HortScience 59(2):220–224. 2024. https://doi.org/10.21273/HORTSCI17485-23

‘Tango’ Female and ‘Hombre’ Male Freeze-tolerant Kiwis (*Actinidia chinensis* Planch var. *chinensis*)

Ralph Scorza, Mark Demuth, Timothy Artlip, and Chris Dardick
US Department of Agriculture, Agricultural Research Service, Appalachian Fruit Research Station, 2217 Wiltshire Road, Kearneysville, WV 25430, USA

Keywords. cold hardy, disease resistant, high quality, insect resistant

Justification for Release

Kiwi growers in the continental United States have several choices of kiwi from which to choose, and selection is, for the most part, based on minimum winter temperatures. The commercial kiwi *Actinidia chinensis* Planch var. *deliciosa* (A.Chev.) (Ferguson 1990) tolerates low winter temperatures of –7 °C (20 °F), and flower buds, flowers, and tender shoots can tolerate –1.5 °C for short durations in the spring (Davison 1990; Hewett and Young 1981). Although flower buds are killed at lower temperatures, the plants may survive (Testolin and Messina 1987). This limits kiwifruit growing of *A. chinensis* Planch var. *deliciosa* (A.Chev.) to US Department of Agriculture (USDA) Plant Hardiness zones 9a (https://planthardiness.ars.usda.gov) and above. Cold-hardy *Actinidia arguta* [*A. arguta* (Sieb. et Zucc.) Planch. ex Miq.] can tolerate low winter temperatures of –30 °C (USDA Plant Hardiness Zone 4b and above) (Williams et al. 2003) and *Actinidia kolomikta* [*A. kolomikta* (Maxim. et Rupr.) Maxim.], to –35 °C (Paulauskiene et al. 2020). Fruit of these cold-hardy species are small (grape size) and have a short storage life compared with *A. chinensis* Planch var. *deliciosa* (A.Chev.) (Paulauskiene et al. 2020; Williams et al. 2003). Zespri™ SunGold™ and ChinaBelle® are *A. chinensis* Planch var. *chinensis* cultivars that are currently being marketed commercially. They are characterized by their “golden” flesh color, and the flavor of these varieties is preferred by consumers to the most common *A. chinensis* Planch var. *deliciosa* (A.Chev.) cultivar Hayward (Ferguson 1999). Although *A. chinensis* Planch var. *chinensis* fruit is considered to be as tender as *A. chinensis* var. *deliciosa* (A.Chev.) fruit, we have identified a female and a compatible male selection that are considerably more cold hardy, allowing cultivation of this species in USDA Hardiness Zone 6b and above vs. 9a for *A. chinensis* Planch var. *deliciosa* (A.Chev.) (Fig. 1).

Origin and Development

Actinidia chinensis var. *chinensis* ‘Tango’ (Scorza and Demuth 2020) and its *A. chinensis* Planch var. *chinensis* pollinizer ‘Hombre’ kiwi vines originated from open pollination of *A. chinensis* Planch. var. *chinensis* selections collected by A. Nicotra, Istituto Sperimentale per la Fruiticoltura, Rome. These original selections were produced from seeds collected in Guanxi Province, China, in 1988. One hundred forty second-generation seedlings that originated from seed collected from 19 vines grown in Rome were field-planted at the USDA, Agricultural Research Service (ARS) Appalachian Fruit Research Station, Kearneysville, WV, USA, in 1995. Only two vines survived the cold winter temperatures between 1995 and 2015, with a recorded lowest temperature during that period of –21 °C (–5.8 °F) on 18 Jan 2003 and again on 23 Jan 2014.

Description and Performance

‘Tango’ and ‘Hombre’ growing on their own roots and spaced 6 feet apart were evaluated from 2002 through 2015 at one location: the USDA-ARS Appalachian Fruit Research Station (lat. 39.3629°N, long. 77.8633°W). This location is in USDA Plant Hardiness Zone 6b, with predicted low weather extremes of –20.6 to –17.8 °C (–5 to 0 °F) (https://planthardiness.ars.usda.gov). The site is southwest facing, 181 m above mean sea level, with no obstructions nearby, and is not considered a frost pocket. Both vines grew vigorously, were untrained, and received little pruning. No fruit thinning was practiced and no supplemental irrigation was applied, nor was fertilizer or pesticides applied.

