

The Pomegranate: A New Look at the Fruit of Paradise

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In this paper, a broad overview is provided for the fruit known as the pomegranate (*Punica granatum*). The pomegranate has a deep association with the cultures of the Mediterranean region and Near East, where it is savored as a delicacy and is an important dietary component, revered in symbolism, and greatly appreciated for its medicinal properties. It is strange that a horticultural icon of such importance has been largely relegated to an ornamental role in the United States and much of Europe. Recent trends indicate that the health-giving and flavor-filled properties of these fruits may soon reverse this oversight.

TAXONOMIC ODDITY AND NAMING

Botanically, the pomegranate (*P. granatum*) is in the subclass Rosidae, order Myrtales, which is home to a few other fruits such as the guava (*Psidium sp.*) and feijoa (*Feijoa sp.*). However, pomegranate is unusual in being one of only two species in its genus, *Punica*, which is the sole genus in the family Punicaceae (ITIS, 2006). Recent molecular studies suggest a taxonomic reconsideration might place *Punica* within the Lythraceae (Graham et al., 2005). The second species in *Punica*, *P. protopunica*, is found only on the island of Socotra, of the Arabian Peninsula, and is considered an ancestral species (Shilikina, 1973) or an independent evolutionary path (Kosenko, 1985).

The name *Punica* is the feminized Roman name for Carthage, the ancient city in northern Tunisia from which the best pomegranates came to Italy. It was initially known as *Malum punicum*, the apple of Carthage. But Linnaeus selected the current name, with the specific epithet *granatum*, meaning seedy or grainy. Its common name in the United States, therefore, means “seedy apple” (Encyclopedia Britannica, 2006c). While considering naming, it is interesting to note that the fruit’s name in French, grenade, provided the name for the weapon because of similarities in appearance (Encyclopedia Britannica, 2006b).

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HISTORY OF CULTIVATION

The pomegranate is widely considered native in the region from Iran to northern India (e.g., Morton, 1987), with apparently wild plants in many forests of these areas. Others (e.g., Mars, 2000) suggest that it is native to the smaller area of Iran and vicinity, and was spread by human movement to a much broader area in prehistory. In India, the fruits of the wild pomegranate have thicker rinds and extremely high acidity compared with cultivated types (Bist et al., 1994). They are also reported to have much smaller arils (Kher, 1999). In Central Asia, the primary difference noted is the higher acidity in wild material (Kerimov, 1934). The pomegranate’s origin in proximity to the ancient cultures of the Mediterranean have provided a long, recorded history for pomegranate. Indeed, some have argued that the pomegranate is the “apple” of the biblical Garden of Eden, but this is disputed in a recent review (McDonald, 2002).

Pomegranate has been naturalized throughout the Mediterranean region (California Rare Fruit Growers, 1997). Edible pomegranates were cultivated in Persia (Iran) by 3000 BCE (Anarincio, 2006), and were also present in Jericho in modern-day Israel. By 2000 BCE, Phoenicians had established Mediterranean Sea colonies in North Africa, bringing pomegranates to modern-day Tunisia and Egypt. Around the same time, pomegranates become naturalized in western Turkey and Greece.

The pomegranate continued to be dispersed around the globe, reaching China by 100 BCE (Anarincio, 2006). By 800 CE, the fruit was spread throughout the Roman Empire, including Spain. At the same time, it was known to be extensively cultivated in Central and southern India (Morton, 1987). By the early 1400s, the pomegranate had made its way to Indonesia (Morton, 1987). In the 1500s and 1600s, the Spanish introduced this species to Central America, Mexico, and South America (LaRue, 1980). The first clear evidence that the pomegranate was in the area to become the United States was in the early 1700s, when they were grown in Spanish Florida and English Georgia. By 1770, the pomegranate made its way to the West Coast and was growing in the missions of California (Morton, 1987; Seelig, 1970).

