'Gold Nugget' Mandarin, A Seedless, Late-maturing Hybrid

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Mandarins (*Citrus reticulata* Blanco) are a major citrus crop in many parts of the world, including Spain, Morocco, Italy, Japan, South Africa, Israel, and Argentina. They are currently of minor importance in the United States, occupying only $\approx 3\%$ of the bearing acreage in California and Florida (U.S. Dept. of Agriculture, 1998). The market for seedless, easy to peel, and rich-flavored mandarins is increasing. Development of a successful mandarin industry would be enhanced if it were possible to produce and market fruit during most of the year. California produces two major classes of oranges [*C. sinensis* (L.) Osbeck] for the fresh market, navels during the fall and winter, and Valencias during the summer. Early- and late-maturing cultivars of navel orange have further extended the season in recent years. This approach has economic benefits in allowing packhouses to operate most of the year. Currently, the early (October–December) maturing satsuma (*C. reticulata*) cultivars are the most widely grown mandarins in California. Recently, markets have been increasing for few-seeded 'Clementine' (*C. reticulata*) cultivars from Spain and Morocco that mature from October to February. Relatively few mid- to late-season mandarins are available, and most of these are quite seedy. A major objective of the citrus breeding program at the Univ. of California, Riverside (UCR) is to develop few-seeded, rich-flavored mandarin cultivars with a range of maturity dates. We are using irradiation to induce seedless mutations in existing cultivars, and hybridization between diploid and tetraploid parents to produce few-seeded triploids (Soost and Roose, 1996). The most recently released mandarins from the UCR breeding program are 'Pixie' and 'Encore', two late-maturing diploid hybrids released in 1965 (Cameron et al., 1965). The cultivar described here is a relatively late-maturing seedless diploid selection with excellent flavor. Additional few-seeded

(triploid) mid- and late-maturing selections are currently being evaluated in replicated trials.

Origin

Citrus reticulata 'Gold Nugget' is a seedless mid- to late-season mandarin developed at UCR as a hybrid of 'Wilking' $\times$ 'Kincy' [(Willowleaf $\times$ King) $\times$ (King $\times$ Dancy)]. Pedigrees of the grandparents are unknown, although 'King' is suspected to be a mandarin $\times$ orange hybrid. The cross was made at UCR in the 1950s. This hybrid (tree 11D 51.8) was first selected by R.K. Soost and J.W. Cameron in 1975, and repropagated for additional evaluation. A virus-free budwood source was established at Lindcove Research and Extension Center, Exeter, Calif. in 1986 as VI 422. During much of its evaluation, it was called "Pixie-like" because of its similarity in appearance and maturity date to 'Pixie', an open-pollinated seedling of 'Kincy' that is few-seeded and has excellent flavor but small fruit size (Cameron et al., 1965). The name 'Gold Nugget' was selected as descriptive of the external appearance of the fruit.

Description

'Gold Nugget' is consistently seedless in mixed plantings with a wide variety of other citrus cultivars, including mandarins, pummelos [*C. maxima* (Burm.) Merrill], and oranges. At maturity, the fruit has a rich, sweet taste and is somewhat oblate with a height : width ratio of ≈ 0.84 (Fig. 1). Fruit from young trees are ≈ 60 mm in length and 70 mm in diameter, and weigh ≈ 150 g. Younger trees tend to have larger fruit than older trees, but fruit size on older trees can probably be increased by pruning or thinning. At UCR, fruit reach maturity in January or February and hold well on the tree, with little granulation into April or even July in some years. Early in the season, fruit may develop rind color and acceptable solids : acids ratio, but juice percentage is still too low for acceptable eating quality. The flesh color is orange, and rind color bright orange (chroma = 68.6, hue = 72.3). The rind tends to be coarse, particularly on young trees, of medium thickness, ≈ 4 –5 mm, and peels fairly easily. The tree is medium in size and moderately vigorous, with a fairly upright shape. In some years, blossom end splitting is a problem and can lead to moderate crop loss, particularly if fruit are held into March or later. The major advantage of 'Gold Nugget' over other mandarin cultivars is the combination of seedlessness, excellent flavor, late maturity, and persistence on the tree. No other commercial mandarin cultivar combines these attributes.

