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'Chujuc', a New Powdery Mildew-resistant U.S. Western-shipper Melon with High Sugar and β-Carotene Content

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The vegetable breeding program at the Texas Agricultural Experiment Station (TAES; now Texas AgriLife Research) in Weslaco, TX, has a 60-year history of developing commercially important cultivars to meet consumer and industry needs such as improved fruit quality, disease resistance, and productivity. Western shipper melon (*Cucumis melo* L., Reticulatus Group) varieties are among some of the important Cucurbit crops grown in Texas for the summer fresh markets. Twelve muskmelon cultivars, including muskmelons, honeydews, and canary types, have been released since 1950 (Correa, 1964; Godfrey, 1953). Melon production in Texas has fluctuated dramatically over the years, from historic highs of more than 11,000 ha to more recent levels of ≈4,600 ha (Smith and Anciso, 2005). High costs of production, increased competition from Central America, and quality control problems have been significant factors contributing to this decline. Over the years, the vegetable breeding program at Weslaco has addressed some of the major limitations to sustainable production of high-quality melon crops in Texas. These include susceptibility to various diseases such as gummy stem blight, *Monosporascus* root rot and vine decline, powdery mildew, downy mildew, and the Cucurbit Yellow Stunting Disorder virus. Hence, disease resistance and fruit quality are some of the major priority areas of the breeding program and have received considerable consumer, industry, and government (U.S. Department of Agriculture) support. Under the "Designing Foods for Health" grant (CSREES 2001-34402-10543, 2003-34402-13647), the program has selected, for genetically enhanced levels of beneficial phytochemicals such as β-carotene as well as total sugars within TAES, commercially improved lines and wild-type germplasm. The outcomes from this program are new inbred lines with both disease resistance and improved fruit quality.

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Origin

'Chujuc' is a Western shipper muskmelon with dense netting that originated from a cross of 'TAM Uvalde' and a single F_3 selection out of 'Cruiser'. 'TAM Uvalde' is a commercial Western shipper melon with size 15 to 18 fruit, which are high in sugars and β-carotene but considered too small to meet current retail standards. It has excellent resistance to powdery mildew (*Podosphaera xanthii*) races 1 and 2 and downy mildew (*Pseudoperonospora cubensis*). The F_3 selection from 'Cruiser' is also a Western shipper type, with large (size 9), firm fruit, a ropy net, and small abscission scar. It is susceptible to powdery mildew, but has a very vigorous vine with tolerance to late-season root and vine decline diseases caused by the fungus *Monosporascus cannonballus* Pollack & Uecker (Martyn and Miller, 1996). A single F_2 plant from the 'TAM Uvalde' by 'Cruiser' cross, showing resistance to vine decline and powdery mildew, was selected and the seed was planted during Fall 2001. Several F_3 plants were selected for excellent fruit quality and resistance to natural infection by powdery mildew (PM) races 1 and 2 and vine decline. The F_4 seed of these best selections was planted in a greenhouse and all plants were manually selfed. The best plants from these F_5 lines were selected and planted in an isolated field plot during Spring 2003. Individual plants were selected for uniform fruit quality, vigor, and mildew resistance. Cuttings of these plants were selfed and sibbed in a greenhouse and the F_6 seeds obtained were planted in Spring 2004. Four generations of bulking the best selections in isolation plots resulted in a uniform F_{10} line resistant to PM races 1 and 2 and intermediately resistant to vine decline disease. A 0.5-ha isolation plot was planted in Las Cruces, NM, during Summer 2006 to increase seed for commercial trials. Superior fruits were selected from powdery mildew-resistant plants, resulting in 25 kg of seed. Thereafter, 40 ha were planted at four locations in Texas (Weslaco, Edinburg, Uvalde, and Amarillo) to verify fruit quality, yield, and adaptation during Spring 2007.

Description

Adaptation. 'Chujuc' has been grown during spring/summer months in replicated field plots at Weslaco, Edinburg, Amarillo, and Uvalde, TX, following standard commercial practices for muskmelon production. Vines have demonstrated exceptional vigor compared with standard commercial hybrids, 'Primo' and 'Caravelle', at all locations. Powdery mildew and vine decline were not detected on plants at these locations. At Edinburg, isolated cases of fruit softening were observed and this was associated with heavy rainfall and excessive soil moisture in low-lying areas of the field. Also, soils at the Edinburg site are extremely sandy and tend to have low nutrient-holding capacity, especially calcium and potassium (K), which have been associated with fruit tissue integrity and firmness. Lester et al. (2006) showed that adequate K nutrition can increase melon tissue firmness by increasing cell and tissue turgor potential. Excessive soil moisture and limited nutrient uptake probably contributed to the fruit-softening problem at the Edinburg site. This problem was not observed at Weslaco or Amarillo, even after excessive rainfall in the field plots. These two locations have heavier clay-loam soils. Growers are encouraged to conduct soil textural and chemical analyses to determine if soil type could potentially impact fruit quality. Yields at all locations were similar to, and in some cases higher than, commercial control hybrids (Table 1). 'Chujuc' appears to be well suited to semiarid, semitropical, and

desert production regions such as south and west Texas and New Mexico.

