Pomegranate (*Punica granatum* L.)

5

Abstract

Pomegranate (*Punica granatum* L.) is one of the important semiarid fruits cultivated commercially in over 1.25 Lakh hectare areas in Western India. Its cultivation is possible even on marginal degraded lands that have previously been found unsuitable for growing crops. Apart from this, its ability to withstand salinity in soil and water has, to some extent, led this crop to emerge as a hardy fruit crop. It is commercially grown for its sweet-acidic fruits, which provide a cool refreshing juice and are valued for their medicinal properties. Its popularity is also due to the ornamental nature of the plant, particularly the bright red flowers that appear throughout the year. Its antioxidant properties are well known. The juice and seed contain large quantities of tannin and agolic acid, which are essential in the cure of several diseases. The fruit can be successfully grown under even purely rain-fed conditions in semiarid areas. In recent years, pomegranate cultivation has become an economically viable proposition. Large acreage is covered with new varieties such as Bhagwa, Arakta, and Mridula. Furthermore, some anardana types have also developed Goma khatta.

5.1 Introduction

Pomegranate is emerging as one of the important fruit crops owing to its hardiness and ability to withstand adverse soil and climatic conditions. Today, India contributes 40–45 % of a global production of 10 Lakh tons. Currently, the export of pomegranates is around 10,000 t, which is just 5 % of the total export. With the increase in population, the domestic demand for fruit has also increased substantially. To date, of a total area of 1,25,000 ha. under pomegranate, the majority is found in the state of Maharashtra. The state has 85,000 ha. (68 % area) under the crop, of which only 51,000 ha is under production. This is followed by Karnataka at 12,727 ha. And Gujarat at 3,787 ha as at 2003–2004 (Anonymous 2005). Earlier orchards were raised mainly with the Ganesh variety, which was the leading variety. However, it is fast being replaced with new cultivars such as Bhagawa and Arakta, the skin and arils of which are an attractive color and, hence, are suitable for export.

The pomegranate is an ancient and favorite table fruit of tropical countries. It is commercially grown for its sweet-acidic fruits, which

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provide a cool refreshing juice and are valued for their medicinal properties. The fruit rind, juice, leaf, and roots are used in the preparation of various ayurvedic medicines. Its popularity is also due to the ornamental nature of the plant, especially the bright red flowers that appear throughout the year. The fruit juice is refreshing and contains both glucose and fructose. The juice and seed contain large quantities of tannin and agolic acid, which are essential in the cure of several diseases. The fruit can be successfully grown under even purely rain-fed conditions. In recent years, pomegranate cultivation has become an economically viable proposition.

Pomegranate (*Punica granatum* L.) belongs to the natural order Punicaceae; Punica perhaps is the only known genus of this family, which includes large shrubs or small trees with two species: *Punica protopunica* Balf. is found wild in Socotra Island, and the other, *Punica granatum*, is cultivated in sub-tropical parts of the world. *Punica granatum* 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 color of the ovary, a stable feature that is retained even when they are reproduced by seed. Sub-species chlorocarpa is mainly found in the *Transcaucasus*, whereas the second sub-species, porphyrocarpa, is mainly distributed in central Asia.

5.2 Uses

The pomegranate is a favorite table fruit in tropical countries. It is greatly liked for its cool refreshing juice and is also valued for its medicinal properties. The juice is considered useful for patients with leprosy, the bark and rind of the fruits are commonly used in dysentery and diarrhea, and the rind is also used as a dye for cloth. The fresh juice of pomegranate retains its flavor and keeps when bottled after sweetening with sugar. A kind of wine is also prepared from pomegranate juice, and is considered superior to grape wine.

5.3 Composition

Water	78.2 %	Potassium/100 g	133 mg
Protein	1.6 %	Iron/100 g	3 mg
Fat	0.1 %	Thiamine/100 g	0.6 mg
Fibers	5.1 %	Riboflavin/100 g	0.1 mg
Calcium/100 g	10 mg	Nicotinic acid/100 g	0.3 mg
Magnesium/100 g	12 mg	Vitamin C/100 g	14 mg
Phosphorus/100 g	70 mg	Oxalic acid/100 g	14 mg

Pomegranate is grown on large acreages in Maharashtra, followed by Karnataka (Table 5.1). However, productivity is highest in Tamil Nadu,

Table 5.1 Statewise area, production, and productivity of pomegranate

	Area (000' ha)			Production (000' Mt)			Productivity (Mt/ha)		
	2008–2009			2009–2010			2010–2011		
State	Area	Production	Pdy.	Area	Production	Pdy.	Area	Production	Pdy.
Maharashtra	82.0	550.0	6.7	98.9	555.5	5.6	82.0	492.0	6.0
Karnataka	14.3	138.1	9.7	13.2	138.5	10.5	13.6	142.6	10.5
Gujarat	4.0	39.3	9.8	4.4	45.6	10.4	5.8	60.3	10.4
Andhra Pradesh	6.5	64.7	10.0	5.6	56.4	10.0	2.8	27.8	10.0
Tamil Nadu	0.4	10.0	25.0	0.4	17.5	39.4	0.5	12.7	27.6
Rajasthan	0.6	3.5	5.5	0.8	4.8	6.4	0.8	5.5	6.6
Others	1.4	1.6	1.1	1.66	2.1	1.2	1.8	2.2	1.2
Total	109.2	807.2	7.4	125.0	820.3	6.6	107.3	743.1	6.9

although the area is the smallest. Growth in Maharashtra reduced over the years 2009–2010, probably due to die back and oily spot diseases. The same trend can be recorded in Andhra Pradesh. Thus, further increases in area under pomegranate must be planned carefully and with disease-free planting material.

5.4 Botany

Bearing Habit

Types of flowers

5.5 Varietal Improvement

5.5.1 Germplasm Evaluation and Breeding

Several types of pomegranates with varying shapes, sizes, and colors are cultivated in India. Fruits are round, obvate in shape, and vary in diameter from 8 to 12 cm. The rind may be thick or thin, and the color ranges from pale yellow to crimson. The seed pulp in superior types is thick, fleshy, and very juicy; but it is thin in inferior types. The seed coat varies in hardness; some of the softer-seeded types are known as seedless (Bedana). A lack of lignifications of the testa is the main cause of so-called seedlessness in the pomegranate. Bedana and Kandhari are considered the best among the numerous types grown.

The varieties Ganesh, Mridula, Arakta, G-123, P-23, P-26, Mastani, and Bhagwa are popular in

Maharashtra. Bassein Seedless, Jyothi, Ganesh, Mridula, Arakta, and Ruby are popular in Karnataka; Dholka in Gujarat; Jalore Seedless, Jodhpur Red, and Jodhpur White in Rajasthan; and Kabul Red, Vellodu, Yercaud-1, and CO-1 in Tamil Nadu.

Although we know a great deal about the pomegranate and its origin, there are a number of seedling varieties in the pomegranate areas. It is better to select a variety with known qualities. Most horticulturists divide pomegranate varieties into three categories: sweet, sweet tart, and sour. However, we prefer to include the seed hardiness in this and divide them into six groups, as follows.

1. Soft-seeded sweet
2. Soft-seeded sweet tart
3. Early variety (mostly sweet)
4. Normal (harder) seeded sweet tart
5. Normal (harder) seeded sweet
6. Sour (nearly always normal seeded)

5.5.2 Breeding Criteria

Pomegranate is genetically heterozygous material, thus there is lot of variability existent in the nature. Therefore, there is scope for crossing two selected genotypes, raising of hybrid populations, and identification of superior types.

1. Cracking and splitting of fruits is a severe menace and occurs with variations in atmosphere and humidity.
2. Resistance to fruit borer and stem borer is desired.
3. To develop varieties with high sugar (16 %) and less acid (1.5 %) content.
4. All varieties bear some sterile flowers. This appreciably reduces yield. The selection of varieties bearing a high percentage of fertile flowers should be achieved.
5. To develop better varieties for Western India by hybridization between the locally adapted Alandi and Dholka types. Alandi types have medium-sized fruits, deep red to deep pink flesh, hard seeds, and quite sweet juice. However, they are slightly more acidic than Dholka types. Dholka types bear larger fruits with greenish white rind, whitish flesh, soft seeds, and sweet juice.
6. To develop better varieties for Southern India by hybridization between prolific bearing Paper Shell or Spanish Ruby, and the soft-seeded Musket Red and the large-sized-fruit-bearing Vellodu types.
7. Breeding varieties with dark red arils and skin.
8. Breeding Anardana-type varieties with dark red bold arils, high acidity, bigger fruit size, and a high yield.

5.5.3 Breeding Methods

5.5.3.1 Selfing

Bag the bud a day prior to anthesis. Tag and label it.

5.5.3.2 Crossing

Select an appropriate young bud that will open the next morning. Insert forceps through petals or remove one petal and take out the stamens. Take care that no anther is left inside the flower, and the ovary is not injured. This can be done easily, as stamens emerge from within the upper half or more of the hypanthium (Calyx tube) and are distant from the ovary. Bag and tag. Collect the desired anthers in yellow stage and incise them with a needle and transfer the pollen with the help of a brush onto the receptive stigma of the emasculated bud the next morning. Bag and label.

5.5.3.3 Hybridization

Hybridization is conducted in the morning before 11.00 am. The steps involved are as follows: emasculation (removing of anthers) using forceps; pollination with the pollen of the desired male parent; covering with butter paper bag and labeling. Fruits require about 120–130 days for maturity. Crossed fruits are harvested. The seeds are extracted and sown in plastic trays; they germinate within 10 days of sowing. The seedlings are transplanted to polythene bags and subsequently to field for further evaluation, Bhandari (1979).

5.5.4 Genetic Evaluation of Germplasm

The world's largest collection, comprising 1,117 entries, is maintained at Turkmenistan (CIS). They exhibit wide variability for fruit size and quality, skin color, resistance to abiotic and biotic stresses; however, most are temperate in nature and do not grow well in the Indian tropics. There is scope to use this material for breeding superior types.

Several varieties have adapted to both the tropical and the sub-temperate climate. They are either evergreen or semi-deciduous or deciduous. The flowering habit, fruiting, and flower physiology alters depending on the habitat. In the tropical climate with the mild winter of south India, growth and flowering are continuous processes; in the sub-tropical climate of north India, the trees remain dormant during the cold winter and flower in the following spring. In temperate climates, flowering occurs in summer.