Older evaluation data come from plots of two to four trees at UCR, and from similar plots at the Univ. of California, Lindcove Research and Extension Center, Exeter. Yield of 'Gold Nugget' has not been recorded, but crop estimates for trees in mixed plantings indicate that production is similar to that of other mandarins. Like many late-maturing

Fig. 1. Fruit of 'Gold Nugget' on 'Carrizo' citrange harvested at UCR in May.

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mandarins, 'Gold Nugget' is prone to moderate to severe alternate bearing, though this problem may be less severe on trees that are pruned and harvested regularly. Fruit from the Riverside test site were smaller (108 g vs. 130 g), more round, and had thinner, slightly smoother rinds and substantially higher acid content (1.10% vs. 0.70%) than those from Lindcove in the San Joaquin Valley. The lower acid content suggests earlier maturity at Lindcove, but at both locations fruit are still green and have low juice content when they reach the 6.5 solids : 1 acids ratio necessary for legal maturity. Response of 'Gold Nugget' to degreening with ethylene has not been evaluated. For these trees, mean fruit weight ranged from 119 to 142 g during 6 of the 7 years between 1992 and 1998. In 1996, when crop load was high, average fruit weight was only 87 g. One postharvest evaluation showed that fruit harvested in January stores well for 3–6 weeks at 5 °C. After 1 week at 20 °C following cold storage at 5 °C, the appearance score (0–5 scale, 0 being best) of 'Gold Nugget' declined from 0.25 to 0.30. For fruit stored 3 weeks at 1 °C, followed by 3 weeks at 5 °C and 1 week at 20 °C, appearance score declined from 0.25 to 0.75 (M. Arpaia, personal comm.).

Trees were also evaluated at four field stations in California. On two or three dates between 6 Dec. 1996 and 1997 and 29 Apr. 1997 and 1998, 10-fruit samples were collected and evaluated from one-to-three tree plots at the Riverside, Lindcove, South Coast (Orange County), and Coachella Valley (Riverside County) Research and Extension Centers. Fruit acid content declined sooner at the warmer Coachella Valley site, and later at the cooler South Coast site, with Riverside and Lindcove intermediate (data not shown). Total soluble solids were relatively similar across locations, ranging from 13.5% to 16% between December and May. The mean number of seeds per fruit from these mixed plantings was 0.05. Fruit weight averaged 120 g, and was somewhat larger in Coachella (170 g) than in the other locations (107–130 g). Rind color changed from green to bright orange between 15 Dec. and 10 Jan. in most years. Rind thickness and texture were similar across locations and sampling dates.

Semi-commercial trials of 8–100 trees per location were initiated in 1993 when a trial was planted at Thermal (Coachella Valley, Riverside County). In 1994, similar trials were planted at nine additional locations: five locations in the San Joaquin Valley; Ojai and Santa Paula in Ventura County; Valley Center in San Diego County; and at the Coachella Valley Agricultural Research Center in Riverside County. In these tests, trees were grown on several different rootstocks, including most of those commonly used in California. With other scions, the rootstocks selected have a wide range of effects on tree growth and fruit quality (Castle, 1987). 'Carrizo' [*C. sinensis* x *Poncirus trifoliata* (L.) Raf.] was used at nine locations, 'C-35' (*C. sinensis* x *P. trifoliata*) at five, 'Rich 16-6' trifoliolate (*P. trifoliata*) at three, and 'Schaub' rough lemon (*C. jambhiri*

Lush.), 'Volkamer' (*C. volkameriana* Ten. and Pasq.), 'Cleo' (*C. reshni* Hort. ex. Tan.), 'Swingle' (*C. paradisi* Macf. x *P. trifoliata*), and '1452' citrumelo (*C. paradisi* x *P. trifoliata*) at one or two locations each. Tree size, crop, and health were measured in 1998 and early 1999. For trees on 'Carrizo' rootstock, the average canopy volume (calculated using the prolate sphere equation) was 3.1 m³, with a range among locations of 1.2 to 5.2 m³. Mean tree health ratings (0–5 scale, 0 = dead and 5 = excellent) ranged from 3.4 to 5.0. In 1999, the first year of significant crops for most locations, the mean crop rating (0–5 scale, 0 = <5 fruit per tree; 5 = a very heavy crop) over all locations was 2.2, with a range over locations of 0.125 to 4.0. On this scale, existing cultivars cannot repeatedly support crops rated at >4.0 because they either die or begin alternate bearing.