‘Tango’ and ‘Hombre’ flowered yearly between 1 May and 15 May at the test

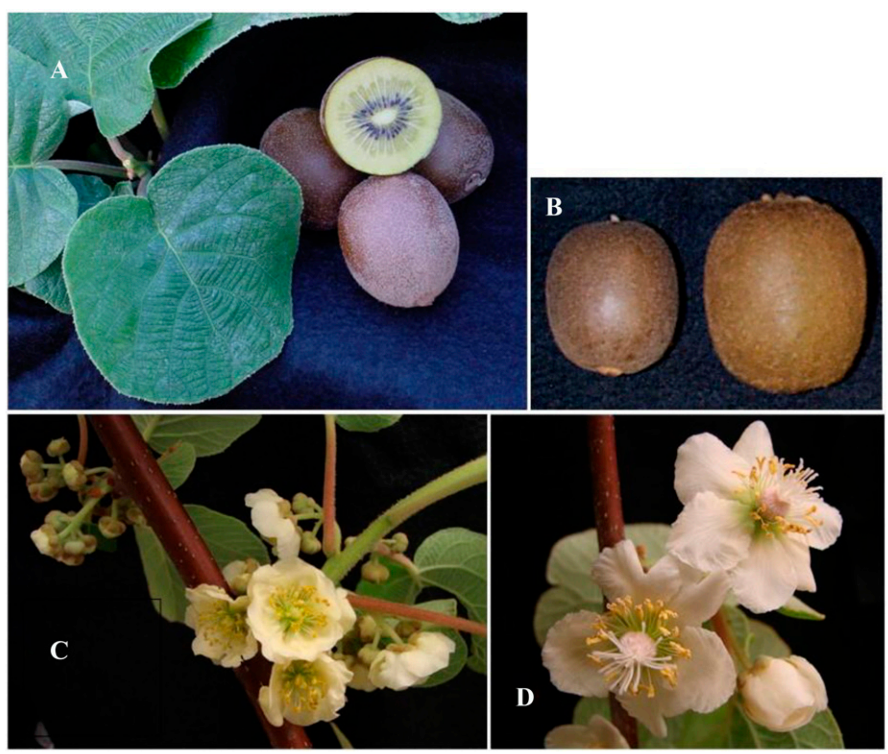

Fig. 1. Images of fruit and flowers of *Actinidia chinensis* var. chinensis ‘Tango’ and ‘Hombre’. (**A**) ‘Tango’ fruit and leaves. Fruit flesh tends toward a “golden” color [yellow-green, Royal Horticultural Society (RHS) 153D] at harvest, then changes to a gray-yellow (RHS 160A) (RHS Colour Chart 2001) when ripe for eating ripe (12–18 °Brix) (data not shown). (**B**) ‘Tango’ fruit (left) and commercial *Actinidia deliciosa* var. deliciosa ‘Hayward’ (right). (**C**) Flowers of male pollinizer ‘Hombre’ (**D**) Flowers of ‘Tango’.

Received for publication 15 Sep 2023. Accepted for publication 20 Nov 2023.
Published online 16 Jan 2024.
This research was supported by the U.S. Department of Agriculture, Agricultural Research Service (CRIS 8080-21000-029-00D).
The findings and conclusions in this publication are those of the authors and should not be construed to represent any official US Department of Agriculture or US government determination or policy. Mention of trade names or commercial products in this publication is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the US Department of Agriculture.
R.S. is retired.
C.D. is the corresponding author. E-mail: chris.dardick@usda.gov.