In India, cultivar 'Ganesh' was one of the leading varieties. It is a seedling selection from 'Alandi' with a large fruit (400–450 g), sweet taste (16–17 °Bx TSS) and soft seeds; however, the aril color is not attractive (pink or light pink). Later on, two new varieties with Ganesh as a base and with red arils were released: Arkta from Mahatma Phule Krishi Vidyapeeth (MPKV) Rahuri and Ruby from the Indian Institute of Horticultural Research (IIHR Bangalore). In both varieties, the red aril color was imparted by the Russian varieties Gulsha Red and Gulsha Rose Pink. Ruby is a multiple hybrid resembling more of Ganesh, while Arkta is an F2 selection. Recently, a large area in Maharashtra has been planted with a new variety (Bhagwa), which is a selection made by a farmer. It has a deep red aril and an attractive skin color, but the variety takes longer to mature (160–170 days). Several other seedling selections are grown on a limited scale across the country: Madugiri, G-137, Muscat, Jyothi, Bassein seedless, Dholka, and Jalore Seedless in the states of Karnataka, Tamil Nadu, Haryana, Gujarat, and Rajasthan. In Himachal Pradesh, a sour type known as Daru is found abundantly in the wild and is mostly used for anardana preparation. A new F1 hybrid developed at IIHR Bangalore and named 'Amlidana' has been released. Most varieties have one or another superior trait that is susceptible to bacterial nodal blight, a disease that has threatened the cultivation of the pomegranate. The quality parameters are strongly influenced by soil and climatic conditions. New varieties with desirable traits such as bold arils with red color and soft seeds and resistance to blight, drought, cracking, and aril browning are needed.

Evaluation of pomegranate germplasm under semiarid rain-fed conditions indicated that seeded varieties bear fruits with higher fruit weight, whereas their aril seed ratio was the lowest and 100 seed-weight the highest. Seasonal variation affected all the physicochemical characteristics studied. In hasta bahar, the quality of the fruit was the best compared with mrig bahar fruits. All characters showed increasing trends except acidity, which declined in hasta bahar. The seeds of hasta bahar were harder than mrig bahar fruits, but the juice color was attractive in hasta bahar. Fruit weight ranged from 200 to 95 g in mrig bahar but from 261 to 141 g in hasta bahar, fruit length varied from 75.5 to 50.0 mm and 75.5 to 66.5 mm in mrig and hasta bahar, respectively. Fruit diameter varied from 73.5 to 50.05 mm and 78 to 70.2 mm in both mrig and hasta bahar, respectively. Aril seed ratio varied from 1.42 to 0.63 in mrig and 3.02 to 0.69 in hasta bahar. Juice percent varied from 58.3 % to 77.3 % in mrig bahar and 78.25 % to 62.29 % in hasta bahar. Acidity of the fruit ranged from 1.45 % to 0.35 % in mrig and 0.90 % to 0.28 % in hasta bahar. Purohit (1985) studied the seed softness of commercial varieties and reported that the thickness of the testa, weight of whole seed, density of the seed, and weight of testa as % of seed weight can be used to determine the seed softness of the pomegranate. His scale indicated that variety in thickness of seed testa <0.5 mm, the density of whole seed <0.6 g/ml, the density of seed testa <0.4 g/ml, weight of the seed testa <50 % of the weight of whole seed. Bedana, Bassein seedless, Ganesh, and Dholka were found to be soft seeded. Although Bedana has soft seeds, it

cannot be grown commercially owing to its deciduous nature and sparse flowering.

Evaluation of 24 pomegranate germplasm genotypes carried out by Meena et al. (2003) indicated that all the characters except total soluble solids (TSS) and total sugar had less pronounced differences between the value of phenotypic and genotypic coefficient of variation. Genotypic coefficients of variation were higher for seed content, weight of 100 aril, weight of 100 seeds, acidity, and average fruit weight. The results indicated that a higher magnitude of variation for the above traits offered better opportunities for improvement through selection. These results are in concordance with those of Chaturvedi et al. (1980) and Pandey and Bist (1998). Higher estimates of heritability were obtained for all the characters except TSS, ascorbic acid and total sugar content, which may be due to environmental effects on these traits. Acidity and weight of 100 seeds had high heritability in spite of low genetic advance, which may be due to introduction of replication in the system (Burton and De Van 1953), while low genetic variability and low genetic advance was noted in total soluble solid. High heritability estimates, coupled with high-expected genetic advance as percent of mean, were observed for mean seed content, weight of 100 seeds, acidity content, and average fruit weight, indicating that high heritability coupled with high genetic advance might be due to additive genes effect on these traits. These characteristics can be considered as reliable selection indices. High to moderate heritability, along with low genetic advance were recorded for total sugar and ascorbic acid content indicating that these characteristics might be controlled by non-additive gene action, and improvement through selection for these characteristics would be rather ineffective. Panse and Sukhatme (1978) noted that, if a characteristic is governed by additive gene action, heritability and genetic advance would both be high. High estimates of heritability, along with high genetic advance, provide good scope for further improvement in advance generation if these characteristics are subjected to mass progeny or family selection (Table 5.2).

Table 5.2 Germplasm evaluation in pomegranate

Variety	Season	Fruit wt. (g)	Fruit length (mm)	Fruit dia. (mm)	Aril / seed ratio	Juice %	TSS °Bx	Acidity %	Juice color	100 seed wt. (g)
P-26	Mrig	153.32	69.1	65.5	1.41	75.21	14.0	0.351	Light pink	2.14
	Hasta	233.00	74.5	75.5	2.19	73.15	15.4	0.31		2.57
Kabul	Mrig	105.15	62.0	59.5	0.88	71.28	13.4	0.427	Light pink	1.63
	Hasta	194.00	74.5	73.5	1.30	75.43	16.4	0.28	Red	2.12
Jalore seedless	Mrig	095.73	54.75	50.5	0.93	61.70	12.4	0.78	Cream	1.87
	Hasta	176.50	67.5	70.5	1.35	76.14	15.2	0.28	Pink	2.25
Musket	Mrig	198.20	75.5	73.5	1.42	74.06	14.4	0.46	Cream	1.55
	Hasta	227.00	71.5	76.2	1.57	77.17	16.4	0.28	Pink	2.49
Jyoti	Mrig	192.14	71.4	73.0	1.41	73.69	14.4	0.35	Light pink	1.29
	Hasta	215.00	73.5	75.5	1.64	78.25	18.0	0.35	Pink	1.85
Ramna-aram	Mrig	200.68	71.0	70.5	0.63	58.32	9.4	0.63	Light pink	3.76
	Hasta	261.00	75.5	78.0	0.69	64.92	13.4	0.49	Red	4.77
Gulsha Rose	Mrig	127.62	56.0	64.5	0.70	77.30	11.4	1.45	Red	2.98
	Hasta	188.00	66.5	75.0	0.90	73.75	13.6	0.90	Dark red	3.56
Appuli	Mrig	117.38	50.05	53.5	0.71	67.05	13.4	0.63	Light pink	2.89
	Hasta	216.00	67.5	74.0	1.34	62.29	16.2	0.49	Pink	3.66
Ganesh	Mrig	134.00	134.0	70.1	1.89	77.0	16.6	0.44	Light pink	1.508
	Hasta	141.00	141.0	70.2	2.70	77.0	17.6	0.34	Pink	1.96
P-16	Mrig	110.48	61.5	57.5	1.26	67.17	13.3	0.462	Cream	1.96
	Hasta	141.83	70.9	70.24	3.03	78.00	16.6	0.369	Light pink	2.57

Hiwale (2001)

Anardana germplasm lines collected at the center were evaluated under rain-fed conditions; all lines flowered and fruited in all the bahar. Some lines had desirable characteristics such as dark red arils, soft seeds, high acidity, bold arils, high sugar acid ratio, etc. Line H in particular had high acidity, large fruit size, soft seeds, and the aril color was light pink. Compared with other crosses, the least growth was observed in line H and hence it is suitable for high-density farming. Based on growth data, the cultivar is found to be dwarf and, at 5×4 m spacing, 500 plants can be accommodated in a hectare. It requires 150–160 days to mature.

There is no long gestation period. The plants start bearing fruit in the third year of planting. There was 15–20 % cracking of the fruits. Suitable for processing as Anardana, mixing with Juice and Squash with other sweet varieties. High acidity, bigger fruit size, and high TSS compared with different crosses make it suitable for processing and export of anardana. Yield per plant was 11.08 kg under the rain-fed conditions of Gujarat. The hybrid also yielded Anardana to the tune of 1.55 kg/plant (Hiwale et al. 2009) (Table 5.3).

5.6 Hybridization

The commercial cultivars Ganesh and Musket, though prolific bearers and soft seeded, lacked the dark red color of the Russian types, which were, however, sour in taste. The hybridization program therefore was initiated at MPKV, Rahuri (Anonymous 1979). The F1 progeny was screened (Kale 1986) but none of the hybrids could be used directly because of defects observed in them. The F2 progeny developed from open-pollinated F1 resulted in the identification of a superior type that combined all the desirable attributes and was named Mridula (Keskar et al. 1994). Hybridization work carried out at IIHR Bangalore resulted in the identification of multiple cross-hybrid 'Arka Ruby', which was released at the institute level but further multiplication was stopped due to the incidence of bacterial blight (Table 5.4).

Hybridization work done at IIHR Bangalore has resulted in the identification of a hybrid Arka Ruby, which was a multiple-cross.

Table 5.3 Physico -chemical characters in anardana-type pomegranate germplasm

Acc. No.	Fruit set/plant	Fruit wt (g)	Fruit length (mm)	Fruit Dia. (mm)	Skin wt (g)	Total aril wt (g)	Juice %	TSS °Bx	100 aril wt (g)	Aril length (mm)	Aril dia. (mm)	Juice color
A.	85.0	77.0	68.3	58.9	53.3	95.3	35.2	17.1	95.3	9.76	6.5	L. pink
B.	59.0	67.0	54.0	48.4	22.0	43.6	39.4	11.1	42.3	9.46	5.16	pink
C.	17.7	104.0	64.5	61.3	37.0	80.6	37.0	17.0	83.6	9.76	5.03	D. pink
E.	48.7	86.3	50.5	53.3	33.3	53.0	36.6	11.5	53.0	9.46	9.93	L. pink
F.	26.3	77.6	54.7	50.0	26.3	45.0	55.4	15.8	44.3	8.03	4.6	D. pink
H.	40.0	137.3	57.3	63.2	35.0	96.6	46.7	16.3	53.0	10.7	5.9	Pink
I.	18.0	88.6	49.3	55.4	25.3	62.0	40.9	16.6	96.6	9.76	8.9	Pink
J.	28.7	95.6	54.7	54.7	20.0	71.6	52.6	14.6	62.0	11.0	8.96	L. pink
K.	29.7	71.6	51.7	48.3	21.6	44.6	77.2	16.6	71.0	9.4	5.23	Pink
C D 5 %	14.9	27.6	NS	9.1	12.2	36.9	–	1.40	44.6	0.57	0.53	–

Table 5.4 Physico chemical character of some of the hybrids identified

Cross	Fruit wt. (g)	Fruit size (cm)	Aril colour	TSS (%)	Acidity (%)	Softness of seed
Ganesh × Shirin Anar	414	9.2×8.9	Pink	16.3	0.36	Soft
Ganesh × Gulsha rose pink	244	7.5×7.7	Dark red	17.9	0.47	Soft
Ganesh × Gulsha red	221	7.6×7.4	Red	19.1	0.55	Soft
Arka ruby	249	7.2×7.8	Dark red	17.2	0.64	Soft

