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Global Scenario of Pomegranate (*Punica granatum* L.) Culture with Special Reference to India

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ABSTRACT

The pomegranate (*Punica granatum* L.), a member of the Punicacae family, is one of the important fruit crops grown in tropical to temperate agro-climatic conditions and has nutritional and therapeutic values due to the presence of several bioactive compounds in its different parts. It is rich in several potentially active phytochemicals like sterols and terpenoids, fatty acids and triglycerides, simple gallyol derivatives, organic acids, flavonols, anthocyanins and anthocyanidins, catechin and procyanidins. India ranks first in the world with respect to pomegranate area (0.125 million ha) and production (1.14 million tonnes). Maharashtra contributes more than 75% of the total area alone followed by Karnataka and Andhra Pradesh. More than 250 germplasms are available in India. The National Research Centre on Pomegranate, Solapur is the nodal centre working exclusively on pomegranate. At present, 187 (both exotic and indigenous) germplasms are available in its national field gene bank. In the last 50 years, 10 pomegranate cultivars have been identified and released for commercial cultivation. Of the released cultivars, 'Bhagawa' and 'Ganesh' are popular among farmers. In India, bacterial blight, wilt, fruit borer, thrips, sun scald, fruit cracking and internal breakdown are some important biotic and abiotic stresses associated with the pomegranate industry. Work done on flowering behaviour, fruit breeding, propagation, plant nutrition and biotic and abiotic stresses have been reviewed, and future challenges and required research strategies are presented in the manuscript.

Keywords: pomegranate industry, research and development in India

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INTRODUCTION

The pomegranate (*Punica granatum* L.) is one of the oldest known edible fruits and is capable of growing in different agro-climatic conditions ranging from tropical to temperate (Levin 2006a; Jalikop 2007). It was prized by many ancient cultures as a symbol of beauty and fertility (Still 2006). No doubt, it had been embedded in human history and its utilization was associated with several ancient cultures for its fruit, pharmaceutical and nutraceutical values. Despite this, its cultivation had been restricted and considered as a minor fruit crop in several countries. In the recent past its wide range of significance in human health, nutritional and livelihood security has been recognized which resulted in a heavy demand for fruit consumption not only in India but also in the western world where it was not popular traditionally. According to an estimate more than 0.119 million tonne pomegranate fruit was exported from Iran, India, USA, Spain, Tunisia etc. to different countries (Holland and Bar-Ya'akov 2008). Now, its commercial cultivation has begun in many countries, including India. Interestingly, every part of pomegranate, namely the root and trunk bark, wood, sprouts, leaves, flowers, fruit, rind and seeds have economic value (Seeram *et al.* 2006). The fruit, which is a high-value food product, is used fresh or to produce juices. There is high demand of pasteurized juice in the global market. Its juice is also popular for culinary purpose. The juice is mainly used to prepare grenadine, extracts, liquors, wines, jelly, etc. (Elyatem and Kader 1984; Holland and Bar-Ya'akov 2008). The arils are used to prepare jam or its dried form as condiments. The young leaves may serve as tea surrogate. The wild fruit is used for citric acid production and its byproducts can be used to produce alcohol, tannin, waxes, frothers, etc. The flowers and rind are good sources of natural dye. Its seed oil can be used for producing enamels, and oilcake for feed meal and some sorts of

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medical compounds. Hard wood of pomegranate is used for making small articles, canes and handles. It is a valuable honey-producing plant too, which can produce 11.5 kg of honey/ha. Besides, it also has a certain reclamation value due to its capability to thrive on saline soils, loose sands and mountains or hills (Levin 2006a).

Since time immemorial, pomegranate had been a universal therapeutic agent owing to the presence of biologically active ingredients in its different parts. But recent modern research findings strengthened the status of pomegranate as an important medicinal fruit crop. There are several potentially active phytochemicals like sterols and terpenoids in the seeds, bark and leaves, alkaloids in the bark and leaves, fatty acids and triglycerides in seed oil (Newman *et al.* 2007), simple gallyol derivatives in the leaves, organic acids in the juice (Ender *et al.* 2002; Miguel *et al.* 2004), flavonols in the rind (Kim *et al.* 2002; Van Elswijk *et al.* 2004), fruit (Heftmann *et al*. 1966), bark and leaves, anthocyanins and anthocyanidins, catechin and procyanidins in the juice and rind (Du *et al*. 1975; Kashiwada *et al.* 1992; Miguel *et al.* 2004; Newman *et al*. 2007). Coronary heart diseases, cancer (skin, breast, prostate and colon), inflamemation, hyperlipidemia, diabetes, cardiac disorders, hypoxia, ischemia, aging, brain disorders and AIDS are potential disease targets in years to come for treatments using pomegranate ingredients (Seeram *et al*. 2006).

In the near future, the most challenging tasks, however, would be the production of high quality pomegranate fruit with attractive appearance full of relatively high content of health promoting ingredients free of pesticide residues. At present, there are many cultivars that are attractive to the consumer and grower, but cultivars that combine most of the desired characters including good taste and colour, high content of anticancer and antioxidant compounds and resistance against major insect pests and diseases are rare. However, modern methods in molecular genetics like mapping, marker-assisted selection (MAS) and biological mutagenesis are yet to be applied in pomegranate research. Only few genes from pomegranate were isolated and identified and no expressed sequence tags (ESTs) or other genetic databases have been established. Recently, *Agrobacterium*-mediated genetic transformation of pomegranate has been reported by Terakami *et al.* (2007). Genetically modified cultivars of pomegranate, however, are not expected in the near future due to restrictions on commercial use of such plants and because transformation systems have not yet been developed for commercial cultivars. The development of a transformation system in 'Nana' is expected to be useful to study genetic manipulation that may help identifying important pomegranate genes for future exploitation and transformation of the function of genes in pomegranate. The full potential of its natural variation has not been completely exploited for which attempts are needed.

Increasing pomegranate production and developing the market are associated with the development of new technologies in fruit processing, storage and agricultural management. Some of the new technologies like the development of industrial methods for aril separation by mechanical means in an efficient way and in large quantities, extension of pomegranate fruit storage period for up to 4 months, development of modern cultivation methods and cultivars that can produce high fruit yield (> 40 t/ha), and also developing techniques to use recycled water for irrigation are needed in the world, especially in the Mediterranean basin. Based on experimental findings from India and Iran, it was confirmed that drip irrigation can save up to 66% of water compared to surface irrigation (Chopade *et al.* 2001), but much more efforts are required to develop optimal and computer-aided effective irrigation systems.

Several insect pests (fruit borer (*Deudorix isocrates*), fruit fly (*Ceratitis capitata*) and thrips (*Rhipiphorothrips cruentatus*)) and diseases (bacterial blight (*Xanthomonas axonopodis pv. Punicae*), leaf, fruit spots (*Cercospora punicae*, *Colletotrichum gloeosporiodes*, *Botryodiplodia theobromae*, *Curvularia pallescens*, *Discosia punicae*, *Nigrospora oryzae*, *Pestalotiopsis versicolor*, *Sclerotium rolfsii* and *Alternaria alternate*) and rots (*Colletotrichum gloeosporiodes*, *Cercospora punicae*, *Alternaria solani* and *Drechslera rostrata*, *Aspergillus variecolor*, *A. niger*, *A. niveus*) and wilt (*Ceratocystis fimbriata*) damage pomegranate crop considerably (Utikar and More 1976; Phillip 1979; Sharma *et al.* 1981; Madhukar and Reddy 1989; Somasekhara 1999; Chadha 2005; Sharma *et al.* 2006; Holland *et al.* 2009; NRCP 2009a, 2009b), and thus, their cost effective management practices need to be developed that will improve the profit margin and encourage farming community to enhance pomegranate production and productivity. The longer period of pomegranate storage and the development of new technologies offer a much higher marketing flexibility for producers and extend the range of markets in the world. Modified atmosphere packaging with special bags (Xtend®) having micro perforation are available in the market (Porat *et al.* 2006; Sachs *et al.* 2006) and these bags result in the maintenance of 5% CO_2 and 12-14% O_2 within the bag surrounding the fruit. Such packaging reduces weight loss from 7-3.5%, scald from 38-21% and finally, reduced crown decay when pomegranate fruits were stored at 6°C for 16 weeks. Therefore, use of the Xtend® packaging technique or controlled atmospheric conditions of 2% O_2 + 3% CO_2 at 6°C permits storage of pomegranate fruit for 4-5 months with good consumer acceptability.