location, and 'Tango' fruit were harvested 1 to 2 d before a predicted frost event, between the first and third week in October [~160 d after flowering, comparable to typical *A. chinensis* Planch var. *deliciosa* (A.Chev.) 'Hayward' time to harvest] (e.g., Gullo et al. 2016). Upon harvest, a sample of 10 fruit was weighed and measured. Over all evaluation years, fruit length averaged 4.3 cm; diameter, 3.5 cm; and weight, 35.0 g; with maxima of 5.6 cm, 4.7 cm, and 62.1g, respectively. This compares with commercially produced *A. chinensis* var. *deliciosa* (A.Chev.) 'Hayward', measuring 7 cm in length and 5 cm in diameter (Fig. 1B), with a weight of 85 to 115 (Cruz-Castillo et al. 1999; Minchin et al. 2010); with *A. chinensis* Planch var. *chinensis* 'Hort16A' (Zespri™ SunGold™), measuring 7.6 to 8.4 cm in length, with a width of 4.7 to 5.5 cm and a weight of 43 to 176 g (average, 80–90 g) (Richardson et al. 2011); and with grape-size, cold-hardy *A. arguta*, with a fruit weight of 5 to 12 g (Kempler and Kabaluk 1995; Pescie and Strik 2004; Williams et al. 2003). Mean fruit yield ± standard error (*SE*) of 'Tango' (n = 45) was 25.7 ± 5 kg/year over the 14-year test period, with a maximum yield of 57.1 kg (Fig. 2), compared with a recorded yield of 32.5 kg/vine for unthinned *A. arguta* (Pescie and Strik 2004).

Soluble solids (measured in degrees Brix) were measured with a digital refractometer (Palette, PR-101; Atago Co., LTD., Tokyo, Japan). Degrees Brix at harvest ranged from 7.2 to 15.4, with a mean of 9.76 ± 0.67 °Brix (n = 45) (Fig. 3). These values are greater than *A. deliciosa* Planch var. *deliciosa* (A.Chev) 'Hayward' at a comparable harvest date (Gullo et al. 2016) and are comparable to *A. kolomikta* cultivars at their harvest dates (Paulauskiene et al. 2020). After harvest, 'Tango' fruit were stored at 5 °C in a covered, but not sealed, container to retain humidity. At multiple intervals from –10 to +75 d after harvest, fruit were again evaluated for soluble solids. During cold storage, soluble solids increased for 75 d postharvest and reached levels of 13.8 ± 0.8 °Brix (n = 45; Fig. 3), with a range of 10.8 to 17.7 °Brix. These data are comparable to those reported for *A. kolomikta* (Paulauskiene et al. 2020) and for *A. chinensis* var. *deliciosa* (A.Chev.) 'Hayward" after 120 d of storage plus 5 d at 20 °C (Gullo et al. 2016). In summary, the fruit of 'Tango' are of high quality in terms of size and soluble solids, are comparable to the commercial *A. deliciosa* cultivar Hayward in many respects, are of significantly larger size than the currently grown cold-hardy species *A. arguta* and *A. kolomikta*, and can be stored for extended periods.

Actinidia chinensis Planch var. *chinensis* 'Sanuki Gold' fruit have been demonstrated to respond to ethylene (Mworia et al. 2012), so 'Tango' was thought to respond similarly. Indeed, it was found that the 'Tango' ripening process could be accelerated by exposing fruit to the natural evolution of ethylene from ripening apples or bananas for 5 to 10 d in a sealed plastic bag (data not presented). This suggests that 'Tango' fruit should be treated