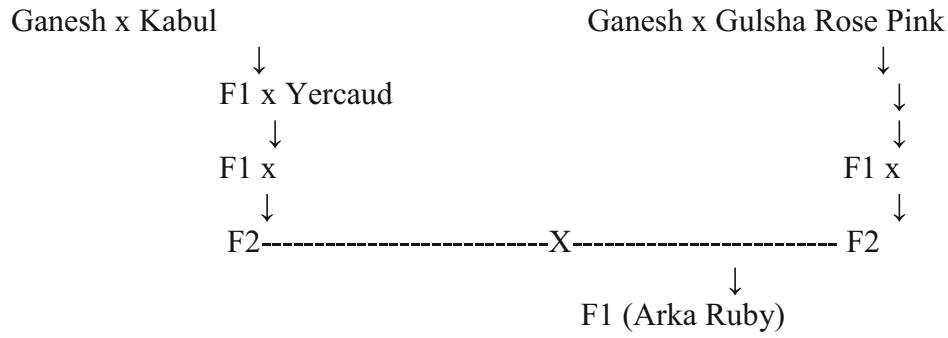


Table 5.5 Characters of hybrids developed at CHES Godhra

Character	Ganesh × Jalore seedless	Ganesh × Sindhuri	Ganesh × (Ganesh × Nana)	R1P2
Male flowers	30	21	10	45
Hermaphrodite flowers	41	20	5	10
No. of fruit set	35	31	43	25
No. of days to maturity	115	120	120	117
Fruit wt (g)	249.66	216	182.5	129
Length (mm)	78.1	66.5	62.06	65
Dia. (mm)	93.0	71.5	68.33	62
Skin wt. (g)	59.66	52.0	41.25	46
Aril wt. (g)	187.00	165.33	138	93
100 aril wt (g)	30.33	26.0	26	19
Aril length (mm)	10.5	10.0	10.75	9.25
Aril dia.(mm)	8.5	7.87	6.5	4.30
Aril color	Pinkish white		Dark red	Red
Aril	Bold	Bold	Medium	Small
TSS °Bx	14.83	15.1	15.1	14
Acidity	0.35	0.47	0.50	0.36

Breeding work initiated at CHES Vejalpur using various cross combinations along with chemical mutagen colchicine @ 0.5 % resulted in the identification of good F1 hybrids. However, mutation resulted in smaller-size fruits, which is not a desirable characteristic (Table 5.5).

5.6.1 Hybrid-1

Hybrid-1 is a hybrid between Ganesh × Line I of anardana-type fruit. The fruit size is superior than the male parent and comparable to the female parent. The hybrid has a dark red aril. The arils are of medium size (10.75 × 6.5 mm) with a fruit-to-aril ratio of 1.32 and fruit-to-skin ratio of 4.42. Percent fruit set was 67.64; fruit retention was 60.29 %. TSS were 15.1 °Bx, with an acidity of 0.48 %. The yield potential was 8.21 kg per plant under semiarid rain-fed conditions.

5.6.2 Hybrid-2

Hybrid-2 is a cross between Ganesh × Sindhuri. The hybrid was found to have bold arils (10.0 × 7.87 mm) and bigger fruit (216 g.). However, the arils are light pink in color, with a fruit-to-aril ratio of 1.31 and fruit-to-skin ratio of 4.15. Maturity occurs in just 120–125 days in the hasta bahar crop under semiarid rain-fed conditions. The hybrid is found to be superior to its

parents in respect of fruit set (70.85 %), fruit retention (59.95 %), and ultimate yield per plant (8.86 kg) in 4-year-old plants.

5.6.3 Hybrid-3

Hybrid-3 is a cross between Ganesh × Jalore seedless. It is superior to both parents in fruit and aril size. The mean fruit size for the 3-year data was 249.66 g and aril size was 10.5 × 8.5 mm (bold aril), with a fruit-to-aril ratio of 1.33 and fruit-to-skin ratio of 4.18. Maturity occurs in just 110–115 days in the hasta bahar crop under semi-arid rain-fed conditions. The hybrid is found to be superior to its parents in respect of fruit set (71.69 %), fruit retention (51.88 %), and ultimate yield per plant (13.73 kg) in 4-year-old plants.

Pomegranate hybrid-1 – (Ganesh x R10 P10)

Pomegranate Hybrid -2 (F1-Ganesh x Sindhuri)

Pomegranate Hybrid -3 (F1- Ganesh x Jalore seedless)

'Selfing' is conducted by bagging the bud a day prior to anthesis. The bud should then be tagged and labeled. Select an appropriate young bud that will open the next morning. Insert forceps through petals or remove one petal and take out the stamens. Take care that no anther is left inside the flower and that the ovary is not injured. This can be done easily, as stamens emerge from within the upper half or more of the hypanthium (Calyx tube) and are distant from the ovary. Bag and tag. Crossing is carried out the next morning: collect the desired anthers in yellow stage and incise them with a needle and transfer the pollen with the help of a brush onto the receptive stigma of the emasculated bud. Bag and label. Hybridization is carried out in the morning before 11.00 am. The steps involved are emasculation (removing of anthers) using forceps. Pollinate with the pollen of the desired male parent. Cover with a butter paper bag and label it. Fruits require about 120–130 days for maturity. Crossed fruits are harvested, and the seeds extracted; they are then sown in plastic trays. Seeds germinate within 10 days of sowing. The seedlings are transplanted to polythene bags and subsequently to field for further evaluation, Bhandari (1979).

5.7 Breeding for Bacterial Blight Resistance in Pomegranate

Kalpitiya was identified as a source of resistance to bacterial blight in the pomegranate. A total of 60 crosses were made with Nana, Daru, Yellow, Double flower, and Ganesh. Advanced breeding lines with favorable traits have been raised.

5.8 Evaluation of Hybrids in Pomegranate

A total of 482 seedlings of Daru and Nana where subjected to challenge inoculation with bacterial blight culture. Screening of 52 hybrids between Nana, Yellow, and Double flower revealed that all had hard seeds. In the second round, Kalpitiya × Ruby (30 hybrids) did not show a positive reaction to challenge with bacteria. A total of 11 plants were planted to test field resistance to bacterial blight of pomegranate (BBP) and the remaining 14 plants were sent to NRCP, Solapur. A total of 50 seedling of a cross between Bhagwa × (Ganesh × Daru) × Daru and Bhagwa × (Ganesh

× Daru) × Nana showing resistance to Bacterial bblight of pomegranate were planted in the field. Screening results revealed that 315 of 476 plants expressed Bacterial bblight of pomegranate symptoms. Further screening of 161 plants not showing Bacterial bblight of pomegranate symptoms is underway.

Rahuri center:

The breeding program developing varieties that were resistant to bacterial blight was terminated as both male parents (i.e. Daru and Nana) were found to be susceptible. The genetic improvement of pomegranate through breeding initiated and crossing of Bhagwa × Kabul yellow, Mridula × Kabul yellow, Phule Arkta × Kabul yellow was undertaken. A total of 192 F1 hybrids of Musket × Mridula, Phule Arkta, and Bhagwa were planted in the field.

- Future Lines of Work

Breeding to resistance/tolerance of biotic and abiotic stresses, particularly bacterial blight, Fusarium wilt, fruit rot, and fruit borer. Identification of genes for increasing storage life through and its incorporation through different breeding methods.

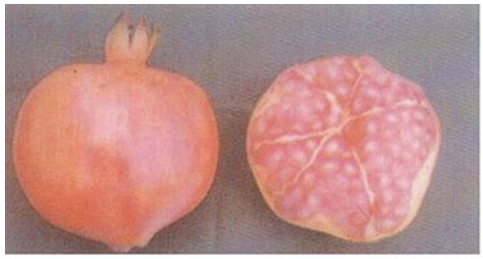
5.9 Commercial Varieties

5.9.1 Ganesh

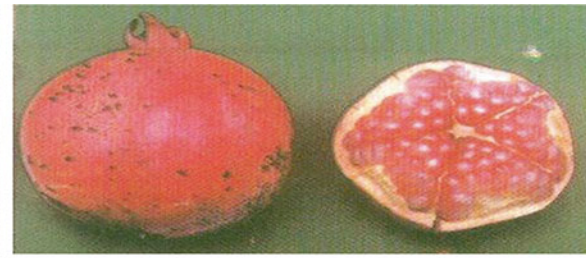
Ganesh is a selection from the cultivar Alandi. The growth habit of the tree is spreading type with evergreen nature. The leaf is entire and elliptic in shape. The tree flowers throughout the year, with three main flushes. Fruit is round, smooth, and pink with a reddish tinge. The maximum weight per fruit was 255 g in mrig bahar and 211 g in ambe bahar. The length of the fruit was found to vary: 7.84 cm in mrig bahar and 7.41 cm in ambe bahar. The breadth also showed a similar trend: 7.96 cm in mrig bahar and 7.23 cm in ambe bahar. Arils are sweet and light pink. The juice percent varied from 52.76 % in mrig bahar and 51.54 % in ambe bahar. The TSS of the juice was observed to be 16.6 °Bx in mrig bahar and 17.4 °Bx in ambe bahar. The acidity was 0.44 % in mrig bahar and 0.34 % in ambe bahar. Seeds were found to be the softest in ambe bahar (1.15 kg/cm^2) compared with mrig bahar seeds (1.59 kg cm^2 pressure). The variety is susceptible to fruit borer (18.55 %), leaf spot (PDI-15.72), and fruit spot (PDI-22.86).

5.9.2 Jalore Seedless

The growth habit of the Jalore seedless tree is spreading type with evergreen nature. The leaf is entire and elliptic in shape. The tree flowers throughout the year, with three main flushes. Fruit is round, smooth, and pink with a reddish tinge. The maximum weight per fruit was 175 g in mrig bahar and 154 g in ambe bahar. Yield per plant on a 6-year-old plant was 9.5 kg. The length of the fruit varied from 7.24 cm in mrig bahar and 6.84 cm in ambe bahar. The breadth also showed a similar trend: 6.67 cm in mrig bahar and 6.35 cm in ambe bahar. Arils are sweet and light pink. The juice percent varied from 51.72 % in mrig bahar to 50.25 % in ambe bahar. The TSS of the juice was 13.2 °Bx in mrig bahar and 15.2 °Bx in ambe bahar. Acidity was 0.59 % in mrig bahar and 0.46 % in ambe bahar. Seeds were soft, with the softest in ambe bahar (2.24 kg/cm^2 pressure) compared with mrig bahar seeds (2.42 kg/cm^2 pressure). The variety is susceptible to fruit borer (29.53 %), leaf spot (PDI-22.66), and fruit spot (PDI-29.66).



