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in

Melgarejo P. (ed.), Valero D. (ed.).
II International Symposium on the Pomegranate

Zaragoza : CIHEAM / Universidad Miguel Hernández
Options Méditerranéennes : Série A. Séminaires Méditerranéens; n. 103

2012
pages 61-66

Breeding Mexican pomegranates to improve productivity and quality and increase versatility of uses

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Abstract. Pomegranate is a marginal fruit crop in Mexico, practiced by small farmers and focused on the national market. The Mexican varieties bear during summer, they are probably segregants of Spanish and American pomegranates, obtained through sexual propagation and informal introduction, they are maintained in gardens and family orchards. Mexico also regularly imports pomegranates from USA under the frame of commercial treaties. INIFAP has been supporting a Genetic Resources and Breeding program since 2002 pursuing the following objectives: to obtain new pomegranate cultivars suitable for export –Wonderful type–, to extend the harvest season into fall and to enhance fruit quality, among others. We have characterized the national germplasm and obtained selections adequate to supplement the local market, others with ornamental value and some with outstanding functional properties, advances that will be discussed in this presentation.

Keywords. Commercial varieties – Segregants – Breeding programme – Gene reservoir – Germplasm bank – Local market – Export.

I – Introduction

The pomegranate probably arrived in Mexico during the XVI y XVII centuries, introduced from Spain by the catholic friars involved in evangelization of the new territories. It was one of the species regularly included in the backyard orchards of the monasteries and missions, they were planted to provided fresh fruit to their tenants (Mondragon and Juárez, 2009). The germplasm base grew with the contributions of migrants of arab origin and the continuous exchange with USA, the natural market for Mexican products and the sink of migrant labor.

The easiness of sexual propagation may explain the presence of numerous segregants of Spanish pomegranates. Along with ornamental appeal, high adaptability favored the spread of pomegranates in gardens and family orchards of central and north central Mexico. Today solitary trees and small family orchards can be found in semiarid, subtropical and even in humid tropical sites of 16 states, however only Oaxaca, Hidalgo and Guanajuato report commercial production. These states provide 62% of the fresh pomegranate consumed in México City, Guadalajara and Monterrey, the main urban centers of the country. Official statistics reported 689 ha and 6,910 ton of annual production in 2010 (SIAP, 2011). Mixed cultivation of pomegranate with cereals, forage and leguminous crops is the rule, the plant is also found in the boundaries of field plots, providing an additional income for small farmers. Therefore pomegranate can be considered a marginal fruit crop in Mexico when compared to other commercial species like guava (23,000 ha), peach (35,000) or cactus pear (53,000) (SIAP, 2011; Gallegos and Mondragon, 2011).

In contrast to the Middle East and the Mediterranean growing areas which produce pomegranate in fall, Mexican pomegranates have adapted to bear fruit in summer – late June to early September, maturing the fruit during the short dry spell or “canícula” inserted in the bimodal rainfall pattern of the highlands. Still, there are some genotypes bearing fruit in early

summer or fall, but the quality of the fruit is not satisfactory. The bulk of the Mexican pomegranate is consumed as fresh fruit, either whole or as loose arils, it is widely available though in small quantities: Large supermarkets offer the produce without discriminating origin or varieties. Non-significant volumes of acidic pomegranates are used as raw material to manufacture liquors at cottage level in the western states of Jalisco and Colima. Under the free trade agreement (NAFTA) with North America a number of food products based on or containing pomegranate juice or arils –refreshing beverages, juices, cereals, etc. are available in the Mexican market.

Surprisingly enough, the most important use for pomegranate arils during season in Mexico is as an ornament or garnish of the special dish "chiles en nogada" (stuffed ancho peppers covered with a creamy nutty dressing) offered in restaurants from July to September, to celebrate independence. The dressing is sprinkled with fresh parsley and pomegranate arils arranged to resemble the colors of the Mexican flag, green-white-red.

Imports of fresh pomegranate from USA during fall have increased, large fruits arranged in fancy packing ensure high prices ($4-8 US/kg) at high-end supermarkets. Lower quality fruit is also available in popular supermarkets ($3-4 US/kg), a large difference on prices when compared to the 0.50 to 0.8 US/kg offered for the national product in summer.