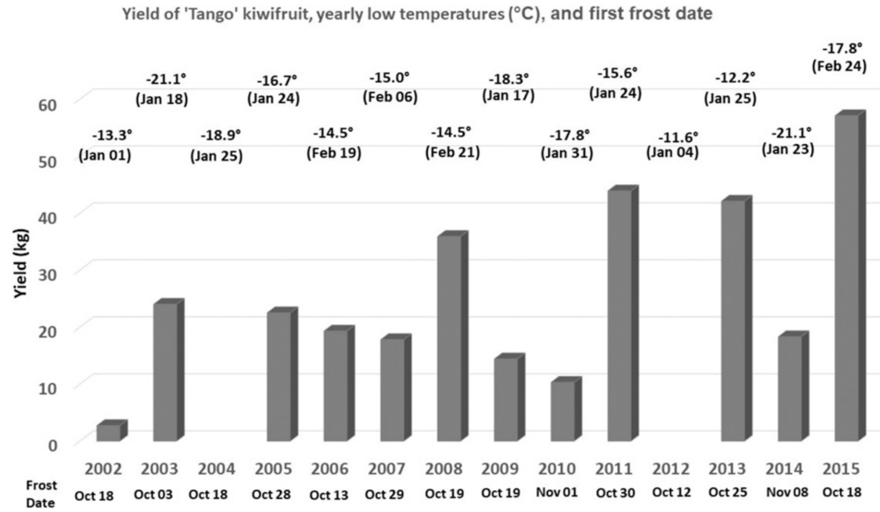

Fig. 2. Yield of *Actinidia chinensis* Planch. var. *chinensis* 'Tango' kiwifruit over a 14-year period. In 2004, fruit were harvested but yield data were not recorded. In 2012, the crop was reduced to a few fruit as a result of a severe frost event during bloom. Extreme low-temperature dates over all years occurred between 1 Jan and 24 Feb, and are indicated at the top of each bar along with the actual date. The first frost date is indicated below the years. Harvest date was 1 or 2 d before the first frost date. Temperature data from the National Weather Service for Martinsburg, WV, USA (https://www.weather.gov/wrh/climate?wfo=lwx).

like other commercial kiwifruit varieties (i.e., no other climacteric fruit in common storage with kiwifruit during shipping or storage).

Kiwi vines have been propagated by cuttings and grafting (Lawes 1990). 'Tango' and 'Hombre' were propagated by single-node

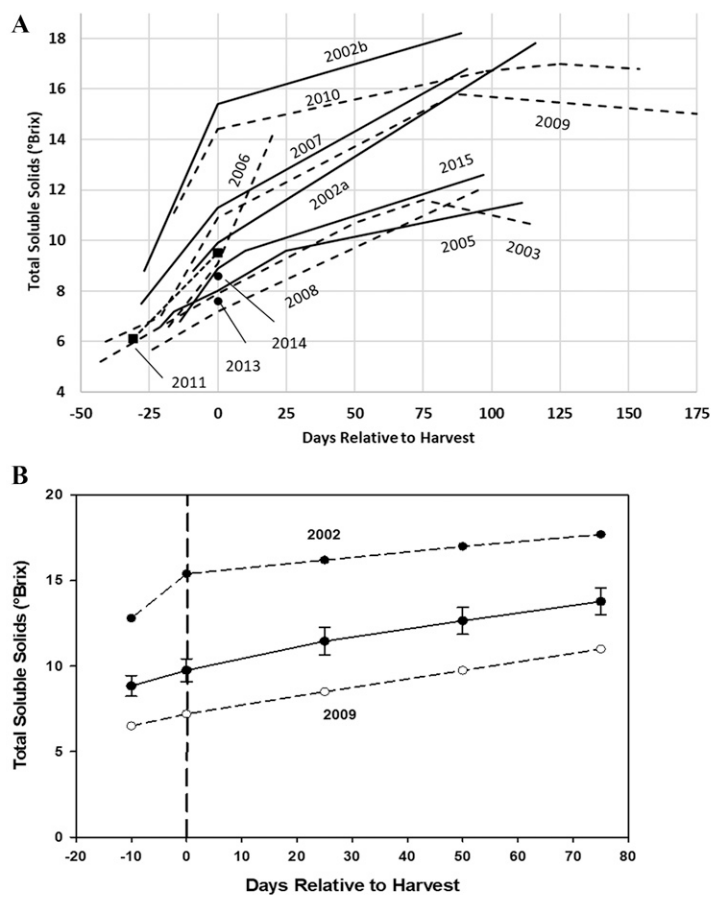

Fig. 3. Total soluble solids measured as degrees Brix for *Actinidia chinensis* Planch. 'Tango' kiwifruit preharvest, at harvest, and postharvest. (**A**) All data from 2002 through 2015. (**B**) Data from (**A**) were replotted on the basis of common dates: preharvest, –10 d; harvest, 0 d; and postharvest, +25, +50, and +75 d. Fruit were harvested on day 0 (long-dashed vertical line) defined as 1 to 2 d before a predicted frost event, which occurred over all years (2002–15) between 3 and 25 Oct. The solid line is the mean ± the standard error (N = 45). Upper and lower soluble solid ranges represented by short-dashed lines, with solid symbols for 2002 and open symbols for 2009. After harvest, fruit were stored at 5 °C. In 2002, half the fruit were harvested at the predicted frost date and half were harvested 9 d earlier based on a degrees Brix sample reading of 8.8.

