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Pomegranate: The Grainy Apple

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The pomegranate (*Punica granatum* L.) is an ancient fruit crop that offers a wide variety of choices for the consumer. Fruit range in color from light yellow to deep maroon to black, from very sweet to lemon-like tartness, and seed hardness can be along the spectrum from very soft (called seedless) to very hard. Hard seeds can be either crunchy or chewy and difficult to bite through. Pomegranates are consumed fresh as arils; processed as juice, candy, confections, or nutraceuticals; fermented into a sweet to semi-dry wine; used as grenadine to flavor cocktails; and dried seeds with attached pulp (anardana) are utilized as a souring agent in Indian cooking, and roasted seeds add aroma and flavor to Middle Eastern dishes. Currently the market in the USA is dominated by 'Wonderful' pomegranate; however, there is a variety of alternative cultivars that may have greater consumer acceptance as a fresh product, such as 'Parfianka' pictured on the cover of this issue and described below.

Pomegranate originates from Iran and Afghanistan (Levin, 2006) and the surrounding areas of the near east, including Turkmenistan and northern India (Holland et al., 2009). Cultivation began in Iran (Kahramanoglu and Usanmaz, 2016), or the Transcaucasia-Caspian region (Still, 2006) sometime in the Neolithic era (9000 BCE to 3000 BCE, Levin, 2006, Holland et al., 2009). It was 3,000 to 7,000 years from the beginning of the Neolithic transition to agriculture when pomegranate was introduced to new regions (Levin, 2006). For example, more than 5,000 years ago, pomegranates had been moved to and were being grown as far away as the Middle East, demonstrating widespread adoption.

Domestication was likely from fruit similar to wild pomegranates, which are generally sour and small. However, wild pomegranates differ depending on where each population evolved. For example, large pomegranates grow wild in the Kandahar region of Afghanistan and soft-seeded fruit are found in the wild in the Tagab Valley, Afghanistan (Levin, 2006). During domestication, pomegranates were selected for larger fruits and seeds, for their color, their resistance to splitting (Still 2006), their sweetness, seed hardness (or lack of), and flavor. This has resulted in more than 500 cultivars throughout the world, but only 50 that are in common use (Still, 2006).

Pomegranate is heterozygous and does not come true from seeds, so it is interesting to note that pomegranates have been propagated by rooting suckers for about 5,000 years in Jericho, Cyprus, Greece, and Mesopotamia (Hummer et al., 2015). The selection of pomegranates for clonal propagation demonstrates that it was known that the desirable phenotypes could only be reliably reproduced vegetatively. This also advanced domestication and widespread adoption of the crop because pomegranate hardwood cuttings root relatively easily, facilitating the movement of the most desirable clones. It is also likely that when selections were made for fruit characteristics, inadvertent selection was also made for rootability because those selections that rooted readily multiplied more quickly and therefore must have become the dominate cultivars in production.

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Pomegranate seeds, and stamen, anther, and skin fragments were recovered from a 14th century BCE ship wreck near Turkey (Ward, 2003). The other items on the ship included ivory, precious metals, amber, and ostrich eggs. Therefore the pomegranates were being shipped with exclusive and luxury items, perhaps indicating that pomegranates were considered an "elite" fruit that was desired by the rich.

Pomegranates became sufficiently important to have some religious significance. They are mentioned in the Hebrew Bible 23 times, three times in the Qur'an, but not at all in the Christian Bible (Janick, 2007). They have also been used on both ancient and modern Jewish coins and in Christian Renaissance artwork.

