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Origin, History and Domestication of Pomegranate

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ABSTRACT

Pomegranate (*Punica granatum* L.) is one of the ancient fruits associated with several human cultures of the world. There is mention of pomegranate in the Bible, the Koran, and in Buddhist and Chinese arts. Based on evidence from archeo-botanical samples, literature, religious iconography etc., it is estimated that pomegranate might have been introduced into culture about 5000 years ago. According to various reports, wild pomegranate grows in Transcaucasia and Central Asia from Iran and Turkmenistan to northern India. Thus, it is considered to be native of these regions. Its nutritional, therapeutic and ornamental values were known to humans since antiquity. Although pomegranate was reported to have a narrow genetic base, its huge collections available in different parts of the world indicate that it has high genetic diversity among the germplasm. The pomegranate family has a single genus *Punica* with two species viz., *P. granatum* and *P. protopunica.* The latter is considered to be the ancestor of the genus *Punica* which might have contributed to the evolutionary process of the cultivated form of pomegranate. Since the pomegranate tree is highly adaptive to a wide range of climate and soil conditions, it is grown in different tropical and subtropical regions. However, its main cultivation is confined to the northern hemisphere. Interestingly, the best quality fruits are produced in arid regions.

Keywords: ancient history, domestication process, taxonomy

CONTENTS

INTRODUCTION 1
POMEGRANATE ANCIENT HISTORY 2
CENTERS OF ORIGIN AND GENETIC DIVERSITY 3
DOMESTICATION 3
TAXONOMY 3
DISTRIBUTION, GROWING CONDITIONS AND FUTURE PROSPECTS 4
ECOLOGY 5
REFERENCES 5

INTRODUCTION

Pomegranate is an old, beloved plant and fruit. Recent research findings corroborate traditional use of pomegranate as a medical remedy as all parts of this plant have several bioactive metabolites (Holland *et al*. 2009). Consequently, its demand has increased tremendously not only in the western world but also in other parts of the globe. It is claimed to have originated in Iran and perhaps surrounding areas from where it spread to different regions. However, N. I. Vavilov stated that it originated in the Near East. It was cultivated in ancient Egypt and in early Greece and Italy. The fruit was very popular in Iraq. Over time, it spread into Asia (Turkmenistan, Afghanistan, India, China, etc.), North Africa and Mediterranean Europe. Interestingly, its domestication process took place independently in various regions (Evernioff 1949; Zukovskij 1950). It was probably introduced into Greece and the areas surrounding the Mediterranean Sea, as far west as Spain and Portugal by ancient sailors and traders. It is estimated that pomegranate was introduced into India and China over the Silk Road and ultimately into Japan (Bretschneider 1935). However, it was introduced in the Indian Peninsula from Iran during the 1st century AD and was found growing in Indonesia in 1416 AD. The Spanish sailors brought pomegranates to the New World and some missionaries introduced pomegranate in Mexico and California (Goor and Liberman 1956; Morton 1987). The ability of pomegranate plants to adjust to variable climatic conditions is reflected in the wide distribution of the wild form throughout Eurasia to the Himalayas (Levin 2006a). There is mention of pomegranate in the Bible, the Koran, and in Buddhist and Chinese arts. The fruit which was described by the Greek botanist Theophrastus about 2350 years before the present (BP) and is mentioned in many Greek and Turkish myths. It is one of the first five domesticated edible fruit crops along with fig, date palm, grape and olive. It has been the symbol of health, fertility and rebirth as mentioned in many ancient cultures. This fruit crop is known to have been domesticated in the Middle East about 5000 years ago (Adsule and Patil 2005; Levin 2006b). The present scientific name *Punica granatum* is derived from the name *Pomum* (apple) *granatus* (grainy), or seeded apple. In ancient Egypt, pomegranate received the name "*Arhumani*". The Romans first called this species "*malum punicum*" (punic apple or apple of Carthage) that evolved to "*Punicum granatum*". C. Von Linne finally gave the name *Punica granatum* (Hodgson 1917; Bretschneider 1935; Hunt 1989). It is considered an excellent fruit crop for growing in arid zones for its tolerance to drought conditions. Now, it is widely cultivated in Mediterranean, tropical and subtropical regions. However, it is cultivated in Central Asia and to some extent in the USA (Cali-

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fornia), Russia, China and Japan for fruit production and is also developed as an ornamental tree in East Asia (Mars 1996; Tous and Ferguson 1996).