AREA, PRODUCTION AND EXPORT

Pomegranate is known to have been domesticated in the Middle East about 5000 years ago (Adsule and Patil 2005; Levin 2006b). Iran (Persia) or its surrounding areas are considered to be its centre of origin. Evidences are available that it was cultivated in ancient Egypt, Greece and Italy long back. In time, it spread into Asia (Turkmenistan, Afghanistan, India, China, etc.), North Africa and Mediterranean Europe. According to Levin (2006a), the modern natural area of pomegranate distribution almost completely fits within Mediterranean and Iran-Turanian floristic regions of the Ancient-Mediterranean subkingdom, which only partially occupies the Circumboreal region (Atlantic-Europe, Balkan, Euxinus, and Caucasus provinces) and the Eastern-Asiatic region (Sikang-Yuennan province) of the Boreal subkingdom of the Holarctic kingdom. It is expected that wildly growing pomegranate spread from the Balkans to the north-western part of India, especially in Western Himalayas.

At present, Morocco, Tunisia, Egypt, Israel, Syria, Lebanon, Turkey, Greece, Cyprus, Italy, France, Spain, Portugal, Iran, Iraq, India, China, Afghanistan, Bangladesh, Myanmar, Vietnam, Thailand, Kazakhstan, Turkmenistan, Tajikistan, Armenia, Georgia, the USA, Mexico, Argentina and Chile are some countries growing pomegranate in the world for table use and as an ornamental tree in East Asia (Mars 1996; Tous and Ferguson 1996). Among these countries, India, Iran, China, the USA, and Turkey are the five major producers of pomegranate (**Table 1**). However, there is no exact data available on its area and production in the world due to the rapid increase in production and expansion. The current total annual world production of pomegranate fruit is estimated to be around 1.5 million tonnes (Holland and Bar-Ya'akov 2008).

India has occupied first position in the world with respect to pomegranate area (0.125 million ha) and production (1.140 million tonnes). 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%). India has the lowest share (3.0%) with respect to export compared to other pomegranate-exporting countries. Earlier India used to import pomegranate fruits from Afghanistan and West Pakistan, but the import scene has changed completely from

Table 1 Estimated world pomegranate area, production and export.[1]

Country	Area (million ha)	Production (million tonnes)	Productivity (t /ha)	Export	
				Total export (t)	% of total production
India	0.125*	1.140*	9.12	35,176	3.07
Iran	0.065	0.600	9.23	60,000	10.00
China	--	0.260	--	--	--
USA	0.006	0.110	18.30	17,000	15.45
Turkey	0.008	0.090	11.30	--	--
Spain	0.002	0.037	18.50	14,000	37.84
Tunisia	0.003	0.025	8.30	2,000	8.00
Israel	0.002	0.017	8.50	4,000	23.53

[1] Holland and Bar-Ya'akov (2008) ; * Jadhav and Sharma (2007)

Table 2 Year wise export and growth of pomegranate in India.*

Year	Export (t)	Value (million rupees)	Growth (%) Over 2002-03
2002-03	6,304	143.4	--
2003-04	10,316	210.9	63.64
2004-05	12,034	258.7	90.90
2005-06	19,652	567.0	211.74
2006-07	21,670	795.7	243.75
2007-08	35,176	911.9	457.99

*http://www.nhb.gov.in

the last decade of the 20th century. Now, India has started export of pomegranate to different countries. Interestingly, the export of pomegranate from India increased about 5-fold in 2007-08 over 2002-03 (**Table 2**), indicating a bright future for export in years to come. At present, the major pomegranate-importing countries from India are UAE (11973 tonnes), the Netherlands (721 tonnes), Saudi Arabia (277 tonnes) and Bangladesh (203 tonnes). Interestingly, the Deccan Plateau of India has highly congenial climatic conditions for quality fruit production throughout the year, which is a unique feature compared to other pomegranate-growing countries in the world. In Spain, the fruits are available during August to March, in the USA from August to November and in Peru from April to July. However, in other countries fruit availability is confined to 2-3 months only in a year (**Fig. 1**).

CULTIVARS AND NUTRITIVE VALUE

Pomegranate cultivars are grown in very diverse regions around the globe and only some commercial cultivars are popular in different countries like 'Wonderful' in the USA, 'Rosh Hapered', 'Acco' and 'Wonderful' in Isreal, 'Mollar de Elche' and 'Malta' in Spain, 'Bhagawa' and 'Ganesh' in India, 'Echen' in China, 'Hicanazar' in Turkey, 'Red Metur' and 'Manafaluty' in Egypt and 'Anar Bedana' and 'Kandhar Large Red' in Afghanistan. 'Wonderful' is a late cultivar with a sweet-sour taste, large size fruit and an appealing appearance having high storability and thus, is highly prized in many countries. In European and American markets, 'Wonderful' is mainly preferred. The Indian evergreen cultivar 'Bhagawa' is grown throughout the year. This is a sweet and medium size late cultivar with a strong red skin and aril colour. Recently, several cultivars such as 'Emek', 'Shani-Yonay' and 'Acco' having a red skin and aril colour, early ripening time and soft seeds have been introduced for commercial cultivation in Israel and they have an excellent taste and colour and ripen one month earlier to 'Wonderful'. These cultivars and 'Bhagawa' are very important for extending the production season and enable much higher flexibility for fruit harvesting and marketing (Holland and Bar-Ya'akov 2008; Holland *et al.* 2009). In general, all commercial cultivars can be grouped into three classes based on acidity viz. sweet (acidity up to 1%), sweet sour (acidity >1-2%) and sour (acidity >2%). Sweet cultivars have a high demand in India and China while sweet-sour cultivars are preferred in America and European countries. Sour cultivars are suitable for *anar-dana* (dried arils) and used as condiments in India.

Based on chemical analysis of the pomegranate fruits, El-Nemr *et al.* (1991) reported that the edible portion (arils) represented 52% of the total fruit weight, which comprised 78% juice and 22% seeds. However, fresh juice contained 85.4% moisture, 10.67% total sugars, 1.4% pectin, 0.1 g/100 ml total acidity (as citric acid), 19.6 mg/100 ml free amino nitrogen and 0.05 g/100 ml ash. Besides, there are several reports available indicating the high nutritive value of pomegranate in terms of protein, carbohydrates, vitamins, organic acids and minerals (Ulrich 1970; Malhotra *et al.* 1983; Nasr *et al.* 1996; Melgarejo *et al.* 2000; Ender *et al.* 2002; Roy and Waskar 2005). Interestingly, among carbohydrates, glucose (5.46%) and fructose (6.14%) are predominant sugars in the juice (Lee *et al.* 1974) with almost no sucrose (Siddappa and Bhatia 1954) and sour cultivars