Table 1. Percentage of rooting of 'Tango' and 'Hombre' Kiwi vine single-node cuttings taken in June and/or July, with basal wounding dipped in 3500 ppm indole-3-butyric acid.

Date of cuttings	Tango (%)	Hombre (%)
7 Jul 2015	70.60	—
28 Jul 2015	36.30	—
1 Jul 2016	64.70	55.00
12 Jul 2016	30.00	60.00
15 Jun 2017	30.80	46.40
30 Jun 2017	26.75	92.50
14 Jul 2017	53.40	100.00

cuttings with basal wounding dipped in 3500 ppm indole-3-butyric acid during June and/or July, with Lawes (1990) suggesting that summer rooting efforts are successful. It was observed that variations in rooting can exist between 'Tango' and 'Hombre' even when cuttings were taken at the same time, and from week to week (Table 1).

During the 20 years of observations, 'Tango' and 'Hombre' kiwi vines were noted to have few significant insect or disease problems. However, scale insects such as white peach scale (*Pseudaulacaspis pentagona*) and *Hemiberlesia* spp. were found on the vines and fruit, respectively. However, neither 'Tango' nor 'Hombre' appeared to experience serious damage from either pest, in contrast to reports of severe losses to multiple host plants (Hanks and Denno 1993; Miller et al. 2005).

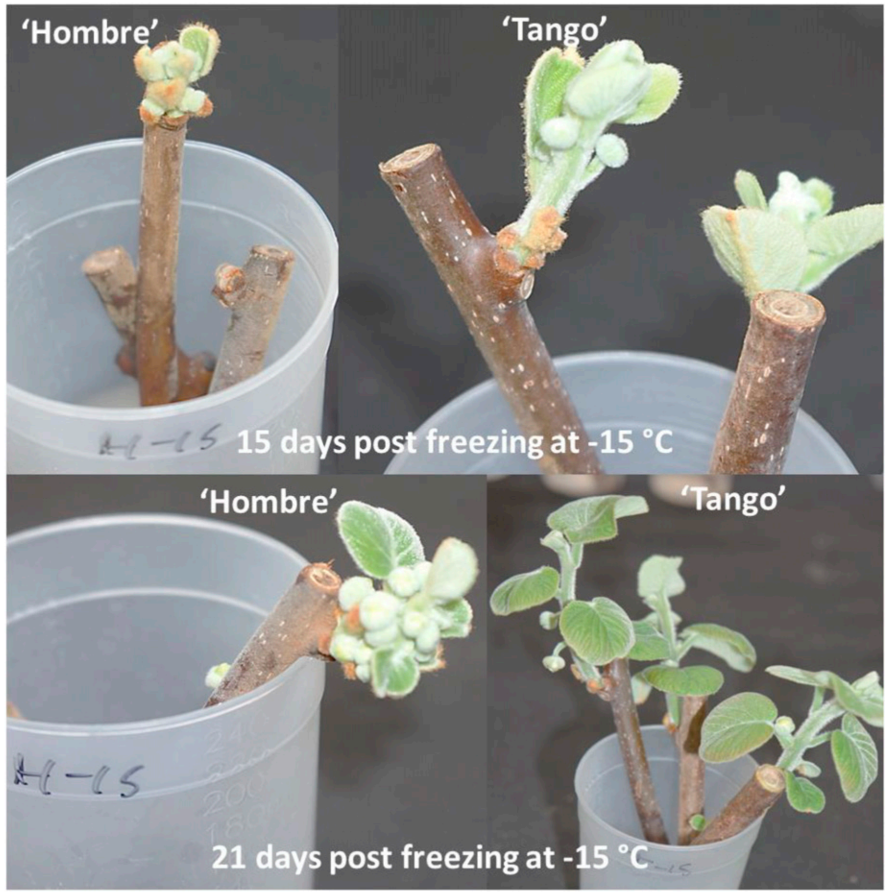

Fig. 4. Cold hardiness test. Field-collected samples of 'Hombre' and 'Tango' (two buds each, three samples per beaker) were subjected to progressive temperatures ranging from 0 °C to –25 °C. The figure displays floral bud development at 15 d (top) and at 21 d (bottom) after the −15 °C treatment. Unopened floral buds are identical to those seen in Fig. 1.