Jalore Seedless



Dholka

5.9.3 Dholka

The Dholka variety is grown in the Dholka area of Gujarat. The growth habit of the tree is spreading type with evergreen nature. The leaf is entire and elliptic in shape. The tree flowers throughout the year, with three main flushes. Fruit is round, smooth, and light green with a reddish tinge. Maximum weight per fruit was 298 g in mrig bahar and 211 g in ambe bahar. The length of the fruit varied from 8.35 cm in mrig bahar to 7.88 cm in ambe bahar. The breadth also showed a similar trend: 8.26 cm in mrig bahar and 7.92 cm in ambe bahar. Arils are sweet and light pink. The juice percent varied from 51.95 % in mrig bahar to 52.53 % in ambe bahar. The TSS of the juice was 16.2 °Bx in mrig bahar and 16.6 °Bx in ambe bahar. The acidity was 0.51 % in mrig bahar and 0.47 % in ambe bahar. Seeds were softest in ambe bahar (1.31 kg/cm^2 pressure) compared with mrig bahar seeds (1.25 kg cm^2 pressure). The variety is susceptible to fruit borer (25.44 %), leaf spot (PDI-18.00), and fruit spot (PDI-25.40).

5.9.4 P-13

The growth habit of the tree is spreading type with evergreen nature. The leaf is entire and elliptic in shape. The tree flowers throughout the year, with three main flushes. Fruit is round, smooth, and yellow with a reddish tinge. Maximum weight per fruit was 233 g in mrig bahar and 217 g in ambe bahar. The length of the fruit varied from 8.21 cm in mrig bahar to 7.84 cm in ambe bahar. The breadth also showed a similar trend: 7.51 cm in mrig bahar and 7.12 cm in ambe bahar. Arils are sweet and light pink. The juice percent varied from 49.52 % in mrig bahar to 53.5 % in ambe bahar. The TSS of the juice was 15.4 °Bx in mrig bahar and 14 °Bx in ambe bahar. Seeds were softest in ambe bahar fruit (1.64 kg/cm^2 pressure) compared with mrig bahar (1.82 kg cm^2 pressure). The variety is susceptible to fruit borer, leaf spot, and fruit spot.

5.9.5 P-16

The growth habit of the P-16 tree is spreading type with evergreen nature. The leaf is entire and elliptic in shape. The tree flowers throughout the year, with three main flushes. Fruit is round, smooth, and pink with a reddish tinge. Maximum weight per fruit was 245 g in mrig bahar and 201 g in ambe bahar. The length of the fruit varied from 8.11 cm in mrig bahar to 7.52 cm in ambe bahar. The breadth also showed a similar trend: 7.89 cm in mrig bahar and 7.35 cm in ambe bahar. Arils are sweet and light pink. The juice varied from 48.92 % in mrig bahar to 52.69 % in ambe bahar. The TSS of the juice was 16.2 °Bx in mrig bahar and 15.8 °Bx in ambe bahar. The acidity was 0.47 % in mrig bahar and 0.38 % in ambe bahar. Seeds were softest in ambe bahar (1.63 kg/cm^2 pressure) compared with mrig bahar seeds (2.14 kg cm^2 pressure). The variety is susceptible to fruit borer (26.97 %), leaf spot (PD-I9.50), and fruit spot (PDI-23.33).

5.9.6 P-23

P-23 is a selection from Muscat. The growth habit of the tree is spreading type with evergreen nature. The leaf is entire and elliptic in shape. The tree flowers throughout the year, with three main flushes. The fruit is round, smooth, and pink with a reddish tinge. Maximum weight per fruit is 260.5 g in mrig bahar and 231 g in ambe bahar. The length of the fruit varied from 8.07 cm in mrig bahar to 7.73 cm in ambe bahar. The breadth also showed a similar trend: 7.94 cm in mrig bahar and 7.62 cm in ambe bahar. Arils are sweet and light pink. The juice percent varied from 49.65 % in mrig bahar to 51.65 % in ambe bahar. The TSS of the juice was 17.2 °Bx in mrig bahar and 16.4 °Bx in ambe bahar. The acidity was 0.49 % in mrig bahar and 0.58 % in ambe bahar. Seeds were softest in ambe bahar (1.92 kg/cm^2 pressure) compared with mrig bahar seeds (2.06 kg cm^2 pressure). The variety is susceptible to fruit borer (34.82 %), leaf spot (PDI-15.5), and fruit spot (PDI-24.00).

5.9.7 P-26

P-26 is also a selection from Muscat. The growth habit of the tree is spreading type with evergreen nature. The leaf is entire and elliptic in shape. The tree flowers throughout the year, with three main flushes. Fruit is round, smooth, and yellow with a reddish tinge. Maximum weight per fruit was 268 g in mrig bahar and 229 g in ambe bahar. The length of the fruit varied from 8.08 cm in mrig bahar to 7.82 cm in ambe bahar. The breadth also showed a similar trend: 7.89 cm in mrig bahar and 7.51 cm in ambe bahar. Arils are sweet and light pink. The juice percent varied from 51.45 % in mrig bahar to 52.69 % in ambe bahar. The TSS of the juice was 14.62 °Bx in mrig bahar and 15.2 °Bx in ambe bahar. The acidity was 0.43 % in mrig bahar and 0.36 % in ambe bahar. Seeds were softest in ambe bahar (1.46 kg/cm^2 pressure) compared with mrig bahar seeds (2.2 kg cm^2 pressure). The variety is susceptible to fruit borer (29.65 %), leaf spot (PDI-11.00), and fruit spot (PDI-20.33).

5.9.8 G-137

The growth habit of the G-137 tree is spreading type with evergreen nature. The leaf is entire and elliptic in shape. The tree flowers throughout the year, with three main flushes. Fruit is round, smooth, and pink with a reddish tinge. Maximum weight per fruit was 270 g in mrig bahar and 232 g in ambe bahar. The length of the fruit varied from 8.41 cm in mrig bahar to 7.83 cm in ambe bahar. The breadth also showed a similar trend: 7.96 cm in mrig bahar and 7.23 cm in ambe bahar. Arils are sweet and light pink. The juice percent varied from 55.23 % in mrig bahar to 54.87 % in ambe bahar. The TSS of the juice was 17.0 °Bx in mrig bahar and 17.4 °Bx in ambe bahar. The acidity was 0.49 % in mrig bahar and 0.42 % in ambe bahar. Seeds were softest in ambe bahar (1.04 kg/cm^2 pressure) compared with mrig bahar seeds (1.27 kg cm^2 pressure). The variety is susceptible to fruit borer (20.42 %), leaf spot (PDI-18.45), and fruit spot (PDI-31.74).

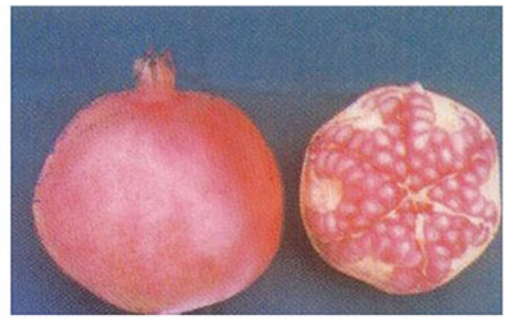
5.9.9 Musket

The growth habit of the musket tree is spreading type with evergreen nature. The leaf is entire and elliptic in shape. The tree flowers throughout the year, with three main flushes. Fruit is round, smooth, and pink with a reddish tinge. Maximum weight per fruit was 310.27 g in mrig bahar and 219.14 g in ambe bahar. The length of the fruit varied from 8.34 cm in mrig bahar to 7.79 cm in ambe bahar. The breadth also showed a similar trend: 8.24 cm in mrig bahar and 7.21 cm in ambe bahar. Arils are sweet and light pink in color. The juice percent varied from 50.33 % in mrig bahar to 49.74 % in ambe bahar. The TSS of the juice was 14.4 °Bx in mrig bahar and 14.8 °Bx in ambe bahar. The acidity was 0.46 % in mrig bahar and 0.39 % in ambe bahar. Seeds were softest in ambe bahar (1.64 kg/cm^2 pressure) compared with mrig bahar seeds (1.82 kg cm^2 pressure). The variety is susceptible to fruit borer, leaf spot, and fruit spot.

5.9.10 Kandhari

The growth habit of the Kandhari tree is spreading type with evergreen nature. The leaf is entire and elliptic in shape. The tree flowers throughout the year, with three main flushes. Fruit is round, smooth, and pink with a reddish tinge. Maximum weight per fruit was 317.63 g in mrig bahar and 190.40 g in ambe bahar. The length of the fruit varied from 8.98 in mrig bahar to 7.24 cm in ambe bahar. The breadth also showed a similar trend: 8.44 cm in mrig bahar and 7.11 cm in ambe bahar. Arils are sweet and light pink in color. The juice percent varied from 52.33 % in mrig bahar to 50.15 % in ambe bahar. The TSS of the juice was 14.8 °Bx in mrig bahar and 14.8 °Bx in ambe bahar. The acidity was 0.41 % in mrig bahar and 0.40 % in ambe bahar. Seeds were softest in ambe bahar (1.26 kg/cm^2 pressure) compared with mrig bahar seeds (1.58 kg cm^2 pressure). The variety is susceptible to fruit borer, leaf spot, and fruit spot.

Kandhari



Kabul

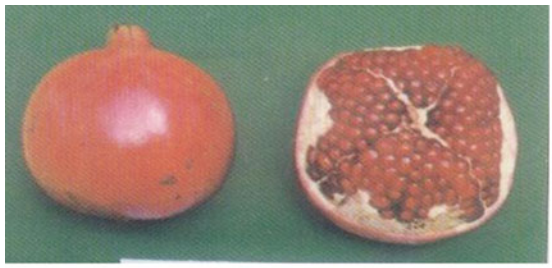
5.9.11 Kabul

The growth habit of the Kabul tree is spreading type with evergreen nature. The leaf is entire and elliptic in shape. The tree flowers throughout the year, with three main flushes. Fruit is round, smooth, and yellow with a reddish tinge. Maximum weight per fruit was 298.18 g in mrig bahar and 193.67 g in ambe bahar. The length of the fruit varied from 8.17 cm in mrig bahar to 6.56 cm in ambe bahar. The breadth also showed a similar trend: 8.3 cm in mrig bahar and 7.03 cm in ambe bahar. Arils are sweet and light pink. The juice percent varied from 48.09 % in mrig bahar to 53.20 % in ambe bahar. The TSS of the juice was 16.2 °Bx in mrig bahar and 17.4 °Bx in ambe bahar. The acidity was 0.55 % in ambe bahar and 0.47 % in mrig bahar. Seeds were softest in ambe bahar (1.66 kg/cm^2 pressure) compared with mrig bahar seeds (1.78 kg cm^2 pressure). The variety is susceptible to fruit borer, leaf spot, and fruit spot.