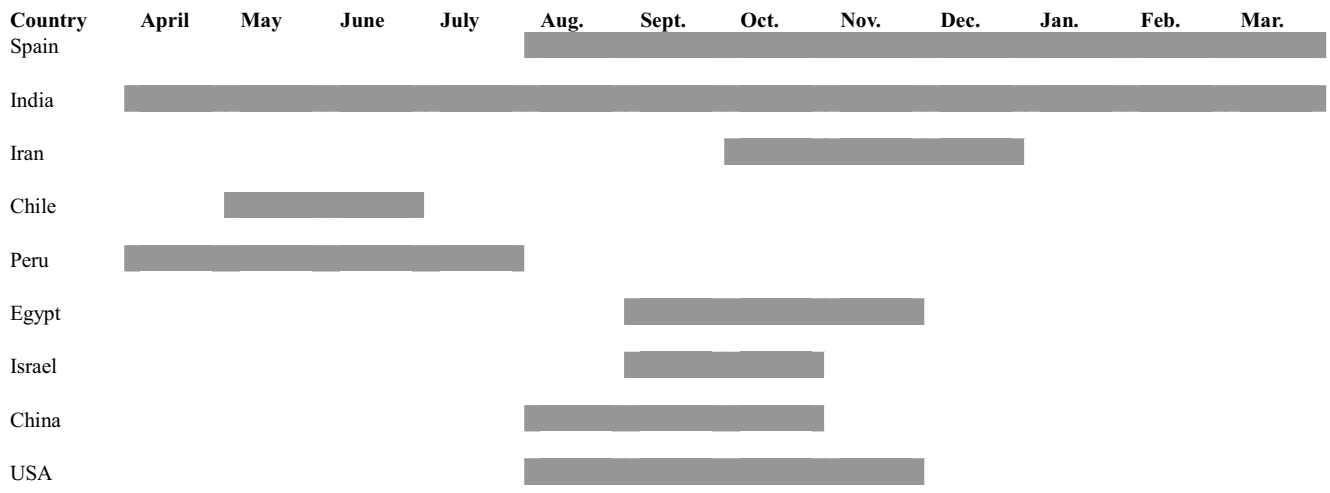

Fig. 1 Pomegranate harvesting period in different countries.

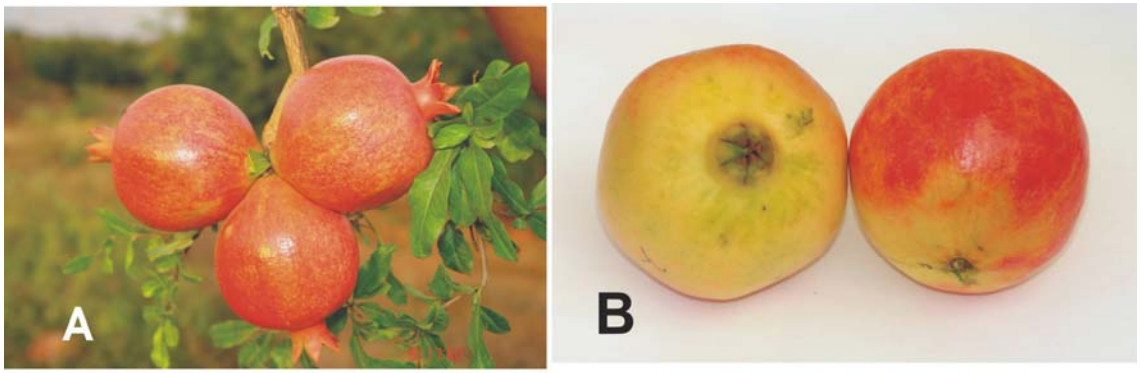

Fig. 2 Promising Indian varieties of pomegranate. (A) Bhagawa, most popular variety. (B) Ganesh, an old variety.

Table 3 Fruit quality of 'Bhagawa' and 'Ganesh' harvested in February.*

Parameters	Cultivars	
	Bhagawa	**Ganesh**
Moisture (%)	81.27	81.17
Total ash (%)	0.53	0.46
Protein (%)	1.41	1.21
Fat (%)	0.31	0.24
Crude fiber (%)	1.6	1.40
Carbohydrates (%)	14.88	15.52
Calorific value (K cals/100 g)	67.95	69.08
TSS (°Brix)	16.20	16.84
Acidity (%)	0.42	0.38
Minerals (mg/100 g)		
Iron	0.39	0.30
Zinc	0.26	0.19
Calcium	2.50	2.71
Magnesium	10.22	7.78
Copper	0.26	0.28
Manganese	0.13	0.13
Phosphorus	34.73	28.23
Vitamins (mg/100 g)		
Thiamine	0.09	0.06
Niacin	0.22	0.25
Ascorbic acid	23.38	22.42
Total carotenoids (µg/100 g)	26	27

* NRCP (2008)

showed lowest fructose and glucose. However, 6 anthocyanin pigments were recorded and found to be responsible for the red colour of pomegranate juice. These were identified as delphinidin 3-glucoside, delphinidin 3,5-diglucoside, cyanidin 3-glucoside, cyanidin 3,5-diglucoside, pelargonidin 3-glucoside and pelargonidin 3,5-diglucoside. However, the fruit skin contained only cyanidin and pelargonidin derivatives (Gil *et al*. 1995; Alighourchi *et al.* 2008). 'Bhagawa' and 'Ganesh' are commercial Indian pomegranate cultivars (**Fig. 2**), but 'Bhagawa' occupies 75-80% of total pomegranate acreage in Maharashtra, Karnataka and Andhra Pradesh. Overall fruit quality aspects of 'Bhagawa' (**Table 3**) were slightly superior to 'Ganesh' when fruits were harvested in February (NRCP 2008).

EXISTING CULTIVATION PRACTICES OF POMEGRANATE IN MAHARSHTRA AND KARNATAKA

Maharashtra is the main pomegranate-producing bowl in India (Jadhav and Sharam 2007). It is situated in the western part of India between 15° 45' to 22° N latitude and 72° 45' to 80° 45' E longitude (Challa *et al.* 1995). It has a tropical monsoon type of climate with three distinct seasons (summer, monsoon and winter). Summer sets somewhere around March, winter in October and the monsoon season in June. It is located in the northern centre of peninsular India which is surrounded by the Arabian Sea in the west and by Gujarat and Madhya Pradesh in the north (Sheth Hetu 2006). It is also encircled by Madhya Pradesh in the east and by Karnataka and Andhra Pradesh on the south dominated by a plateau. At present, about 96,000 ha area is available under pomegranate in Maharashtra. Solapur and Nasik districts of Maharashtra have maximum cultivated area under pomegranate, but its sporadic cultivation is also common in Pune, Ahmadnagar, Usmanabad, Sangli, Satara, Latur, Dhule, Jalana and Kolhapur districts (National Horticulture Board www.nhb.gov.in). Interestingly, the best quality pomegranate fruits are harvested from Sangola, Pandharpur, Malshiras and Mohol Tehsils of Solapur