Pomegranates were brought to the New World (Central and South America) by the Spanish in the 1500s and 1600s (Stover and Mercure, 2007) and in the 1700s, they were planted in Florida and Georgia. By 1770, Jesuit missionaries had introduced them to California (Holland et al. 2009). According to Father Eusebio Francisco Kino, Dolores 1695, "This mission has his church adequately furnished with … Castilian fruit trees, grapes, peaches, quinces, figs, pomegranates ..." (Garcia-Yanez and Emanuel, 2016). When writing about pomegranates and other fruits at the American missions, Ignaz Pfefferkorn, 1725 stated: "These fruits are superior in size, juiciness, sweetness, and flavor to those which are grown in Europe…" (Garcia-Yanez and Emanuel, 2016). The increased quality of the fruit could be related to better growing conditions in the new world, or perhaps the clonal selections that were sufficiently valuable to make it to the new world were among the most desirable.

Remnants of these old pomegranates remain in the New World. For example, PomNatural, LLC, from Steinhatchee, FL has been scouting and finding pomegranate trees that are at least 50-100 years old in Florida and Georgia (Bonsteel and Bice, 2015). Old pomegranates that apparently have greater cold hardiness than most have been found at old estates in Georgia, and several of those discovered in Florida seem to have adapted well to the humidity and rainfall of the southeastern USA because their fruit have few blemishes. It is unclear if these trees are of seedling or clonal origin. If they are seedlings, this could indicate some selection for the humid climate and genetics that might be exploited to breed better adapted fruit. Therefore, there may be gems in some of these old heirloom cultivars or selections that can be exploited for production, lack of splitting, and possible disease resistance.

By 1916, there were five USDA Plant Introduction Gardens or Field Stations receiving new germplasm that entered the USA (Dorsett, 1916). At these Stations, plants were grown, evaluated for economic importance, and the best were propagated for distribution based on orders received in Washington, DC at the home location of the Office of Foreign Seed and Plant Introduction. The recipients of the plants released by the Plant Introduction Gardens were state experiment stations, private researchers, special cooperators, and plant breeders throughout the USA. Specifically, pomegranates were received by the Chico Plant Introduction Field Station, and the pomegranate with the lowest Plant Inventory number, PI 179 was received in March, 1898 from Turkestan by N.E. Hansen (USDA, 1898). Under the description of the accession, they state in quotation marks: "Seeds saved from large, fine fruits picked in the garden of the Emir of Bokhara's summer palace in Old Amu Daria." (The Emirate of Bokhara is now part of Uzbekistan; USDA, 1898, p.22). The first clonal cultivar , PI 731, had large red fruit and was received from Tiflis, Transcaucasia, Russia through N.E. Hansen in 1897 (USDA, 1898).

By 1922 (Anon, 1922), the Chico Station was offering plants of 6 pomegranate cultivars (Table 1). Interestingly, they offered accessions (presumably identical) with the same name under different plant introduction numbers, indicating different origins and

Table 1. Pomegranate cultivars available for researchers from the Plant Introduction Garden, Chico, CA in 1922 (Anon, 1922).

Cultivar	Inventory Number	Passport Information
Granado de Rogises	33229	From: Granada, Spain, purchased by P. Giraud at the request of W.T. Swingle, received March 23, 1912. One of the 3 principal cultivars grown in Granada, Spain (Galloway, 1913).
Krylezy-Kabuk	27049	From: near Sukhum-Kale, Caucasus, Russia from a collection of named cultivars via F.N. Meyer, March 10, 1910. (Galloway, 1911a).
Krymisi Kabugh	27966	From: Geok-Tepe, Caucasus, Russia from A. Shelkovnikoff, via F.N. Meyer, April 12, 1910. Large, bright red, sour-sweet fruit. F.N. Meyer thought it to be the same as Inventory No. 27773, 'Cumzi gabuch', which was received from Tiflis, Caucus, Russia on March 22, 1910 (Galloway, 1911b).
Krymisi Kabugh	30615	From: R.H. Kearney, April 26, 1911, who received the cuttings from I. Munro, Putnam, GA. Red, sweet fruit (Galloway, 1912).
Legrellei	24825	From: La Tour-de-Peilz, Vaud, Switzerland.Purchased by J. Brunner at the request of O.F. Sillig (USDA), Received March, 9, 1909. Double flowered cultivar with salmon-red petals with white variegation. Vigorous and hardy and can ripen fruit in the climate of central France (Galloway, 1909).
Negro Monstruoso	33227	From: Granada, Spain, purchased by P. Giraud at the request of W.T. Swingle, received March 23, 1912. One of the 3 principal cultivars grown in Granada, Spain (Galloway, 1913).
Nejidi	8646	From: Bassorah, Arabia (now Iraq) through Mr. Lathrop and David Fairchild, No. 849, Feb. 26, 1902. Large fruit with thin skin, very soft seeded, red-arils (Galloway, 1905).
Nejidi	13298	From: the Georgetown custom-house on March 29, 1905. It had arrived in New York on the steamship Umbria. (Galloway, 1907).