5.9.12 Mridula

Mridula is a hybrid developed at MPKV Rahuri from the open-pollinated population of F1 from the cross Ganesh × Gul-E-Shah Red. The growth habit of the tree is spreading type with evergreen nature. The leaf is entire and elliptic in shape. The tree flowers throughout the year, with three main flushes. Fruit is round, smooth, and pink with a reddish tinge. Maximum weight per fruit was 252 g in mrig bahar and 244 g in ambe bahar. The length of the fruit varied from 8.94 cm in mrig bahar to 7.21 cm in ambe bahar. The breadth also showed a similar trend: 7.52 cm in mrig

bahar and 7.19 cm in ambe bahar. Arils are sweet and light pink in color. The juice percent varied from 51.79 % in mrig bahar to 50.15 % in ambe bahar. The TSS of the juice was 14.92 °Bx in mrig bahar and 14.8 °Bx in ambe bahar. The acidity was on par in both the seasons, at 0.45 %. Seeds were softest in ambe bahar (1.09 kg/cm^2 pressure) compared with mrig bahar seeds (1.28 kg cm^2 pressure). The variety is susceptible to fruit borer, leaf spot, and fruit spot.



Mridula

Bhagwa

5.9.13 Bhagwa

The Bhagwa variety is known by various names: Shendri, Asthagandh, Mastani, Jai Maharashtra, and red Diana in various parts of Maharashtra. The variety is, to date, the leading variety in Maharashtra state. It is a heavy yielder and possesses fruit characteristics desirable for the domestic as well as the export market, such as an attractive fruit color, dark red arils, and no cracking. The fruits mature late at 180–190 days after fruit set. An average yield is 30–40 kg fruit per tree. The fruit has attractive thick, glossy, saffron-colored skin, and bold dark red arils. The variety is less susceptible to fruit cracking, fruit spot, and thrips. The market price is 2–3 times higher than that gained for other varieties.

5.9.14 Phule Arakta

The Phule Arakta variety is released by MPKV. It is a heavy yielder and suitable for export due to the attractive skin and aril color. Fruits are ready for harvest within 120–130 days.

5.9.15 Alandi

Alandi is a local variety found growing in Maharashtra. A spreading type variety, it produces medium-sized fruits with hard seeds, red arils, and a sweet taste.

5.9.16 Jyoti

Jyoti is a highly promising type previously known as GKVK-1. It is a selection from basin seedless and produces fruits with soft seeds and red aril.

5.9.17 Arka Ruby

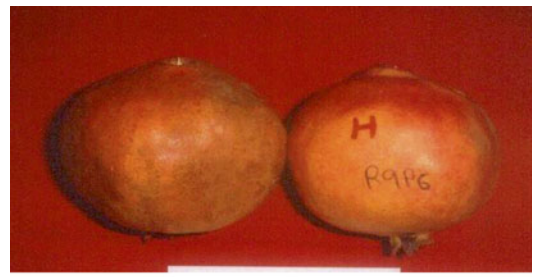
Arka Ruby is a multiple hybrid between Ganesh × Gulsha rose pink. It is released from the IIHR Bangalore. It was developed for its aril color, which is dark red in winter. The seeds are softer. The fruit is small with deep red arils. The variety is a medium yielder.

5.9.18 Amlidana

Amlidana is an F1 hybrid (Ganesh × Nana). It grows well in the tropical climate and has good-quality fruit attributes. Amlidana is superior to the sour Daru variety, whose trees grow naturally in temperate regions of north India. Its fruits provide more acidic (16–18 %) anardana; the fruit yield per tree is higher, and short-statured trees are suitable for high-density planting, resulting in an increased fruit yield per unit area. It is therefore recommended for commercial cultivation (Jalicop et al. 2002).

5.9.19 Goma Khatta

Goma Khatta is an F1 hybrid between Ganesh × Nana cultivar identified for high acidity, high yield and yield of fruits and anardana. Subsequently releasd at Central Horticultural Experiment Station Godhra, Gujarat. The cultivar is suitable for preparation of anardana. Flowering takes in two flushes. A higher number of fruit set per plant than nine other crosses, resulting in higher fruit retention and, in turn, a higher yield. It also has high acid content, an ideal characteristic for making anardana (Table 5.6).



Goma Khatta

Table 5.6 Performance of Bhagwa and Mridula at CHES Vejalpur

Character	Bhagwa Mrig	Bhagwa Hasta	Mridula Mrig	Mridula Hasta	Ganesh
Male flowers	185.6	112	98.6	75	124.2
Hermaphrodite fl.	76.3	46	37.3	31	140
Total flowers	261.9	158	135.9	106	264.2
No. of fruit set	31.6	38.5	26.0	42.8	82.2
No. of fruit retained	27	22.6	21.3	13.6	65.0
% set	36.75	29.13	55.28	29.24	52.99
% retention	85.44	77.58	81.92	31.77	79.07
No. days to maturity	180	200	140	135	130
Fruit wt g	137	180	171	215	195
Length (mm)	64.1	65.4	60.6	69.5	68.7
Dia. (mm)	64.7	66.8	68,8	71.3	70.4
Skin wt. (g)	61	113	68	84.6	58
Aril wt. (g)	77	112	107	139.4	132
Aril color	Dark red	Dark red	Dark red	Dark red	Light pink
TSS °Bx	9.5	14	11.0	13	16
Acidity	0.58	0.47	0.33	0.38	0.32

5.10 Plant Propagation and Nursery Management

The pomegranate is emerging as an important fruit crop for semiarid and arid areas of India. With the identification of superior varieties such as Ganesh, Mridula, Arka Ruby, and Bhagwa, the area under pomegranate is rapidly increasing. Therefore, the demand for elite planting material is also rapidly increasing. Pomegranate has traditionally been propagated vegetatively, either by cutting or air layering. However, modern orchards raised from tissue culture are also very common. Nursery as a business proposition can be as profitable as raising a crop.

Different methods of pomegranate propagation

5.10.1 Seed

Raising of seedlings from seeds either in situ or in a nursery

In situ raising of seedlings is necessary because it helps in the development of strong root systems, creating sturdy plants that can better withstand the vagaries of the monsoon and have a longer life than notified plants. However, the gestation period is higher.

Another method of raising seedlings is by sowing seeds in raised beds at 30 × 30 cm spacing and, once the seedlings are 5–10 cm tall, transplanting them to already filled polythene bags with a mixture of soil, Farm yard manure (FYM), and sand in the ratio of 1:1:1; the use of vermicompost in place of FYM is advocated. The soil should also be drenched with copper fungicides at 3 g/L water to prevent infection with soil-born fungi. Before sowing, the seeds are treated with bacterial culture or vesicular arbuscular mahycorhize (VAM). The method is easy and less expensive, with a high percent of success with a long orchard life. It is currently mostly used for the evaluation of breeding materials and germplasm material obtained from overseas. The disadvantages are a long gestation period, genetic variability in the material, a long dormancy period and very low viability in some seeds. The seeds can be treated with bacterial culture of azotobacter at 30 g/kg seed or with VAM culture to improve germination and rooting.

5.10.2 Cutting

The commercial propagation of pomegranate through cuttings is not as successful as air layering due to unsatisfactory rooting. However, it is still successfully used in humid areas. Although root augmentation through growth regulators like auxin is a dependable option, it is costly.

Semi-hard woodcuttings of young healthy plants from the matured stem with light white streaks on them are more successful. Cuttings approximately 20–25 cm long are removed from the plants and their leaves are immediately removed to control loss of water from the cutting. The cuttings are then wrapped in moist sphagnum moss or newspaper if they are to be transported long distances. However, the percent rooting in these cutting is found to be very low at 20 %. Treating these cuttings with 4-indole-3-butyric acid (IBA) at 2,000 ppm for 15–20 min was found to be useful in increasing percent success to 60 %. The best time for taking a cutting is at the onset of the monsoon. Raised beds at 30 × 30 cm spacing are prepared, and the cutting receives a slanting cut at the bottom; a one-third portion is inserted into the soil to facilitate rooting. Once the seedlings are 5–10 cm tall, they are transplanted to already filled polythene bags with a mixture of soil, FYM, and sand at a ratio of 1:1:1. Vermicompost can be used in place of FYM as it contains a good amount of nutrients. The soil should also be drenched with copper

Table 5.7 Percent rooting of cutting in cultivar Ganesh

Treatment	Cutting rooted (%)	Survival (%)	Auxine (ug/ml)
IBA 200 ppm	53.30	66.82	
Trichoderma harzianum	73.30	76.77	51
Azospirillum brasilense	23.30	74.68	32
Azospirillum lipoferum	36.20	60.07	21
Control	33.33	34.07	–
CD at 5 %	17.57	–	–

fungicides at 3 g/L water to prevent infection by soil-born fungi. Before sowing, the cuttings are treated with bacterial culture or VAM to obtain more roots. Using beneficial microbes is a novel approach to reducing the cost of chemicals and enhancing rooting/survival of the cuttings Liberman (1993). *Agrobacterium rhizogenes* and *Trichoderma harzianum* are known to produce growth regulators that have a beneficial effect on plant growth (Riker et al. 1930). The unique root-initiating ability of these microorganisms may lead to early setting and better rooting, resulting in improved vigor of freshly transplanted material. Percent rooting of cuttings was maximized in cultivar Ganesh in *Trichoderma harzianum-treated* rooting of cuttings. Maximum indole-3-acetic acid (IAA) (51 ug/ml) was also noted in the same treatment Patil et al. (2004) (Table 5.7).

5.10.3 Air Layering

Air layering is one of the most successful methods for large-scale propagation of pomegranate. However, it is time specific, i.e. can be most successful when performed after one or two showers. The success percent is as high as 80 % even under rain-fed conditions. The matured shoots of healthy plants are selected, and a 1.5–2 cm portion of shoot cambium is removed; the cut portion is then covered with sphagnum moss dipped in water or in a solution prepared as below:

Potassium nitrate 0.28 g/L	Calcium nitrate 0.8 g/L
Potassium hypophosphate 0.2 g/L	Magnesium sulphate 0.2 g/L
Ferric tartrate 1 ml of 0.5 % solution	

Vermiwash can also be used as it also has been found to have hormonal and anti-fungal properties. Sphagnum moss can withhold about five times its weight in water and hence can provide a suitable atmosphere for rooting. The moss is then placed on 15 × 15 cm pieces of polythene sheeting, wrapped around the cut portion and tied with sutli at both ends. The air layers root in about 30 days, when they can be removed from the mother plant; their leaves are removed to prevent loss of water and to allow for easy transportation. After removing the polythene sheet, but keeping the moss intact, the layers are planted in polythene bags pre-filled with the soil mixture. Root length and weight was higher in air layers than in cuttings under semiarid rain-fed conditions. The maximum root length was 27 cm with air layering as compared with 12.45 cm in rooted cuttings. Fresh root weight was 1.45 g as compared with 0.513 g in cuttings, indicating greater success in the nursery after detachment of air layers from the plant as compared with cuttings.