Performance and fruit quality. The fruit of 'Chujuc' are round and densely netted with a small, dry abscission scar. Interior quality is excellent with deep orange flesh, closed seed cavity, high soluble solids, and β-carotene (Table 1). The excellent flavor is reminiscent of caramel with little or no muskiness. More than 70% of the fruit in trials at Weslaco and Uvalde were size 12 with 20% size 15 and 10% size 9. At Edinburg, fruit sizes were larger, with 40% size 9 and 60% size 12 (data not shown).

Replicated field trials were planted at Weslaco and Uvalde during 2006 to compare fruit quality and yield with commercial hybrid checks 'Primo' or 'Caravelle'. Four replications of 50-plant plots were direct-seeded on black plastic mulch with subsurface drip irrigation. All fertilizer and pesticide applications followed standard commercial practices. 'Chujuc' fruit had higher soluble solids and β-carotene levels than the popular commercial hybrids (Table 1). In both locations, total soluble solids averaged ≈13%, which was higher than the commercial Western shipper control varieties that ranged from 10% to 12%. Rind texture and appearance were also more desirable for 'Chujuc' than either 'Primo' or 'Caravelle'. The seed cavity of 'Chujuc' was consistently closed, compared with the control varieties, which leads to less seed loosening and subsequent loss of quality during shipping (Fig. 1; Table 1). The excellent flesh thickness of 'Chujuc' also results in heavier fruit in the same size class and a larger edible portion. Yields have been equal or superior to commercial hybrids in south and west Texas as a result of strong vine growth with excellent powdery mildew resistance. The large, vigorous root system (data not shown) also provides intermediate resistance to vine decline diseases caused by *M. cannonballus* and *Macrophomina phaseolina* (Mertely et al., 1993). Ratings for plants exhibiting vine decline symptoms were taken on field plots at both Weslaco and Uvalde (Table 1). These plots were not replicated, so simple percentages were calculated based on 200 plants in each plot. At each location, root segments were collected from plants already declining (mostly 'Primo' and 'Caravelle') or showing symptoms of root infection but no decline (mostly 'Chujuc') and plated onto water agar after surface sterilizing with 10% bleach for 5 min. Hyphal tips were subcultured onto V8 agar and allowed to grow for 30 d before confirmation of *M. cannonballus*. Pathogen presence was confirmed on roots of all three cultivars, indicating that 'Chujuc' has tolerance to the fungus, because it does not decline rapidly as do 'Primo' and 'Caravelle'. 'Chujuc' should be suitable as an open-pollinated cultivar based on its performance compared with F_1 hybrid cultivars, which currently dominate the Texas melon production. It may also be useful as a parent in F_1 hybrid combinations to generate additional cultivars.

Table 1. Performance of 'Chujuc' in field plots at Weslaco and Uvalde, TX, during the spring growing season of 2006.

	Weslaco		Uvalde	
	Chujuc	Primo	Chujuc	Caravelle
Fruit size[y]	9–12	6–12	9–12	12–15
Flesh thickness (cm)[x]	4.6 a[z]	4.5 a	4.5 a	4.3 a
Yield (22 kg·ha^{-1} box)	1,580 a	1,560 a	1,470 a	1,370 b
Total soluble solids[w]	13.0 a	10.8 b	12.4 a	12.0 a
β-carotene (μg·g^{-1})	58.5 a	56.7 a	61.1 a	58.2 b
Closed seed cavity (%)[v]	100 a	70 b	98 a	90 b
Powdery mildew rating[u]	0	3	0	2
Vine decline (%)	0	30	0	10
Days to maturity	80	78	82	80

[z]Mean separations within rows by least significant difference ($P \leq 0.05$). Means followed by the same letter are not significantly different within a given location.
[y]Number of fruits based on a standard 22-kg melon box.
[x]Average distance between rind and seed cavity/placenta.
[w]Measured at 25 °C with a handheld Atago refractometer (Atago USA, Bellevue, WA).
[v](Seed cavity diameter – airspace diameter)/seed cavity diameter·100.
[u]Based on scale from 0 to 5, with 0 = no colonies present, 1 = colonies on less than 10% of leaf surface, 2 = colonies on 20% to 30% of surface, 3 = colonies on greater than 50% of surface, 4 = colonies on 100% of abaxial and adaxial surfaces, 5 = dead leaves.