APPRECIATION AND SYMBOLISM

Both the Arabic name for pomegranate (rumman) and the Hebrew name (rimmon)

are reported to originate as “fruit of paradise,” which provides abundant demonstration of its appreciation in these cultures. In startling contrast, it was considered by the Greeks to be the “fruit of the dead” and provided sustenance to the residents of Hades (Lansky et al., 2000). These two considerations may demonstrate the amazing breadth of the pomegranate’s potential consumer base. The fruit’s unique flavors, with sweetness often counterbalanced by acidity, makes pomegranate easy to appreciate by most who try it. In addition to their use as a fresh fruit or fruit juice, the juice of the pomegranate also contributes distinctive character to many mideastern dishes, such as the Iranian fesenjan. As a practical contributor to the diet, these fruits were likely invaluable to early desert travelers as an easily carried, well-protected form of water (Morton, 1987).

In Zoroastrianism, the pomegranate symbolizes both fecundity and immortality, and is an emblem of prosperity (Panthaky, 2006). Pomegranate has long been associated with love and was one of the symbols of the love goddess Aphrodite (Encyclopedia Britannica, 2006a). In the biblical *Song of Songs*, Sheba ecstatically replies to Solomon’s blandishments: “Let us get up early to the vineyards; let us see if the vine flourish, whether the tender grape appear, and the pomegranates bud forth: there will I give thee my love.” Indeed Solomon describes Sheba as a garden whose “plants are an orchard of pomegranates” and says, “As a piece of a pomegranate are thy temples within thy locks.” Sheba then says she wants Solomon to drink “the spiced wine of the juice of my pomegranate.” Pretty potent stuff!

It is easy to imagine that the seediness of the pomegranate encouraged association with fertility. Perhaps this gave rise to the Greek myth in which Persephone must spend 6 months in the underworld after Hades forced her to eat six pomegranate seeds, but her return is celebrated with the coming of spring. A bit more mysterious is the rationale for Hebrew priests wearing vestments adorned with pomegranates (Exodus 28:31), or the 480 BCE attempt by King Xerxes to capture Greece with an army carrying spears adorned with pomegranates.

HORTICULTURE

The plant. The pomegranate plant inherently develops numerous trunks. In orchards, plants are normally trained to a single trunk,

forming a large shrub or small tree, and reaching a height of 12 to 20 ft at maturity. Trees may be trained to multiple trunks in colder areas, to reduce risk of total tree loss. Very dwarf pomegranates (such as 'Nana') are known with small plant, flower, and fruit sizes, and are widely used as ornamentals. The pomegranate plant is more or less spiny and deciduous, with small, narrow, oblong leaves with short stems (Morton, 1987). Plants aggressively sucker from the crown area and the roots.

The flower. The pomegranate flowers are most commonly red to red-orange and are funnel shaped, although "double" and variegated flowers are found in some ornamental selections, which are not grown for fruit. Pomegranate can be self-pollinated or cross-pollinated by insects (Morton, 1987). Flowers are primarily borne subterminally, primarily on short lateral branches older than 1 year (El-Kassas et al., 1998), although some cultivars flower on spurs. Flowers occur as single blossoms or in clusters of up to five.

In the Central Valley of California, pomegranate blooms from early May to November, with most flowering from mid May to early June. Pollination in California is primarily affected by insects or hummingbirds. Stigma receptivity lasts 2 to 3 d and declines quickly in unpollinated flowers (Melgarejo et al., 2000).

Pomegranate flowers are heterostylous. Long-styled perfect flowers are larger, have larger ovaries, and set more fruit than short-styled types, which are either intermediate or functionally male only. The proportion of these two flower types varies among cultivars and year to year (Martinez et al., 2000).

The fruit. The pomegranate fruit is berry-like with a leathery rind (or husk) enclosing many seeds surrounded by the juicy arils, which comprise the edible portion of the fruit (Watson and Dallwitz, 1992). The aril juice sack is composed of many epidermal cells. According to cultivar, arils range from deep red to virtually colorless, whereas the enclosed seed varies in content of sclerenchyma tissue, which affects seed softness. The number of locules and arils (and enclosed seeds) varies, but may be as high as 1300 per fruit (Levin, 2006). The fruit has a prominent calyx, which is maintained to maturity and is a distinctive feature of the pomegranate fruit. The husk is comprised of two parts: the pericarp, which provides a cuticle layer and fibrous mat; and the mesocarp (known also as the albedo), which is the spongy tissue and inner fruit wall where the arils attach. Septal membranes are the papery tissue that further compartmentalizes groups of arils, but arils do not attach to this tissue (Matthew Quist, pers. comm.). There is interest in identifying or developing cultivars that have more locules to fill the fruit interior, fewer septal membranes for easier eating, and a thinner mesocarp.