Pomegranate air layer

5.10.4 Tissue Culture

Micro propagation is an improved technique that can be used for large-scale propagation of elite plant material under controlled conditions. This technology is increasing in India, and it is becoming an industry with the opening of trade for the export of plant material. This has the potential to be a profitable industry. In pomegranate, protocols have also been standardized for tissue-culturing of the shrub via a shoot tip culture or cotyledon callusing, as follows. Elite material was collected and sterilized with sodium hypochlorite 0.5 % for 5 min, followed by treatment with 0.1 % $HgCl_2$. This was followed by successive rinsing with distilled water and placing the sterilized materials on Murashige and Skoog (MS) media. Murukute et al. (2002) worked on profuse callusing and differentiation of callus into whole plants in pomegranate cultivar Ganesh using leaf segments and cotyledon explants. Cotyledon explants were found to be free from lethal leaching of phenolic compound on MS basal medium fortified with 6-benzyl amino purine (BAP) and naphthalene acetic acid (NAA). Better performance was obtained with a BAP + NAA combination; cotyledon explants responded better than leaf segments. Profuse callusing was obtained in a MS medium with BAP (1.0 mg L^{-1} + NAA 0.5 mg L^{-1}), and good rooting was obtained in a one-half MS + IBA 1.0 mg L^{-1} combination. Direct regeneration of shoots, roots, and whole plant with callusing intervention has also been investigated by Naik et al. (1999). Use of the anther wall (Morgud et al.) and leaf segment (Omula et al.) resulted in the production of only a few seedlings. In somatic embryo genesis (Narayana and Neelambica), there was no scope for screening of variants.

5.10.5 Green House Propagation

High-quality reliable green houses with controlled atmospheric conditions are required to achieve the desired success. Temperature control is most commonly manipulated via mechanical ventilation, along with fog cooling and adequate shading systems. In pomegranate, mist propagation increases success in cuttings to 80 %; however, the cost of establishing a mist chamber is around Rs. 1.5 Lakh.

5.11 Cultural Management

5.11.1 Soil and Climate

Commercial pomegranate orchards are confined mainly to the Mediterranean and semiarid regions of the world. It is a hardy fruit that can be grown successfully, even in low fertile soils. Although high-quality pomegranate can only be grown in locations with a cool winter and a hot dry summer, the trees grow under a wide range of climatic conditions—from the plains to an elevation of about 1,829 m. The tree can withstand frost but is injured by temperatures below 11.1 °C.

The tree is deciduous in areas with low winter temperatures but is evergreen or partially deciduous under tropical and sub-tropical conditions. The tree cannot produce sweet fruits unless temperatures are high for a sufficiently long period. The quality of fruit is adversely affected in humid climates. It is a hardy plant and can withstand a considerable amount of drought but does better when irrigated regularly. It can also flourish well on land that is too wet for many other crops.

The pomegranate can be grown on diverse soil types, including those that are considered unsuitable for most other fruit trees. It can grow quite well in both foothills and at high elevations. It can tolerate soils that are limy and slightly alkaline. The deep loamy or alluvial soils are ideal for its cultivation, though it can be grown in medium or light black soils of minimum depth of 60 cm.

5.11.2 Preparation of Land and Planting

Land selected for cultivation of the pomegranate is ploughed deeply with a furrow turning plough, followed by 3–4 fine tillage, and layout is according to a square or hexagonal system. Planting is in previously dug pits of 1 m^3. The pits should be

filled with two to three baskets of FYM, 250 g of super phosphate, along with red earth and a small quantity of sand mixed thoroughly before the start of the rainy season. Planting should be carried out during monsoon for better and more rapid establishment of the plants. The planting should be spaced 3–6 m apart. In Maharashtra, a spacing of 3–5 m is generally followed, while in south India, a spacing of 2 m is common. However, the trees should be given a spacing of 5–6 m in poor, shallow soils of the Deccan and 6–7 m in the rich alluvial soils of Gujarat and North India.

- *Spacing*: In pomegranate, earlier recommendations were for spacing of 5 × 5 m; however, the mechanization of cultivation and adaptation of drip irrigation has seen the spacing adopted by farmers move to 14 × 14 ft, 12 × 12 ft, 15 × 10 ft, 10 × 10 ft, or 12 × 10 ft.

5.11.3 Bahar/Resting Treatment to Regulate Fruiting

Bahar treatments such as root pruning, root exposure, withholding of water, defoliation of plants by hand or by chemical means, etc. are practiced to induce moisture stress, so the plants drop their leaves and growth can be controlled. The main object of these treatments is to regulate the crop by forcing the tree to rest and profusely flower and fruit during any one of three bahars. The treatment also helps obtain uniform and good-quality fruits with maximum production and a lower incidence of pests and diseases. Normally, only two bahars are practiced in Maharashtra and the Dholka area of Gujarat. The trees shed their leaves, and recommended doses of fertilizers are applied depending on the selection of the bahar; however, a basal dose of FYM, phosphorus, and potash with a one-half dose of nitrogen are applied at the onset of monsoon, and fertilizers are applied.

Allowing a particular bahar or flowering depends on the market rate of fruits, the arrival of produce to the market, water availability to the plants, type of soil, insect pest threat, and weather conditions during the crop growth period. Under tropical south Indian climatic conditions, the pomegranate flowers continuously throughout the year. In central and western India, there are three distinct seasons for flowering: ambe bahar (January–February), mrig bahar (June–July), and hasta bahar (October). Ambe bahar is most commonly practiced by the growers of Maharashtra because of high yield, consequent to profuse flowering as compared with other bahars. However, assured irrigation is a must to utilise this bahar. In mrig bahar there will also be profuse flowering. In Karnataka, flowering is observed in June–October and March. Under north Indian conditions, the trees remain dormant during winter and flower only during spring. During monsoon, a flush of flowers are observed from April to June. Under Delhi conditions, depending on cultivars grown, flowering may be once or twice a year. In Himachal Pradesh, which is a temperate climate, flowering is seen during the middle of April.

For mrig bahar, plant growth must be suppressed during December to April by withholding water. This practice is generally followed in south India. By doing so, the trees shed their leaves in March and remain dormant until May. The land is then ploughed, followed by the application of manures and fertilizers. Plants are irrigated until the rainy season, and the fruits are harvested during October–November. In northwest India, irrigation is withheld from December to May, then regular digging is taken up followed by the application of manures and fertilizers during June along with normal irrigation until the rains start. Plants start growing by June, and fruits are harvested during October–December. Flower and fruit thinning is practiced to encourage good-size fruits. To induce flowering and fruit drop, applications of 2,000 ppm ethephon and 500–3,000 ppm alar have been tried. Fruit-let thinning has also helped in growing good-size fruit. At Rahuri, the fruit size in Muscat pomegranate during ambe bahar progressively increased when the number of fruits per tree was decreased from 70 to 20; the gross income was highest when only 50 fruits were retained per tree. Flowering varied widely during mrig and hasta bahar (Table 5.8).

Table 5.8 Effect of bahar on flowering in pomegranate cultivar Ganesh

	Mrig				Hasta			
	1986	1987	1988	Mean	1986	1987	1988	Mean
No. of hermaphrodite flower	219.5	236.57	301.7	**252.59**	249.6	304.8	284.5	**279.63**
	(28.88)	(12.29)	(28.32)	**(20.21)**	(22.13)	(34.10)	(28.44)	**(27.76)**
No. of staminate flowers	468.57	1,054.71	568.6	**697.29**	788.8	420.4	531.2	**580.13**
	(61.63)	(54 82)	(53.37)	**(55.80)**	(69.95)	(47.03)	(53.11)	**(57.59)**
No. of unopened flowers	72	617.14	195	**294.71**	89.2	168.6	184.5	**147.43**
	(9.47)	(32.08)	(18.30)	**(23.58)**	(7.91)	(18.86)	(18.44)	**(14.64)**
No. of flowers dropped	540.57	1,671.85	763.6	**992.01**	878.0	489.0	715.7	**694.23**
	(71.12)	(86.91)	(69.14)	**(79.38)**	(77.86)	(54.71)	(71.55)	**(68.92)**
Total flowers	760.07	1,923.57	1,065.3	**1,249.6**	1,127.6	893.80	1,000.20	**1,007.2**

Figures in parentheses are percent values

The highest total number of flowers was produced in mrig bahar (1,249.6). Total flower drop was highest (28 %), and maximum hermaphrodite flower production (27.76 %) and reduced flower drops (68.92 %) was observed in hasta bahar, which resulted in higher fruit set and ultimate yield (Raturi and Hiwale 1991).

5.11.4 Fruit Development

In mrig bahar, fruit development in cultivar Ganesh indicated that, after fruit set on the onset of monsoon, it took around 120 days for the fruit to reach maturity. Fruit length and diameter initially increased at a faster rate (up to 60 days) and remained constant. Fruit weight and volume increased constantly until maturity. A similar trend was also observed in hasta bahar crops.

5.12 Irrigation/Drip/Fertigation

Pomegranate is considered to be drought-hardy fruit crop. However, supplemental irrigation is necessary to realize a higher fruit yield and better quality. Irrigation is also used to regulate cropping in pomegranate; the total water applied therefore depends on the crop for a desired bahar. In Gujarat and Maharashtra, where ambe bahar is taken, regular irrigation is required during March to July and irrigation is withdrawn after the fruit harvest until January. For mrig bahar, crop irrigation is not required from July to September. However, in prolonged breaks in the monsoon, one or two supplementary irrigations are required at an interval of 10–15 days during October to December. In hasta bahar (September flowering), the prolonged rainy season helps reduce the requirements for irrigation. Three to four irrigations at monthly intervals after cessation of rainfall are necessary to obtain good fruit size and higher yield (Table 5.9).

Table 5.9 Crop coefficient for different crops

Name/age of tree	1st year	2nd year	3rd year	4th year	5th year
Pomegranate	0.4	0.4	0.6–0.65	0.6–0.65	0.60–0.65
Ber	0.4	0.4	0.6–0.65	0.6–0.65	0.60–0.65
Fig	0.4	0.4	0.6–0.65	0.6–0.65	0.60–0.65
Aonla	0.4	0.4	0.5	0.6	0.65–0.70
K. Lime	0.4	0.4	0.5	0.6	0.70–0.75
Guava	0.4	0.4	0.5	0.6	0.70–0.75

Formula for calculation of quantity of water to be applied per plant per day

$$A \times B \times C \times D \times E$$

A = Evapotranspiration/day × Pan Coefficient (0.7–0.8)
B = Crop Coefficient (From table)
C = Crop Canopy (At 12 noon)
D = Spacing
E = Area wetted = Crop canopy/Spacing (Table 5.10)

Table 5.10 Growth parameters of pomegranate Ganesh

Year	Pl. height (m)	Stem dia. (mm)	Spread (m) NS	Spread (m) EW	No. of fruit set/plant
3rd	1.4	14.1	1.35	1.4	45
4th	1.76	17.9	1.58	1.7	75
5th	2.36	36.4	2.35	2.2	120
6th	3.03	48.4	2.8	2.7	80

5.12.1 Quantity of Water to Be Applied Per Plant Per Day in Pomegranate Cultivar Ganesh

In case of flood irrigation during winter, irrigation should be conducted at an interval of 12–15 days, and during summer at an interval of 5–7 days depending on the bahar. However, with the modern limited water availability, drip irrigation/fertigation is becoming popular. According to one estimate, this method leads to a 98 % increase in production, with water savings to the tune of 45 %. The total area brought under drip in Maharashtra is around 27,217.39 ha (10.26 %).