The Instituto Nacional de Investigaciones Forestales Agrícolas y Pecuarias (INIFAP) included pomegranate in its research programs since 2002, to rescue a naturalized plant resource and to diversify the portfolio of options for growers in semiarid regions. The aim is to characterize and enhance the Mexican germplasm with new cultivars accepted by the international markets, and to extend the harvest season in order to reduce imports. We are also aware that the growers involved in pomegranate cultivation need crop technology suitable to their conditions. In this paper we describe the importance of pomegranate and the progress and prospects of genetic enhancement in Mexico.

II – Pomegranate growing areas

Table 1 presents a the description of outstanding sites for pomegranate production, they share some common features; they are scattered across Central Mexico, orchards are usually less than 0.5 ha, located in places receiving less than 700 mm of annual rainfall, insufficient for commercial production unless supplementary irrigation is provided. A common problem of these areas is the occurrence of significant volume of rainfall at the late stage of ripening, associated to fruit cracking. Mexico also has large tracts of land with Mediterranean climate suitable for pomegranate expansion in the north, and interest on the crop is rising in Sonora, Baja California and Chihuahua.

Table 1. Basic agroclimatic features of outstanding areas of pomegranate production in Mexico.

Location	Altitude (masl)	Climate	Soil type	Annual rainfall (mm)
Apaseo el Alto, Gto.	1850	Semiarid	Vertisol, Feozem	642
Tecozautla, Hgo.	1700	Subtropical	Feozem	517
Metztitlán, Hgo.	1320	Subtropical	Feozem	378
Tasquillo, Hgo.	1655	Subtropical	Feozem	344
Metzquititlán Hgo.	1380	Subtropical	Feozem	497
Tehuacán, Pue.	1676	Semiarid	Litosol	473
Venado, SLP	1790	Semiarid	Coluvial y aluvial	493
Tecomaxtlahuaca, Oax.	1680	Temperate	Cambisol cálcico	580
Cuatro Cienegas, Coah.	740	Semiarid Mediterranean	Xerosol, litosol, Yermosol, vertisol	246

III – Pomegranate genetic resources

1. Comercial varieties

The most common varieties available in the Mexican market are:

Apaseo (Fig. 1). Originary from Apaseo el Alto, Gto. Trees of bushy growth habit –numerous stems. Deciduous tree which looses foliage at the end of fall, flowering occurs in april, when the risk of late frost is over. Highly productive >200 fruits per tree. Average fruit size >300 g, that can reach 700 if properly thinned, they are ready for harvest from July to early septembre. Thick epidermis somewhat sensitive to cracking specially under heavy rains. The aril is bright red, with sweet juice, seeds of intermediate size and moderate hardness. The yield of clean arils is approximately 50% of the total fruit weight.

Tecozautla (Fig. 1). Originary from Tecozautla, Hgo. Caduceous trees of bushy growth habit. Tolerate well slightly alkaline and heavy soils. Productive, long lived reports of trees older than 40 years are available. Highly productive > 200 fruits/tree. Well adapted to Hidalgo, Queretaro and Guanajuato states. Flowers open at the end of March and April, ahead of the risk of late frosts, fruit ripening occurs from the end of June and early August. Intermediate to large fruits (>250 g), round, yellow-orange skin with a slight pink-reddish blush. Respond well to thinning. Up to 60% of aril yield. Deep-red arils, sweet juice with small and soft seeds. A choice cultivar to combine with peach production.

Fig.1. Apaseo (left) and Tecozautla (right) pomegramate varieties.

2. Segregants of Spanish type and other origins

This type of pomegranates are widely found in Central Mexico. Fruits ripen in summer presenting variations of green, yellow and orange skin with or without reddish blush. The fruits vary in size, they are presented to the consumer as a mix of varieties. Arils are predominantly red and sweet. Usually the fruits are locally marketed. This pool represents a gene reservoir for adaptation to specific environments, as well as quality traits prized by local and regional consumers, they were developed through informal selection and continuous cultivation during more than four centuries.

3. Germplasm bank

INIFAP maintains a field collection –unique in the country- containing 2218 plants of varied ages; 13.5% are adult productive plants, and the rest are juvenile plants obtained from hybridizations carried out during 2009 and 2010. The orchard is located at Celaya, Gto. (20^{o} 35´

52´´ N; 100 º 49´ 28´´ W) at 1,767 m of altitude. The climate of the site is warm semiarid, receiving 600-700 mm of annual rainfall. Regarding the genetic origin the collection contains samples of commercial varieties, segregants of American, North African and Middle East origin, as well as segregants of Wonderful variants (Fig. 2). From this pool we selected a group of six candidates for registration, they include selections for fresh fruit consumption, ornamental use and dry flower production.