POMEGRANATE ANCIENT HISTORY

Pomegranate has a long and exceptionally colourful history, having been embraced by a number of different cultures, while at the same time it had been a minor horticultural fruit crop in different countries. Yet, despite its wide geographic distribution across several continents, very little information is available pertaining to its genetic origin and centers of diversity (Still 2006). In different regions of the natural habitat of wild pomegranate, the period of time between the first appearance of the modern type of humans and the transition of their different populations to agricultural activities is anywhere between 2000 and 6000 BP. Ancient civilization of Sumers first appeared in South Dvurechje (area of two rivers: Tigris and Euphrates) at the end of 2500 BP and at the beginning of 2600 BP. The crop was brought into the area during their migration from the Zagros Mountains, and the appearance of the culture was witnessed during the third dynasty of Ura (4100-4200 BP). Although, by this time the Sumer civilization had already reached prosperity, which quite reasonably allows moving the time of domestication of pomegranate into 5000 BP. However, there is also mention in the literature that it was first found growing in Jericho (modern day Israel) around 6000 BP. There is no doubt that it repeatedly domesticated at different points of time in different parts of the natural habitat. It might have taken about 3000-7000 years from the beginning of the Neolithic age (12,000 years ago), transition from hunting and collecting to agriculture and cattle-raising, to the time of its introduction into the culture in different regions. However, initially the selection process might have been slow. The changes mainly involved the size and quality of the fruit, while in other aspects newly evolved varieties differed little from the wild type. Subsequently, it had spread quickly throughout the ancient world. Records are available that during 1000 BC Carthago supplied Rome with large seedless pomegranates. From the regions, where pomegranate entered the culture within its natural habitat, it gradually spread out west, east and north. However, the evidence of pomegranate culture in Asia Minor goes back to 3300-3400 BP. It has been estimated that Phoenicians might have spread out its cultivation throughout the Mediterranean region. It was already cultivated in Carthago (900 BC), Pyrenean peninsula, Greece and in Italy (400 BC). To the north of Dvurechje, there is an evidence of pomegranate culture within the Urartu region, about 800 BC. The movement of the Urartu towards Transcaucasia probably began at the end of 900 BC. There are also sites of spreading wild pomegranate in Central Asia, which indicates a possibility of its domestication in this region. An assortment of Central Asian pomegranate, however, is generally similar to that of Middle Eastern countries. It is estimated that its cultivation started in Central Asia during 3000 BP. In fact, in the subtropical climate of Southern Turkmenistan, regular irrigation might have appeared at the end of 4000 BC to the beginning of 3000 BC. By 4000 BP, its cultivated forms were present. The reports are available that pomegranate made its way from Central Asia to China in 4000 BP. During the age of great geographic discoveries (1600-1700 AD) and later it might had been spread in many subtropical and tropical countries throughout the world (Levin 2006a). Pomegranate's arrival in California predates its inclusion into the United States. In 1769 AD, Franciscan missionaries from Spain led by Father Junipero Serra, established Roman Catholic Christian centres and spread pomegranate culture into the southern and northern coastal regions of California (Seelig 1970; LaRue 1980; Morton 1987).