Based on a survey of the major pomegranate-growing areas of Maharashtra, the information on existing cultivation practices and important abiotic and biotic stresses of pomegranate industry have been narrated (Chandra *et al.* 2006; NRCP 2007a, 2008, 2009a). The crop is grown in sub-marginal and dry areas in black, red, gravel and rocky lands. The land holding of the growers under pomegranate ranged from 0.4 to 80 ha, but the majority of farmers had more than 2 ha of orchards. Medium density (520-750 trees/ha) planting was more common. Generally, pits (60-90 cm length, width and depth) are dug for planting. Among promising cultivars, 'Bhagawa' and 'Ganesh' were preferred by the growers, but the area under 'Bhagawa' was maximum (> 75% area in Deccan Plateau). Application of Farmyard manure (10 kg/tree) with chemical fertilizers, particularly N, P and K, was common practice, but some of the growers applied micronutrients (salts of Zn, Mn, B, Cu and Fe each 15-25 g/plant) too and higher quantity of manures (50-70 kg/plant), including vermicompost (3-5 kg/plant) and *neem* cake (1-3 kg/plant). Almost all farmers had a drip irrigation system with two drippers/plant for irrigation and fertigation. Mainly air-layered plants were raised by nurserymen and sold to the growers for planting. All three season's crops viz. winter (January-February flowering), rainy (June-July flowering) and autumn (September-October flowering) are taken, but autumn and winter crops are most popular among growers. The single-stem training system is not common and the multi-stem training system with 2-4 stems is preferred by growers. Generally, 40-60 days stress is imposed by withholding water. Ethrel (1-3 ml/l), thiourea (5-20 g/l) or curacron (3-5 ml/l) are used to senesce leaves and induce flowering, while ethrel and curacron are commonly used by the farmers to senesce (defoliation) of leaves. Light pruning is done during the last part of the stress period and subsequently, manures and fertilizers are applied and then light irrigation is provided, which induces bud sprouting and flowering. The crop has a tendency to induce suckers from the stem at the ground level and their timely removal is essential to obtain better plant growth and fruiting. In general, the suckers arising from the stem are removed regularly (2-4 times a year). To facilitate better drainage, raised bed planting was observed to be a common practice in the Solapur district. Intercropping in pomegranate orchards with fruit tree or vegetables or field crop was rarely observed. However, in some pomegranate orchards, sapodilla (*Manil-*

kara achras), drumstick (*Moringa oleifera*), sweet orange (*Citrus sinensis*), ber (*Ziziphus mauritiana*), gram (*Cicer arietinum*), tomato (*Lycopersicon esculentum*), watermelon (*Citrullus lanatus*) were included as intercrops. Based on soil and plant analysis, it was observed that the soil was saline to alkaline in nature (7.35-8.8 pH) and low to medium in organic carbon (0.15-0.76 %). Calcium carbonate content in soil varied from 0.5 to 22.7%. Nitrogen and potassium in soil varied form 169-301 and 134-1024 kg/ha, respectively with a low to medium quantity of phosphorus. However, iron and zinc deficiencies were noted in some orchards. The establishment cost of orchards ranged from 0.045-0.1 million/ha and net income from 0.05-0.15 million/ha of 4-10-years old orchards. Bacterial blight (*Xanthomonas axonopodis pv. Punicae*) was a severe problem in Maharashtra, but wilt (*Ceratocystis fimbriata*), fungal leaf and fruit spot diseases (*Cercospora punicae*, *Colletotrichum gloeosporiodes*, *Botryodiplodia theobromae*, *Curvularia pallescens*, *Discosia punicae*, *Nigrospora oryzae*, *Pestalotiopsis versicolor*, *Sclerotium rolfsii* and *Alternaria alternate*) were also noted. Among insect pests, fruit borer (*Deudorix isocrates*), stem borer (*Euzophera* sp.) and thrips (*Rhipiphorothrips cruentatus*) were found to cause considerable crop loss (NRCP 2007a, 2008, 2009).

Karnataka is situated in between 11° 30' N and 18° 30' N latitudes and 74° E and 78° 30' E longitude on the Deccan Plateau and is bordered by the Arabian Sea to the west, Goa to the northwest, Maharashtra to the north, Andhra Pradesh to the east, Tamil Nadu to the east and southeast, and Kerala to the southwest (Sheth Hetu 2006). In Karnataka, an estimated area of about 13,000 ha is available under pomegranate (National Horticulture Board (www.nhb.gov.in)). However, Bagalkot, Bijapur, Koppal and Bellary are the main pomegranate-growing districts of Karnataka. The crop is grown in sub-marginal and dry areas in red, gray, black and stony land. About 42% of pomegranate orchards had red soils and 73% of orchards have a soil depth of more than 1 m. Land holding of the growers under pomegranate ranged between 0.33 and 24.4 ha but the majority (38%) of the growers had > 2 ha of orchards. Medium density (500-750 trees/ha) planting was more common and 54% growers maintained 500-750 trees/ha. 'Bhagawa' and 'Ganesh' were commercially grown with 80% area under 'Bhagawa'. More than 77% of growers adapted a flat bed planting system. The application of farmyard manure (5-50 kg/tree), *neem* cake, vermicompost with or without chemical fertilizers, particularly N, P and K in the form of solid or liquid fertilizers was used by the growers. However, the application of micronutrients was also a common practice. A drip irrigation system with two drippers/plant was used by 88% of growers. Mainly air-layered plants were used for planting. All three seasons viz. winter, rainy and autumn are common, but autumn season was followed by 62% of growers. As far as training is concerned, a multi-stem system with 2-5 stems was general practice. In general, 45-65 days stress was given for flower induction in each season. During the stress period, defoliation was a common practice to induce flowering using ethrel or thio-urea. Pruning was done after chemical defoliation during the stress period (NRCP 2008). The suckers arising from the ground were removed regularly (2-3 times a year). Papaya (*Carica papaya*), groundnut (*Arachis hypogaea*), sapodilla, mango (*Mangifera indica*), sweet orange, wheat (*Triticum aestivum*), vegetables, etc. were cultivated in some orchards. Crop residues or locally available materials were used for mulching by some of the growers. Although drip irrigation system was quite beneficial for water conservation in dry areas, but sometimes it caused deposition of salts on the upper surface of soil, particularly in very dry areas. Even nutrient deficiency was observed in some orchards. Fruit productivity ranged between 7.4 and 61 t/ha. More than 46.0% of growers obtained a yield between 10.0 and 20.0 t/ha. The establishment cost of the orchard varied from Rs. 0.025-0.11 million/ha but 50.0% of growers spent Rs 0.05-0.10 million/ha for establishment of the orchards. Net income was from Rs. 0.025-0.265 million/ha of 2-10-year old trees and the majority of growers (58%) earned a net income of Rs. 0.10-0.20 million/ha. Bacterial blight and wilt diseases were severe problems. However, stem borer (*Euzophera* sp.), fruit borer (*Deudorix isocrates*), thrips (*Rhipiphorothrips cruentatus*), aphid (*Aphis punicae*), white fly (*Siphoninus phillyreae*), sun scald (caused by exposure of fruits to high intensity of sunlight), shot hole borer (*Xyleborus fornicatus*) were also recorded causing economic loss to the growers.

The soil physico-chemical properties and leaf nutrient contents (macro and micro) are summarized next. Soil pH, EC, OC, $CaCO_3$, and available N, K, Fe, Cu, Mn and Zn ranged from 6.8-8.90, 0.13-1.41 dS/m, 0.37-1.93%, 0.13-10.24%, 83.9-335.6 kg/ha, 95.2-1741.6 kg/ha, 1.0-7.6 ppm, 0.6-15.0 ppm, 4.1-36.2 ppm and 0.3-14.0 ppm, respectively. In Bagalkot and Koppal districts, OC, K, Zn, Cu and Mn were optimum to high in the soil, while N and Fe were deficient in the majority of orchards. Most of the orchards in Bijapur showed optimum to high levels of OC, K, Cu and Mn but were deficient in N, Zn and Fe contents. In general, the surveyed orchards showed optimum levels of leaf N, P, K, Fe and Mn contents in Bagalkot and Koppal districts, but Cu was deficient in both districts. However, Zn content was optimum in Koppal and low in Bagalkot. In Bijapur, the leaf nutrient contents, particularly N, K, Fe, Mn and Zn, were optimum, while Cu and P were deficient (NRCP 2008).

