Effect of Healing Chamber Design on the Survival of Grafted Eggplant, Tomato, and Watermelon

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SUMMARY. Successful grafting of vegetables requires high relative humidity (RH) and optimal temperatures for ≈ 1 week following grafting to reduce transpiration of the scion until rootstock and scion vascular tissue are healed together and water transport is restored. This study evaluated the effect of three healing chamber designs on the survival of grafted eggplant (*Solanum melongena*), tomato (*Solanum lycopersicum*), and watermelon (*Citrullus lanatus*). The three healing chamber designs were 1) an industry design, which was hand-misted, 2) a research design, which contained a humidifier, and 3) a simplified design, which was shade cloth only and hand-misted. All plants were self-grafted using the splice grafting technique, placed in the healing chamber for 7 days after grafting and evaluated for signs of wilting and graft failure from day 6 to day 14 after grafting. During the 7-day healing period, the industry design had the greatest fluctuation in temperature, the research design had the greatest fluctuation in RH, and the shade cloth only design had the least fluctuation in both temperature and RH. When the healing chambers were closed on day 2 after grafting, the industry healing chamber had higher mean temperature and RH (24.9 °C, 98%) than both the research (23.4 °C, 81%) and shade cloth only (23.3 °C, 52%) healing chambers. These results suggest that a humidifier may not be necessary to maintain high RH. Mean graft survival rates in the industry (69%) and research (66%) healing chambers were similar, and both were higher than that in the shade cloth only healing chamber (52%). Tomato had the highest rate (98%), eggplant was intermediate (82%), and watermelon had the lowest mean survival rate (7%); there was no interaction between healing chamber and crop. The very low survival rate of watermelon was most likely due to the grafting technique used in this study, which is not optimal for watermelon. Tomato graft survival was high in all three healing chambers (96% to 98%), suggesting that high RH is not essential for tomato graft survival. Eggplant graft survival decreased from 90% to 60% when RH was decreased, suggesting that high RH is essential for eggplant graft survival.

High-value vegetable crops such as eggplant, tomato, and watermelon are grafted to increase vigor, yield, tolerance to salinity and temperature extremes, and disease resistance (Lee, 1994, 2003, 2007; Paroussi et al., 2007; Rivard and Louws, 2008). Production and demand for grafted vegetable plants continues to increase across Asia and Europe and has begun to expand to North America (Kubota et al., 2008; Lee, 2003). Grafted vegetable plants are not widely available in North America, and large-scale plant propagators as well as small-scale producers are looking for recommendations for grafted vegetable transplant production (Kubota et al., 2008).

The splice grafting technique, also known as top grafting or tube grafting, is widely used among vegetable grafting operations as it is efficient and easy to learn. By using splice grafting, producers can graft two to three times faster than with other grafting techniques, thereby optimizing labor costs and greenhouse space (Hartmann et al., 2002; Lee, 2007; Oda, 2007; Rivard and Louws, 2006). In splice grafting, rootstock and scion

are cut at 45° angles, and cut surfaces are held together by a grafting clip (Hartmann et al., 2002; Oda, 2007). It takes an average of 5 to 8 d for the graft union of an herbaceous plant to develop vascular connectivity between rootstock and scion (Fernandez-Garcia et al., 2004; Turquois and Malone, 1996). During this time, the scion is not able to access water from the rootstock. Therefore, it is important to maintain proper environmental conditions to prevent water loss from the scion and promote rapid formation of the graft union (Davis et al., 2008). Survival of grafted plants will be higher if plants are kept in a controlled environment with high RH and optimal temperatures (Davis et al., 2008; De Ruiter Seeds, 2006; Hassell et al., 2008; Oda, 2007).

