidity of the air did not show any differences regardless of the use of nets or under shade nets of different colors; this was a similar observation to that obtained by Ayala-Tafuya et al. (2014), who also did not find any differences in the maximum temperature under colored net covering and no netting in a pepper crop. The lack of a difference in the temperature and relative humidity under different-colored shade nets and no netting was likely because the shade

Fig. 2. Spectral photon flux distributions in the netting treatments; (A) beige, (B) blue, (C) white, (D) red, and (E) black.

nets covered only 75% of the upper part of the structure (Fig. 1).

Morphological and growth variables. The analyses of variance indicate that the colored shade nets and no netting showed significant differences ($P \leq 0.05$) for all the variables evaluated. The plants cultivated under white shade nets had the highest height, stem diameter, and number of branches, with 141.89, 1.29, and 66.22 cm, respectively (Table 3), whereas the lowest values of these

variables were obtained under the red shade net and no netting. These results contradict those obtained by Oren-Shamir et al. (2001) and Shahak et al. (2008), who indicated that the red color stimulates vegetal growth, increasing the vigor of leafy vegetables. Márquez-Quiroz et al. (2014) found a greater plant height with the blue shade net in cherry tomatoes under macro tunnels, whereas Martínez-Gutiérrez et al. (2016) obtained a greater height in basil with the black shade

Table 1. Intensity of the photon flux ($\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$) and illuminance (Lux) in the netting treatments.

Netting color	PAR	Lux
Beige	549 $\pm$ 177	11,778 $\pm$ 1,688
Blue	480 $\pm$ 25	17,382 $\pm$ 1,990
White	714 $\pm$ 123	18,725 $\pm$ 1,123
Red	659 $\pm$ 28	16,485 $\pm$ 1,844
Black	530 $\pm$ 42	17,518 $\pm$ 3,564

Values represent the mean of three replications and standard deviation; PAR = photosynthetically active radiation.

Fig. 3. Photosynthetically active radiation in the interior of wooden structures with different netting colors and without netting.

net. Authors such as Urrestarazu et al. (2016) mentioned that it is important that not only is the quantity of light applied to horticultural crops sufficient for their development but also that the spectral quality favors the growth and organic matter of peppers, tomatoes, and lettuces; specifically, the use of red light vs. white light results in an increase of up to 170% in the leaf area of tomatoes.

Fruit classification and yield. There were differences among the treatments ($P \leq 0.05$) in terms of their equatorial and polar diameters, total number of fruits, fruit weight, and total yield. Under the white and blue nets and no netting, the plants produced large fruits with equatorial diameters of 5.28, 5.27, and 5.32 cm, respectively, which are greater than the equatorial diameters of 4.6 and 3.5 obtained in the *P. ixocarpa* Tecamac variety by Ponce-Valerio et al. (2012) in a greenhouse. The colors red and black resulted in fruits with smaller equatorial and polar diameters. These results contrast with those obtained by Rodríguez and Morales (2015), who obtained greater equatorial diameters in cranberry fruits under red nets but similar to those in the present study under black shade nets, under which fruits with smaller equatorial and polar diameters were also obtained.

Under the white net, there was a greater total number of fruits per plant; 30% more than under the other colored nets and no netting. Likewise, the average weight of the fruit and the yield were significantly higher, surpassing the colored nets and no netting by 33% and 120%, respectively.

Table 2. Integrated photosynthetically active radiation, temperature, and relative humidity in the interior of wooden structures with different netting colors and without netting.