5.12.2 Mulching and Drip Irrigation in Pomegranate Cultivar Jyothi

Drip irrigation and mulching maximizes water use efficiency of pomegranate. Total flower and hermaphrodite flower numbers were significantly higher at 0.70 E.pan and 200 gauge polyethylene mulch. The ratio of hermaphrodite to staminate flowers was maximum (2.54) in the interaction of three emitters per plant at 0.70 E.pan irrigation with 400 gauge polyethylene. Fruit set (56.39 and 51.94) and fruit per plant (55.36 and 45.89) were significantly higher with 0.70 E.pan replenishment with 400 gauge black polyethylene mulch, respectively Jagannath et al. (1999).

5.13 Fertigation in Pomegranate

Application of fertilizers through drip is gaining importance because of the following reasons:

- Reductions in the application costs of fertilizers, along with water.
- Balanced application of fertilizers based on the needs of the plant.
- The fertilizers are applied near the active root zone of the plant, which helps absorption by the roots.
- High fertilizer use efficiency can be achieved.
- Savings in the total quantity of fertilizer applied.
- Fertilizers are applied based on the stage of the crop.

5.13.1 New Growth, Flowering

For uniform and profuse flowering, phosphorus should be applied 3-4 times more than nitrogen, quantity of potash applied is lowered. In the beginning, to achieve uniform growth 20:20:20 fertilizer should be applied. Therefore, after shoot growth until fruit set, the ratio of fertilizer applied should be either 12:61:0 or 13:40:13.

5.13.2 Fruit Set and Development

To retain a higher number of leaves on the plant to ensure that maximum photosynthetic activity takes place during fruit development, the ratio of NPK (nitrogen, phosphorus, potassium) should be 2:1:3 (e.g. 16:8:24 or 13:5:26). Demand for calcium is increased at this stage; therefore, calcium nitrate should be applied via drip. This will help reduce fruit cracking and improve fruit size (Tables 5.11 and 5.12).

At MPKV Rahuri, fertilizers were applied via conventional methods and via drip. The study revealed that the yield obtained (11.88 t/ha) with the 100 % NPK recommended dose of solid soluble fertilizers via drip was significantly superior over the 100 % recommended dose of conventional fertilizer and was on par with 70 % nitrogen, 80 % phosphorus and potassium, and 70 % NPK. Thus, the maximum fertilizer saving (N, P, and K) was 30 % each compared with conventional fertilizer. The yield-contributing parameters were significantly influenced by different

Table 5.11 Application of liquid fertilizers

Liquid fertilizer	Total fertilizer required (kg/acre)	Weekly dose applied (kg/week/acre)	Time of application
20:20:20 + urea	10 + 10	10 + 10	First irrigation
20:20:20 + 12:61:0 + urea	15 + 50 + 22	3 + 10 + 4.40	6–25 days (5 weeks)
13:40: 13 + 16:8:24	50 + 25	10 + 5 (5 weeks)	36–70 days (weeks)
13.00:45	50	12.50 (4 weeks)	71–98 days (4 weeks)
00:00:50	50	10	91–133 days (5 weeks)
06:12:36	25	12.50	After 134 days

levels of solid soluble fertilizer over conventional applications. Fertigation levels did not significantly influence the juice quality and organoleptic evaluation for color and taste Firke and Kumbhar (2002) (Table 5.13).

Prasad and Bankar (2003) reported that fruits become ready for harvesting 4–5 months after fruit setting. They are harvested when their rind color turns yellow and pink to red. Fruits give a 'crunch' sound when pressed. Thus, a yield of 60–100 fruits per tree may be obtained. The right time for fruit picking is from the first week of December to the end of February. On average, 25–30 kg of fruit per plant may be harvested under arid conditions.

Table 5.12 Yield and yield-contributing parameters of pomegranate

Treatment	Fruit no. /tree	Fruit wt. (g)	Fruit size (cm)	100 aril wt. (g)	Yield (t/ha)	Water use efficiency (kg/ha/mm)
Conventional fertilizers						
T1 (100 % RDCF + SL)	73.45	191.0	7.00	31.27	8.71	7.71
T2 (100 % RDCF + DI)	76.50	200.0	7.46	33.60	9.54	12.08
T3 (100 % RDCF, N drip)	80.25	209.0	7.72	36.77	10.36	13.12
Solid soluble fertilizers						
T4 (100 % NPK + DI)	84.80	226.0	8.22	42.95	11.88	15.05
T5 (70 % N, 80 % P & K + DI)	82.60	220.0	8.10	40.20	11.27	14.28
T6 (70 % NPK + DI)	81.50	212.0	7.85	37.87	10.81	13.70
T7 (50 % N, 80 % P & K + DI)	75.15	145.0	7.23	33.40	9.14	11.58
T8 (50 % N, 70 % P & K + DI)	75.25	191.0	7.81	32.75	8.90	11.27
C. D. at 5 %	6.21	0.02	0.57	4.20	1.12	–

Table 5.13 Effect of drip irrigation on yield and quality of fruits

Treatment (L/h)	Juice (%)	Cracking (%)	Fruit weight (g)	TSS °Bx	Yield (kg/plant)
4	46.3	25.8	204.9	18.0	18.8
8	53.6	18.9	319.4	18.4	28.2
12	53.0	18.6	314.7	17.4	30.1
Control	44.4	30.1	160.2	19.3	17.7

5.13.3 Fruit Ripening

At the fruit ripening stage, the requirement for potash is higher than that for nitrogen and phosphorus, therefore 0:0:50 + 18 % sulphur is applied. However, light soils deficient in nitrogen are fertilized with 13:0:45 grade fertilizer. After the initial harvest of big fruit, a second dose of fertilizer is applied to increase development in under-developed fruits through 6:12:36 grade fertilizer.

5.14 Manures and Fertilizers

Although pomegranate grows well in soils of low fertility, production can be increased with the application of manures and fertilizers. Initial soil analysis is desirable for proper scheduling of fertilizer. The nutrition recommendation depends on fertility of the soil and also the age of the plant. For young plants (2–3 months old), application of 200 g Neem cake along with 3–4 kg FYM per plant is recommended. After 3 months, each plant may be given 250 g di ammonium phosphate (DAP), along with 250 g Neem cake and 5 kg FYM. Again, after 9 months, application of 500 g DAP, 250 g potassium sulphate, 1 kg Neem cake, and 10 kg of FYM per plant is recommended.

The first harvest is desirable when the plant is around 12–16 months old. There are three distinct periods of fruiting for the pomegranate, called 'bahars'. Before each bahar, the plant needs 1–1.5 months of rest. During this time, the nitrogen level in the soil should be low. Once the fruits are harvested, the plants must be supplied with a first dose of fertilizers along with a fungicide and insecticide spray. The recommended dose of fertilizer per plant is 20 kg of FYM, 1 kg (7:10:5), 1 kg DAP, 1 kg Neem cake, 100 g magnesium sulphate, and 10 kg of borax. The plant is given 1–1.5 months of rest. After this period, apply 250 g ammonium sulphate along with 250 g of 19:19:19, 500 g 7:10:5, 500 g Neem cake, and 500 g muriate of potash per plant. When the plants are 4–5 years old, the fertilizer dose should be increased 1.5 times. In general, a basal dose of about 25–35 cartloads of FYM per hectare, besides the recommended dose of NPK, must be applied during January, June, and September in equal proportions. From 4 to 5 years onwards, nitrogen should be applied in two split doses: the first during irrigation after bahar treatment, and the second after 3 weeks. The full dose of phosphorus and potassium should be applied as a single dose. The requirement for chemical fertilizers also varies from place to place. In Gujarat, recommendations are for 375 g nitrogen, 375 g phosphorus, and 375 g potassium per tree per year. Under Udaipur conditions, recommendations are that a 4-year-old tree needs 720 g nitrogen, 200 g phosphorus, and 220 g potassium per year. Under Yercaud conditions, recommendations are that young plants are started with 50 g nitrogen, 200 g phosphorus, 100 g potassium, and that, as the plant becomes old, the dose should be increased to 125 g nitrogen, 1,000 g phosphorus, and 500 g potassium. Under Jodhpur conditions, 700 g nitrogen per plant is ideal for 10-year-old Jalor seedless plants.

Under Rahuri conditions, plants that are 1.5–2 years old need 250 g nitrogen, 125 g phosphorus, and 125 g potassium; plants aged 2.5–3 years need 500 g nitrogen, 125 g phosphorus, and 125 g potassium; those aged 4.5–5 years need 500 g nitrogen, 250 g phosphorus, and 250 g potassium; and plants aged 6–7 years need 625 g nitrogen, 250 g phosphorus, and 250 g potassium (Tables 5.14, 5.15, and 5.16).

At IIHR Bangalore, the application of 500 g nitrogen + 250 g phosphorus + 125 g potassium per plant per year to the Bassein seedless variety of pomegranate gave the highest yield: 8.2 kg of fruit from a 3-year-old plant (first crop). Application of 500 g nitrogen, 250 g phosphorus, and 250 g potassium per plant per year to cultivar Ganesh gave the highest yield of 78.67 kg (50 fruits per plant) during the fourth year of cropping.

Based on the survey, it is recommended that combined foliar application of 0.3 % zinc sulphate and 0.1 % boron at pre-bloom, bloom, and post-bloom stages should be conducted to augment the deficiency of these nutrients. Soil application can also be carried out by incorporating boron (10 ppm) and zinc (50 ppm) in compost 3

Table 5.14 Critical levels of pomegranate leaf composition

Nutrient	Concentration (%)	Sr. no.	Nutrient	Concentration (%)
Nitrogen	2.5	6	Sulphur	0.18
Phosphorus	0.2	7	Iron (ppm)	95
Potash	1.47	8	Manganese (ppm)	45
Calcium	1.30	9	Zinc (ppm)	22
Magnesium	0.70	10	Boron (ppm)	30

Table 5.15 Pomegranate orchard survey in Maharashtra soil characteristic (mean six orchards)

Place	P^H	E.C. (dsm^1)	Org. carbon	K (ppm)	Zn (ppm)	Mn (ppm)	Cu (ppm)	Fe (ppm)	B (ppm)
Pune	8.05	0.81	0.53	174	0.51	8.83	0.25	6.42	0.47
Solapur	8.35	1.42	0.24	189	0.46	8.13	0.36	5.3	0.48

Sharma and Hiwale (2005)

Table 5.16 Leaf composition (mean of six orchards)

	Zn (ppm)	Mn (ppm)	Fe (ppm)	K (%)		B (ppm)
Place	Young leaf	Young leaf	Young leaf	Old leaf	Mg (ppm)	Young leaf
Pune	12.33	73.5	161.0	0.79	0.32	22.0
Solapur	12.00	44.66	99.33	0.59	0.31	27.0

Sharma and Hiwale (2005)

months before its application. Though the soils are rich in calcium, fruit cracking may be due to a combined deficiency of calcium and boron. Hence, two sprays of calcium chloride at 0.5 % and boric acid at 0.1 % is recommended at 15-day intervals to avoid cracking.