Research programs and industry guidelines recommend a wide range of temperature and RH levels for healing grafted vegetable seedlings. De Ruiter Seeds (2006) suggests that the optimal temperature range for healing grafted tomato is 21 to 22 °C with a maximum temperature range of 28 to 29 °C. Other research programs suggest healing cucurbit plants at 28 to 30 °C (Hassell et al., 2008; Lee, 2007; McAvoy, 2005; Oda, 2007). The healing environment should be maintained between 85% and 100% RH for both tomato and cucurbit plants (Davis et al., 2008; Rivard and Louws, 2006). Some authors specifically state that the environment should be maintained at greater than 95% RH for cucurbits (Hassell et al., 2008; Lee, 2007; McAvoy, 2005; Oda, 2007). Although some large-scale commercial grafting operations often use environmentally controlled growth chambers to hold plants during the healing process, these chambers are not cost effective for most operations (Hassell et al., 2008; Oda, 2007). Instead, many growers and grafting researchers construct healing

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Units

To convert U.S. to SI, multiply by	U.S. unit	SI unit	To convert SI to U.S., multiply by
29.5735	fl oz	mL	0.0338
0.3048	ft	m	3.2808
0.0283	ft ³	m ³	35.3147
25.4	inch(es)	mm	0.0394
25.4	mil	μm	0.0394
6.8948	psi	kPa	0.1450
10.7639	W/ft ²	W·m ⁻²	0.0929
(°F - 32) ÷ 1.8	°F	°C	(1.8 × °C) + 32

chambers, which are small structures covered in plastic and placed within a greenhouse (Davis et al., 2008; Hassell et al., 2008; Rivard and Louws, 2006).

Healing chambers are an economical option for creating a humid environment. Maintaining temperatures within the optimal range and high RH is of primary concern when healing grafted vegetable seedlings. Temperature within the healing chamber is directly impacted by temperature within the greenhouse. RH can be increased by spraying the healing chamber with water, flooding the bottom of the chamber with water, or using a humidifier within the healing chamber (Hassell et al., 2008; McAvoy, 2005; Rivard and Louws, 2006). Little information is available regarding recommended design, dimensions, and management of healing chambers. The objective of this study was to compare the survival of grafted eggplant, tomato, and watermelon plants in three different healing chamber designs modeled after research, industry, and small-farm designs commonly used in North America.

Materials and methods

EXPERIMENTAL CONDITIONS. This study was conducted at the Washington State University (WSU) Northwestern Washington Research and Extension Center (NWREC) greenhouse facilities in Mount Vernon, WA (lat. 48°26'23.09"N, long. 122°23'44.04"W). The mean outdoor temperature during this period was 5.3 °C with a mean daily solar radiation of 92.7 W·m⁻² (WSU, 2011). The healing chambers were located in a heated greenhouse where temperature and RH ranged from 20.2 to 24.8 °C and 29% to 68%, respectively (Argus Control Software Firmware, version 14.12; Argus Control Systems, White Rock, BC, Canada) during the study period. Natural light was supplemented with 03-high-intensity discharge lights to achieve a 12-h photoperiod to simulate a typical daylength when vegetable plants would be grafted for field production. Greenhouse temperature and RH were measured throughout the study period.

PLANT MATERIAL. Three commonly grafted vegetable crops and cultivars grown in the Pacific northwestern U.S. ('Epic' eggplant, 'Cherokee Purple' tomato, and 'TRI-X Brand

313' watermelon) were chosen for the study. Seeds were sown into 72-cell (59 mL) plug trays containing commercial sphagnum-peat-based media (Sunshine #1 Natural & Organic; Sun Gro Horticulture, Vancouver, BC, Canada) on 7, 14, and 21 Jan. Before grafting, plants for each crop were randomized and transferred into two 72-cell plug trays with an empty cell between each plant and neighboring plants in adjacent rows. On 24 Jan., 31 Jan., and 7 Feb., 14 to 17 d after seeding, when stems had reached 1.5 to 2.5 mm diameter, plants were self-grafted below the cotyledons using the splice grafting technique. A self-grafted plant is cut and grafted back together, and this method was used in this study to minimize potential random variation as a result of differences in rootstock and scion stem diameters, uneven grafting cuts, and incompatibility between scion and rootstock (Hartmann et al., 2002). Plants were held together using 1.5- or 2-mm silicon grafting clips.

