



Review Article

Quality Evaluation of Pomegranate Crop – A review

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ABSTRACT

Generally pomegranate is not similar to other fruit crops of temperate, tropical or subtropical fruits except that it behaves as deciduous in temperate but in tropical and subtropical regions it behaves as an evergreen or partially deciduous. Most of the trees are 5-6 branched per tree and the air temperature is one of the main causes of fruit cracking. The hermaphrodite flowers in different cultivars ranged from 19.67 to 49%. The chemical characters particularly total soluble solids, total sugars, ascorbic acid and anthocyanin contents play a major role in crop due to their essentiality in fruit quality and postharvest life of harvested produce. Besides affecting plant growth, the micro-nutrients play main role in disease and cracked incidence in cultivated crop species. Anar-butterfly and cracking incidence are the major limiting factors in cultivation and are mostly prevalent throughout the world. Foliar application of some micronutrients particularly Mn, Zn and B has received greater attention in the studies involving the use of inorganic fertilizer application. There is an evidence to indicate that number of exotic as well as indigenous cultivars give better yield and are economical as compared to other fruit crops. The predominant sugars present in pomegranate were fructose particularly glucose, sucrose and maltose contents were almost negligible. Novel approaches include use of superior cultivars having resistance to fruit cracking and anar-butterfly and genetic improvement regarding the traits. In view of the importance of different cultivars in today's world, it is felt that evaluation of horticultural crops particularly pomegranate crop will play a definite and major role in addressing the economy of the nations in coming years mostly in under developed countries. © 2012 Friends Science Publishers

Key Words: Evaluation; Cultivation; Pomegranate; Nutrient application; Fruit quality

INTRODUCTION

Pomegranate (*Punica granatum* L.) is a well-known table fruit of tropical and subtropical regions of the world. The Romans received it from Carthage, hence the name of the genus *Punica*. Some botanists place it in the family Lythraceae, of the peculiar type of fruit, called as balausta, most authorities make it the only genus in the family Punicaceae. It belongs to genera *Punica* and family Punicaceae (Chatterjee & Randhawa, 1952; Joshi, 1956). It is a genus of large shrubs or small trees with 2 species. One is *P. protopunica* Balf. S. found wild on Socotra island and the other is *P. granatum* cultivated in tropical and subtropical parts of the world for its edible fruits. The species has been classified into two sub-species *chlorocarpa* and *porphyrocarpa*, each having two varieties. These sub-species have been established on the basis of the colour of the ovary, a stable feature, which is retained even when they are reproduced by seeds. Sub-species *chlorocarpa* is mainly found in the Transcaucasus, whereas, the second sub-species *porphyrocarpa* is mainly Central Asian in distribution. Another species of pomegranate *P.nana* L. (dwarf pomegranate) is double flowered in habit and on the Pacific coast it is grown as a hedge plant (Shukla *et al.*, 2004).

According to De Candolle (1967), pomegranate is an ancient fruit originated in South-west Asia, probably in Iran and some adjoining countries. According to Smith (1979), *P. granatum* has $2n = 16$ and 18 chromosomes. The number of chromosomes in somatic complements of Dholka, Ganesh, Kandhari, Muscat White and Patiala varieties was found to be $2n = 16$, while the variety Double flowered had $2n = 18$ (Nath and Randhawa, 1959a). The chromosome number in Vellodu and Kashmiri varieties was found to be $2n = 18$ with 1 or 2 quadrivalent associations at meiosis (Raman *et al.*, 1963). Two ornamental types (Japanese Dwarf and Double flower giving red, yellow and white flowers) are planted in ornamental gardens (Nath & Randhawa, 1959d).

Pomegranate can be grown from plains to an elevation of 2000 m amsl. Under temperate climate, pomegranate behaves as deciduous but in sub-tropical and tropical climate it behaves as an evergreen or partially deciduous. It thrives best under hot dry summer and cold winter provided irrigation facilities are available. There are three main seasons of flowering known as *Ambe bahar*, *Mrig bahar* and *Hasta bahar*. To maintain productivity of the plants, generally one bahar fruiting is regulated, which depends upon market factors and availability of water.

There are three types of flowers present on same plant of pomegranate i.e., *male*, *hermaphrodite* and *intermediate*. Ovary of male flower is rudimentary whereas that of intermediate flowers are degenerating type. If fruit set takes place in such flowers they may drop before reaching to maturity, even if some fruits reach maturity those become mis-shaped. The time of dehiscence of anther varies in different cultivars and no general sequence was found at the time of anthesis (Nath & Randhawa, 1959b; Josan *et al.*, 1979a).

Both self and cross pollinations are reported in pomegranate. The greater percentage of fruit set was observed by hand pollination and pollination under natural conditions i.e., open pollination (Nath & Randhawa, 1959c). According to Singh (1977) pomegranate is often cross-pollinated crop whereas Nalawadi *et al.* (1973) reported it as cross pollinated crop.

Flowers, fruits and seeds of the pomegranate are of various shades. The floral parts are hard and remain as a stiff crown on the fruit until ripe. The seeds are the edible parts of the fruit and contain a large amount of sap which is usually red (Winton & Winton, 1935; Coombe, 1976). The red color of the peel and juice is due to the presence of anthocyanins (Nerd, 1965; Harborne, 1967). Citric and malic acids have been identified as the major acids in the fruits (Nerd, 1965; Ulrich, 1970). The juice has a sugar content of 12-16%, consisting mainly of glucose and fructose (Nerd, 1965; Whiting, 1970).

