‘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. delicosa (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. delicosa (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. delicosa (A.Chev.) cultivar Hayward (Ferguson 1999). Although A. chinensis Planch var. chinensis fruit is considered to be as tender as A. chinensis var. delicosa (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. delicosa (A.Chev.) (Fig. 1).

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. delicosa ‘Hayward’ (right). (C) Flowers of male pollinizer ‘Hombre’ (D) Flowers of ‘Tango’.

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 Frutticoltura, 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...
location, and ‘Tango’ fruit were harvested 1 to 2 d before a predicted frost event, from the first and third week in October (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 62.1 g, respectively. This compares with commercially produced Actinidia chinensis var. delicosa (Act. 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 Actinidia chinensis 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 Actinidia delicosa Planck var. delicosa (Act. 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 °C 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 Actinidia chinensis var. delicosa (Act. 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. delicosa 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 Planck 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 like other commercial kiwifruit varieties (i.e., no other climacteric fruit in common storage with kiwifruit during shipping or storage).

Kiwivines have been propagated by cuttings and grafting (Lawes 1990). ‘Tango’ and ‘Hombre’ were propagated by single-node cuttings and grafted.
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).

**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 μmol·m⁻²·s⁻¹). Budbreak was then recorded for 21 d.

<table>
<thead>
<tr>
<th>Date of cuttings</th>
<th>Tango (%)</th>
<th>Hombre (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>7 Jul 2015</td>
<td>70.60</td>
<td>—</td>
</tr>
<tr>
<td>28 Jul 2015</td>
<td>36.30</td>
<td>—</td>
</tr>
<tr>
<td>1 Jul 2016</td>
<td>64.70</td>
<td>55.00</td>
</tr>
<tr>
<td>12 Jul 2016</td>
<td>30.00</td>
<td>60.00</td>
</tr>
<tr>
<td>15 Jun 2017</td>
<td>30.80</td>
<td>46.40</td>
</tr>
<tr>
<td>30 Jun 2017</td>
<td>26.75</td>
<td>92.50</td>
</tr>
<tr>
<td>14 Jul 2017</td>
<td>53.40</td>
<td>100.00</td>
</tr>
</tbody>
</table>

**Fig. 4.** Cold hardness 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.

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. chinesis var. delicosa (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 2000 h of chilling. |
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 of chilling required 480 h (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 pollinator ‘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. delicosa (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 pollinator ‘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