Cold Hardiness Evaluation

Quantitative evaluation of 'Tango' and 'Hombre' cold hardiness was pursued to supplement and expand the data shown in Fig. 2. Two-node cuttings of current-year canes from 'Tango' and 'Hombre' were collected in January from field-grown plants. Approximately 1100 chilling units [Utah model (Richardson et al. 1974)] had accumulated, with 220 chilling units accumulating in the 2 weeks before sampling. The cuttings were kept chilled during transport from the field, and three cuttings each were placed in sealable bags. The bags were placed in an environmental chamber (Tenney Environmental Model T20S-1.5; Williamsport, PA, USA) at 0 °C for 1 h. The following freezing program was then enacted: 2-°C decrement for 30 min, 30-min soak, with the cycle repeated until –10 °C was reached (i.e., –2 °C, –4 °C, –6 °C, –8 °C, –10 °C). At –10 °C, 5-°C decrements per 30 min were enacted with 30-min soaks until –25 °C was reached (i.e., –15 °C, –20 °C, –25 °C). A bag with three cuttings was removed at each temperature point and was placed at 0 °C for 24 h. The bags were then placed at room temperature (≈20 °C) for 1 h. The cuttings were removed from the bags, placed in beakers with water, and the ends recut under water to reestablish vascular continuity. The beakers were then placed in an environmental chamber (model AR-36L3; Percival Scientific Perry, IA, USA) with the following program: 24 ± 0.5 °C, 70% relative humidity, 16-h light/8-h dark photoperiod (≈150 $\mu mol \cdot m^{-2} \cdot s^{-1}$). Budbreak was then recorded for 21 d.

A simple cambial scratch test confirmed that the cambial tissue was alive in all cuttings, even those exposed to a temperature of –25 °C (data not shown). Vegetative budbreak was observed 7 d after placement at 24 °C. By 15 d postfreezing, floral buds were visible on several cuttings—most notably on 'Tango', which was subjected to a temperature of –15 °C (Fig. 4, top). By 21 d postfreezing, floral buds were also visible on 'Hombre', which was subjected to –15 °C, and with those from 'Tango' nearing bloom (Fig. 4, bottom). Vegetative buds also broke on 'Hombre' subjected to –20 °C and on 'Tango' subjected to –25 °C (data not shown). The cold hardiness test demonstrated that 'Tango' and 'Hombre' survive at a temperature of –25 °C, with floral buds surviving to at least –15 °C. This is consistent with field observations, as shown in Fig. 2, when a yield of 50 kg was achieved even after a minimum temperature of –17.8 °C was recorded (National Weather Service, Martinsburg, WV; https://www.weather.gov/wrh/climate?wfo=lwx). In contrast, the most common *A. chinensis* var. *deliciosa* (A.Chev.) cultivar Hayward is tolerant only to –10 °C (Hewett and Young 1981). It must be noted that when floral buds deacclimate and bloom begins, they are susceptible to frost, as evidenced in 2012 (Fig. 2) (National Weather Service, Martinsburg, WV; https://www.weather.gov/wrh/climate?wfo=lwx).

Chilling and Heating Requirements

In addition to cold hardiness information, growers need chilling and heating requirement data. Two- to 3-year-old 'Tango' plants in 10-inch pots were stripped of leaves and placed at 5 °C in the dark. Eight or 10 pots each were removed at 500, 1000, 1500, and

Table 2. Chilling requirement of 'Tango' plants.[i]

Chilling units	Initial budbreak	All plants with budbreak (h at 24 °C)	No. of plants
500	480	624	8
1000	144	384	8
1500	144	240	10
2000	96	192	10

[i] Greenhouse-grown plants were subjected to chilling at constant 5 °C for the chilling units indicated [Utah model (Richardson et al. 1974)]. The plants were then removed to a greenhouse set at 24.7 °C, with ≈16 h light (supplemental light via high-pressure sodium lamps), the current-year wood pruned back to seven buds, and the hours to initial budbreak and hours to all plants exhibiting budbreak recorded.