Even though a native fruit of Iran, it is extensively cultivated in Spain, Morocco, Egypt, Afghanistan and Baluchistan. The cultivation has also been initiated on small scale in countries like USA (California & Florida), Mexico, Palestine, Israel, China, Japan, Burma, the USSR, Pakistan and many parts of India (Singh, 2000). In India, it is found from Kashmir to Kanyakumari, but is cultivated commercially only in Maharashtra. Small scale plantations are also seen in Gujrat, Rajasthan, Karnataka, Tamil Nadu, Andhra Pradesh, Uttar Pradesh, Punjab and Haryana. In India, it is considered as a crop of the arid and semi-arid regions because it withstands different soil and climatic stresses (Kaulgud, 2001).

The mid zone of Jammu division of J and K State is rich enough in wild pomegranate plantation and millions of wild trees exist on Dhar-Udhampur road, part of Reasi tehsil, on both sides of Batote Doda road and on the national high way right from Udhampur to Ramban. The seeds along with the fleshy portions are dried and commercially marketed as *Anardana* and widely used as condiment. The main assembling centre for *Anardana* is Udhampur from where distribution is done all over the country (Shant & Sapru, 1993). In Kashmir valley, the fruit was grown in downtown area of Srinagar on large scale during fifties of 20th century but the plantation was of local genotype which succumbed to anar-butterfly (*Virachola isocrates*) attack and secondly due to population explosion, the areas were used for residential houses and commercial establishments.

However, there is still sporadic plantation in Lal Bazar, Nowshehra, Anarbagh, Soura and other areas of the Valley.

Pomegranate is a favorite table fruit. The juice is valued for its medicinal properties mainly for leprosy patients. Juice is also used as cooling ingredient refrigerant of mixtures and some medicines for dyspepsia. The bark and rind of the fruits and seeds are used as astringent in cases of diarrhoea and dysentery. In peninsular India, a kind of wine is prepared from pomegranate juice which is considered superior to grape vine. The sweet types of pomegranate are said to be mildly laxative, while the less sweet types are believed to be good in inflammation of stomach and in heart pain. The powdered flower buds are used in bronchitis. The seeds are considered to be stomachic and the pulp cardiac and stomachic (Anonymous, 1998).

For effective utilization, the evaluation of genotypes for biotic and abiotic stresses and value addition are the areas of concern. Now-a-days orchardists focus on hybrids as it is a craze towards maximization of production by growing hybrids at the cost of original taste and quality for which consumers are vying. So, the original taste and quality is vanishing day by day. Besides, aspects like anar-butterfly incidence and cracking are the limiting factors in pomegranate cultivation and are prevalent throughout the country. The control of pest by chemical means provides partial solution. Therefore, obvious choice is to maintain a natural balance for growing best variety with desired characters. Therefore, this review article is about the advances made in the evaluation studies in pomegranate.

Nutrition in pomegranate production: Even though pomegranate grows well in low fertility soils, production can be increased by application of manures and fertilizers. Plant height, number of leaves, stem diameter, plant spread, leaf area, plant mortality, leaf chlorophyll and leaf and root N, P, K, Ca, Mg, Na, Zn, Fe, Mn and Cu contents were determined over 19 months in plants growing in pots and in soil with ESP of 1.6 to 50. All indices studied decreased with increasing soil ESP except for plant mortality and leaf and root Na contents, which increased, however, Cu level was unaffected (Patil & Patil, 1982). Bambal *et al.* (1991) studied the effect of foliar application of some micronutrients such as Fe, B, Mn and Zn. The Mn and Zn increased yield of the plant, whereas B reduced the percentage of cracked fruits. The micronutrients when sprayed in combinations were found promising and the highest number of fruits was obtained in Fe + Zn combination (Table I). Chattopadhyay and Patra (1992) made comparison between different mulches and found that soil around pomegranate plants was covered in October with black polyethylene, banana trash or saw dust. Plants with no soil cover acted as control. Black polyethylene resulted in the greatest plant growth, early flowering, fruiting and highest yield (164.8 q ha⁻¹).

Balamohan *et al.* (2001) conducted an experiment with four pomegranate cultivars to study their early vigor in the sodic soils of Tamil Nadu and found that Zn, K and P

contents were highest in Mridula. YCD 1 had the highest N, Fe and Cu contents. Saraf *et al.* (2001) studied fourteen treatments of different nutrient sources alone or in combination spaced at 4×4 m distance. The results revealed that maximum plant height (194.53 cm) was obtained under the treatment poultry manure at 5 kg plant⁻¹ followed by FYM at 10 kg plant⁻¹ (180.00 cm), bone meal 1 kg + N:P:K plant⁻¹ (178.48 g), and FYM 10 kg + N: P: K plant⁻¹. On the basis of the experimental findings it was concluded that application of 10 kg FYM plant⁻¹ alone or in combination with N:P:K, poultry manure 5 kg plant⁻¹ and bone meal 1 kg with N:P:K are the effective treatments to boost up the all growth of pomegranate plants.

The quality of irrigation water is deteriorating due to increasing use of chemical fertilizers. Idate *et al.* (2001) observed that cv. Mridula in medium black soils under drip irrigation system, showed an increasing trend in the yield from 50 to 75% RRF (recommended rate of fertilizers). The results further indicated that the application of 75% RRF with 20% wetted area recorded the maximum yield (19.35 kg plant⁻¹) without affecting fruit quality. Hence, application of 75% RRF through fertigation has been recommended for cv Mridula along with irrigation level at 20% wetted area.