In many ancient cultures, the pomegranate figures prominently. In Greek mythology, it served as a symbol of the indissolubility of marriage; in Persian mythology, Isfandiyar ate a pomegranate and became invincible; in Judaism, the number of pomegranate seeds in a single fruit is said to be number 613 - one for each of the Bible's 613 commandments; in Buddhism, the pomegranate is one of the three blessed fruits; in Chinese ceramic art, the pomegranate is associated with fertility abundance, posterity, numerous and virtuous offspring and a blessed future; in Christianity and Bedouin tribes it is associated with fertility; in Islam, the Koran describes a heavenly paradise that contains pomegranate (Langley 2000; Newman *et al.* 2007). Even Egyptians were buried with pomegranates. The Babylonians believed chewing the seeds before battle made them invincible. It has a calyx like a crown and thus, in Jewish tradition, the crown of the emperor was designed in the shape of a calyx. Interestingly, it was the personal emblem of the Roman Emperor. Still, there is a tradition in Greece to break a pomegranate on the ground at weddings, on New Year's and during the new home entry ceremony. The word hand grenade and Grenada, an island nation of the coast off South America were derived from the name of the pomegranate (Still 2006).

The historians have long debated whether the pomegranate or date palm was the tree of life portrayed in various archaeological artifacts from Mesopotamia, the Levant and India. An analysis from a botanical archaeologist concluded the tree of creation or immortality that recurs in many archaeological materials from the first through third millennium BP is actually the Egyptian locust tree (McDonald 2002), although its design has been used in artistic works throughout ancient history. Earlier, paper wrappers which were bound to be designed primarily to protect or adorn unbound pamphlets before they were bound together with other pamphlets in a more permanent larger volume, are known to have been produced during the 15th and early 16th centuries in Augsburg, Ferrara and Venice. One of the oldest surviving wrappers dating from 1486 AD takes the form of a pomegranate as part of its pattern (Hirsch 1959). The pomegranate was well established by the late Bronze Age (1200-1550 BC) and it is found perhaps as artwork for its symbolism in a number of Egyptian 18th Dynasty tomb paintings and funerary garlands (Still 2006).

According to the available records, seafaring in the ancient Mediterranean began more than 10,000 years ago and evidence of the dependence on ships to transport merchandise is reflected in texts dating from the end of the 4th millennium BP. A ship carrying the finest luxury goods of the late Bronze Age sank off the coast of Ulu Burun, Turkey, in the late 1400 BP. Its discovery yielded great insight into cultural life during Egypt's 18th Dynasty and the LH IIIB period in Greece. The ship contained ceramic containers in which more than 1000 archaeo-botanical samples were retrieved. These contained pomegranate seeds along with seeds of other fruit plants, indicating its importance during that time (Haldane 1993). Archaeo-botanical evidence from military sites shows that it was brought to Central Europe by Roman soldiers during their occupation of this area. Because of climatic conditions, pomegranate could not be cultivated in these areas and thus, it remained an imported luxury item (Bakels and Jacomet 2003). In addition to the symbolic nature of pomegranate, its chemical properties made it useful for a number of widely disparate purposes, ranging from perfumes to birth control. A classical list of perfume ingredients from Pliny's Natural History included pomegranate rind, while its juice was used as an astringent to prepare oil to get a scent. It was a highly valued fruit during the Late Bronze Age (Ward 2003). Ironically, however, pomegranate peels or rinds were included in recipes for different medicinal purposes during classical and medieval times (Riddle 1991). Use of pomegranate as a medicine is mentioned in the ancient Greek medical papyrus by Ebers, which represents a complied reference-book of the 16th century BC. Even Plinii emphasized that it had been considered a universal therapeutic agent and used by the prominent medical healers of the ancient world and Middle Ages viz. Hypocrite, Galen, Oribasii, Paul Eginskii, Jovan Damaskin, Er-Razi, Jovan-ibn-Masua Ibn Sina (Avicenna).

The spectrum of therapeutic effects of pomegranate is quite wide. In folk medicine of the Orient, Mediterranean and Africa, it is included in 32 out of 56 groups of pharmacological and therapeutic treatments, 14 out of 17 pharmacotherapeutic groups of plants, used to treat diseases related to 15 out of 16 classes of diseases according to the international classification (Levin 2006a). Based on studies conducted over the past many decades, it is confirmed that almost all parts of pomegranate have some biologically active ingredients (Seeram *et al.* 2006; Newman *et al.* 2007).