HEALING CHAMBER CONSTRUCTION AND MANAGEMENT. All healing chamber frames were constructed from polyvinyl chloride (PVC) pipe and set on greenhouse benches. The floors of the research and industry healing chambers were lined with clear plastic sheeting, and the healing chambers were covered in 6-mil polythene plastic [90% light transmission in photosynthetically active radiation (*PAR*); Ginegar Plastic Products, Ginegar, Israel]. The plastic covering the research and industry healing chambers was tightly attached with clips to the bottom plastic to minimize moisture loss. A high-density

woven polypropylene shade cloth (27% light transmission in *PAR*) was used to cover all three healing chambers.

The covering materials, misting applications, dimensions, and volumes of the three chambers included in this study are presented in Table 1. The research healing chamber dimensions, coverings, and management were based on healing chamber designs used in other research programs (Rivard and Louws, 2006; X. Zhao, personal communication). The humidifier (Herrmidifier 707U, model 356686-001C; Herrmidifier, Phoenix, AZ) was placed at one end of the healing chamber, and the water supply system was embedded in the concrete flooring so water temperature was about the same as the current soil temperature, which averaged 5.2 °C during the time when this study was conducted. The industry healing chamber dimensions, coverings, and management were similar to those used in a commercial grafting production facility. Hand-misting was with a spray nozzle attached to a hose. The shade cloth only chamber dimensions were similar to the industry chamber dimensions, and coverings were intended to reduce light but not to increase RH.

All plants were hand-misted with a spray bottle immediately after grafting and then placed into one of the three healing chamber treatments (research healing chamber, industry healing chamber, or shade cloth only chamber) for 7 d. When plants were placed in the healing chambers, the interior of the research healing chamber was not misted, the inside of the industry healing chamber was sprayed with water, and grafted plants in the

Table 1. Description of materials, misting treatment, dimensions, and internal volume of the three healing chamber designs.

Healing chamber design	Materials ^z	Treatment	Dimensions (m) ^y	Volume (m ³) ^y
Research	Shade cloth, plastic, humidifier	Plants misted every 5 min by humidifier for 20 s	3.0 × 1.2 × 0.8	2.88
Industry	Shade cloth, plastic	Inner surfaces of plastic hand-misted on days 1, 3, 5, and 6	2.2 × 0.9 × 0.6	1.19
Shade cloth only	Shade cloth	Plants hand-misted twice daily	1.7 × 0.8 × 0.5	0.68

^zShade cloth was high-density woven polypropylene [27% light transmission in photosynthetically active radiation (*PAR*)], and a double layer was used for all three healing chambers; plastic was 6-mil (152.4 μm) polythene (90% light transmission in *PAR*; Ginegar Plastic Products, Ginegar, Israel); humidifier was a centrifugally atomizing humidifier (Herrmidifier 707U, model 356686-001C; Herrmidifier, Phoenix, AZ).

^y1 m = 3.2808 ft, 1 m³ = 10.7639 ft³.

shadecloth only healing chamber were misted again. The day when grafting occurred was referred to as day 1 with subsequent days during healing and acclimation numbered chronologically following day 1. Healing chambers were not opened, and plants were not disturbed on days 1 and 2. Plants were not watered while in the healing chamber, all moisture was from misting: 20 s every 5 min in the research healing chamber; hand-misting on days 3, 5, 6, and 7 in the industry healing chamber; and hand-misting twice per day, days 2 to 7 in the shadecloth only healing chamber. Temperature and RH in the three healing chambers were monitored every 5 min with a Hobo Micro Station data logger for 7 d after grafting (Hoboware H21-002; Onset Computer Corp., Bourne, MA). Day 2 was selected for analyzing temperature and RH since research and industry healing chambers had not been disturbed for at least 40 h, including 8 h before and after this time period.