Plant and Fruit Characteristics

Vegetative attributes: Pomegranate plants can be trained on single stem or in multi-stem system. Generally pomegranate plants do not require pruning except removal of ground suckers. Takhmazov and Aliev (1975) studied four pomegranate cultivars trained with 1, 2, 4, 6, 8, or 10 branches. The most economic were the 6 branches per tree owing to high yields and ease of picking. The most productive cv. was Gyuleisha Rozovaya (85 centners/ha) followed by VIR (80.8), Shakh-Nar (75) and Ulucheshennyi Kazake (72.7). Pawar *et al.* (1994) reported the effect of pruning on growth and yield of pomegranate trees. Shoot length and number of leaves per shoot increased with pruning intensity but delayed the bud sprouting, flower appearance and harvesting. The highest yield was obtained from unpruned trees, although the number and percentage of better grade fruits increased with the severity of pruning. Some workers carried an experiment on a black soil and pruned the pomegranate crop to a single stem, or 2, 3 or 4 stems from ground level (Balasubramanyan *et al.*, 1997). Manivannan and Rengasamy (1999) made eight crosses of 6 varieties and evaluated for plant height, number of branches, plant spread and production of hermaphrodite flowers and found five hybrids with superior fruit yield.

Balamohan *et al.* (2001) studied on biometrical characters of pomegranate and revealed that although YCD 1 was the tallest plant, Mridula performed best based on the highest number of branches per plant crop canopy coverage. Thirty evergreen cultivars of pomegranates in Punjab were studied and observed maximum girth and height in Ganesh, PS-77 and Moga-Local and minimum in Basse-in-Seedless (Sharma & Dhillon, 2002). Mir *et al.* (2007a & c) showed significant variations on all the growth and yield parameters

due to various cultivars. The highest plant height and spread was recorded in cv. Kabuli kandhari, whereas maximum number of suckers was recorded in cv. Jyoti. Recently number of pomegranate cultivars have been studied in temperate region and found high range of variability for plant height and spread (Mir *et al.*, 2010a).

Floral attributes: Flowering in pomegranate depends on the conditions of the place where it is grown so also the fruiting season. The pomegranate plants flower and provide fruits through out the year in Central and Southern India. However, it needs to be thrown into rest period so as to enable prolific harvest at a given time. Flowering in three varieties of pomegranate were studied during June, October and March. The stigmas were receptive in Dholka one day before anthesis and were most receptive on the day of anthesis and remained receptive for three days overall. The studies showed that pomegranate is highly cross-pollinated crop. Male, intermediate and hermaphrodite flowers were observed and the sex ratios in this order were 20:24:50% in cv. GBI, 47.27:14.54:38.18% in Dholka and 20:20:60% in cv. Local (Nalawadi *et al.*, 1973).

Singh *et al.* (1978) observed that three pomegranate cultivars showed similar flowering behavior. The inflorescence developed from mixed buds situated terminally on the previous season's growth as well as on old-spurs. The highest percentage of hermaphrodite flowers was in Anar Shirin-e-Mohamad Ali (49%), followed by Anar Post-e-Shifid Shirin (39%) and Anar Alak (19.67%). Josan *et al.* (1979b) reported that after open pollination in 21 pomegranate cvs, fruit set was highest in the cv. Dholka (63.81%), Bedana (63.03%) and Kali Shirin (62.74%). After self-pollination, fruit set was appreciably lower. Six varieties of pomegranate were also studied and found that most flowers were open from 10.00 to 12.00 h except in Surkh Anar, which showed maximum anthesis from 12.00 to 14.00 h. Cultivar Kazkai had the largest pollen grains and the highest pollen fertility (88%). The maximum pollen germination (73.5%) was observed in 12.5 per cent sucrose solution. Stigmas of cv. Kali Shirin were receptive one day before anthesis until two days after anthesis (Singh *et al.*, 1980), Shulman *et al.* (1984) observed fruit development under continental (Bet Shean Valley) and moderate maritime (Coastal Plain) conditions and reported that fertile flowers were vase shaped and developed into fruits whereas, bell-shaped flowers with few egg cells were sterile and did not produce fruits.

Floral organogenesis was studied in the single flowered cv. Gyuleisha Rozovaya and the double-flowered forms viz. fertile red, fertile cream coloured, infertile pink variegated and infertile red. In the fertile double flowered forms flowers were observed on the same plant with (1) marked doubling and staminoid and deformed carpels without ovules, (2) sterile anthers or pollen and undeveloped ovules, often with normal styles, (3) fertile pollen and undeveloped ovules, or vice-versa and (4) fertile pollen and developed ovules. In infertile forms, flowers were

encountered with multiple petals and various pistil abnormalities but fewer with undeveloped reproductive organs (Iskenderova, 1988). Derin and Etis (2001) studied pollen viability levels, pollen germination level and pollen production capacity in both male and bisexual flowers of pomegranate cultivars Hicaz and 33 N 26. The studies showed that the highest pollen viability and germination rate were obtained from male flowers of Hicaz. The rates of fruit set in self and open pollination were lower than those of cross pollination.

Flower buds of some varieties were removed manually on and after 7, 15 and 22 April in pomegranate cultivar Ganesh-1 and 15, 22 and 30 April in cv Kandhari. Control trees were left to flower continuously. The periodic increase in fruit growth (length, diameter & volume) was higher in treatments where deblossoming was resorted to on an early date than in the control. Tree scoring at the time of fruit maturity and marketable fruits at harvesting were highest in early deblossoming dates than the late deblossoming dates in both cultivars (Sharma & Singh, 2002). For different cultivars, Sharma and Dhillon (2002) observed that Ganesh and PS-77 were the earliest to flower, while cv Panipat was the last and also Ganesh had the heaviest grains among the cultivars. Dhillon and Kumar (2004a & b) evaluated the cultivars of pomegranate and observed that fruits of Kandhari, Nabha and Ganesh took 140 days after anthesis to attain harvest maturity. Minimum days taken to first flowering were observed in cv. Local check followed by Chawla from reference date. Maximum duration of flowering and days taken from first flower opening to fruitlet development was recorded in cv. Jyoti among the cultivars under study (Mir *et al.*, 2007a, 2007c & 2010b).