Netting color	October	November	December	January
IPAR (mol·m ⁻² ·d ⁻¹)				
Beige	19.71 c ^z	17.14 c	16.85 c	15.96 c
Blue	16.37 c	14.24 c	13.03 c	12.35 c
White	25.68 b	22.33 b	22.44 b	21.26 b
Red	17.78 c	15.46 c	13.98 c	13.25 c
Black	16.49 c	14.34 c	12.80 c	12.12 c
Without netting	48.98 a	42.59 a	40.46 a	38.33 a
cv	15.22	18.41	12.55	20.04
Temperature (°C)				
Beige	18.50 b	18.75 b	17.65 b	17.29 a
Blue	18.91 b	18.16 b	17.86 b	17.43 a
White	19.05 b	18.19 b	17.78 b	17.40 a
Red	18.60 b	18.07 b	17.74 b	17.30 a
Black	17.92 b	17.70 b	17.46 b	17.11 a
Without netting	20.54 a	20.04 a	19.65 a	18.83 a
cv	10.24	12.35	11.56	8.32
Relative humidity (%)				
Beige	70.22 a	70.57 a	70.59 a	71.61 a
Blue	71.12 a	71.03 a	71.02 a	71.98 a
White	70.20 a	70.06 a	70.50 a	71.53 a
Red	69.24 a	69.56 a	69.43 a	70.92 a
Black	70.05 a	70.52 a	70.31 a	71.36 a
Without netting	66.32 b	66.18 b	66.61 b	70.06 a
cv	12.87	16.04	17.62	15.46

^zValues with the same letter within each column are statistically equal according to the Tukey test ($P \leq 0.05$).

cv = coefficient of variation.

Fruit quality. Significant differences in fruit quality were observed under the colored nets and no netting (Fig. 4). In general, the fruits produced under the colored nets were less acidic than those produced without netting, being only in this environment that fruits with pH values close to 4.13 were obtained, which are similar to those obtained

by Benito-Bautista et al. (2016) in tomatoes of the *Tecozautila* variety in a greenhouse but far from the pH values of 3.93–4.23 obtained by Ramírez-Godina et al. (2013) in *P. ixocarpa*. The total soluble solids values obtained under shade nets and no netting were lower than the range of 5.27–5.50 reported by Benito-Bautista et al. (2016) and distant from

Table 3. Morphological variables of *Physalis ixocarpa* cultivated under different netting colors and without netting.

Netting color	Plant ht (cm)	Stem diam (cm)	No. of branches
Beige	123.89 bc ^z	1.10 bc	51.67 bc
Blue	119.33 c	1.03 c	48.78 c
White	141.00 a	1.29 a	66.22 a
Red	119.00 c	1.11 abc	52.56 bc
Black	126.00 b	1.03 c	57.00 b
Without netting	112.94 d	1.28 abc	59.39 b
CV	1.64	6.02	12.52

^zValues with the same letter within each column are statistically equal according to the Tukey test ($P \leq 0.05$).

CV = coefficient of variation.

Fig. 4. Fruit quality of *Physalis ixocarpa* Tecozautla variety cultivated under different netting colors and without netting. Different letters indicate significant differences at the level of $P \leq 0.05$.

the range of 5.95–6.63 found by Ramírez-Godina et al. (2013). The results obtained for fruit quality indicate that all colored shade nets except the white ones increased the acidity and decreased the total soluble solids of the fruit, properties that are important in the sauce packaging industry and elaboration of sauces.

Conclusions

Under the colored shade nets, the PAR and IPAR were highest under the white nets, but these values were lower than those obtained in the absence of netting. The relative humidity and environmental temperature behaved similarly under the different-colored nets; in the absence of netting, the temperature was higher and the relative humidity was lower. The height of the plant, the number of fruits and their weight, and the yield increased under the white net. The colors red and black and no netting increased the number of fruits and decreased the fruit size. The white net increased the pH of the fruit. The total soluble solids of the fruit did not change under the shade nets. The white net can be used as an option to cover structures for the protection and intensive production of *Physalis*.