VAPOR PRESSURE CALCULATIONS. To understand RH differences in the research and industry healing chambers, the saturation vapor pressure (e_s), the maximum possible amount of water vapor at a given temperature (T), was calculated from the mean temperature (T) using Tetens formula (Buck, 1981; Campbell and Norman, 1998):

$$e_s(T) = 0.611 \exp\left(\frac{17.502T}{T + 240.97}\right) \quad [1]$$

Partial vapor pressure (e_a), the actual amount of vapor pressure in the system, was determined from mean RH (h_r) and the saturation vapor pressure [$e_s(T)$]:

$$e_a = h_r e_s(T) \quad [2]$$

The vapor deficit is the difference between existing RH and maximum RH in a given body of air and is measured by calculating the difference between saturation vapor pressure (Eq. 1) and partial vapor pressure (Eq. 2) (Campbell and Norman, 1998). The vapor deficit was calculated for the industry and research healing chambers to better understand the relationship between temperature and RH within these two chambers.

EVALUATION OF PLANT RESPONSE. The acclimation process used in the

study was developed for grafted tomato plants (De Ruiter Seeds, 2006). From days 5 to 8, plants were gradually acclimated to the greenhouse environment, and plants in all three healing chambers followed identical acclimation schedules. Shadecloth and plastic sheeting were removed from the healing chambers for 30 min on day 5, 1 h on day 6, and 6 h on day 7. On day 8, plants were removed from the healing chambers. Graft survival was counted every day beginning on day 6 and ending on day 14. Graft survival was defined as turgidity of scion leaves and stem; failed grafted plants had entirely wilted scion leaves and stems.

EXPERIMENTAL DESIGN AND STATISTICAL ANALYSIS. The experiment was a randomized complete block design with a two-way treatment structure with three time replicates conducted between 7 Jan. and 21 Feb. 2011. The two treatments were healing chamber design (research design, industry design, and shadecloth only design) and crop (eggplant, tomato, and watermelon), and there were 72 plants per crop per healing chamber.

The survival data in this study followed binomial rather than normal distribution and, therefore, could not be analyzed using analysis of variance or a general linear model. Based on survival counts for each day, a logit model (logistic regression) was used to estimate the probability of survival and compute test statistics using SAS (version 9.2; SAS Institute, Cary, NC) with PROC GLIMMIX at $P \leq 0.05$. Temperature and RH data were analyzed with one-way analysis of variance in SAS with PROC MIXED at $P \leq 0.05$. Treatment differences were assessed using the LSMeans statement to analyze differences in least squares means. Mean values for temperature and RH were calculated using SAS.

Results and discussion

TEMPERATURE AND RH DURING THE 7-D HEALING PERIOD. There was a diurnal fluctuation in temperature in all three healing chamber structures with the lowest mean temperature of 22.2 °C at 0200 to 0400 HR and the highest mean temperature of 25.6 °C at 1400 to 1600 HR (Fig. 1). The temperatures within the healing chambers were very similar to the

greenhouse temperature, which were between 20.2 and 24.8 °C. The industry healing chamber had the greatest fluctuation in temperature and the highest daily temperature throughout most of the 7-d healing period. The daily high temperature in the industry healing chamber averaged 2 to 4 °C greater than the research and shadecloth only healing chambers at the beginning of the healing period when the chamber was closed, and by day 6 after grafting, it was equal to the shadecloth only healing chamber but remained 1 to 2 °C greater than the research healing chamber. The research healing chamber had the lowest night temperature and averaged 0.5 to 2 °C less than the industry and shadecloth only healing chambers.

RH fluctuated diurnally for all three healing chambers when the chambers were closed, days 2 to 4, and on average was highest at 0200 to 0400 HR and lowest at 1600 HR; this diurnal pattern was opposite that for temperature. The industry healing chamber had the highest RH on days 1 to 3, the research healing chamber was highest on day 4, and both chambers had similar RH on days 5 to 7. More frequent misting with cool water and greater internal volume in the research healing chamber as compared with the industry healing chamber likely resulted in the observed differences in temperature and RH between these two chambers. The shadecloth only healing chamber had the lowest RH every day during the healing period, likely because there was no plastic covering to maintain the moisture. Temperature and RH within the healing chambers are directly affected by greenhouse environmental conditions. Greenhouse conditions are directly affected by artificial lights, thermostat regulation, and incoming solar radiation. Artificial lights and incoming solar radiation cause increased temperature within healing chambers, and increased temperatures will affect the RH.