Physical attributes of fruit: The fruit is a very important character for any fruit crop and in pomegranate it is nearly round and crowned at the base by the prominent calyx. The tough leathery skin or rind is typically yellow overlaid with light or deep pink or rich red. The interior is separated by membranous wall and white spongy, bitter tissue into components packed with sacs filled with sweetly acid, juicy, red, pink or whitish pulp or aril. According to Josan *et al.* (1979b) on 8th August, the cvs Kazkai, Shirin Anar and Achikdana had the largest fruits (6.5, 6.32 & 6.26 cm in diameter, respectively). Fruit cracking was lowest in the cv. Kazkai, Guleshah and Bedana. Malhotra *et al.* (1983a) studied the physical characteristics of different pomegranate cultivars. The seeds of all the cultivars attained various shades of pink or rose colour. The fruit form, in general, was either round or globose. Significant variations in the fruit weight, fruit size and seed number were recorded.

Some high quality fruits were produced between 14 April and 14 May in the *Punica granatum* varieties Manfalouty and Nab- El-Gamal and between 4 April and first week of May in Arabi. Fruit set after the end of May in Manfalouty and Nab- El-Gamal and after the first week of June in Arabi, produced immature, unsalable fruit. Fruit

weight of both cvs. were higher than Arabi, but Arabi had superior seed percentage (El-Sese, 1988).

Godara *et al.* (1989) reported that ten cultivars were assessed over 3 years for fruit physical and chemical indices. The results revealed that Chawla and Nabha were the best dessert cultivars, having large size fruit, soft to medium hard seeds among the cultivars. Two soft-seeded Bassein, seedless and Ganesh, and one hard seeded cultivar Alandi were studied. Fresh weight of fruits of all the 3 cultivars increased continuously from fruit set to harvest time and a growth pattern followed a simple sigmoid curve upto 20 days after fruit set, the rind weight was greater than the seed weight from 20 to 40 days and from 40 days onwards seed weight was greater than rind weight. The dry matter content of fruits of all cultivars increased up-to 50 days and gradually decreased towards maturity due to juice formation (Kumar & Purohit, 1989). The edible parts of pomegranate fruit represented 52% of the total weight, comprising 78% juice and 22% seeds as reported by El-Nemr *et al.* (1990).

Khodade *et al.* (1990) studied the seedling selections of P-23 during the early, middle and late stages of fruit development. Fruit size, weight and volume increased whereas, the specific gravity decreased gradually throughout fruit development. Chattopadhyay and Patra (1993) reported that effect of mulches (black polyethylene, saw dust & banana trash) on yield and quality of pomegranate. Black polyethylene resulted in highest fruit weight (171 g), largest fruit size (7.34 cm long, 7.47 cm in diameter), highest specific gravity, seed number (489 fruit⁻¹) and aril weight (102 g).

Bist *et al.* (1994) studied morphology and fruit characteristics of wild genotypes and found average fruit weight of 82.68 g fruit⁻¹ but rind thickness was thicker than in commercial cultivars (4.25 mm). Pawar *et al.* (1994) reported rind and aril colour and seed hardness were not influenced by pruning treatments. However, research on fruit bagging using colored polyethylene bags, the highest average fruit weight was recorded with green bags (338.8 g) and fruit diameter with red bags (8.31 cm). Bagging did not influence fruit physical and chemical parameters. Pink fruit colour was obtained with transparent bags and with no bagging (exposed fruits). However, fruits under colored bags were light green in colour (Padmavathamma & Hulamani, 1996). Balasubramanyan *et al.* (1997) reported that fruit yield in terms of number and weight was greatest when 4 stems were left. This treatment also produced the greatest canopy spread, largest fruits and highest juice and TSS content.

Jalikop and Kumar (1998) studied 18 genotypes representing soft, semi-soft and hard-seeded pomegranate (*Punica granatum* L.) for 11 fruit attributes. Significant variations were observed within soft types for 100 aril weight, within semi-soft varieties for 100 aril weight, seed mellowness and aril weight 100⁻¹ g of fruit and within hard-seeded entries for rind thickness and aril weight 100⁻¹ g of

fruit. Others reported that fruit growth and development in pomegranate to ascertain the proper stage of maturity under sub-tropical conditions. The size and weight of the fruit increased up-to 150 days after anthesis to maturity. The initial elongated oval shape of the immature fruit changed to round at harvest maturity. Texture of the fruit remained smooth during the period of growth. Fruit color changed from light green to deep red in Kandhari and from light green to yellow green with light red tinge in Nabha and Ganesh at maturity (Dhillon & Kumar, 2004a). Ten pomegranate (*Punica granatum* L.) cultivars namely Kubuli Kandhari, Chawla, Ganesh, Mridula, Jyoti, G-137, Dholka, Bedana, Kandhari and Local check were evaluated for different physical and chemical characteristics of fruit. Fruit weight, diameter and volume was significantly more in cv. Bedana compared to rest of the cultivars under study (Mir *et al.*, 2007a-c).