CENTERS OF ORIGIN AND GENETIC DIVERSITY

Wild pomegranate grows in Transcaucasia and Central Asia from Iran and Turkmenistan to northern India (Levin 2006a; Holland *et al*. 2009). According to Levin (2006), there are three mega-centers (primary, secondary and tertiary) and five macro-centers (Middle Eastern, Mediterranean, Eastern Asian, American and South African) of origin and genetic diversity of pomegranate. The primary one, which is the Middle Eastern mega-center, the region within the boundaries of the natural habitat of pomegranate (Iran, Afghanistan) was included by N.I. Vavilov into the Front-Asian center of origin and evolution of cultivated plants. The secondary mega-centers (Mediterranean and Eastern Asian) were formed in the process of introduction of pomegranate to east and west. However, formation of macro-centers inside the primary and secondary mega-centers took place non-synchronously. But the tertiary centers took more time to form. Based on the varietal potential, mega and macro-centers are very non-uniform. It was estimated that the principal conglomerate of pomegranate varieties were developed by the process of domestication. Interestingly, further selections in the regions were close to the center of the natural habitat. It was estimated that they might have been introduced by sexual and/or vegetative means from there into the surrounding regions and became a base for evolution of local varieties. Although by the 13th century, the Arabs described and classified all local varieties of pomegranate grown in Arabia and Mesopotamia (Levin 2006a). Subsequently from the secondary centers, the valuable varieties were collected. And a similar process might have been repeated in the tertiary centers too. Interestingly, during ancient times, North Africa was the most fertile region of the Mediterranean basin. Enhancement of agriculture under Romans, development of virgin lands and cutting down mountain forest resulted in progressive erosion. In fact, vandals and later herds of nomads might have completely destroyed the flourishing site. And thus, the famous ancient center of pomegranate was destroyed. Recently, an increasing trend in its commercial cultivation has been observed in the Indian-Pakistani and other macro-centers.

Levin also mentioned that among the endemic microgenetic centers of pomegranate, in the Kandahar oasis (Afghanistan), grows the large seedless varieties of pomegranate. Similarly, in Dashnabad (Uzbekistan) the most frost-resistant varieties are grown. Nevertheless, among varieties of pomegranate there are those with a wide reaction rate, which can be seen from the wide zoning of the best Azerbaijani and Central Asian varieties. In the beginning of the 20th century, the American Pomological Society recommended several varieties for Florida, Alabama, Mississippi, Louisiana, Arkansas and Texas (Levin 2006a). The leading and oldest variety in the USA is 'Wonderful', which was isolated by Birs in 1896 AD from a mixture of varieties obtained from Florida (LaRue 1964; Levin 2006b; Day and Wilkins 2009). Almost all the varieties in the Mediterranean region are of a local type selected by unknown persons and maintained by vegetative propagation (Levin 1995; Mars 1996; Ozguven 1996; Mars and Marrakchi 1998). These materials may be considered as the pomegranate primary gene pool; they grow wild in the near east, Transcaucasia, Dagestan and also in Asia Minor. In these regions, hybridization between cultivated and wild forms is probably still taking place (Zukovskij 1950) and such wild forms would be considered as the secondary gene pool looking at the variability available in the region. According to the available records, however, one of the richest areas for the secondary gene pool of pomegranate exists in Turkmenistan (IPGRI 2001; Still 2006). The tertiary pomegranate gene pool would consist of forms of the pomegranate wild relative *P. protopunica*. It is presumed that *P. protopunica* played a role in the origin of pomegranate cultivars. At present, more than 500 varieties are known around the world but less than 50 of them are commonly cultivated. In fact, the trend of their commercial utilization is low out of the total genetic diversity of the world. Though, the botanical differences between wild and cultivated pomegranate are not obvious except for *P. protopunica* (Holland *et al.* 2009). Collection, evaluation, characterization and *ex situ* conservation of pomegranate germplasm are in progress in Italy, Spain, Israel, Russia, Commonwealth of Independent States (CIS), Tunisia, Turkey, Ukraine, India, Syria, the USA, Uzbekistan, Portugal, Hungary, Germany, France, Cyprus, Turkmenistan, Albania, Morocco, Greece, Egypt, Tajikistan, Iran and China (Frison and Servinsky 1995; Mars 2000; Fadevi *et al.* 2006; Still 2006; Zamani *et al.* 2007).