TEMPERATURE AND RH WITHIN CLOSED CHAMBERS. Temperature on day 2, when the research and industry healing chambers were closed, differed significantly among healing chambers but followed a diurnal pattern such that temperature from 0700 to 2100 HR was greatest in the industry healing chamber, lowest in the shadecloth only healing chamber, and intermediate in

Fig. 1. (A) Mean temperature and (B) relative humidity (RH) in three healing chambers (industry, research, and shade cloth only) and greenhouse during the 7-d healing period following grafting of eggplant, tomato, and watermelon plants. Healing chambers were placed in a greenhouse with temperature and RH of 20.2 to 24.8 °C and 29% to 68.4% and a 12-h photoperiod using 03-high-intensity discharge lights. The research and industry healing chambers were covered in clear plastic, and all three healing chambers were covered in shade cloth. The research design included a humidifier that misted the chamber for 20 s every 5 min, the industry design was hand-misted on days 3, 5, 6, and 7, and the shade cloth only design was hand-misted twice daily on days 2 to 7; $(1.8 \times ^\circ\text{C}) + 32 = ^\circ\text{F}$.

the research healing chamber ($P < 0.0001$; Fig. 2). By contrast, from 0000 to 0600 HR and 2200 to 2300 HR, temperature was greater in the shade cloth only healing chamber, lower in the research healing chamber, and intermediate in the industry healing chamber. The industry healing chamber had significantly higher mean temperature (24.9 °C) than the research and shade cloth only healing chambers

(23.3 and 23.4 °C, respectively), which were statistically equivalent ($P < 0.0001$; Table 2). All healing chambers maintained temperatures within the general temperature recommendations (21 to 30 °C).

Mean RH differed significantly among all healing chambers and was greatest in the industry healing chamber (98%), followed by the research healing chamber (82%), and

was lowest in the shade cloth only healing chamber (52.6%) ($P < 0.0001$; Table 2). The industry healing chamber maintained RH within the recommended range (85% to 100%), whereas mean RH in the research and shade cloth only healing chambers were lower than the recommended (Davis et al., 2008; Hassell et al., 2008; Lee, 2007; McAvoy, 2005; Oda, 2007; Rivard and Louws, 2006). RH in both the research and industry healing chambers was greater than that in the greenhouse as both of these healing chamber structures were covered in plastic which maintained moisture. Without plastic to retain moisture, temperature and RH in the shade cloth only healing chamber (23.4 °C and 52.6%, respectively) were very similar to greenhouse conditions during the study period (22.3 °C and 47%, respectively). The shade cloth and daily misting likely account for the slight increase in temperature and RH in the shade cloth only healing chamber as compared with the greenhouse.

VAPOR PRESSURE. The industry healing chamber and research healing chamber had mean vapor deficits of 0.06 and 0.51 kPa, respectively. Vapor deficit close to 0 kPa indicates the highest possible RH in a given environment. Both healing chambers were covered with plastic, which was clipped closed to form a nearly closed system. In closed systems, evaporation occurs until all the available moisture is evaporated or the air at that temperature becomes saturated; that is, the saturation vapor pressure is reached. The rate at which the air reaches saturation vapor pressure depends on the temperature and the volume of air relative to the volume of water within the system (V_a/V_w). Higher temperatures result in an increased rate of evaporation and decreased RH although the evaporation rate slows as the air approaches saturation vapor pressure (Giancoli, 2005). The volume of air within a healing chamber is defined by the chamber's structural dimensions. The research healing chamber was 2.88 m³ and the industry healing chamber was 1.19 m³; thus, the industry healing chamber had 58% less internal volume than the research healing chamber. Based on the vapor pressure calculations, it appears that the water volume within the industry healing

Fig. 2. (A) Mean temperature and (B) relative humidity in three healing chambers and greenhouse during the first full day (day 2) after grafting eggplant, tomato, and watermelon plants. Vertical bars represent the SE. Healing chamber structures were not disturbed for at least 8 h before and after this 24-h time period. Healing chambers were placed in a greenhouse with temperature and RH of 20.2 to 24.8 °C and 29% to 68.4% and a 12-h photoperiod using 03-high-intensity discharge lights. The research and industry healing chambers were covered in clear plastic, and all three healing chambers were covered in shadecloth. The research design was misted for 20 s every 5 min by a humidifier, the industry design was hand-misted on days 3, 5, 6, and 7, and the shadecloth only design was hand-misted twice daily on days 2 to 7; $(1.8 \times ^\circ\text{C}) + 32 = ^\circ\text{F}$.