Celik and Erasl (2009) studied physical characteristics of pomegranate cv. 'Eksinar' and found that fruit mass and volume were between 154.4 to 289.5 g and from 150.9 to 295.8 cm³ respectively. Fruit dimensions varied from 52.9 to 75.00 mm for length, 60.6 to 85.9 mm for width and 63.4 to 81.4 mm for thickness. Arils dimensions varied from 8.4 to 11.4 mm for aril length, 5.3 to 8.8 mm for aril width and 3.9 to 6.3 mm for aril thickness. Number of arils/fruit varied from 368 to 618, whereas aril ratio ranged between 51 to 70%. Varasteh *et al.* (2009) evaluated important fruit characteristics of five commercial pomegranate cultivars in Iran and reported that 'Malas-e-yazdi' had the highest fruit weight, volume, length, diameter, aril percentage and juice content (699.94 g, 715.60 cm³, 103.55 mm, 109.50 mm, 73.88 & 58.31%, respectively). Whereas, Malase-Torsh-e-Saveh had minimum fruit weight, volume, length and diameter (408.32 g, 419.40 cm³, 83.60 mm & 91.76 mm respectively). Physical and chemical properties of 12 pomegranate cultivars indicated that maximum fruit weight was produced by cv Khazar-e-Bardaskan (505 g) and minimum by cv Lamsari-e-Behsaar (103.38 g). Fruit volume ranged from 99.41 to 547.88 cm² (Lamsari-e-Behshahr & Khazar-e-Bardeshan respectively) and fruit density ranged from 0.91 to 1.04 g cm⁻³ (Tabrizi & Lamsarie-e-Behshahr, respectively). Significant variations were observed in fruit aril per cent and aril thickness (Akbarpour *et al.*, 2009). Mir *et al.* (2010 a & b) observed high range of variability in pomegranate for fruit weight, fruit volume, number of seeds, fruit colour and general appearance among the cultivars under study.

Chemical attributes of fruit: Pomegranate is considered as highly nutritious fruit (Table II). The edible parts of fruit contain considerable amount of proteins, carbohydrates, minerals, sugars, vitamins, polysaccharides and polyphenols. The fruit is mainly used for dessert purpose. The fresh fruit is of exquisite quality while its processed products like bottled juice, syrups, jams and jelly are highly appreciated. Because of huge market demand, it has become very important to characterize the different varieties and

clones to obtain a highly quality product with commercial interest. Shaybanay and Sharifi (1973) applied 0-2000 ppm ethephon to Rabbab pomegranate trees 18 days before harvest. With increased ethephon concentrations the percentage TSS, pH, vitamin C content and TSS/ acid ratio of the juice decreased appreciably as leaf abscission, fruit drop and percentage juice acid increased. They concluded that ethephon applications delayed ripening, and fruit drop was a direct effect of ethephon rather than of ripening. Another trial was carried out on 16 cultivars of pomegranate and found that most intensively coloured juice (containing 600-765 mg 100⁻¹ g anthocyanin) was noticed in cv Wonderful, Gyuleisha Krasnaya, Gyuleisha Kzyl-Atrekskaya, Shaartuzskii and Seyanets (seedling). The cultivars Bumazhnji and Sevil-skii had pale juice (about 200 mg 100 g⁻¹ anthocyanin). The anthocyanins of intensively coloured juice comprised of cyanidin, 3-glucoside, cyanidin 3,5-diglucoside, delphinidin 3-glucoside and delphinidin 3,5-diglucoside (Kariventsov & Arendt, 1981).

Chemically fruits of three pomegranate cultivars were good source of carbohydrates, minerals (Ca, Fe & S) and a moderate source of pectin. The cultivar Chawla was superior in its nutritive value to Akanar and Nabla (Sood *et al.*, 1982). Malhotra *et al.* (1983b) observed high juice content (62.5%) in various cultivars. Similarly, TSS, sugars (reducing & non-reducing), acids and vitamin C in the seed juice and total phenolics as tannins in the fruit skin revealed great inter-varietal differences. In general, all the cultivars were found to contain high fraction of reducing sugars as part of total sugars. The fruit skin was quite rich in tannins ranging from 47 to 68% in different cultivars (Malhotra *et al.*, 1983 b). Among the different cultivars, cv. Srinagar Special gave the highest ascorbic acid and sugar content (Misra *et al.*, 1983).

Shulman *et al.* (1984) studied the growth curve of fruits from both climatic regions and showed a single sigmoid curve. Juice, TSS and anthocyanin content increased continuously during maturation while acidity decreased. Fruits of cv. Mule's Head ripened early and had a low acid content, whereas fruits of the late ripening cv. Wonderful had high content of juice, TSS, acidity and anthocyanin content, and therefore, was suitable for processing. In the hot Bet Shean Valley, fruits matured more rapidly than in the coastal plain but acidity and anthocyanin contents were low. Among others Chawla and Nabha were the best dessert quality having higher TSS and average value of percentage juice and acidity. The cv Dholka was the best for processing (Godara *et al.*, 1989). Kumar and Purohit (1989) studied two soft seeded (Bassein Seedless & Ganesh) and one hard seeded cultivar Alandi and observed that juice and TSS increased but acidity decreased during fruit development.