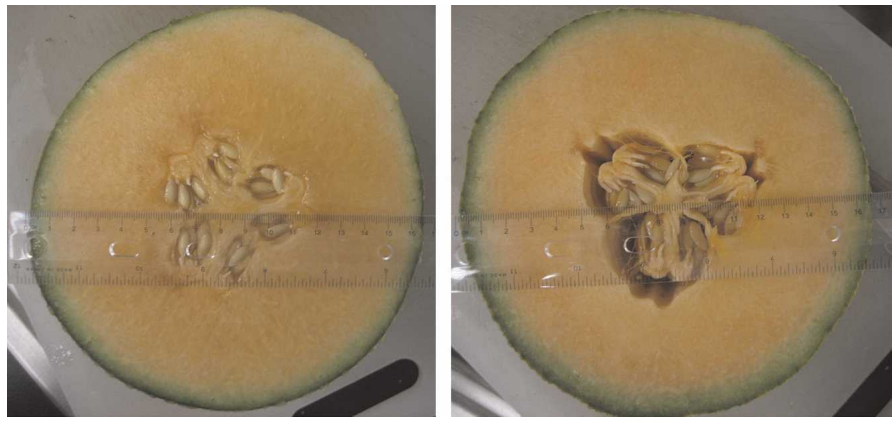

Fig. 1. Cross-section of 'Chujuc' fruit (left) showing typical fruit characteristics such as closed seed cavity and edible mesocarp tissue thickness compared with the commercial hybrid cultivar Primo (right).

Powdery mildew resistance. Powdery mildew in melon is incited by the fungal pathogen, *Podosphaera xanthii* (Jahn et al., 2002) and has been a serious threat to melon production in south Texas for more than 50 years (Godfrey, 1953). It is ubiquitous throughout melon production regions of Texas and spreads rapidly by windborne spores. This pathogen is difficult to culture in vitro, so screening is conducted by natural infection in field plots as well as greenhouses, where conditions are favorable for development. Several sources of resistance have been identified involving some major, dominant genes (Bohn and Whitaker, 1964). More than 28 races are now proposed, and resistance has only been confirmed against a few of these (McCreight, 2006). Traditionally, races 1 and 2 have been predominant in Texas. R.T. Correa (Texas Agricultural Experiment Station, Weslaco, TX) released several cultivars with excellent resistance to races 1 and 2, including 'Perlita', 'Dulce', 'Uvalde', and 'TAM Dew Improved' (Correa, 1964). This resistance has been effective in Texas for more than 40 years, but these cultivars do not produce fruit size or yields to meet current market demands. However, both 'Perlita' and 'Dulce' have recently been reported as susceptible to new strains of the fungus in California (McCreight, personal communication). We have screened all four of these cultivars in field plots at multiple south Texas locations for the last 8 years and have not seen a breakdown of resistance despite severe mildew infestation on most commercial cultivars and susceptible checks. 'Chujuc' has been screened in the same plots to verify the presence of the resistance genes derived from its 'Uvalde' parent. Although some reports have indicated single dominant genes for resistance to races 1 and 2, we have observed different degrees of infection in F_2 and backcross progeny, suggesting the presence of multiple genes for resistance to race 2. None of the F_1 lines derived from 'Uvalde' or 'Dulce' crossed with a susceptible parent were highly resistant, suggesting that some of these modifier genes are recessive in nature (data not shown). During the 2007 spring growing season, there was a severe powdery mildew infestation in fields in the Weslaco region. More than 300 breeding lines and cultivars were planted in our field plots and mildew ratings were taken three times: at fruit set,

Fig. 2. Leaves of mature 'Chujuc' (left) and 'Caroline' plants (right) in field plots in Weslaco, south Texas, showing differences in powdery mildew susceptibility.

first harvest, and after the last harvest. Leaves were rated on a 0 to 5 scale with the final rating indicated in Table 1. 'Chujuc' (Fig. 2) and 'Uvalde' demonstrated the highest levels of resistance (0 to 1). 'Dulce', and 'TAM Dew Improved' also performed well, whereas the majority of commercial hybrid cultivars were highly susceptible, including some of the most popular commercial cultivars such as Primo, which have been reported to be resistant to races 1 and 2 (data not shown).

Availability. Breeder's seed will be maintained by the Texas AgriLife Research and Extension Center at Weslaco. Application for plant variety protection is being filed for 'Chujuc'. This variety may be licensed through Texas AgriLife Research for commercial seed production.

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