chamber was sufficient for it to reach a greater saturation vapor pressure and thus a higher RH than the research healing chamber. Thus the industry healing chamber had a greater RH than the research healing chamber during the 7-d healing period, despite higher mean temperature in the industry healing chamber and greater

water input in the research healing chamber. Results from this study suggest that healing chamber dimensions should be minimized to reduce the internal volume of air and decrease the ratio of air volume to water volume, thereby maintaining RH near saturation and minimizing evapotranspiration from scion leaves.

PLANT SURVIVAL. Graft survival (complete wilting of all crops) was similar in the research and industry healing chambers but was significantly lower in the shadecloth only healing chamber ($P \leq 0.05$; Table 3). Graft survival for the research and industry healing chambers was initially 20% greater than the shadecloth only healing chamber, but declined $\approx 7\%$ from day 6 to day 14, whereas graft survival in the shadecloth only healing chamber remained low but constant over the 14-d period. Mean survival of eggplant, tomato, and watermelon was significantly different and did not change for each crop from day 6 to day 14; tomato had the highest survival (98%), eggplant was intermediate (80%), and watermelon had the lowest survival (7%). Complete wilting does not equate plant death; some plants may appear completely wilted on one day and will recover from wilting by producing new growth in following days. Thus, the percent survival is variable over time. However, complete wilting was the most logical method available to us for monitoring graft failure daily from day 7 to day 14. There was no significant interaction between healing chamber structure and crop during the healing period ($P < 0.0001$; Table 3).

A survival rate of greater than 90% is necessary to justify the added cost and labor of grafting (L. Benne, personal communication). Tomato had very high survival rates in all three healing chamber structures. Mean RH in the shadecloth only healing chamber was 53%, and the tomato graft survival was at 96% in this chamber, suggesting that grafted tomato plants tolerated lower RH during the healing period when temperatures were 23 to 25 °C. Although maintaining constant high RH in healing chamber structures resulted in slightly higher survival (98%), our results suggest that maintaining high RH levels is not necessary to attain greater than 90% tomato graft survival. Eggplant had 90% survival in both the research and industry healing chambers and 60% in the shadecloth only healing chamber, suggesting that high RH increased graft survival of this crop.

Watermelon had very low survival in all three healing chamber structures, regardless of temperature and RH levels. Watermelon are mainly grafted

using the hole insertion technique, tongue approach, or one-cotyledon splice grafting technique (Hassell et al., 2008). However, to maintain consistency within this study's experimental design, all crops were grafted using the same technique, splice grafting, and acclimated from healing chamber to greenhouse conditions in the same manner. Splice grafted watermelon can have very low survival rates if temperature and RH are not carefully controlled, that is, with RH maintained above 85% and temperature between 20 and 25 °C (Cushman, 2006; Hassell et al., 2008). Both the research and industry healing chambers

maintained temperature and RH within this recommended range for cucurbit grafting; however, survival in both these chambers was low (6% and 15%, respectively). Watermelon may need a longer healing period than tomato within the healing chamber environment or a more gradual acclimation period.

Results from this study suggest that grafted tomato plants are more tolerant of lower RH and variable temperatures within the healing chamber than eggplant, and watermelon is the least tolerant of the three crops. While tomato had an acceptably high survival rate in the shade cloth only

healing chamber, labor requirements for daily misting were higher. Further studies are needed to determine if daily misting is required to attain high graft survival in the shade cloth only design. No significant differences in survival rates of the three crops between the research healing chamber and the industry healing chamber were noted. This finding suggests that a humidifier is not a necessary component of a healing chamber for successful grafting. It is important to note, however, that under certain conditions (i.e., cool humidifier water temperature), a humidifier may lower the temperature within the healing chamber, and this could be advantageous, especially in warmer environments where it is more difficult to maintain lower temperatures within the greenhouse. Although RH generally decreases with an increase in temperature, the industry design had significantly higher RH and temperature than the research design. The research design had much larger volume than the industry design, and these results suggest that RH is influenced by healing chamber dimensions and subsequent internal volume of air. The low survival rate observed in grafted watermelon suggests that different grafting techniques and/or acclimation methods are necessary for successful grafting of watermelon.