Literature Cited

- Ayala-Tafoya, F., R. Sánchez-Madrid, L. Partida-Ruvalcaba, M.G. Yáñez-Juárez, F.H. Ruiz-Espinoza, T.J. Velázquez-Alcaraz, M. Valenzuela-López, and J.M. Parra-Delgado. 2014. Producción de pimiento morrón con mallas sombra de colores. Rev. Fitotec. Mex. 38(1):93–99.
- Ayala-Tafoya, F., D.M. Zatarain-López, M. Valenzuela-López, L. Partida-Ruvalcaba, T.J. Velázquez-Alcaraz, T. Díaz-Valdés, and J.A. Osuna-Sánchez. 2011. Crecimiento y rendimiento de tomate en respuesta a radiación solar transmitida por mallas sombra. Terra Latinoam. 29(4):403–410.
- Benito-Bautista, P., N. Arellanes-Juárez, and M.E. Pérez-Flores. 2016. Color y estado de madurez del fruto de tomate de cáscara. Agron. Mesoam. 27(1):115–130.
- Chang, X., P.G. Alderson, and C.J. Wright. 2008. Solar irradiance level alters the growth of basil (*Ocimum basilicum* L.) and its content of volatile oils. Environ. Expt. Bot. 63:216–223.
- Díaz-Pérez, J.C. 2013. Bell pepper (*Capsicum annuum* L.) crop as affected by shade level: Microenvironment, plant growth, leaf gas exchange, and leaf mineral nutrient concentration. HortScience 48:175–182.
- Faust, J.E. 2002. Light management in greenhouses. I. Daily light integral: A useful tool for the U.S. floriculture industry. 6 Jan. 2016. <www.specmeters.com/assets/1/7/ A051.pdf>.

- Fischer, G., P.J. Almanza-Merchán, and D. Miranda. 2014. Importancia y cultivo de la uchuva (*Physalis peruviana* L.). Rev. Bras. Frutic. 36(1):1–15.
- Ilic, Z.S., L. Milenković, L. Šunić, D. Cvetković, and E. Fallik. 2014. Effect of coloured shade-nets on plant leaf parameters and tomato fruit quality. J. Sci. Food Agr. 95(13):2660–2667.
- Jiménez-Durán, K. and F. Cruz-García. 2011. Incompatibilidad sexual, un mecanismo genético que evita la autofecundación y contribuye a la diversidad vegetal. Rev. Fitotec. Mex. 34(1):1–9.
- López-López, R., R. Arteaga-Ramírez, M.A. Vázquez-Peña, I.L. López-Cruz, and I. Sánchez-Cohen. 2008. Producción de tomate de cáscara (*Physalis ixocarpa* Brot.) basado en láminas de riego y acolchado plástico. Rev. Chapingo Ser. Hort. 15:83–89.
- Márquez-Quiroz, C., V. Robledo-Torres, and A. Benavides-Mendoza. 2014. Uso de mallas de colores: Una alternativa para la producción de tomate cherry. Ecosist. Recur. Agropecu. 1(2):175–180.
- Martínez-Gutiérrez, G.A., R. Díaz-Pichardo, G. Juárez-Luis, Y.D. Ortiz-Hernández, and J.Y. López-Cruz. 2014. Caracterización de las unidades de producción de tomate en invernaderos de Oaxaca. Agr. Soc. Desarro. 11:153–165.
- Martínez-Gutiérrez, G.A., L. Nicolás-Santana, Y.D. Ortiz-Hernández, I. Morales, and G.F. Gutiérrez-Hernández. 2016. Crecimiento y contenido de aceite en albahaca (*Ocimum basilicum* L.) bajo mallas sombra de colores. Interciencia 41(6):428–432.
- Möller, M. and S. Assouline. 2007. Effects of a shading screen on microclimate and crop water requirements. Irr. Sci. 25:171–181.
- Ombodi, A., Z. Pek, P. Szuvandzsiev, T.Z. Tothne, A. Kohazi-Kis, A. Kovacs, H.D. Ledone, and L. Helyes. 2015. Effects of external coloured shade nets on sweet peppers cultivated in walk-in plastic tunnels. Not. Bot. Horti Agrobot. Cluj-Napoca 43(2):398–403.
- Oren-Shamir, M., E.E. Gussakovsky, E. Shpiegel, A. Nissim-Levi, K. Ratner, R. Ovadia, Y.E. Giller, and Y. Shahak. 2001. Coloured shade nets can improve the yield and quality of green decorative branches of *Pittosporum variegatum*. J. Hort. Sci. Biotechnol. 76:353–361.
- Peña-Lomeli, A., J.J. Ponce-Valerio, F. Sánchez-del-Castillo, and N. Magaña-Lira. 2014. Desempeño agronómico de variedades de tomate de cáscara en invernadero y campo abierto. Rev. Fitotec. Mex. 37(4):381–391.
- Ponce-Valerio, J.J., A. Peña-Lomeli, J.E. Rodríguez-Pérez, R. Mora-Aguilar, R. Castro-Brindis, and L.N. Magaña. 2012. Densidad y poda en tres variedades de tomate de cáscara (*Physalis ixocarpa* Brot. ex Horm.) cultivado en invernadero. Rev. Chapingo Ser. Hort. 18(3):325–332.
- Ramírez-Godina, F., V. Robles-Torres, R. Foughbakhch-Pournabav, A. Benavides-Mendoza, J.L. Hernández-Piñero, M.H. Reyes-Valdés, and M.A. Alvarado-Vázquez. 2013. Yield and fruit quality evaluation in husk tomato autotetraploids (*Physalis ixocarpa*) and diploids. Austral. J. Crop Sci. 7:933–940.
- Rodríguez, B.M. and U.D. Morales. 2015. Shading nets effect on the production and quality of blueberry fruit (*Vaccinium corymbosum* L.) cv. Brigitta. Sci. Agropecu. 6(1):41–50.
- SAGARPA (Secretaría de Agricultura Ganadería, Pesca y Alimentación). 2016. Sistema de información agroalimentaria. 10 Dec. 2016. <http://infosiap.siap.gob.mx/gobmx/datos-Abiertos.php>.
- Santiagoullo, H.J.F., P.O. Vargas, J.O. Grimaldo, L.N. Magaña, V.F.J. Caro, L.A. Peña, and M.J. Sánchez. 2012. Diagnóstico del tomate de