DOMESTICATION

It is estimated that the domestication process started somewhere in the Neolithic era (Levin 2006a; Still 2006). It was initially domesticated in Transcaucasia-Caspian region and northern Turkey (Zohary and Speigel-Roy 1975; Harlan 1992). Approximately 13% outcrossing has been reported in pomegranate (Jalikop and Kumar 1990), therefore, seedlings are not "true to type" resulting in plant-to-plant variation. Consequently, morphological changes might have occurred during domestication by which one can distinguish them from the non-domesticated progenitor. However, pomegranate selections are made on the basis of flower, rind and aril colour, fruit size, sugar and acid contents, resistance to biotic and abiotic stresses, yield, keeping quality, seed hardiness, etc. (Harlan 1992; Hancock 2004; Levin 2006a; Holland *et al.* 2009). It is believed that domestication of different crops might have started earlier in Africa, Southeastern Asia and/or Central America than in Southwestern Asia. As discussions of plant domestication usually begin with those parts of modern Jordan, Israel, Lebanon, Syria, Turkey, Iraq and Iran now often known collectively as the Levant or the Fertile Crescent. Evidence shows that cereals were the earliest crops to be domesticated during 10,000-12,000 BP in the fertile Crescent (Allard 1999), an area of land extending from the Nile Valley along the Mediterranean to northern Syria, down the Tigris and Euphrates valleys toward the Persian Gulf. With the exception of figs and grapes, fruits trees were only domesticated within the last 5000 years or so. The spread of pomegranate can be estimated by archaeological evidence, as described by Zohary and Spiegel-Roy (1975). Carbonized pips and fragments of pomegranate peels have been found from the early Bronze Age in Jericho and Arad and remains of *Punica* species have been found in Nimrud. By the middle ages, pomegranate grew throughout the Levant and appeared in Egypt during the Middle Kingdom. Many wild groves can still be found thriving in the bottom of gorges throughout the Mediterranean and Central Asian region (IPGRI 2001).

TAXONOMY

Pomegranate belongs to the order Myrtales and most likely originated from Saxifragales. The Lythraceae family is likely to be an initial form, which initiated the Sonneratiaceae and Punicaceae families. However, the genus *Punica* had tropical ancestors close to Lythraceae and Sonneratiaceae. Arogenesis of *Punica* resulted from evolution along the xerophilic and cryophilic lines of development. Punicaceae contains a single genus *Punica* of two species, *Punica granatum* L. and *P. protopunica* Balf. f., (syn *Socotria proto-*

punica) with the latter endemic to Socotra Island (Yemen). In *P. protopunica* 2n = 14, thus the haploid number of chromosomes is n = 7 in Punicaceae, which can be considered as a more primitive characteristic from an evolutionary point of view, while n = 8 in *Punica* is a factor of advancement (Levin 2006a). However, based on xylem anatomy, *P. protopunica* has been suggested as the ancestor of the genus (Shilkina 1973). Graham *et al.* (1998) placed the genus *Punica* in the Lythraceae, which was previously placed in Punicaceae; however, confusion still exists among taxonomists regarding the pomegranate family. According to Smith (1976), *P. granatum* has 2n = 16, 18 chromosomes. The somatic chromosome number of 'Dholka', 'Ganesh', 'Kandhari', 'Muskat White' and 'Patiala' is 2n = 16 while the cultivar double flower is 2n = 18 (Nath and Randhawa 1959). The chromosome number in 'Vellodu' and Kashmiri varieties is 2n = 18 with 1 or 2 quadrivalent associations at meiosis (Raman *et al.* 1963). Further, some cytologists have reported that the diploid set of pomegranate has 16, 18 and 19 chromosomes (Yasui 1936; Darlington and Janaki Ammal 1945; Raman *et al.* 1971; Sheidai and Noormohammadi 2005; Levin 2006a). The species *P. granatum* has two subspecies viz. Chlorocarpa and Porphyrocarpa. The former is found in the Transcaucasus region, the latter in Central Asia (Patil *et al.* 2002). "Its chromosomes are very small (1-2 µm) and differ significantly in size. Different varieties reveal differences in size and morphology of chromosomes, chromosomal strangulation, presence of 4 satellite metacentric chromosomes and shoulder size. It is believed that differences in karyotypes in different varieties and forms expressed in the shape and size of chromosomes that can be used when resolving issues related to evolution phylogenetics and intraspecific systematization of pomegranate" (Levin 2006a). In India, a spontaneously appeared tetraploid clone (2n = 32) was found. Its flowers and fruit exceed the size of the original form, and its pollen sterility reaches 85.4% as compared to 7.4% in the diploid (Das and Sur 1968).