Table 2. Relative humidity (RH) and temperature within three healing chambers on day 2 after grafting eggplant, tomato, and watermelon plants. The study was conducted in a greenhouse with temperature and RH of 20.2–24.8 °C and 29% to 68.4% and a 12-h photoperiod using 03-high-intensity discharge lights.

	RH [mean ± SE (%)] ^z	Temperature [mean ± SE (°C)] ^y
Healing chamber design ^x		
Research	82.18 ± 1.13 b ^w	23.36 ± 0.11 b
Industry	98.09 ± 0.40 a	24.94 ± 0.15 a
Shade cloth only	52.62 ± 1.16 c	23.29 ± 0.08 b

^zRH and temperature were analyzed with analysis of variance using SAS (version 9.2; SAS Institute, Cary, NC) using PROC MIXED at $P \leq 0.05$.

^y $(1.8 \times ^\circ\text{C}) + 32 = ^\circ\text{F}$.

^xThe research and industry healing chambers were covered in clear plastic, and all three healing chambers were covered in a double layer of shade cloth. The research design included a humidifier that misted the chamber for 20 s every 5 min, the industry design was hand-misted on days 3, 5, 6, and 7, and the shade cloth only design was hand-misted twice daily on days 2 to 7.

^wMeans in columns followed by same letters were not significantly different at $P \leq 0.05$. Treatment differences were determined using least squares means at $P \leq 0.05$.

Table 3. Effect of vegetable crop type and healing chamber design on graft survival 6 to 14 d after grafting eggplant, tomato, and watermelon plants. The study was conducted in a greenhouse with temperature and relative humidity (RH) settings of 20.2–24.8 °C and 29% to 68.4% and a 12-h photoperiod using 03-high-intensity discharge lights.

Effect ^y	Survival (%) ^z								
	Day 6	Day 7	Day 8	Day 9	Day 10	Day 11	Day 12	Day 13	Day 14
Healing chamber treatment ^x									
Research	73 a	74 a	66 a	70 a	69 a	68 a	67 a	66 a	66 a
Industry	77 a	74 a	70 a	72 a	71 a	71 a	70 a	69 a	69 a
Shade cloth only	52 b	50 b	52 b	54 b	53 b	53 b	49 b	49 b	52 b
Crop ^w									
Eggplant	83 b	81 b	81 b	85 b	85 b	84 b	81 b	79 b	82 b
Tomato	98 a	98 a	98 a	98 a	98 a	98 a	97 a	97 a	98 a
Watermelon	20 c	19 c	9 c	14 c	11 c	10 c	8 c	08 c	07 c
Significance of effect									
Chamber	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Crop	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Chamber × crop	0.12	0.88	0.49	0.52	0.63	0.63	0.06	0.22	0.40

^zMean percent survival, by effect. Survival was counted daily beginning 6 d after grafting and ending on 14 d after grafting. Means in columns followed by same letters are not significantly different at $P \leq 0.05$. Graft survival was defined as successful formation of graft union and turgidity of scion leaves; scion leaves of failed grafts were entirely wilted.

^yEffects were analyzed using SAS (version 9.2; SAS Institute, Cary, NC) with PROC GLIMMIX at $P \leq 0.05$. Treatment differences were assessed using the LSMeans statement to analyze differences in least squares means.

^xThe research and industry healing chambers were covered in clear plastic, and all three healing chambers were covered with a double layer of shade cloth. The research design included a humidifier that misted the chamber for 20 s every 5 min, the industry design was hand-misted on days 3, 5, 6, and 7, and the shade cloth only design was hand-misted twice daily on days 2 to 7.

^wCrops chosen for the study are high-value crops that are commonly grafted for disease resistance and increased vigor.

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