- cáscara. Universidad Autónoma Chapingo, Chapingo, México.
- Santiaguillo-Hernández, J.F., T. Cervantes-Santana, and A. Peña-Lomelí. 2004. Selección para rendimiento y calidad de fruto de cruces planta x planta entre variedades de tomate de cáscara. *Rev. Fitotec. Mex.* 27(1):85–91.
- SAS (Statistical Analysis System). 2002. SAS/ETS 9 user's guide, Vols. 1 and 2. SAS Institute Inc., Cary, NC, EUA. 2143.
- SECOFI (Secretaría de Comercio y Fomento Industrial). 1982. Norma Mexicana NMX-FF-54-1982. Productos alimenticios no industrializados para uso humano—hortalizas en estado fresco—tomate con cáscara.
- Shahak, Y., E. Gal, Y. Offir, and D. Ben-Yakir. 2008. Photosensitive shade netting integrated with greenhouse technologies for improved performance of vegetable and ornamental crops. *Acta Hort.* 797:75–80.
- Shahak, Y. and E.E. Gussakovsky. 2004. ColorNets: Crop protection and light-quality manipulation in one technology. *Acta Hort.* 659:143–151.
- SIAP. 2015. Sistema de información agroalimentaria y pesca. 25 Jan. 2017. <<http://www.siap.gob.mx/cierre-de-la-produccion-agricola-por-cultivo/>>.
- Soldevilla-Canales, C.S., A. Peña-Lomelí, M.F. Solís-Mendoza, T.R. Vázquez-Rojas, and M.T. Colinas-León. 2002. Aplicación al suelo de CO₂, uso de acolchados plásticos y sistemas de manejo en tomate de cáscara (*Physalis ixocarpa* Brot.). *Rev. Chapingo Ser. Hort.* 8:25–38.
- Tanny, J., S. Cohen, A. Grava, A. Naor, and V. Lukyanov. 2009. The effect of shading screens on microclimate of apple orchards. *Acta Hort.* 807:103–108.
- Teitel, M., M. Atias, and M. Barak. 2010. Gradients of temperature, humidity and CO₂ along a fan-ventilated greenhouse. *Biosyst. Eng.* 106:166–174.
- Urrestarazu, M., C. Nájera, and M. Gea. 2016. Effect of the spectral quality and intensity of light-emitting diodes on several horticultural crops. *HortScience* 51:268–271.
- Valera, D.L., L.J. Belmonte, F.D. Molina, and A. López. 2014. Los invernaderos de Almería. Análisis de su tecnología y rentabilidad. Cajamar, Almería, España.
- Vargas-Ponce, O., L.E. Valdivia-Mares, and J. Sánchez-Martínez. 2015. Potencial alimenticio de los tomates de cáscara (*Physalis* spp.) de México. *Agroproductividad* 8(1):17–23.