DISTRIBUTION, GROWING CONDITIONS AND FUTURE PROSPECTS

It was reported that pomegranate was cultivated around the world within the area lying between latitude 41° N and 42° S (Hodgson 1917). Now, the scenario of its cultivation has changed. Commercial orchards of pomegranate are now grown in the Mediterranean basin and in Asia (Holland and Bar-Ya'akov 2008) and India became the largest producer (Jadhav and Sharma 2007). Even so, new orchards are traditionally cultivated in the southern hemisphere in South America, South Africa and Australia (Holland *et al.* 2009).

G M Levin surveyed Central Asia and Caucasus and reported that there were about 20.5 million plants of pomegranate in the CIS during 1984. Out of which, 90.1% of the total number of plants were grown in Azerbaijan, Uzbekistan and Tajikistan. These republics as well as Turkmenistan have considerable prospects for the commercial cultivation of pomegranate. Uncoverable cultivation of pomegranate was possible in a narrow sea side strip from Sudak to Sevastopol. In the Krasnodar region, it is cultivated in the sea-side and moderate elevation zones within Adler and Lazarevskoe regions. In Dagestan, its cultivation is confined in the Derbent, Magaramkent and other southern region. However, in Georgia, it is found in Kakhetia, Abkhazia, Adzharia, Guria, Kartly, etc. In Armenia, it is concentrated in Megrinskii, Gorisskii, Kafanskii, Idzhevanskii, Shamshedinskii, Noemberyanskii and Alaverdskii districts as well as in some regions of Ararat Plain. In this Republic, it is grown in 52 out of 60 regions, but is mainly concentrated in Gyanzhinskii, Agdamskii, Akhsuinskii, Kasum-Izmailovskii, Mirbashirskii, Samukhskii, Geokchaiskii, Agdashskii districts as well as in Apsheron. Though, Shirvanskii zone has more prospects for its cultivation. At present, in Turkmenistan, the major orchards of pomegranate are located in Garrygalynskii and Kizil Atrekskii districts. In Uzbekistan, it occupies large areas in Surkhan-Daryinsk, Fergana, Andizhan, Namangan, Bukhara and Kashka-Daryinsk regions and has further scope for its area expansion. In Tadzhikistan, the cultivation is confined in Vakhshaskaya and Nizhne Kafriniganskaya valleys as well as in Leninabad and Gissar zone. Interestingly, modern farms have been established in these areas. In Kirghizia, it is grown in Fergana valley mainly concentrating in Suzakskii and Dzhelalabadskii districts. However, in Kazakhstan, it is also grown on a small scale in the Chimkent region. In Western Europe, the decorative forms of pomegranate are grown at 51-52° N latitude. In England, its fruits ripen seldom, only in places protected by the walls, same as in the continental part with the exception of South of France, where it is already cultivated. In the USA, it is grown up to 35° N, where it gets damaged only during extreme winters. However, it is also grown in numerous tropical countries of Asia, Africa, America isles of Pacific and Indian oceans in India where it produces poor harvest with low-quality fruit, unless it climbs up into high mountain regions (Levin 2006a; Day and Wilkins 2009). Kulenkamp *et al.* (1985) reported that about 0.1 million wild pomegranate trees were in the USSR (Transcaucasia 70%, Kopet-Dag 20%). Interestingly, based on a vertical scale, pomegranate reaches different limits. In its cultivated form, it spreads up to the same heights as in nature and even higher, although in these cases fruit production becomes irregular or even episodic. Even in Northern Iran and Egypt, it is cultivated in areas below sea level while in China, the Himalayas, Baluchistan, Afghanistan, Iran and Iraq it grows up to 1600-3330 m above sea level. But, in Europe, it is distributed below 1000 m above sea level. However, in tropics it usually occupies areas more than 1000 m above sea level. Below this level fruit production is generally poor. Thus, at the northern boundary of its natural habitat, it is grown in the mountains in separate micro-regions. As it moves south it climbs higher and higher while continuing to grow at lower elevations. In the zone of geographical optimum, it is spread across the entire profile reaching its upper limits. While moving further south, it climbs even higher and its elevation amplitude narrows down.