Dhillon and Kumar (2004b) reported that during fruit development stages fruit volume, aril weight, juice percentage and organoleptic rating increased, while per cent rind weight decreased with advancement of maturity in

Table I: Chemical characteristics of pomegranate as influenced by various foliar micro-nutrients sprays

Treatment	Average fruit weight (g)	Average volume of fruit (ml)	Percentage of grain	Percentage of peel	No. of grains in 100 g	Percentage of juice	TSS (°Brix)	Acidity (%)	Color of fruit	Aril color
Control	313.89	296.22	58.36	41.64	318.89	69.33	13.44	0.34	Yellowish green	Light pink
Fe	328.33	322.44	62.82	35.85	310.57	72.77	14.73	0.32	Greenish yellow	Light pink
B	381.11	365.55	63.12	36.88	316.56	71.72	13.63	0.31	Red	Dark pink
Fe+B	368.88	359.77	64.18	35.80	309.78	72.33	14.61	0.32	Reddish yellow	Dark pink
Mn	400.77	376.88	64.54	35.46	321.11	78.00	13.85	0.34	Greenish yellow	Light pink
Fe+Mn	315.53	311.11	66.17	33.83	350.11	73.22	14.39	0.34	Greenish yellow	Light pink
B+Mn	325.00	317.22	66.71	33.89	309.57	76.89	14.82	0.34	Reddish yellow	Dark pink
Fe+B+Mn	361.11	344.00	67.40	32.60	312.57	77.78	14.12	0.34	Reddish yellow	Pink
Zn	338.33	325.00	66.85	33.15	341.44	76.78	14.02	0.32	Greenish yellow	Pink
Fe+Zn	344.55	333.33	68.31	31.69	314.78	70.56	14.41	0.33	Greenish yellow	Pink
B+Zn	367.77	355.00	64.21	35.79	317.56	72.77	14.12	0.34	Red	Dark pink
Fe+B+Zn	350.52	329.66	68.26	31.74	320.00	72.73	14.06	0.33	Red	Dark pink
Mn+Zn	368.55	352.78	67.32	32.68	309.78	73.00	13.94	0.36	Greenish yellow	Pink
Fe+Mn+Zn	333.00	306.22	67.83	32.16	318.67	76.89	14.02	0.34	Greenish yellow	Pink
B+Mn+Zn	333.33	328.33	67.36	32.64	312.56	73.33	13.87	0.34	Reddish yellow	Pink
Fe+B+Mn+Zn	379.44	362.33	63.73	36.27	312.00	79.67	13.73	0.34	yellow	
S.E.	12.52	10.63	1.29	1.28		8.22	2.64	0.28	0.01	
CD at 5%	36.16	30.70	3.75	3.72	N.S	N.S	N.S	N.S		

Details of treatment:

Iron as FeSO₄ at 0.4%; Boron as Boric acid 0.2%; Manganese as MnSO₄ at 0.3%; Zinc as ZnSO₄ at 0.3%

Source: Bambal et al (1991)

Table II: Mean performance of pomegranate cultivars for various chemical characters under temperate climatic conditions

Cultivar	TSS	Total sugars	Acidity	TSS/acid ratio	Ascorbic acid (mg/100 mL)	Anthocyanin mg/100 g	Juice content (%)
Kabuli Kandhari	15.60	8.10	0.62	25.56	13.48	19.34	19.34
Chawla	13.72	8.24	0.46	30.25	9.41	10.18	10.18
Ganesh	14.46	8.17	0.42	34.70	12.86	20.36	20.36
Mridula	15.60	8.48	0.78	20.11	13.05	15.27	15.27
Jyoti	14.16	8.56	0.43	33.02	12.10	11.20	11.20
G- 137	15.57	8.30	0.45	34.91	11.45	13.23	13.23
Dholka	15.24	8.41	0.51	30.24	10.61	14.26	14.26
Bedana	15.80	9.50	0.82	19.35	13.30	16.29	16.29
Kandhari	15.85	9.78	0.56	28.75	10.37	18.32	18.32
Local check	13.94	8.32	0.43	33.15	9.84	14.25	14.25
CD 0.5%	1.29	0.26	0.10	6.89	1.17	1.43	1.43

Source: Mir et al. (2007a)

cultivars Kandhari, Nabha and Ganesh. El-Nemr *et al.* (1990) reported that fresh juice contained 85.4% moisture, 10.67% total sugars, 1.4% pectin, 0.1 g 100 mL⁻¹ total acidity (as citric acid), 0.7 mg 100 mL⁻¹ ascorbic acid, 19.6 mg 100 mL⁻¹ free amino-nitrogen and 0.05 g 100 mL⁻¹ ash. The seeds were rich in total lipids, proteins, crude fibre and ash, representing 27.2, 13.2, 35.3 and 2.0%, respectively and also contained 6.0% pectin and 4.7% total sugars. The iron, copper, sodium, magnesium and zinc contents of the juice were lower than those of seeds, except potassium which was 49.2 mg L⁻¹ in the juice. TSS, TSS/acid ratio and the contents of total sugars, reducing sugars and carbohydrates increased during development in seedling selection P-23 whereas, acidity, juice and rind tannin content decreased (Khodade *et al.*, 1990).

The chemical composition of 29 pomegranate cultivars procured from different sources showed that TSS, acidity, total sugars and vitamin C content and varied from 8.60 to 16.20%, 0.28 to 3.86, 6.20 to 15.64% and 7.86 to 13.48 mg 100 mL⁻¹ of juice, respectively. The exotic

cultivars introduced from temperate zone were very high in acidity, and low in sugars and vitamin C content. Amongst the indigenous type, Ganesh, G-137, K.R.S and Coimbatore White were promising (Jagtap *et al.*, 1992). Chattopadhyay and Patra (1993) studied the effect of various mulches on quality characters. TSS and reducing sugar content (14.0 °Brix & 10.8%, respectively) were highest with polyethylene mulch, while the highest pulp seed ratio and juice percentage were obtained with saw dust mulch (4.9 & 61.3%, respectively). Fruit acidity was lowest and ascorbic acid content was highest with no soil cover. Bist *et al.* (1994) found that fruit of wild genotype had 14.8° Brix on an average. The total sugar content was 7.45% and the fruits were more acidic than those of commercial cultivars (4.48%). Pawar *et al.* (1994) reported that juice content and TSS percentage increased with increasing severity of pruning.