Fruits ripen about 6 to 7 months after flowering (Morton, 1987) and are harvested when qualities are deemed most appropriate for expected market use. In Israel, they

harvest 'Wonderful' when soluble solids reach 15% (Morton, 1987). Minimum maturity for 'Wonderful' in California is based on titratable acidity less than 1.85% and color darker than an established reference (Kader, 2006). In a Spanish study, soluble solids of the cultivars examined did not vary greatly from mid August through mid November, and the principal acids were malic and citric (Legua et al., 2000).

Unlike most horticultural fruits, inherent seed dispersal is not achieved through consumption of all or most of the fruit and seeds with accompanying spread. Rather, the pomegranate fruit structure has apparently evolved to ensure splitting of the leathery husk, and exposure of the tempting arils and seeds (Morton, 1987) to the many happily cooperative birds and so forth serving as dispersal agents.

POMEGRANATE PRODUCTION

Current global production estimates for pomegranate are unavailable. However, it is widely grown in many countries where it is well adapted. In India more than 100,000 ha of pomegranate are produced. It is considered one of the most important fruits of the tropical and subtropical areas because of low maintenance cost, good yields, good keeping quality, and ability to thrive with limited moisture (Indian Council of Agricultural Research, 2005). In Iran, 65,000 ha of pomegranate produces 600,000 tons of fruit annually, with about 30% of yield exported (Mehrnaws, 2006). Turkish production in 1997 was 56,000 tons/year (Gozlekci and Kaynak, 2000). Spain, with \approx 3000 ha, is the largest western European producer of pomegranate, and production has been increasing as a result of high market prices (Costa and Melgarejo, 2000).

In the United States, there are 5600 ha of commercial pomegranate, mostly in the San Joaquin Valley. The 'Wonderful' cultivar dominates almost completely, but there is interest in earlier and later cultivars to extend the market season (Kotkin, 2006).

POMEGRANATE CULTIVARS

More than 500 cultivars of pomegranate have been named (IPGRI, 2001), but such ancient and widespread fruits often have considerable synonymy, in which the same basic genotype is known by different names in different regions. Synonymy is likely further encouraged by the fact that husk and aril color can vary markedly when grown in different regions. A number of characteristics vary between pomegranate genotypes and are key to identification, consumer preference, preferred use, and potentially niche marketing. The most important traits are fruit size, husk color (ranging from yellow to purple, with pink and red most common), aril color (ranging from white to red), hardness of the seed, maturity, juice content, acidity, sweetness, and astringency.

The 'Wonderful' cultivar was discovered in Florida and brought to California in 1896 (California Rare Fruit Growers, 1997). This is the primary cultivar of commerce in the United States. It is also grown in western Europe, Israel, and Chile (Sepulveda et al., 2000). 'Wonderful' is among the most deeply colored of pomegranates in both husk and juice, with a rich flavor, good juice yield, and both sprightly acidity and slight thirst-quenching astringency similar to that of grapefruit juice and cranberries. Many pomegranate lovers consider it to be among the best-tasting cultivars (Karp, 2006). 'Wonderful' is nearly ideal for juicing, with excellent juice percentage as well as quality. It also has useful resistance to fruit cracking after rainfall on mature fruit (Karp, 2006). Other commercial U.S. cultivars include 'Granada' (a 'Wonderful' sport), 'Early Wonderful' (also a 'Wonderful' sport), and 'Early Foothill'. The cultivars 'Mollar de Elche' and 'Valenciana', in Spain, are among the most widely marketed pomegranate cultivars in western Europe (Costa and Melgarejo, 2000). The 'Valenciana' cultivar is harvested early (August), with very little sun damage and lower risk from pest attack or bad weather, but also has low yield, average to poor internal fruit quality, and small fruit size. The 'Mollar' cultivar is harvested much later (end of September until mid November) and displays more sun and split damage, but has higher yield, excellent internal fruit quality, larger size, longer harvest period, and greater consumer acceptance (Costa and Melgarejo, 2000).

Because of differences in quality and productivity observed in commercial plantings, Spanish researchers have selected distinct clones of their most important cultivars. Selections were made in 1986, in the provinces of Alicante and Murcia. Numbered clones were propagated and are undergoing replicated trials to identify the best materials (Amoros et al., 2000).