Fig. 2. A sample of fruit variability of pomegranates of the Spanish type, and segregants obtained from foreign accessions, compared to the local Cv, Apaseo (right, upper right) all share the summer bearing habit.

IV – Breeding objectives

To extend the harvest season. The actual demand of pomegranate covers July to early September, a season expected to extend into fall driven by the continuous imports of American fruit. Therefore it is imperative to develop late bearing varieties, a short term goal is to extend it at least a month from September 15 to October 15, when the American pomegranates arrive.

To improve fruit quality. Mexican consumer prefers large pomegranates >250 g –similar trend of other fruits (Gallegos and Mondragon 2011), associated to premium prices. The arils can be red to dark red, but should be sweet with low acidity. Soft and small seeds are also a plus. According to the market trend, packed loose arils are becoming common in supermarkets, therefore it is necessary to develop genotypes with large "yield" of loose arils, Tolerance to fruit cracking will increase revenues to farmers and industrial processors and reduce health risks.

Generation of Wonderful-type pomegranates with the summer and early fall bearing habit. Mexican pomegranates are yellow-orange with a reddish blush when ripe, well accepted in the national market. However the export market is taken by the Wonderful variety. The program attempts to combine the early bearing habit of the Mexican and the attractiveness of the Cv. Wonderful, aiming at a specific window of opportunity in the American market.

V – Breeding strategy

Collection and characterization of the national germplasm. Focused on genotypes of evident agronomic value and suitable for fresh consumption as well as industrial processing.

Introduction of selected foreign germplasm. Introduction of selected germplasm bearing traits not available in the national pool, according to the objectives of the program.

Hybridization and selection. The best individuals are included in a dynamic hybridization program, Up to now we have the F1 and selfs on the field in the juvenile phase.

Agronomical, chemical and functional characterization. A complete description of plant productivity, phenology, chemical and functional properties is included in the process. In some specific cases in vivo essays will be performed.

Propagation and evaluation. Advanced selections are propagated and tested in traditional production areas. We started evaluation of our selections in new potential areas (Sonora, Aguascalientes, Chihuahua) in 2010.

Documentation and registration. Descriptors are complete for the traditional varieties, four selections for fruit production, one with ornamental value and two for dry flower production. They will be protected under the current Mexican legislation.

VI – Progress

Table 2 summarizes the basic features of the fruits of the first generation of improved pomegranates developed for the Bajío and similar regions, sweet and sub-acid (sa) with potential industrial value are included.

Table 2. **Fruit traits of pomegranate selections obtained by INIFAP**

Selection	Diam. (cm)	Calix length (cm)	Peel thickness (mm)	Fruit weight (g)	Aril weight (g)	Seed weigth (g)	Total sugar (ºBrix)	Seed hardness
37-12 sa	8.6	2.1	5.1	395.6	192.1	-	19.2	Intermediate
39-2 sa	9.3	2.5	5.6	501.6	218.6	10.9	16.6	Intermediate
34-20	8.4	2.8	6.35	315.8	125.1	7.5	17.7	Soft
Jerecuaro	8.7	2	2.7	343.5	203.8	-	17.2	Soft
33-17	8.6	1.6	2.3	326	207	7.5	17.5	Intermediate
34-15	8.6	2	2.6	288.7	261.3	8.8	14.5	Soft
Tecozautla	9.1	2.3	5	407	225.3	8.2	16	Soft
33-12	9.2	2.3	4	375	262	-	15.6	Intermediate
Apaseo	8.3	-	-	289.2	182	10.1	11.5	intermediate

VII – Versatility of uses

The program has developed selections specific for dry flower production, they flower profusely with orange, red and deep red colors, they have been characterized (Meillon 2010; Reynoso *et al.*, under review), a field trial is underway to optimize production. According to our preliminary data it is possible to produce at least 1 kg of dry flower per tree/year. High density planting, training and pruning could increase dry flower yield to highly profitable levels.

Acknowledgments

Research on pomegranate has been supported by Fundación Guanajuato Produce A.C., Gobierno del Estado de Guanajuato and the Instituto Nacional de Investigaciones Forestales Agrícolas y Pecuarias, Mexico.

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