Waskar and Deshmukh (1994) carried out an investigation on pomegranate to study the juice extraction method. They used crushed pomegranate grains by heating

at 40°C, which gave maximum juice recovery (60.21%) with an adequate quantity of anthocyanins, sugars and comparatively lower tannins, which were recorded the highest score during organoleptic evaluation. Evaluation of 33 cultivars (selected from the mediterranean & Aegean regions of Turkey) of pomegranate for different characters like juice content, TSS and acidity indicated that some of the cultivars were adapted to local conditions (Ozyguven *et al.*, 1997). Jalikop and Kumar (1998) studied various genotypes representing soft, semi-soft and hard seeded for different parameters and observed that the estimated juice 100⁻¹ g fruit for hard-seeded types was as low as 28 g in contrast to 44.5 and 40.5 g for soft and semi-soft seeded pomegranate, respectively. Changes in juice anthocyanin contents were analysed during fruit development and ripening in the pomegranate cvs ME5, ME17, MO6 and MA4, grown in Spain. The amount of pigment increased during fruit development, as the juice changed from colourless to dark colour. During early stages of development, diglycoside forms (particularly delphinidin 3,5-diglycoside) were predominant in all cultivars, but during the ripening stages the predominant compounds were monoglycosides (Legua *et al.*, 2000a).

Three pomegranate cultivars (ME5, ME17 & MO6) were studied during fruit development and ripening in Spain. The predominant sugars were fructose, particularly glucose, sucrose and maltose contents were almost negligible. Malic acid was the most abundant organic acid. pH stabilized during early fruit development, while an increase in soluble solids was observed approaching ripening (Legua *et al.*, 2000b). Melgarejo *et al.* (2000) reported that six anthocyanin pigments were found to be responsible for the red colour of pomegranate juice in different cultivars. These were analyzed quantitatively and qualitatively using HPLC and identified as delphinidin, 3-glycoside and 3,5-diglucoside, cyanidin 3-glycoside and 3,5-diglucoside and pelargonidin, 3-glucoside and 3,5-diglucoside. In the early fruit development stages, delphinidin 3,5-diglucoside was the main pigment, followed by cyanidin 3,5-diglucoside, while in the later stages of fruit development, the glycoside of cyanidin and delphinidin increased considerably. The pelargonidin derivatives were always present in much smaller amounts, and were even difficult to quantify in some instances. The juice content was lowest in G-137 among the 30 evergreen cultivars grown in Punjab (Sharma & Dhillon, 2002).

Dhillon and Kumar (2004b) studied the biochemical changes in pomegranate and indicated that TSS and vitamin C content increased up to 150 days of anthesis but acidity decreased during fruit development. High total soluble solids and total sugars were recorded in cv. Kandhari. The highest TSS/acid ratio was recorded in cv G-137. Cultivar Kabuli kandhari observed the highest ascorbic acid content followed by Bedana. The anthocyanin content was observed higher in Ganesh followed by Kabuli kandhari and lowest in

Chawla. The juice content was found to be highest in Bedana (Mir *et al.*, 2007a & b).

Varasteh *et al.* (2009) evaluated five commercial cultivars in Iran for different fruit characteristics and observed total soluble solids, titrability acidity and anthocyanin index which varied from 16.60-18.26, 0.79-1.35 and 1.04-1.92, respectively. Akbarpour *et al.* (2009) studied 12 pomegranate cultivars for different physical and chemical characters. Their reducing sugars ranged from 13.89 to 29.83 g/100 mL and TSS ranged from 15.17 to 22.03%. Cultivar Syah-e-Saveh had significantly more TSS (22.03). The maximum acidity was found in Lamsari-e-Behshahr (3.36%) and minimum in Khazar-e-Bardaskan (0.35%). Vitamin C ranged from 9.68-17.45 mg/100 mL and anthocyanin from 225.17 to 705.50 mmol/100 g.

Cracking incidence: Fruit cracking is mainly associated with fluctuation of soil moisture, day and night temperatures, relative temperatures, relative humidity and of rind pliability. The disorder is reported to be due to boron and calcium deficiency. There is further attack of insects or fungal attack on the cracked fruits. So fruits become unfit for marketing. Fully developed pomegranates crack due to moisture imbalances, as they are very sensitive to variation in soil moisture and also to day and night atmospheric moisture deficit. Prolonged drought causes hardening of the peel. If this is followed by irrigation or rains, the pulp grows and ultimately the peel cracks. Pant (1976) observed that air temperature rise was found to be the cause of fruit cracking. It amounted to 63 per cent in the spring crop (January-June), 34% in the winter crop (October-March) and only 9.5% in the rainy season crop (July-December). The fruit cracking was quite high in almost all the cultivars as reported by Malhotra *et al.* (1983a). Trapaidze and Abuladze (1989) studied that out of 15 cultivars only Shirvan, Burachni, Apsheronskii-Kranji, Sulu-nar, Kyrmyz Kabukh and Francis were resistant to cracking. They were characterized by heavy crop of good quality fruit and were recommended for the subtropical zone of eastern Georgia. Prasad and Bankar (2000) reported that out of 9 cultivars studied, Jalore Seedless had the lowest incidence of fruit cracking (36.60%) while as maximum was recorded in Jodhpur Red (78.20%).