The countries of pomegranate origin grow innumerable cultivars, with many regional favorites. Local pomegranate germplasm collections have been established in several Mediterranean countries, including Spain, Morocco, Tunisia, Greece, Turkey, and Egypt (Mars, 2000). India has three collections containing at least 30 accessions each (Gulick and Van Sloten, 1984). Azerbaijan, the Ukraine, Uzbekistan, and Tajikistan have collections of 200 to 300 accessions, and the collection of the Turkmenistan Experimental Station of Plant Genetic Resources is the largest in the world, containing more than 1000 accessions (Levin, 1995). The U.S. National Clonal Germplasm Repository, in Davis, CA, has almost 200 pomegranate accessions, including many obtained from the Turkmenistan collection. Included in this collection are several types with very soft seeds, a trait sometimes optimistically called "seedless." Interestingly, in a preliminary molecular marker study, genetic variability was found to be quite low among the diverse cultivars in the U.S. collection (M. Aradhya, pers. comm.).

Little detailed information is available on pomegranates grown outside of western Europe and the United States, although efforts have been made to assemble cultivar summary information for this paper (Table 1). Cultivars mentioned as important in the literature, but with no descriptions, include 'Ahmar', 'Aswad', and 'Halwa' from Iraq; 'Mangulati' from Saudi Arabia; and 'Red Loufani' and 'Ras el Baghl' from Israel and Palestine (Morton, 1987).

Pomegranate cuttings root with great ease, facilitating spread of desirable clones. Efforts to graft pomegranate are reported not to be successful, but air-layering and root-sucker transplantation can be used for vegetative propagation (Morton, 1987).

CULTIVATION

Pomegranate is especially well adapted to Mediterranean environments with cool winters and hot summers, but can be grown in the humid tropics or subtropics, and the plant will survive as far north as Washington, DC, but is injured by temperatures less than -11°C (Morton, 1987). Commercial production is concentrated in dry summer climates, and pomegranate is extremely drought tolerant once established, but crops much better with more generous moisture. Pomegranate thrives on a wide variety of soils and has a high resistance to salinity (Melgarejo, 2003).

In all regions, newly planted trees require adequate moisture for establishment. For example, in California, plantings are established in late winter to spring when soil moisture is abundant from winter rain. Similarly plantings are made in India during the monsoon season (L.S. Dinkar, pers. comm.). Pomegranate cuttings root so easily that unrooted cuttings are sometimes placed directly into the orchard (Blumenfeld et al., 2000). Plants are trained to one to five trunks and should receive light annual pruning to maintain the production of short spurs, which bear most fruit, and such pruning also reduces the potential for wind scarring on long whippy shoots.

Pomegranates will set a few fruit in the second or third year after propagation, but generally reach good commercial production at 5 to 6 years. Mature yields of $33\text{ t}\cdot\text{ha}^{-1}$ are expected in California commercial orchards (Karp, 2006). When possible, providing adequate moisture is recommended throughout the growing season (with soil moistures similar to those used in citrus production), which contributes to growth, production, and a reduction in splitting (LaRue, 1980). It is especially important to avoid drought stress during initial fruit set (Still, 2006). Pomegranate orchards benefit from 0.2 to 0.5 kg N/tree per year, applied once in fall or winter, or a split application in late winter and in spring. High or late N application may compromise fruit maturity and color. Zinc is the only other nutrient recommended for application to pomegranate in California. When Zn deficiency is evident, sprays should be applied to foliage in spring and early summer (LaRue,

1980). In Israeli conditions, K_2O is applied at rates similar to N (Blumenfeld et al., 2000).

Serious disease does not routinely affect pomegranate trees in California, but *Alternaria* heart rot, may sometimes affect fruit (LaRue, 1980). There are two widespread arthropod pests on commercial pomegranates in California: 1) the flat mite *Brevipalpus lewisi* and 2) the leafroller *Platynola stultana*. Both these pests cause russetting and checking on fruit. However, a number of species have caused localized damage in some years. In some other regions, *Virachola* species of moths are a severe threat and require multiple sprays each year (Blumenfeld et al., 2000; S. Dinkar, pers. comm.). This moth bores into the fruit, causing widespread fungal infections in the arils and bruising on the fruit surface.