It is well known that arid regions have vast scope for its intensive cultivation and quality fruit production (Chandra *et al.* 2008). However, cultivation of pomegranate is mainly concentrated in countries of arid zones of the northern hemisphere. It was estimated that pomegranate occupied 25,000 ha during 1930-1935 (Levin 2006a). Now, the scenario of its cultivation from the beginning of the 21st century has changed completely. At present, India, Iran, China, the USA and Turkey are the main pomegranate producers globally. Although, there is no exact data available on their area and production in the world due to the rapid increase in the production and expansion, it is estimated that around 1.5 million tonnes of pomegranate fruits are produced in the world annually (Holland and Bar-Ya'akov 2008). India ranks first in the world with respect to pomegranate area and production. But productivity-wise Spain holds prime position with 18.5 t/ha followed by the USA (18.3 t/ha). As far as export is concerned, Iran secured first rank with an annual export of 60,000 tonnes followed by India (35,176 t). Although Spain has very little area (2,000 ha), its export share is 37.8% of total production (37,000 t) followed by Israel (23.5%) and the USA (15.5%). However, India has the lowest share with respect to export. Earlier India used to import pomegranate fruits from Afghanistan and West Pakistan, but the import scenario has been changed from the last decade of the 20th century. Now, India has started to export to different countries. Interestingly, the Deccan Plateau of India has highly congenial climatic conditions for quality fruit production throughout the year (Chandra *et al.* 2006; Chandra *et al.* 2008).

Commercial culture of pomegranate is practically concentrated within its natural habitat and mainly within boundaries of the primary centers of its origin. More than 90% of its world plantation is concentrated in Asia and Europe;

about 9% in North Africa and less than 1% in North America. The optimal conditions for pomegranate cultivation include high insolation, the sum of active temperatures of 4000-4600°, annual precipitation of 18-55 cm and mild winters. However, optimal combination of environmental conditions for the cultivation of pomegranate is different in different regions and also depends on soil variations, microclimate and agro-techniques followed (Levin 2006a, 2006b).

In the ancient world, the best quality pomegranates were grown in Carthage, in ancient Italy–in the Campan city of Abella. Though, in Spain, it is concentrated in the provinces of Alicante, Cordoba, Murcia, Seville, Granada, etc. However, pomegranate grown in Cyprus has better fruit quality than those produced in Spain. Similarly, Taif near Mecca is famous for pomegranate in Saudi Arabia. In Iraq, the best pomegranate is grown in the area between two rivers with its silty, deep damp and fertile soils. In Turkey, the best pomegranate grows near Lake Van and close to Urfa. In Iran, the major pomegranate micro-regions are located near Saveh, Yazd and in Sangum near Khaf. This is also well known that pomegranate fruits from Kandhar (Afghanistan) are famous throughout the world. In Pakistan, the best quality fruit is grown in the northwestern regions and in Baluchistan near Kharnai. Similarly, in India, the quality of pomegranate fruit is better in the Deccan Plateau as compared to its northern provinces (Chandra *et al.* 2006). In China, the best quality fruits are produced in Xinjiang-Uighur, Yunnan, Jiangsu and Henan. Similarly, the internal valleys of California and Arizona in USA and Tehuacan and Puebla in Mexico produce superior quality pomegranate fruits (Levin 2006a).