In 1997 and 1998, fruit samples were collected from the semicommercial trials for fruit quality studies. The Thermal location was not sampled because too few fruit were produced. At each location, between one and five samples (10 fruit each) were collected in Feb. and May 1997, and Feb., Apr., and May

1998. Each sample was collected from one to three trees. Not all locations were sampled on each date, but most locations were sampled twice each year; 55 samples were analyzed in 1997 and 92 in 1998. For trees on 'Carrizo', averaged over locations and sampling dates, values for most traits (Table 1) were within the range observed previously at UCR and Lindcove. Soluble solids content ranged from 11.1% to 15.5%, generally increasing between Feb. and May in 1997, but not in 1998, when heavy spring rains occurred. Titratable acid content ranged from 0.49% to 1.14%, and decreased over the season at each location (Table 2). Solids : acids ratio increased over the season (Table 2), primarily because of the decrease in acid. Juice content varied among locations at some sampling dates, with February values being lower at the Santa Paula location where fruit mature later. Fruit weight did not vary significantly over locations or sampling dates. In the Coachella Valley, a desert area with high summer temperatures, fruit had acceptable quality in January or February, and was sometimes acceptable in December. In 1999, quality was good, but in 1998, fruit granulated or dried before they

Table 1. Summary of fruit quality characteristics of 'Gold Nugget' on 'Carrizo' citrange rootstock in semi-commercial trials in California.

Trait	1997			1998		
	Loc'ns	Mean ^a	Range	Loc'ns	Mean	Range
Fruit wt. (g)	7	152	123–211	9	156	94.0–224.0
Fruit length (mm)	7	59.1	52.6–69.5	9	55.6	47.0–64.4
Fruit width (mm)	7	69.8	64.5–82.2	9	67.3	58.2–77.4
Neck rating ^b	7	0.22	0.00–0.50	9	0.66	0.00–2.00
Rind color ^c	7	11.4	10.7–12.0	9	11.6	11.5–11.9
Rind texture ^w	7	6.49	5.13–7.25	9	5.31	3.75–6.88
Rind thickness (mm)	7	5.19	4.75–6.13	9	4.62	3.50–6.00
Peelability ^v	7	7.01	6.33–8.00	9	7.47	5.25–9.00
Soluble solids (%)	7	13.9	11.3–14.7	8	12.8	11.2–15.5
Acids (%)	7	0.73	0.62–0.89	8	0.78	0.61–1.05
Solids : acids ratio	7	19.7	15.8–23.4	8	17.6	12.9–22.4
Juice content (%)	7	42.5	32.3–48.2	8	36.9	28.5–42.4

^aAveraged over one to three sampling dates (February–May) per year. At each sampling date, one to five samples (10 fruit each) were analyzed for each location. 1997 means are based on a total of 55 samples, and 1998 means on 92 samples.

^bVisual rating on a scale of 0–3; 0 = no trace of neck, 3 = neck with a diameter at least 50% of fruit diameter.

^cVisual rating on scale of 0–13; 0 = green, 13 = red-orange.

^wVisual rating on a scale of 1–8; 1 = very smooth, 8 = extremely coarse.

^vSubjective rating of ease of peeling a single fruit; 1 = very difficult, 10 = a fruit with completely separated rind and segments. Fruit with ratings of 7 or higher would be relatively easy to peel.

Table 2. Fruit quality characteristics of 'Gold Nugget' on 'Carrizo' rootstock in semi-commercial trials at several locations and sampling dates in 1997 and 1998.