dates from which the material was sourced by the Plant Introduction Station. It is common for genebanks to give different accession numbers when plants are acquired at different times, even if two plants have the same name. It is possible that they are indeed the same, but in some cases, cultivars with the same name will be different because of misidentification, or because of a name being used repeatedly over the centuries to name different genotypes. Therefore, having different PI numbers for the same named cultivar is logical.

In the early 20th century, pomegranate accessions were arriving at the Chico Station from various locations, including Russia, Spain, Switzerland, what is now Iraq, and the USA state of Georgia (Table 1). Spellings of cultivar names can change as they move around, different people handle them, or during translation to English. There are some cultivars at the USDA-ARS, National Clonal Germplasm Repository in Davis, CA (NCGR) with similar or rearranged spellings of two of the cultivars offered in 1922. These may be a result of utilization of the Chico

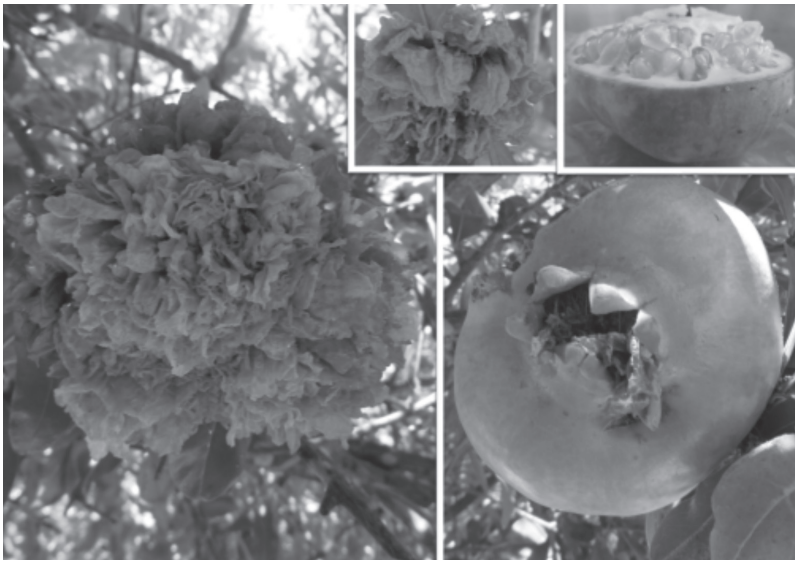

Fig. 1: WEO42, an unnamed pomegranate that was brought to the University of California, Davis from the Chico Plant Introduction Station, between 1954 and 1960 that has similarities with 'Legrellei' that was offered by the USDA Chico Plant Introduction Station in 1922. It is now part of the NCGR collection and has salmon-red double flowers with white variegation. The chimera is not stable (inset), and flowers can be red or have red sectors. WEO42 only had this one mature fruit in 2016. The skin is pink with white arils and crunchy seeds. Remnants of the double flower parts remain attached to the fruit.