Significant variations were reported in fruit cracking among different cultivars and found maximum cracking in Jodhpur Red (72.40%) and least in Malta (5.20%) as reported by Singh (2004). Selection of proper planting material, controlled and systematic irrigation, regulation of bahar, spraying of boron and GA₃ and control of mites at right stage controlled cracking in pomegranate (Singh *et al.*, 2006). Mir *et al.* (2007b) reported among the different cultivars under study, cultivar Chawla exhibited less cracking incidence (6.32%) followed by Kandhari. However, highest cracking was observed in cultivar G-137 (31.40%) followed by Ganesh (26.30%).

Yield attributes: Pomegranate being non-climacteric fruit should be picked when fully ripe. Harvesting of immature or overripe fruits reduces the quality. The fruits are ready for

harvest in 5 to 6 months after the appearance of blossom. The fruits are harvested when the skin turns slightly yellow and fruit gives a metallic sound when tapped or pressed. Misra *et al.* (1983) reported that out of 10 varieties of pomegranate, only Srinagar Special, gave the highest yield (18.45 kg plant⁻¹). Chattopadhyay and Patra (1993) studied the effects of different mulches on yield of pomegranate and found that black polyethylene resulted in highest yield (164 q ha⁻¹), while as control gave the lowest yield (97 q ha⁻¹). From different pomegranate trees, the highest yield was obtained from unpruned trees, although the number and percentage of better grade fruits increased with severity of pruning (Pawar *et al.*, 1994).

Kafyova (2003) studied collection of 29 pomegranate accessions from Azerbaijan for viticulture and fruit growing at Derbent in Southern Dagestan. Data revealed that fruit yield ranged from 0.65 t ha⁻¹ in cv Kaim-anar to 7.25 t ha⁻¹ for cv Krmyzy Shirin. Accessions G15-3 (374 g) and VIR Krupnoplodnyi (370 g) produced the largest fruits. Out of 13 cultivars studied for different characters, cultivar 'Jalore Seedless' recorded the highest yield followed by 'P-23', G-137, Ganesh and Mridula. Based on best performance for desired characters 'Jalore seedless', P-23, G-137, Ganesh and Mridula are suitable for cultivation in arid and semi-arid region (Singh, 2004). Different studies revealed that among the different cultivars, the highest number of fruits/plant, gross fruit yield and marketable produce was recorded in cv. Dholka followed by Bedana (Mir *et al.*, 2007a & c).

Pest incidence: Pomegranate trees are attacked by about 45 species of insects and fruit is the most vulnerable to the attack of the pest. The fruits are attacked by several physiological disorders and insects, which is the main cause for decline of its production in the Kashmir Valley. Malik *et al.* (1965) observed that the average extent of damage by *Virachola isocrates* to pomegranate ranged from 40 to 50% and in several cases reached to 100% in Kashmir. Zaka-ur-Rub (1980) also reported serious infestation of anar-butterfly in Kashmir Valley. Misra *et al.* (1983) reported that from the different cultivars studied, Shirin-Anar revealed the maximum incidence of attack (63.01%), whereas minimum was recorded in Srinagar Special (24.30%).

The leaves of pomegranate fruit tree were found to be greatly damaged by *Aphis punicae* Passerini, recorded for the first time from Kashmir. This pest was widely prevalent during the April and early July. At many places the aphid colonies were found to infest the twigs and blossom of the fruit (Bhagat, 1986). Fruits of wild pomegranate infested with pests were collected from the fields of Jammu and Kashmir in autumn and spring. Four pest species were identified, the *Pyralid cataremna albicostallis*, the tortricid *Olethreutes* sp. near *O. celliflora*, the hycaenid *Deudorix epijarbas* and the tephritid *Dacus* sp (Parry & Pawar, 1988). Tirathsing (1992) reported incidence of pomegranate fruit borer in different areas of Kashmir Valley and found

maximum incidence in Srinagar (45.52%) followed by Kupwara and Pulwama while as minimum incidence was found in Budgam (35.09%). Mir *et al.* (2007c) reported that among the different cultivars studied in temperate region, cultivar Ganesh recorded the least incidence of pomegranate butterfly attack (8.33%), whereas highest incidence (12.49%) was found in cultivar Kabuli Kandhari.

CONCLUSION AND FUTURE PROSPECTS

In order to face challenges within and outside the country, research strategies needs to be reoriented. Evaluation, conservation and cataloging of both exotic and indigenous pomegranate cultivars having especially compact, dwarf and thorn less types so that they can be brought under high density program. More information pertaining to evaluation studies at different stages of development is needed. Farmers interest will be taken care of when pomegranate crop is used/planted not only to increase gross yield but also improving marketable yield by improving quality and postharvest life which ultimately bringing more economy to farmers hand. Management will also go a long way in implementing value addition at the farmers level. To be able to fully exploit the potential of evolving varieties with high yielding, resistance to biotic and abiotic stresses, better flowering behavior and better aril (soft) characters for domestic as well as export purpose. Some of the varieties evolved by different institutions is rather hard seeded instead of soft seeded fetching good market value. Main focus should be on identification of varieties by using molecular characterization through DNA and isozyme markers. The relative effectiveness of different cultivars and training systems in different geographical regions needs to be ascertained. At present, we still lack development of eco-friendly pest management practices using new molecules and the factors governing mineral nutrient uptake by the pomegranate.

Acknowledgement: Authors gratefully acknowledge the guidance from Professor A Q. Jhon (Emeritus Scientist, Sher-e-Kashmir University of Agricultural Sciences & Technology, Kashmir) and Professor A.A. Sofi (Emeritus Scientist, Central Institute of Temperate Horticulture, Srinagar) for their constant support and help during preparation of the manuscript.

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(Received 17 November 2011; Accepted 29 March 2012)