Fig. 5. Chilling requirement test for 'Tango'. Photos demonstrate that 500 chilling units result primarily in distal budbreak, whereas at least 1000 chilling units result in additional budbreak.

2000 chilling units [Utah model (Richardson et al. 1974)] and placed into a greenhouse. The current-year growth was pruned back to seven buds. An additional five plants were stripped and pruned back, but were kept in the greenhouse as controls. The greenhouse temperature set point was 24.7 ± 1 °C. Supplemental light (high-pressure sodium) extended the daylength to 16 h.

The 500-chilling unit plants exhibited initial budbreak after 480 h, with 624 h required for all plants (Table 2). Fewer hours were necessary for budbreak with the 1000-, 1500-, and 2000-chilling unit plants (Table 2). The distal buds were the only buds that broke on the 500-chilling unit plants over a period of 1 month (data not shown), with subsidiary buds breaking about 6 weeks after placement in the greenhouse (Fig. 5). In contrast, more chilling hours increased the number of buds that eventually broke along the cane (Fig. 5). As is common in such studies, an inverse relationship was observed between chilling units and hours at an elevated temperature necessary to achieve budbreak (i.e., heat requirement; Guo et al. 2014). Indeed, 500 h of chilling required 480 h (20 d) of 24.7 °C for initial budbreak, and an additional 144 h (6 d) for all plants to reach budbreak (Table 2). Additional chilling units reduced the hours of heat needed for budbreak. This is consistent with research summarized by Davison (1990), who noted budbreak is delayed significantly with fewer chilling units. Based on the cold hardiness data and the chilling requirement data, a minimum of 1000 to 2000 chilling units is suggested for vegetative budbreak and floral bud evocation. However, alternating day/night temperatures may further decrease the hours needed for budbreak (Davison 1990).

Although no testing of 'Tango' under managed cultivation conditions, including intensive pruning, training, and fertilization, was undertaken, the performance of 'Tango' and its pollinizer 'Hombre' was such that we recommend them as worthy cultivars for more extensive testing as valuable kiwis for production in the colder regions of the United States, in areas down to USDA Plant Hardiness Zone 6b, which currently are not suitable for the cultivation of other *A. chinensis* var. *chinensis* or *A. chinensis* var. *deliciosa* (A.Chev.) cultivars. 'Tango' and 'Hombre' are also suggested for limited trials in colder zones. Lastly, studying the freeze tolerance and genetics of these selections may allow the further development of kiwi rootstocks or scions in place of less cold-hardy cultivars of *Actinidia*.

Availability

The female kiwi 'Tango' is patented by the USDA-ARS under US Plant Patent 32,617 (Scorza and Demuth 2020) and can be distributed upon obtaining a licensing agreement. The male pollinizer 'Hombre' is not patented and is released publicly. Limited quantities of budwood and/or plants from 'Tango' and 'Hombre' are available upon request. For more information, contact the USDA-ARS Appalachian Fruit Research Station, 2217 Wiltshire Road, Kearneysville, WV 25430-2771, USA (phone: 1-304-725-3451).

References Cited

Cruz-Castillo JG, Woolley DJ, Lawes GS. 1999. Effects of CPPU and other plant growth regulators on fruit development in kiwifruit. Acta Hortic. 498:173–178. https://doi.org/10.17660/ActaHortic.1999.498.20.

Davison RM. 1990. The physiology of the kiwifruit vine, p 127–152. In: Warrington IJ, Weston GC (eds). Kiwifruit science and management. New Zealand Society for Horticultural Science, Ray Richards, Auckland, New Zealand.

Ferguson AR. 1990. Botanical nomenclature: *Actinidia chinensis, Actinidia deliciosa*, and *Actinidia setosa*, p 36–57. In: Warrington IJ, Weston GC (eds). Kiwifruit science and management. New Zealand Society for Horticultural Science, Ray Richards, Auckland, New Zealand.

Ferguson AR. 1999. New temperate fruits: *Actinidia chinensis* and *Actinidia deliciosa*, p 342–347. In: Janick J (ed). Perspectives on new crops and new uses. ASHS Press, Alexandria, VA, USA.