POMEGRATAE RESEARCH AND DEVELOPMENT IN INDIA

Germplasm collection and conservation

Plant genetic resources are basic raw materials for improvement of any crop species. A wider genetic diversity is fundamental for the development of new variety with good quality and higher yield. At present over 70 cultivars, both from indigenous or exotic sources, are available in India. Wild pomegranate grows in western Himalayas (Jammu and Kashmir, Himachal Pradesh and Uttarakhand). Recently, diversity in wild pomegranate has also been reported from Himachal Pradesh by Singh and Singh (2006). High variability was found with respect to number of fruits per tree (215-769), fruit weight (54.28-85.12 g), number of arils per fruit (48-165.7), TSS (17.5-20.5 °Brix) and acidity (2.46-6.60%). Similarly, variability in plant height, leaf and fruit size, stem, rind and aril colour, number of thorns and their size, TSS, acidity, etc. has been noted in accessions collected from Uttarakhand (NRCP 2007a).

Although genetic base in pomegranate is low, but still variability is available in India in the seedlings, landraces, primitive cultivars etc. owing to cross pollination and their high adaptability in diverse situations ranging from the tropical to temperate climates (Jalikop and Kumar 1990). Earlier National Bureau of Plant Genetic Resources (NBPGR) made attempts to collect pomegranate wild germplasm from western Himalaya and exotic materials. These materials have been conserved in the field gene banks at their regional stations. Since the Central Institute of Arid Horticulture (CIAH) was looking after the pomegranate research in India till 2004, maximum number of accessions (190) was collected and maintained in its pomegranate repository. After the establishment of National Research Centre on Pomegranate (NRCP) in 2005, the entire responsibility of germplasm collection was entrusted to this centre. It has established a National Field Gene Bank of pomegranate in 2007 with 187 germplasm. Of which, 59 (31.56%) is exotic and 128 (68.44%) as indigenous collections consisting of 10 cultivars, 57 genetic materials and 61 wild types. At present, 7 Indian Agricultural Universities and 6 ICAR Institutes maintain germplasm of pomegranate in their repositories (**Table 4**).

Table 4 Status of germplasm of pomegranate in India.

Centres	Accessions / collections
Punjab Agricultural University, Punjab	19
Acharaya NG Ranga Agricultural University, Andhra Pradesh	29
Tamil Nadu Agricultural University,Tamil Nadu	24
Chandra Shekhar Azad University of Agriculture and Technology, Uttar Pradesh	9
Central Institute of Arid Horticulture, Rajasthan	190
Central Institute of Temperate Horticulture, Jammu and Kashmir	10
Indian Institute of Horticultural Research, Karnataka	20
Rajasthan Agricultural University, Rajasthan	9
Central Arid Zone Research Institute, Rajasthan	34
Mahatma Phule Krishi Vidyapeeth, Maharashtra	61
National Bureau of Plant Genetic Resources, New Delhi	170
Sardarkrishinagar Dantiwada Agricultural University, Gujarat	52
National Research Centre on Pomegranate, Maharashtra	187

Crop improvement

The pomegranate breeding work in India was first started at College of Agriculture, Pune in 1905. Seedlings from selected open pollinated fruits of 'Alandi' were raised at Pune in 1932 from which a promising type, GBG-1, was identified for cultivation in 1936. This was renamed as 'Ganesh' and released in 1954. This cultivar has pinkish sweet arils and soft seeds unlike the deep pink and sour aril and hard seeds in 'Alandi' (Keskar *et al.* 1993). This variety was very popular till the last decade of the 20th century. After release of cultivar 'Bhagawa' in 2003 by Mahatma Phule Krishi Vidyapeeth (MPKV), the major cultivated area of pomegranate was occupied by this cultivar and the area under 'Ganesh' reduced considerably in India. Ramu *et al.* (1996) reported a new seedless selection 'RCR-1' from 'Alandi' that recorded fruit yield of 58.7 kg/tree in the 10th year. Five promising clones viz. 'G-107', 'G-132', 'G-133'. 'G-134' and 'G-137' were identified from 'Ganesh' (Sawant 1973) and further evaluation of these promising selections was done by Keskar *et al*. (1990). They reported that 'G-137' was distinctly superior to 'Ganesh'. Work on seedling selection from the seedlings of 'Muskat' was initiated by Choudhury and Shirsath (1976) and over 47 high yielding individuals superior in fruit quality (soft seeded with high TSS) were identified for further studies. Later, a progeny of over 4000 seedlings were developed (Patil 1976; Bhapker 1976; Karale 1977; Kolhe 1980). Further, Naik (1975) surveyed the orchards originated from 'Muskat' and identified five better types viz. 'P-13', 'P-16', 'P-23', 'P-26' and 'SK-1' and finally, 'P-23' and 'P-26' were released for commercial cultivation in 1986 (Keskar *et al.* 1993).

Hybridization work was initiated in order to incorporate blood red colour of Russian types into 'Ganesh' and, thus, several crosses were made at MPKV in 1976. Out of 122 F_1 hybrids, seven had deep red aril colour but hard seeds with inferior taste than 'Ganesh' (Kale 1986). Back crossing with 'Ganesh' also did not result in improvement in fruit quality attributes. However, some desirable recombinants in F_2 progeny raised from open pollinated fruits and finally a few hybrids were identified (Keskar *et al.* 1989, 1993). A promising selection from the F_2 population combining all desirable fruit quality attributes had been released under the name 'Mridula' in 1994. In addition to MPKV, some other institutions in India also started crop improvement programme on pomegranate in the past and released promising cultivars (**Table 5**). From Tamil Nadu Agricultural University (TNAU), a soft seeded superior pomegranate cultivar 'CO-1' was selected from the assemblage of 28 genotypes (Khader *et al.* 1982). Further, clone 455 was found promising and subsequently, it was released as 'Yarcaud-1' in 1985 for cultivation in Tamil Nadu (Sayed *et al.* 1985). Earlier, 'Jyothi', a selection from the seedlings of 'Bassein Seedless' and 'Dholka' having soft seeds and pink aril was released by University of Agricultural Sciences (UAS), Karnataka in 1985. During 1984, Indian Institute of Horticultural Research (IIHR) started pomegranate breeding with the major emphasis on development of vigorous growing plants having attractive fruits, deep red, bold arils, soft, small seeds, sweet juice and resistance towards bacterial blight. More than 2900 hybrids of single, double, three way and other complex crosses including F_2's were evaluated (Prasanna Kumar 1998). They not only exhibited heterosis but combined such attributes like superior fruit quality of 'Ganesh' and 'Kabul', deep red colour of 'Gulsha Rose Pink' and vigour of 'Yarcaud'. Hybrid 15-9-94 had dark red, non-sticky arils and soft seeds with high sweetness and low tannin (Pareek 1996) and thus, released as 'Ruby' in 1997.

Table 5 Important varieties released during the past 50 years in India.

Variety name	Year of release	Breeding method	Institute/University*
Ganesh	1954	Clonal selection	MPKV
CO-1	1983	Clonal selection	TNAU
G-137	1984	Clonal selection	MPKV
Jyothi	1985	Clonal selection	UAS
Yercaud -1	1985	Clonal selection	TNAU
Mridula	1994	Cross	MPKV
Ruby	1997	Cross	IIHR
Amlidana	1999	Cross	IIHR
Phule Arakta	2003	Cross	MPKV
Bhagawa	2003	Clonal selection	MPKV

* Indian Institute of Horticultural Research (IIHR), Mhatma Phule Krishi Vidyapeeth (MPKV), Tamil Nadu Agricultural University (TNAU), University of Agricultural Sciences (UAS).