Since ancient times, pomegranate fruit was the object of export-import in Egypt, Palestine and Carthage. During the middle Ages, pomegranate trade flourishing in the East. However, in the 20th century, it remained as one of the objects of world trade. During 1925, up to 67 tonnes of pomegranate fruit per year was exported from Levantine countries to Egypt until export was terminated due to huge damage done to the fruit by the pomegranate fruit moth (*Cryptoblabes gnidiella*), competition with Cyprus and growth of pomegranate plantation in Egypt. In 1950, Spain exported 5,700 tonnes of pomegranate per year primarily to England and France. Earlier, pomegranate processed products were exported from Spain and France to the USA. In London, it was also imported from South Africa and other subtropical countries. In a number of Oriental countries the juice was also exported. Until the last quarter of the 20th century, Afghanistan, whose annual production ranged between 16,000 and 18,000 tonnes of which about 75% was exported to India, CIS, Pakistan and other Middle Eastern countries. However, Iran, Turkey, Syria, Tunisia, Pakistan, Spain, Morocco, Egypt and Algeria had been the main pomegranate producers in the world (Levin 2006a). At present, Iran is the largest exporter (60,000 tonnes) of pomegranates (Holland and Bar-Ya'akov 2008). It is expected that India would be its leading exporter globally in coming years (Jadhav and Sharma 2007).

ECOLOGY

G. M. Levin visited most of the pomegranate-growing regions of the world and observed that it grows on heavy clay, clay loam, chestnut, loamy, loamy-pebble soils, sandy loam soils rich with humus, black earth (chernozem), light humus soils with pebble inclusions, yellow soils (zheltozen), on podzolclay, alluvial soils, on seaside sands, gravel talus dry rocky hills, alkali soils, lime-rich soils as well as on limestone rich lands of arid hills. However, the best soils for pomegranate cultivation are considered to be fertile, rich with humus, deep, medium density with good drainage and especially alluvial soils. And such soils produce the best quality fruits. Even it can be grown well in slightly saline soils as it is considered a saline-tolerant plant (Patil and Waghmare 1983; Rao and Khandelwal 2001; Ram Asrey *et al*. 2002). Accumulation of salts, in excess of 0.5% of the soil mass causes dying off of growing roots. Interestingly, application of Paclobutrazol (250 ppm) was reported to reduce salinity damage (Saeed 2005). The presence of water-soluble salts like sulphates and chlorides and exchangeable sodium negatively affect root formation. It can tolerate soil salinity due to the ability of its root system which can accumulate the majority of toxic salts present in the soil and thus prevent their intensive flow-out to the above-ground organs (Levin 2006a; Marathe *et al.* 2009). It is well documented that pomegranate tissues accumulated sodium, chlorine and potassium in response to irrigation with saline water (Doring and Ludders 1987; Naeini *et al.* 2004, 2006). 'Perhaps under such situation, xylopodium, a wood like underground stem performing a function of vegetative reproduction and accumulation organ, acts as a buffer. Intensive absorption of toxic sodium ion, reduces the content of potassium and phosphorus, protein and phospho organic compounds, nitrogen supply from the soil and utilization of phosphorus compounds as a result the content of chlorophyll carotenoids, sugars and tanning substance are reduced in the plant. This leads to decline in crop yield and fruit quality' (Levin 2006a).

Basically, pomegranate is a light-loving plant and reacts negatively to excessive shading (Chadha 2005). At the same time, direct sun-light and considerable heating often causes harmful effect on fruits leading to sun-burns (Sharma *et al.* 2006). However, best quality fruit are produced in arid regions having a long, hot and dry summer. It can easily withstand temperatures up to 45-48°C in combination with dry hot winds. It is well known that pomegranate is not frost resistant and thus can not tolerate temperatures lower than –18°C. For its higher fruit yield, regular irrigation is required. Even it hardly tolerates excessive water (Badizadegan 1975; Kulenkamp *et al.* 1985; Levin 2006a) and high soil moisture may lead to wilt disease in India (Sharma *et al.* 2006).

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