Gullo G, Dattola A, Liguori G, Vonella V, Zappia R, Inglese P. 2016. Evaluation of fruit quality and antioxidant activity of kiwifruit during ripening and after storage. J Berry Res. 6:25–35. https://doi.org/10.3233/JBR-150111.

Guo L, Dai J, Ranjitkar S, Yu H, Xu J, Luedeling E. 2014. Chilling and heat requirements for flowering in temperate fruit trees. Int J Biometeorol. 58:1195–1206. https://doi.org/10.1007/s00484-013-0714-3.

Hanks LM, Denno RF. 1993. The white peach scale, *Pesudalacaspis pentagona* (Targioni-Tozzetti) (Homoptera: Diaspididae): Life history in Maryland, host plants, and natural enemies. Proc Entomol Soc Wash. 95(1):79–98.

Hewett EW, Young K. 1981. Critical freeze damage temperatures of flower buds of kiwifruit (*Actinidia chinensis* Planch.). N Z J Agric Res. 24:73–75. https://doi.org/10.1080/00288233.1981.10420873.

Kempler C, Kabaluk JT. 1995. Fruiting and ripening characteristics of *Actinidia arguta* hardy kiwi. HortScience. 34:807–808. https://doi.org/10.21273/HORTSCI.30.4.807F.

Lawes GS. 1990. Propagation of kiwifruit, p 297–318. In: Warrington IJ, Weston GC (eds). Kiwifruit science and management. New Zealand Society for Horticultural Science, Ray Richards, Auckland, New Zealand.

Miller DR, Miller GL, Hodges GS, Davidson JA. 2005. Introduced scale insects (Hemiptera: Coccoidea) of the United States and their impact on U.S. agriculture. Proc Entomol Soc Wash. 107:123–158.

Minchin PEH, Snelgar WP, Blattmann P, Hall AJ. 2010. Competition between fruit and vegetative growth in Hayward kiwifruit. N Z J Crop Hortic Sci. 38:101–112. https://doi.org/10.1080/01140671003781728.

Mworia EG, Yoshikawa T, Salikon N, Oda C, Asiche W, Yokotani N, Abe D, Ushijima K, Nakano R, Kubo Y. 2012. Low-temperature-modulated fruit ripening is independent of ethylene in 'Sanuki Gold' kiwifruit. J Expt Bot. 63:963–971. https://doi.org/10.1093/jxb/err324.

Paulauskiene A, Taraseviciene Z, Zebrauskiene A, Pranckietiene I. 2020. Effect of controlled atmosphere storage conditions on the chemical composition of super hardy kiwifruit. Agronomy. 10:822. https://doi.org/10.3390/agronomy10060822.

Pescie MA, Strik B. 2004. Thinning before bloom affects fruit size and yield of hardy kiwifruit. HortScience. 39:1243–1245. https://doi.org/10.21273/HORTSCI.39.6.1243.

Richardson AC, Boldingh HL, McAtee PA, Gunaseelan K, Luo Z, Atkinson RG, Burdon JN, Schaffer RJ. 2011. Fruit development of the diploid kiwifruit *Actinidia chinensis* 'Hort16A'. BMC Plant Biol. 11:182. https://doi.org/10.1186/1471-2229-11-182.

Richardson EA, Seeley SD, Walker DR. 1974. A model for estimating the completion of rest for 'Redhaven' and 'Elberta' peach trees. HortScience. 9:331–332. https://doi.org/10.21273/hortsci.9.4.331.

Royal Horticultural Society Colour Chart. 2001. Royal Horticultural Society, London.

Scorza R, Demuth M (inventors). 2020. Hardy kiwi named 'Tango'. US Department of Agriculture (assignee). US Plant Patent 32,617. (Filed 26 Jun 2019, granted 15 Dec 2020).

Testolin R, Messina R. 1987. Winter cold tolerance of kiwifruit: A survey after winter frost injury in northern Italy. N Z J Exp Agric. 15:501–504. https://doi.org/10.1080/03015521.1987.10425604.

Williams MH, Boyd LM, McNeilage MA, MacRae EA, Ferguson AR, Beatson RA. 2003. Development and commercialization of 'Baby Kiwi' (*Actinidia arguta* Planch.). Acta Hortic. 610:81–86. https://doi.org/10.17660/ActaHortic.2003.610.8.