Besides a crossing programme, an attempt was also made to introduce deciduous varieties namely 'Sellimi', 'Roman', 'Chokab', 'Suffami', 'Wellingi', 'Ras-el-Baghi' from Baghdad, Palestine and other Mediterranean countries but they failed to establish in warm climate of India. Similarly, introductions like 'Gulsha Rose Pink', 'Shirin Anar', 'Gulsha Red' from erstwhile USSR showed poor performance owing to their deciduous habit. Later, some introductions like 'Gulsha Red Pink', 'Appuli', 'Gulsha Red', 'Lupania', 'Bedana Sedana', 'Kandhari' and 'Khog' were used in breeding programmes to induce dark red aril pigment in the popular cultivars (Keskar *et al.* 1993; Pareek and Sharma 1993). In recent years, some commercial cultivars including soft seeded dark red aril types viz. 'Wonderful' from the USA; 'Males', 'Be Hastah', 'Alah', 'Agha Mohammad Ali', 'Post Sephid', 'Sirin' from Iran and 'Rannyiz G-1-8-23', 'Rannyiz G-1-3-34', 'Cherenyj G-1-8-7' and few cultivars from Tunisia have been introduced and they show variability in their morphological and qualitative traits (Singh and Rana 1993).

At present, the main objectives in pomegranate breeding are aimed at to obtain types which produce small soft seeds with attractive reddish (pink) bold arils and fruit skin. Priority is given to a variety having thicker, sweet juicy aril and large number of seeds with an easily manageable upright growth having semi tall and dwarf habit of the tree. Thornlessness of the twigs is also a desirable character as it helps in cultural management of the tree. However, recently

emphasis is needed to develop bacterial blight resistant cultivars (Sharma *et al.* 2006). Besides, wilt is also an emerging problem for which resistant rootstocks and tolerant varieties are to be identified. Among the insect pests and physiological disorders, fruit borer (*Virachola isocrates*), fruit cracking, internal breakdown of arils and sun scald are also important problems to be solved. Sources of resistance to these problems need to be identified for further breeding programme.

Flowering behaviour, propagation, plant nutrition and biotic and abiotic stresses

In tropical climate, pomegranate flowers almost throughout the year and flower bud differentiation takes place at varied times, while in subtropics it flowers once a year. The tree is deciduous in areas having low winter temperature. But in tropical conditions, it is evergreen or partially deciduous. The time span between the start of the flower bud elongation and anthesis varies between 14 and 28 days depending on the variety and climatic conditions (Gur 1986; NRCP 2009). In subtropical climates of the northern India, flowering occurs from the last week of March till the second week of May (Singh *et al.* 1978). Interestingly, in subtropical central and western India, there are 3 distinct flowering seasons (winter, rainy and autumn). Winter season is most commonly preferred by the growers because of high yield as compared to other flowering seasons (Singh *et al.* 1967; Prasanna Kumar 1998). In different agro-climatic conditions the flowering habit differs considerably (Nath and Randhawa 1959c; Nalawadi *et al.* 1973; Josan *et al.* 1979; Parmar and Kaushal 1982). It has been described variously as self-pollinated, self and cross- pollinated, highly cross-pollinated or often cross-pollinated crop. The use of a gene marker, governing the pigmentation of bud flower and petiole base, confirmed the fact that pomegranate ('Ganesh' and 'Kabul Yellow') is self and in low proportion (13%) cross-pollinated crop (Jalikop and Sampath Kumar 1990). The trials conducted with several cultivars showed that fruit set was 79% and 43.3%, respectively for intact open and self pollinated flowers or 26.4 and 66.2% for the same after emasculation (Karale *et al.* 1993). The pomegranate flowers are short peduncled or sub-sessile and generally, three types of flowers, i.e. hermaphrodite and male flowers as well as intermediate forms are found on the same plant (Nath and Randhawa 1959b). As far as the fruit yield is concerned, the role of hermaphrodite flowers is supreme (Chaudhari and Desai 1993). However, the percentage of hermaphrodite flower on a pomegranate tree depends on the cultivar, the flowering season and environmental factors. In the beginning of the main flowering season, this percentage is higher than at the end of the season (Gur 1986). In several cultivars, 25-60% hermaphrodite flowers, 20-47% male flowers and 14-24% intermediate forms had been reported (Nath and Randhawa 1959a; Nalawadi *et al.* 1973; Singh *et al.* 1978). The fruit retention increased from about 30% during early flowering to about 80% during full bloom and/or late flowering (Hussein *et al.* 1994). The flowers produced 4-5 weeks after the onset of blooming gave the highest fruit set (90%) with the best fruit quality.

In cultivated pomegranate, seed germination is not a problem. In general, 60-75% seed germination has been observed in most of the cultivated varieties. The seedling population shows high degree of variability, consequently a number of seedling origin varieties were selected in India. But, for commercial cultivation vegetatively propagated materials are preferred and seedling plants are avoided. In main pomegranate growing areas, air layered saplings are used for planting (Hegde and Sulikeri 1989; Hore and Sen 1994). Recently, in some parts of India rooted hardwood, semi-hardwood and softwood stem cuttings are also utilized. Generally, quick dip and prolonged dip methods (Sandhu *et al.* 1991; Panwar *et al.* 2001) using plant growth regulators (Panda and Das 1990; Reddy and Reddy 1989, 1990) are practiced to induce rooting in stem cuttings of pomegranate. Length and diameter of the stem cuttings play vital role in its success and field survival. Several reports are available that its 20-30 cm long stem cuttings having 0.8-1.25 cm thickness give better cutting success (Reddy and Reddy 1989; Dhillon and Sharma 2002). Even root cuttings can also be used for its propagation (Mendilcioglu 1968). Recently, grafting has been found successful in pomegranate (NRCP 2008; Chandra *et al.* 2009) that may help popularization of single stem training system. Earlier attempts were made to standardize micro-propagation techniques in this crop but mass multiplication through this technique could not become popular in the world so far.

Pomegranate is highly tolerant to soil salinity (Patil and Waghmare 1983; Jain and Dass 1988; Rao and Khandelwal 2001; Ram Asrey *et al*. 2002), but balance nutrition is needed to young and bearing trees for better growth and sustainable production. It has been reported that to get 30 t fruit yield/ha in 'Ganesh', 33.6 kg N, 6 kg P, 52.2 kg K, 13.6 kg Ca, 2.0 kg Mg and 4.4 kg S, 55 g Fe, 28.5 g Mn, 78g Zn and 38.8 g Cu are removed (Raghupathi and Bhargava 1996). Thus, replenishment of nutrients in soil is of paramount importance. Raghupathi and Bhargava (1998) noted that yield of pomegranate was limited by 2 or 3 nutrients as it is mainly grown on marginal soils having low fertility. Like other fruit crops, leaf nutrient contents of pomegranate also found to vary with season, cultivar and the crop growth (Bacha 1975; Munde *et al*.1980; Bhargava and Dhandar 1987; Singh 1987; Yamdagni *et al*. 1988). They made attempts to standardize leaf sampling technique in pomegranate and advocated seven-month-old leaves for diagnosis of N, P, K, Ca and Mg, four-month-old leaves for Fe and Zn and 11-month-old leaves for Mn in 'Ganesh'. However, Bhargava and Dhandar (1987) suggested taking the 8th leaf pair from the growing tip for sampling. Integrated supply of organics (farmyard manure, oil cake, wood ash, etc.) and inorganics and/or with or without microbial inoculations found to be beneficial for non-bearing and bearing trees of pomegranate (Kulkarni 1920; Nagpal 1954; Roy 1955; Mishra 1969; Vachaspati and Chauhan 1973; Phadnis 1974; Chougule 1976; Singh 1976; Shende 1977; Pareek 1981; Nehra 1984; Singh *et al.* 1988; Padmavathamma and Hulamani 1998; Saraf *et al*. 2004). Even foliar application of nutrients found beneficial in improving growth, yield and fruit quality of pomegranate (Pathak and Pundhir 1981; Sen and Chauhan 1983; Singh 1987; Bambal *et al*. 1991; Balakrishnan *et al*. 1996; Balakrishnamoorthy 1999; Muthumanickam and Balakrishnamoorthy 1999; Khatri *et al*. 2001; Prasad and Mali 2003; Singh *et al*. 2003). However, information on pomegranate fertilization and fertigation (Firake and Kumbhar 2002) is limited in India.