Plant Introduction Station material in breeding. One cultivar is 'Dotch Legrelley' from Turkmenistan (similar spelling to 'Legrellei'; however, 'Dotch Legrelley' has double variegated red-white flowers and 'Legrellei' is described with double variegated salmon-red and white petals. Additionally, in the NCGR collection is an accession with the number WEO42 (Fig. 1), and is unnamed and was introduced to Wolfskill Experimental Orchard between 1954 and 1960 from the Chico Plant Introduction Station. It has similar salmon-red and white double variegated petals to "Legrellei." WEO42 has white arils and crunchy seeds. Using 16 SSR markers (unpublished, Aradhya and Preece, 2016), 'Dotch Legrelley' and WEO42 clustered together with other double-flowered cultivars in the NCGR National collection. This is considered evidence that 'Dotch Legrelley' is a seedling of the genotype represented by WEO42, which has a likelihood of being 'Legrellei.'

Another accession in the NCGR collection with a link to a cultivar offered in Table 1 is Hyrdanar x 'Kirmizy-Akbuh,' which was introduced into the collection in September, 1995 as cuttings from Turkmenistan. Interestingly, the pedigree is a cross between a mutant of American dwarf Chico x Kirmizy-kabuh (similar spelling to and most likely the same as 'Krymisi Kabugh' from Table 1, USDA, 2016).

The NCGR maintains and curates the national pomegranate collection that currently consists of approximately 280 accessions that are available for distribution to the research and educational communities. The oldest trees in the collection were collected at the Chico Plant Introduction Station, received by the University of California Davis, and established at Wolfskill Experimental Orchard, Winters, CA between 1954 and 1960 (Kennedy, 2010). These trees include the variegated double-flowered WEO42

listed above. The original names and identifications of most of the remaining 47 trees are missing. Dr. John Lovell was a Professor of Experimental Psychology at Cal. State Hayward who gave some of these trees new cultivar names, including: 'Cloud,' 'Crab,' 'Cranberry,' 'Gold,' and 'Elf.' These names are listed in the Germplasm Resources Information Network (GRIN-Global); whereas their original names are lost.

With the exception of the trees that arrived at the NCGR in the 1950s, the next new pomegranate accessions were received in the late 1980s and are ornamental cultivars, including double flowered cultivars from Japan, some of which are fruitful and others sterile. In 1995, the first accessions from the Turkmenistan Experimental Station of Plant Genetic Resources (TESPGR), Garrygala arrived, and in 1997, 17 accessions from TESPGR and other locations in the Caucus region came into the collection via Byron, GA. These were presumably among most cold hardy accessions in the collection at TESPGR. In 1999, an additional 65 Turkmenistani accessions were received from G. Levin, TESPGR. In 1996, T. Kennedy donated 19 accessions of various backgrounds and both that year and the next, J. LaRocca and J. Chater donated accessions, several of these were from the Chater breeding program. In the 2000s, accessions were received from Albania, Armenia, Azerbaijan, India, and The Republic of Georgia. The collection has been sourced from at least 11 countries.

Some of the variation among fruit characteristics is presented in Table 2 as an example of the diversity in the NCGR pomegranate collection. Pomegranate juice was compared for soluble solids (°Brix), color parameters, and titratable acidity. Juice from 'Girkanets' was the sweetest with soluble solids concentration (SSC) of 16.8 %, and those with the lowest soluble solids were 'Ariana' and 'Nikitski ranni' at 14.6%. The reliably sour 'Haku-Botan' the most acidic with a titratable acidity of 2.10, however, with 15.7% SSC, it had higher soluble solids than the industry standard, 'Wonderful.' 'Wonderful' is intermediate for both soluble solids and titratable acidity, demonstrating that there are sweeter and more sour fruited cultivars, which could offer much more culinary diversity to consumers. For example, 'Parfianka' with its moderate soluble solid level of 15.2% and titratable acidity of 1.04% offers a nice sugar/acid balance and the soft seeds make eating the arils a pleasure. They are a nice addition sprinkled on top of a tossed lettuce-based salad.