Trait	Sampling date	No. locations	No. samples	Mean	Range
Acid (%)	Feb. 1997	7	14	0.79	0.69–0.89 ^{NS}
	May 1997	6	10	0.60	0.49–0.69 ^{NS}
	Feb. 1998	7	23	0.87	0.72–1.14 ^{***}
	Apr.–May 1998	9	17	0.60	0.48–0.99 ^{***}
Solids : acid	Feb. 1997	7	14	17.2	13.8–20.7 ^{**}
	May 1997	6	10	24.1	21.6–27.2 ^{NS}
	Feb. 1998	7	23	15.2	11.0–18.8 ^{***}
	Apr.–May 1998	9	17	22.0	14.0–26.9 ^{**}
Juice content (%)	Feb. 1997	7	14	43.9	39.8–46.8 ^{**}
	May 1997	6	10	38.2	21.5–47.4 [*]
	Feb. 1998	7	23	37.8	27.9–43.3 ^{***}
	Apr.–May 1998	9	17	34.4	29.7–38.8 ^{NS}

^{NS}, ^{*}, ^{**}, ^{***}Differences among locations within sampling dates nonsignificant or significant at $P \leq 0.05$, 0.01, or 0.001, respectively, by analysis of variance.

Table 3. Fruit characteristics of 'Pixie' and 'Gold Nugget' mandarins grown in Riverside, Calif.

Sampling date	Soluble solids (%)		Acid (%)		TSS : acid		Fruit wt (g)	
	Pixie	Gold Nugget	Pixie	Gold Nugget	Pixie	Gold Nugget	Pixie	Gold Nugget
15 Feb. 1984	14.8	16.2	1.10	1.20	13.4	13.5	74	103
20 Mar. 1984	14.7	16.0	0.92	1.02	16.2	15.8	87	117
17 Jan. 1985	12.0	15.2	1.02	0.97	12.0	16.2	73	93
1 Mar. 1985	11.7	17.6	0.72	1.00	16.3	17.6	80	75
1 Mar. 1986	16.3	16.6	1.15	1.35	14.1	12.3	nd ²	nd
9 Apr. 1987	14.3	15.9	0.85	1.25	16.8	12.7	nd	nd
Mean	14.0	16.3	0.96	1.13	14.8	14.7	78.5	97.0

²No data.

became juicy. At present, we have insufficient data to recommend this cultivar for desert areas. In cooler, coastal areas, as represented by Santa Paula and Irvine, soluble solids content is lower and acid content is higher than at warmer locations.

'Gold Nugget' was compared with 'Pixie', the cultivar most similar in maturity date and seedlessness, using data from six samples from comparable trees grown at UCR (Table 3). 'Gold Nugget' fruit were larger than 'Pixie' fruit in three of four samples for which weight was recorded, slightly more oblate, with a slightly thicker and rougher rind, thicker membranes, and slightly coarser flesh. 'Gold Nugget' had deeper orange flesh color, somewhat higher soluble solids in all six samples, and higher acidity in five of six samples. The total soluble solids : acid ratios of the two cultivars were generally similar. The stylar scar was depressed in 'Gold Nug-

get', and level or slightly raised in 'Pixie'. For fruit harvested in January, 'Gold Nugget' did not store as well as 'Pixie' although both deteriorated only slightly. The major advantage of 'Gold Nugget' over 'Pixie' is the larger fruit size.

Culture

Nursery propagation is generally similar to that of other mandarins. Buds initiate growth more rapidly during the spring than the fall unless a heated greenhouse is used. 'Gold Nugget' trees grow well on 'Carrizo', 'Troyer', 'trifoliate', and 'C-35' rootstocks. Performance of young trees on 'Cleopatra' mandarin and 'Swingle' citrumelo is also acceptable. Longevity and long-term productivity of trees on various rootstocks have not been evaluated. Tree growth is generally vigorous with normal cultural practices. The productivity of 'Gold

Nugget' in large solid-block plantings with no available pollinizer is unknown. A tree grown in a bee-proof screenhouse has produced few fruit, but 75 trees $\approx$ 35–70 m from the nearest pollinizer have been uniformly productive. We do not recommend planting this variety in isolated blocks until its pollination requirement is better understood. Pollen viability, estimated by germinating pollen on agar plates, was 23%. Thus this cultivar may cause moderate levels of seediness in compatible cultivars.

Availability

'Gold Nugget' requires a license for propagation and sale. The license (Reference Number: 1999–266) is available from Office of Technology Transfer, University of California, 1111 Franklin Street, 5th Floor, Oakland, CA 94607–5200.

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