Premium prices for fresh fruit are obtained only for large blemish-free pomegranates. In India, developing fruit are sometimes protected from birds and other threats by bagging them on the tree (Morton, 1987). Another practice in India is the "Mirg Bahar" practice of inducing drought stress from December through May so that the peak of production is in October and November (L.S. Dinkar, pers. comm.). Hand thinning is practiced in Israel to produce larger and more uniform fruit (Blumenfeld et al., 2000), and is also practiced in Spain.

Storage life of the pomegranate is quite long and equals the apple, and the fruits ship very well (Morton, 1987), although bruising can be an issue. The pomegranate fruit is not climacteric (Kader et al., 1984). Harvest and storage factors affecting postharvest quality of pomegranate have been summarized in a recent review (Kader, 2006).

MEDICINAL PROPERTIES

According to Eber's papyrus (ca. 1550 BCE), the ancient Egyptians used tannin-rich pomegranate root extracts for the riddance of tapeworms (Wren, 1988). Hippocrates (400 BCE) used pomegranate extractions for a wide variety of ailments, such as a plaster to reduce skin and eye inflammation, and as an aid to digestion (Adams, 1849). No discussion of ancient medical applications of plants is complete without mention of Dioscorides (40–90 CE), who indicates: "All sorts of pomegranates are of a pleasant taste and good for ye stomach" and further suggests the juice for "... ulcers, and for ye paines of ye eares, and for the griefs in ye nostrills" (Gunter, 1934). Other traditional uses of pomegranate products have included treatments for contraception, snakebite, diabetes, and leprosy (reviewed in Lansky et al., 2000). Extracts of tannins (bark, leaves, immature fruit) have been used to halt diarrhea and hemorrhage, whereas dried, crushed flower buds are made into a tea as remedy for bronchitis. In Mexico, extracts of the flowers are used as a gargle to relieve mouth and throat inflammation (Morton, 1987). Interestingly, many of these uses are at least somewhat supported by recent scientific

studies (Seeram et al., 2006). However, it must be noted that there is no report of trials using pomegranate to treat snakebite.

Presumably because of its association as the "fruit of love" rather than empirical observation, the pomegranate has been considered a love potion in some cultures. The prophet Mohammed advised, "Eat the pomegranate, for it purges the system of envy and hatred" (Encyclopedia Britannica, 2006c). Seemingly these properties represent a medicine we would all like to see widely prescribed!

Today, pomegranate juice has been shown to contain polyphenol antioxidants (primarily ellagic acid and punicalagin) that may lower risk of heart disease (Aviram et al., 2004) and may slow cancer progress (Adams et al., 2006). The antioxidant content of pomegranate juice is among the highest of any foods (Guo et al., 2003). An analysis of diverse pomegranate cultivars shows considerable diversity of antioxidant content, with 'Wonderful' among those displaying the highest levels (unpublished data).

Largely because of the interest in health benefits of pomegranate, 40 journal publications were produced on this fruit in 2005 versus 30 total from 1945 to 2000 (Schulman, 2006). Many of these papers, primarily focusing on medical implications of pomegranate and its products, are reviewed in a book edited by Seeram et al. (2006).

OTHER USES FOR POMEGRANATES

There are a number of other useful applications for the product of the pomegranate tree. Pomegranate bark produces tannins that help create Moroccan leather. Extracts of the flowers and fruit husks have been used as dyes for textiles. Extracts of pomegranate rinds provided a major source of medieval ink in Europe (Carvalho, 1999), and specialty craft inks are still created from pomegranate.

Clearly, the most widespread "nonfood" use of pomegranate is for visual aesthetics. Several ornamental plant forms have been touched on already, and these are widespread in the nursery industry where pomegranate is adapted. The distinctive appearance and long life of the mature harvested pomegranate fruit results in their widespread use in table arrangements. In the United States, this is especially common during the Thanksgiving through Christmas season. The longstanding nature of this use is apparent from pomegranate's frequent inclusion in paintings and as graphic elements in architecture, for example. This visual aesthetic use is so widespread that most of the pomegranates purchased as fresh fruit in the United States are likely never actually consumed (California Rare Fruit Growers, 1997)!