To keep pace with growing export market, growers have adapted new improved varieties and hi-tech horticultural practices. Consequently, some of the diseases which were practically unknown or of little economic significance have become serious problem today. Among various fungal and bacterial diseases of pomegranate, bacterial blight and wilt are the two most important diseases in India. The blight of pomegranate was first reported in India from Delhi in 1952 by Hingorani and Mehta. Later it was reported from Bangalore (Karnataka) in 1959 by Hingorani and Singh. The causal organism of the blight is *Xanthomonas axonopodis pv. Punicae*, it is a serious threat to pomegranate industry in Karnataka and Maharashtra (Chand *et al*. 1991; Yenjerappa *et al*. 2004). The disease was not serious till 1991. It appeared in epidemic proportions in Banaglore (Chand *et al.* 1991) and caused 60-80% yield losses. The disease was effectively checked with Paushamycin (500 ppm) + copper-oxychloride (0.2%) applied 3 times at fortnightly intervals (Suriachandraselvan *et al.* 1993). Bacterinasak (500 ppm) and streptocycline (500 ppm) + copper oxychloride (2000 ppm) were also found effective (Ravikumar and Yenjerappa 2005).

Outbreak of wilt in recent years has staggered the pomegranate industry in India. Wilt incidence was 5.69% and causing monetary loss of about 34.3 million rupees (Soma-

sekhara *et al.* 2009). Wilt is reported to be a complex disease as many fungal pathogens viz. *Fusarium solani*, *Rhizoctonia solani*, *Ceratocystis fimbriata* and other pests like shot hole borer and nematodes were found associated with diseased plants. Besides, faulty soil and water management practices have also been reported to cause wilt disease. However, Somasekhara (1999) reported *C. fimbriata* to be the major cause of pomegranate wilt. Chavan and Dake (2001) reported occurrence of wilt due to *Fusarium oxysporum* in Maharashtra. The disease has been reported to be controlled by fungicidal sprays of propiconazole, mancozeb, ziram and chemicals like boric acid and phosphoric acid (Somasekhara and Wali 2000).

In addition to bacterial blight and wilt, there are some other diseases like leaf/ fruit spots and fruit rots, under specific conditions, may cause economic losses in pomegranate. Several leaf spot pathogens like *Fusarium fusariodes* (Sherkar and Utikar 1982), *Colletotrichum gloeosporiodes*, *Botryodiplodia theobromae*, *Curvularia pallescens*, *Discosia punicae*, *Nigrospora oryzae*, *Pestalotiopsis versicolor*, *Sclerotium rolfsii* and *Alternaria alternata* (Madhukar and Reddy 1989) have been reported in pomegranate. Among the fruit rot pathogens, *Glomerella cingulata* (Singh and Chohan 1972), *Alternaria tenuis*, *Aspergillus nidulans*, *A. clavatus*, *Rhizopus arrhizus*, *R. stolonifer*, *Rhizoctonia* sp., *Spicaria* sp., *Cephalosporium* sp., *Coniothyrium* sp. (Kanwar and Thakur 1972), *Alternaria solani* and *Drechslera rostrata* (Utikar and More 1976), *A. niger* (Phillip 1979), *Aspergillus variecolor*, *A. niveus* (Sharma *et al.* 1981), *A. niger*, *Penicillium frequentans*, *Rhizopus* sp. *A. alternata*, *Aspergillus flavus*, *A. fumigatus*, *G. cingulata*, *Phoma* sp. *P. punicae* and *Phomopsis* sp. (Sonawane *et al.* 1986) were associated to cause fruit rot. Several fungicides were tried against these pathogens and reported effective. However, the most effective was Benlate (Benomyl) against *A. alternata* followed by Dithane Z-78 (Zineb), Bavistin (Carbendazim) against *A. Niger*, Dithane M-45 (Mancozeb) against *C. gloeosporiodes*, Difoltan (Captafol) against *Cercospora lunata*, Cuoxinate against *Pestalotiopsis versicolor* (Utikar *et al.* 1986). Mahla *et al.* (1989) reported Macuprax (Cufraneb + Bordeaux mixture) most effective against leaf spot *Pseudocercospora granati* followed by Burcop (Bordeaux mixture). Even warm solution treatment with Tilt (Propiconazole) was found effective against *Alternaria* sp. (Jitendra *et al.* 2002). Raghuwanshi *et al.* (2005) reported satisfactory control of leaf and fruit spots with Carbendazim followed by Mancozeb and Bordeaux mixture.

Among the abiotic disorders, fruit cracking, sun scald/ sunburn and internal breakdown or blackening of arils are very common in pomegranate. Apart from biotic fruit cracking caused by bacterial blight, it is also associated with improper irrigation, environmental factors and boron deficiency. Deficiency of nutrients like calcium and potash also leads to fruit cracking in pomegranate. It is a serious problem in Rajasthan and some districts of Maharashtra. Pant (1976) and Sonawane *et al.* (1994) recorded fruit cracking to approx. 63% in the spring crop (January-June), 34% in the winter crop (October-March) and only 9.5% in the rainy season crop (July-December). However, micronutrients and growth regulators (Khatri *et al.* 2001) are also known to control fruit cracking. Some reports are available that application of boron at 0.2% (Singh *et al.* 2003) and pinolene (an anti transpirant) at 5% (Bacha and Ibrahim 1979) had reduced fruit cracking. Reduction in fruit cracking was also reported by Singh *et al.* (2003) following regular irrigation and use of mulch and micronutrients. In Deccan region, pomegranate fruits are damaged owing to high solar radiation. In case of sun scald, the fruit skin turns brown or bronze colour. Generally, the fruits facing sunlight are more affected during April to June by solar radiation (Sonawane *et al.* 1994). Usually, high temperature along with excessive light, drought, and low relative humidity are responsible for sun scald injuries. Another important problem of pomegranate fruit is internal breakdown in which apparently healthy looking fruits, when cut open, show light creamy brown to dark blackish brown arils. Such arils are unfit for consumption. Most of the Indian cultivars are prone to this malady. The incidence of the disorder develops 150 days after anthesis in 'G-137' and its intensity increases if the fruits are left on the tree up to 165 days (Khodade 1987). He found that TSS, acidity, ascorbic acid, total sugar, reducing sugars, calcium, phosphorus and the enzyme catalase were low whereas non-reducing sugar, starch, tannins, nitrogen, potassium, magnesium, boron, polyphenoloxidase and peroxidase enzymes were high in affected arils of 'Ganesh' and 'P-23' as compared to the healthy ones (Prabhu Desai 1989).