Pomegranates are typically propagated clonally by rooting cuttings. Adding about 3,000 ppm (mg/L) auxin, such as indolebutyric acid (IBA), naphthaleneacetic acid (NAA) or a combination will enhance rooting. Pomegranate plants tend to grow more as bushes than trees because they freely produce suckers from the base of the plant. *Punica granatum* grows naturally in areas where fires are an ecological feature. Suckering is an adaptation to fire and the plants are quickly able to recover following fire events by resprouting via these suckers. However, suckers mean work and expense for growers who typically prune them off and train the plants as trees for ease of management. This pruning is an annual event and therefore a recurring orchard expense. There is now a non-suckering *P. granatum* rootstock named 'Pjered One' that was selected in Italy in 2007 (Preka et al., 2016). This rootstock roots readily from hardwood cuttings and grafts well using cleft grafting. The result is a non-suckering pomegranate tree. It would appear that the extra expense of grafting, compared to rooting cuttings, would pay for itself quickly with the great reduction in pruning costs.

Pomegranate production practices are described in Kahramanoglu and Usanmaz (2016), which is reviewed in this issue and are therefore not detailed here. The authors also include pest, disease, and weed management, harvest and postharvest considerations, as well as the health benefits of this crop in their book.

Table 2. Pomegranate juice soluble solids concentration (SSC), color, and titratable acidity on selected accessions harvested on 25 November from the USDA-ARS National Clonal Germplasm Repository, Davis, CA.

Cultivar	Accession Number	SSC (%)	Juice Color L	C	h	Titratable Acidity (%)
Al-sirin-nar	DPUN0060	14.8	53	34	26	0.63
Andalib	DPUN0137	15.4	42	53	30	1.85
Myagkosemyannyi						
Rozovyi	DPUN0139	14.9	68	15	18	1.11
Ariana	DPUN0125	14.6	44	53	32	1.16
Desertnyi	DPUN0108	15.1	44	55	33	1.24
Fleishman's	DPUN0028	15.4	70	10	45	0.18
Girkanets	DPUN0126	16.8	40	54	31	0.97
Haku-Botan	DPUN0007	15.7	73	07	97	2.10
Ink	DPUN0167	16.3	40	52	28	0.85
Kara Gul	DPUN0155	15.4	36	54	31	1.83
Kara-Kalinskii	DPUN0118	16.2	37	53	31	1.43
Khoramabad	DPUN0078	15.4	42	53	30	1.04
Medovyi Vahsha	DPUN0109	14.9	49	43	23	0.21
15/4 Pamyati						
Rozanova	DPUN0113	15.4	43	53	28	1.11
Molla-Nepes	DPUN0128	15.8	39	58	33	1.79
Nikitski ranni	DPUN0067	14.6	54	38	22	0.88
Dorosht 5 hahanshahi						
Palermo	DPUN0093	16.2	36	54	30	1.22
Parfianka	DPUN0015	15.2	44	52	31	1.04
Purple Heart	DPUN0056	15.8	40	54	31	0.92
Sakerdze	DPUN0059	16.0	43	52	29	1.10
Sirenevyi	DPUN0151	15.2	53	38	23	0.22
Sogdiana	DPUN0143	15.6	48	45	23	0.20
Vina	DPUN0035	14.8	71	09	43	0.25
Wonderful	DPUN0037	15.6	43	52	17	0.90
Average Deviation		0.6	10	14	8	0.45

Currently, Iran is the largest producer with 63,733 ha cultivated, followed by India, the USA, Turkey and Spain (54,755, 14,000, 8,500, and 3,000 ha, respectively, Iran Fruit Center, 2016).

The fruit are berries and the seeds are borne in arils, which are juicy, specialized outgrowths of the seeds, making what resembles a small juice and seed-filled sac. Linneaus gave it the name *Punica granatum* which was a change from its original name, *Malum punicum*, which meant the apple of Carthage because Punica is a Roman name for Carthage; Linneaus chose to retain the reference to Carthage (Punica) in the genus (Stover and Mercure 2007). The specific epithet "*granatum*" means that the fruit is grainy or seedy. Apples are pome fruits, therefore the word "pomegranate" actually means seedy or grainy apple and "*Punica granatum*" references the grainy apple from Carthage.

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