THE FUTURE

Increased interest in phytonutrients appears likely to sustain and increase interest in pomegranate within the United States. 'Wonderful' juice is widely available in the

Table 1. Summary of primary characteristics for pomegranate cultivars that are indicated as "important" in the literature and for which there are reported data.

Cultivar	Fruit size (g)	Traits	Origin	Reference
Agridulce de Ojós 4	524	Red arils with hard seeds, bitter/sweet, medium acid	Spain	Amoros et al., 2000
Alandi (or Vadki)		Deep-pink arils and very hard seeds, sweet/sour	India	Morton, 1987
Asinar	505	Large fruit, red arils, sweet/sour, soft seeds	Turkey	Gozlekci & Kaynak, 1997
Bedana		Medium-large, brownish white rind, pink-white arils, seeds soft, sweet	India	Morton, 1987
Borde de Albaterra	370	Deep-red arils with hard seeds, bitter, high acid	Spain	Amoros et al., 2000
Dholka		Large, yellow-red rind, white arils and hard seeds, sweet	India	Morton, 1987
Early Foothill		Deep-red arils, medium-hard seeds, sweet/sour	USA, 2-4 weeks earlier than 'Wonderful'	LaRue, 1980
Early Wonderful		Deep-red arils, medium-hard seeds, sweet/sour	USA, 2 weeks earlier than 'Wonderful'	California Rare Fruit Growers, 1997
Eksilik		Sour (5% TA), red arils	Turkey	Gozlekci and Kaynak, 1997
Emar		Dark-red skin, red arils, sweet with low TA	Turkey	Gozlekci and Kaynak, 1997
Eversweet		Pink to red fruit with pink arils, soft, seeds, sweet even when immature	USA	Dave Wilson Nursery, 2005; Karp, 2006
Fellahyemez		Large pink arils, sweet with low TA, soft seeds	Turkey	Gozlekci and Kaynak, 1997
Ganesh		Yellow-pink rind and pink-red arils, very soft seeds, sweet/sour	India	L.S. Dinkar, pers. comm.
Golden Globe	"Very large"	Golden green fruit with pink blush, pink to red arils, soft, small seeds, sweet	USA	Karp, 2006
Granada		Deep-red arils, medium-hard seeds, sweet/sour	USA, redder, 1 month earlier sport of 'Wonderful'	California Rare Fruit Growers, 1997
Hicaznar		Dark-red skin, red arils, sweet/sour	Turkey	Gozlekci and Kaynak, 1997
Kandhari (also called Arakta)		Large fruit, deep-red rind, with deep-pink to blood-red arils, hard seeds, sweet/sour	India	Morton, 1987
Katirbasi	517	Large fruit, large red arils, sweet/sour	Turkey	Gozlekci and Kaynak, 1997
Mollar de Elche 15	272	Deep-red arils with soft seeds, sweet, low acid	Spain	Amoros et al., 2000
Mollar de Orihuela	414	Red-pink arils with soft seeds, sweet, low acid	Spain	Amoros et al., 2000
Piñón Tierno de Ojós 9	405	Red-pink arils with soft seeds, sweet, low acid	Spain	Amoros et al., 2000
Valenciana		Small, early, but not top quality	Spain	Costa and Melgarejo, 2000
Wonderful		Deep-red arils, medium-hard seeds (we would call medium-soft), sweet/sour	USA	Morton, 1987

TA, titratable acidity.

refrigerated produce section of supermarkets and has displayed considerable sales growth. Numerous techniques are being explored to enhance postharvest life and quality of fresh pomegranate (Artés and Tomás-Barberán, 2000). Consumer reluctance to open and eat intact fruits, which some suggest is best "best performed naked, outdoors or in the bathtub" (Karp, 2006), has encouraged development of methods to blow out arils and package these beautiful jewels as a minimally processed fresh product (Sepulveda et al., 2000). These will soon find their way to market and will likely be eaten as snacks and used as garnishes in salads and savory dishes. The

preference of some consumers for cultivars with less acid or softer seeds is also compelling consideration of more diverse cultivars, which should broaden consumer interest. When these "wonderful" properties are combined with a Food and Drug Administration label as a "love potion" and the prophet's prescription for curing "hatred and envy," it may be impossible to keep up with the demand for this amazing fruit.

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