Research infrastructure and development

For promotion of pomegranate industry in India, Indian Council of Agricultural Research (ICAR) started work under ad-hoc Scheme entitled, "Research on some selected fruits of the arid and semi-arid areas in India" financed by the AP Cess fund of ICAR in 1976 at 10 centres. The scheme was merged during the Sixth Five Year Plan to form the Cell III of the All India Coordinated Fruit Improvement Project (AICFIP) in 1978. During the Seventh Five Year Plan, the Cell III of the AICFIP was restructured to form an independent project entitled, "All India Coordinated Research Project on Arid Zone Fruits" which was later strengthened during the VIII Plan. At present, the project has 12 centres located in different parts of the country. Out of 12 centres, three are located in Rajasthan, two in Gujarat and one each in Tamil Nadu, Karnataka, Andhra Pradesh, Punjab, Haryana, Uttar Pradesh and Maharashtra. Looking into its increasing demand for internal consumption and export, threat created by diseases and pests, ICAR felt necessary to create more infrastructural facilities for pomegranate research. This resulted in establishment of a full-fledged National Research Centre on Pomegranate in 2005 at Solapur in Maharashtra to solve the problems of pomegranate industry in India and also to act as a nodal agency. Recently, Indian government has taken initiative to develop collaborative programmes with Israel, Kenya, California, Kazakhstan, Cambodia and Surinam, especially for pomegranate germplasm exchange. However, crop production, soil and water management, plant protection, postharvest management and climate change are important areas for collaboration with international institutions working on pomegranate.

SWOT analysis

1. Strengths

- The crop is hardy by nature and adaptable to wider range of agro-climatic conditions viz. tropical, subtropical and temperate. Shallow, rocky, black, sandy soils, marginal and calcareous waste lands of arid and semi-arid regions, which are not suitable for many horticultural crops, can easily be utilized for pomegranate culture in India.
- The export potential of pomegranate in India has increased tremendously since beginning of the 21th century and occupied its important position among the main pomegranate exporting countries.
- In western Himalayas (Jammu and Kashmir, Himachal Pradesh and Uttarakhand), wild population of pomegranate exhibits wide range of genetic diversity, especially in sour types which can be exploited for various purposes (processing, medicinal, leather, dying industries, condiments, apiculture, etc.).
- It is expected that there may be high demand of processed products and its byproducts due to the renewed interest in its health promoting effects.

2. Weaknesses

- The disease and insect pest resistant varieties are not available at present.
- Adequate infrastructural facilities are yet to be deve-

loped for multiplication of elite planting materials.
- Early and synchronized flowering varieties are to be developed.
- There is shortage of low cost packaging materials.
- Adequate processing, marketing and export facilities are not available.

3. Opportunities

- There is high demand of pomegranate fruits harvested during November-February for export on premium price in Middle East and European countries.
- Exploitation of this fruit crop through out the year as per the local conditions and market demand is possible.
- The demand of fruit juice, concentrate, wine, jelly, jam etc. is increasing that can be promoted through product diversification and value addition.
- The vast organic resources available in the country can be exploited to produce organic pomegranate that has high demand in international market.
- Adequate infrastructure for Research and Development would be available within a short period.

4. Threats

- Diseases (bacterial blight and wilt) and insect pests (fruit borer, thrips and nematodes) are the major threats to pomegranate industry.
- Indiscriminate use of pesticides leading to pesticide residues in the fruits that may affect pomegranate export.
- The export competition from South East Asian countries is expected.
- The native pomegranate biodiversity available in Western Himalaya is eroding due to deforestation and area expansion for arable crops (NRCP 2007b).

Scope to promote pomegranate in non-traditional areas

India has vast land under its arid and semi-arid regions. Though in Maharashtra, Karnataka and Andhra Pradesh, rocky terrains are being utilized for cultivation of pomegranate but still marginal and sub marginal lands in these states are available which would be suitable for its area expansion with moderate soil and water conservation measures. Even there is scope to utilize saline water to promote pomegranate industry in the Deccan Plateau. Besides, dry areas of Madhya Pradesh, Gujarat, Rajasthan, Western Uttar Pradesh, Punjab, Haryana and Tamil Nadu have further scope for area expansion under pomegranate where traditionally its area is very limited. In all those areas where annual rainfall ranges between 25 and 60 cm and monthly average temperature does not exceed 40°C can be brought under its cultivation with assured irrigation facilities. In subtropical and subtemperate climatic conditions experiencing rainfall between 75 and 110 cm with moderate relative humidity can also be exploited with suitable varieties after rigorous testing. Though fruit quality in such areas my not be very desirable due to low temperature and high humidity but the fruits can be utilized for preparation of fruit juice, juice concentrate, wine, and *Anar-dana*. However, for sweet and sweet sour varieties, dry areas having high temperature during summer and moderate temperature during winter will certainly help in quality fruit production.

FUTURE CHALLENGES AND STRATEGIES

Assured market stability is most essential for the development of any crop based industry. Pomegranate is becoming export oriented crop for the last one decade in India and its area and production is increasing with a faster pace. The demand for internal consumption and export is a driving force for promotion of its cultivation in India. At present, major produce is consumed as fresh fruit and hardly 2% of it is processed (NRCP 2007b) and 3% is exported (0.035 million tonnes) that is very low as compared to other pomegranate growing countries like Spain, Israel, the USA, Iran and Tunisia.

To maintain and sustain the competitive edge and share in the world market under WTO regime, it is necessary to produce adequate quantity of food materials to meet the internal demand and also to promote export. Presently, the export demand is more from European and South East Asian countries. No doubt, South East Asian countries might be competitors in years to come and thus quality production having minimum pesticide residue level in fruits will get better demand and such produce will also pay premium price. This is also observed that the major production of the fruit is coming from the marginal and sub-marginal lands (degraded or low fertile waste lands). Therefore, such trend will check the land degradation and bring environmental protection in long run. Besides, it would generate rural employment and improve socio-economic condition of the farmers. Area expansion may be sought from non-traditional areas too that can cater the needs of local market and processing industries for product diversification and value addition. It may also be necessary to develop packaging technologies that should be cost effective to minimize the cost of production and promote mechanization (cultivation and processing). However, further demand in dye and tanning industries, and also for ornamental purposes is expected to a considerable extent in years to come. Therefore, for transforming these perspectives into reality, sound and economically viable technologies need to be developed following basic, strategic and applied research programmes to increase area from 0.125 million ha to 0. 75 million ha, production from 1.14 million tonnes to 11.40 million tonnes (Jadhav and Sharma 2007), export from 0.0352 million tonnes to 0.08380 million tonnes and export value from 911.9 million rupees to 1839.0 million rupees in next 15-20 years. The following main strategies are to be addressed to sustain pomegranate industry in India:

- Bringing more area under pomegranate cultivation particularly in arid and semi-arid regions and also in non-traditional areas with improved varieties.
- Attention on germplasm introduction, conservation, propagation for mass and fast multiplication, nutrition and soil water conservation is to be given.
- Developing varieties possessing high yield potential, better quality and resistance against major biotic (bacterial blight, wilt and fruit borer) and abiotic (fruit cracking, aril browning and sun scald) stresses.
- Special attention on canopy management, crop regulation, organic production techniques and farming system research is needed.
- Enhancing water and nutrient use efficiency through computer based irrigation and chemigation system.
- Exploitation of bio-agents for nutrition, propagation and plant protection.
- Watershed management following soil and water conservation measures should be the priority.
- There is utmost need to reduce post-harvest losses by developing appropriate post-harvest technologies.
- Food safety, pesticide residue management and IPM need immediate attention.
- Emphasis is also required to create marketing, export and storage facilities.

CONCLUDING REMARKS

Earlier, the crop was considered as minor fruit in India, but now it has occupied first position in area and production at global level (Jadhav and Sharma 2007). The Deccan Plateau consisting of Maharashtra, Karnataka and Andhra Pradesh is most suitable for culture of good quality pomegranate due to its unique geographical situation and environmental conditions. However, recently bacterial blight and wilt have become major threats to pomegranate industry in India causing enormous loss (NRCP 2008, 2009) and has created

panic among the growers. Out of 10 released varieties, 'Bhagawa' is most common and thus there is a need for diversification of varieties to sustain the production of pomegranate. In last 50 years research outputs on pomegranate is meager in India. However, there is a need for promotion of its cultivation in traditional and non traditional areas to make the country competitive in the global markets, especially for export.

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