Commercial micronutrient formulations are used to increase fruit growth, yield, and quality. Two sprays of 0.33 % Macroliq proved to be the best, followed by 1 % Macroliq. Soil application of 12.5 g boron and 45 g zinc sulphate per tree per year gave fruits with higher sugar content. Application of three sprays of ferrous sulphate (0.4 %) + manganese sulphate (0.3 %) + boric acid (0.2 %) along with zinc sulphate (0.3 %) at monthly intervals before flowering, at full bloom and at fruit set stage increased tree growth, yield, and fruit quality in cultivar Ganesh.

5.14.1 Organic and Inorganic Fertilizers

An investigation carried out on pomegranate cultivar Ganesh regarding the suitability of bahar under rain-fed semiarid conditions revealed that hasta bahar was the best. Organic farming is increasing in importance in India, with rising threats to food security and natural resources. Indiscriminate use of chemical fertilizers, pesticides, and weedicides has adversely affected soil fertility, productivity, and produce quality. Soil and water pollution with heavy metals released by fertilizers and pesticides have resulted in health hazards. The organic farming system relies on crop rotation, crop residues, animal manures, and legumes in an intercropping system, and green manure organic cakes as byproducts of plants. A trial was conducted at Central Horticultural Experiment Station (CHES) Vejalpur, with the objective of reducing the use of chemical fertilizers and increasing the use of organic fertilizers without compromising the production potential of the pomegranate. In the study, a six-treatment combination of organic and inorganic fertilizers, along with the recommended doses for semiarid regions, was applied at the onset of monsoon in the 4th and 5th years of plant growth in cultivar Ganesh. Leaf sampling was conducted via the collection of the 8th pair of leaves from the growing tip as suggested by Bhargava and Dhandhar (1987).

Fruit retention and yield per plant were significantly influenced by various treatments. Maximum fruit set (96.50 fruits per plant), fruit retention (57 fruits per plant), and yield (10.75 kg per plant) were recorded in treatment application of nitrogen 50 % through FYM, 25 % through castor cake, and urea. Similar results were reported by Shinde (1977). Phadnis (1974) also recommended mixed doses of organic and inorganic fertilizers to obtain maximum fruiting and yield. Wavhal et al. (1985) also recommended the application of nitrogen along with *azotobacter* for obtaining higher production in pomegranate cultivar Ganesh.

Fruit weight and fruit length (but not fruit diameter) were significantly influenced by all the treatments, and TSS by various treatments. Fruit weight (188.75 g), fruit length (69.72 mm), fruit diameter (66.15 mm), and TSS (16.90 °Bx) were highest with the application of nitrogen 50 % through FYM and 25 % through castor cake and urea. Bankar et al. (1990) reported that increased doses of nitrogen did not affect fruit size and TSS in pomegranate.

Nutrient analysis of leaf samples collected (8th leaf pair from tip used as indicator tissue for all analysis) 1 month after fertilizer application showed significant influence in respect of nitrogen and potassium. No significant differences in respect of phosphorus content in various treatments were observed. Maximum leaf nitrogen content (3.15 %) was observed in full nitrogen application through urea. Maximum phosphorus (0.14 %) and potassium (0.74 ppm) content was observed in treatment application of nitrogen through FYM, 50 % and 25 % through castor cake and urea. Similar results are reported by Wavhal (1981). Oil cakes, though insoluble in water, are quick-acting organic manures; their nitrogen quickly becomes available to plants in about a week to 10 days (Guar et al. 1971) (Table 5.17).

5.14.2 Biofertilizers

Biofertilizers are preparations containing live or latent cells of efficient strains of nitrogen fixing, phosphate solubilizing, or cellulolytic microorganisms used for application to seed, soil, or compost with the objective of increasing the number of such organisms, in order to accelerate the process of nutrient availability to the plant. They are very efficient, even when applied in small quantities. Careless management of orchards and the ruthless use of chemicals have

Table 5.17 Effect of organic and inorganic source of nitrogen application on fruit and nutrient composition of pomegranate cultivar Ganesh

Treatment	Fruit wt. (g)	Fruit length (mm)	Fruit dia. (mm)	TSS °Bx	N (%)	P (%)	K (ppm)	Fruits retained/plant	Yield (kg)/plant
100 % FYM	179.0	65.7	62.5	16.2	2.74	0.13	0.69	46	8.23
100 % Castor cake	178.5	63.6	63.5	16.3	2.93	0.13	0.68	46	8.20
50 % FYM + 50 % castor cake	185.2	65.7	63.2	16.3	2.82	0.12	0.73	48	8.84
50 % FYM + 50 % castor cake	188.7	69.7	66.1	16.9	2.95	0.14	0.74	57	10.75
50 % FYM + 50 % urea	175.5	64.1	62.9	16.3	3.02	0.11	0.74	46	8.11
100 % urea	169.7	60.4	60.9	16.0	3.15	0.11	0.66	33	5.80
CD at 5 %	8.21	3.81	NS	NS	0.21	NS	0.07	12.05	2.19

Hiwale (2004)

Table 5.18 Effect of bio-fertilizers on yield and yield attributes of pomegranate cultivar Ganesh

Treatment	No. fruit set/pl.	No. fruit retained/pl.	Fruit yield kg/pl.	N (%)	P (%)	K (%)
PSB culture	123.50	73.50	8.37	2.88	0.156	0.68
Azospirillum	144.75	83.00	8.29	2.67	0.177	0.71
PSB + azospirillum	135.50	78.25	11.08	2.92	0.178	0.84
VAM culture	136.50	79.80	8.56	2.79	0.173	0.76
Control	72.50	51.00	7.16	2.52	0.121	0.70
CD at 5 %	34.77	14.18	0.872	NS	0.017	0.06

Hiwale (2004)

Table 5.19 Effect of bio-fertilizer application on quality of pomegranate cultivar Ganesh

Treatment	Fruit wt. (g)	Dia. (mm)	Length (mm)	Aril wt. (g)	Skin wt. (g)	Juice (%)	TSS
PSB culture	201.25	67.62	76.41	136.75	62.50	72.57	15.17
Azospirillum	173.75	67.27	74.75	106.25	53.25	73.89	14.65
PSB + azospirillum	213.00	70.12	78.87	137.37	66.62	74.62	16.05
VAM culture	188.75	98.02	72.75	117.00	58.12	73.29	15.86
Control	153.25	67.50	68.75	95.12	43.87	74.46	15.43
CD at 5 %	24.97	NS	NS	24.30	6.59	NS	0.86

Hiwale (2004)

already shown deleterious effects on pomegranate crop performance in Andhra Pradesh, Karnataka, and Maharashtra. Excessive fertilization and water application has led the orchards to succumb to pests and diseases, and soil health is also spoiled. Unless and until balanced management is practiced, it will not be possible to save these orchards. Organic fertilizers play a significant role in maintaining the sustainability of the soil and improving soil physico-chemical properties and micro-fauna activity. Therefore, an experiment was carried out with different bio-fertilizers to investigate their effect on sustainability and productivity of the pomegranate cultivar Ganesh.

Biofertilizers had no influence on the vegetative parameters of the pomegranate. Azospirillum at 100 g per plant resulted in a higher leaf nitrogen content as well as higher fruit set and retention; however, fruit weight and fruit size and yield was maximized with the combined application of phosphorus solubilizing bacteria (PSB) + azospirillum at 50 g per plant. Use of biofertilizers such as azotobacter has reduced the requirement for fertilizers. Application of 250 g azotobacter culture with 100 g nitrogen has provided the same effect as application of 300 g nitrogen per plant, i.e. saves 200 g nitrogen per plant. Nutrient analysis of leaf samples collected 1 month after fertilizer application showed a significant influence in terms of phosphorus and potassium, but no significant differences in respect of nitrogen content in various treatments (Tables 5.18 and 5.19).

Maximum leaf nitrogen content (2.92 %) was observed in azospirillum. Maximum phosphorus (0.178 %) and potassium (0.84 %) content were observed in treatment application of 50 g azospirillum + PSB culture, which may be due to solubilization of phosphorus by the bacteria, leading to higher uptake. Oil cakes, though insoluble in water, are quick-acting organic manures; their nitrogen is quickly available to plants in about a week to 10 days (Guar et al. 1971).

Maximum fruit set (144.75 fruits per plant) and fruit retention (83 fruits per plant) was recorded in azospirillum 100 g per plant and yield (11.08 kg per plant) in 50 g azospirillum + PSB culture (Table 5.8). Phadnis (1974) also recommended mixed doses of organic and inorganic fertilizers to obtain maximum fruiting and yield. Wavhal et al. (1985) also recommended

the application of nitrogen along with azotobacter to obtain higher production in pomegranate cultivar Ganesh. Shinde (1977) reported similar results.

Fruit weight, aril weight, skin weight, and TSS were significantly influenced by all biofertilizers. Fruit weight (213 g), fruit length (78.87 mm), fruit diameter (70.12 mm), and TSS (16.05 °Bx) were highest with treatment application of 50 g azospirillum + PSB culture (Table 5.19), which may be due to the beneficial effect of phosphorus solubilizers with nitrogen fixers. Bankar and Prasad (1992) reported that increases in doses of nitrogen did not affect fruit size and TSS in the pomegranate. Ram and Rajput (2000) observed a good response to azotobacter in guava under Uttar Pradesh conditions. Day et al. (2005) reported a beneficial effect from phosphorus solubilizers with nitrogen fixers in guava L-49.

The application of biofertilizers influenced nitrogen content: maximum nitrogen content (2.92 %) was recorded with the combined application of PSB with azospirillum. Similarly, maximum phosphorus (0.178 %) and potassium content (0.84 %) was recorded in the same treatment. Leaf sampling was conducted by collecting the 8th pair of leaves from the growing tip as suggested by Bhargava and Dhandhar (1987). Plant material (20 g) was ground in a mixture grinder, and a 1 g sample was taken for nitrogen, phosphorus, and potassium analysis from the oven-dried leaf samples.

5.15 High-Density Orcharding

India is the second-largest producer of pomegranate (41.5million tons) in the world. However, the productivity of almost all fruits in India is very low (12 t/ha) compared with other fruit-growing countries of the world. This is a major cause of concern to our scientists, extension personnel, and orchardists. Many reasons may be attributed to the low productivity, and, to solve this problem, our scientists must develop high-yielding varieties/hybrids that are resistant to biotic and abiotic stresses and develop better agro-techniques for realizing the maximum potential of fruit cultivation in India. Although we have achieved this distinction, the per capita consumption of fruit in our country is still 80 g per day due to our huge population. This is far below the recommendation of 120 g per capita per day. There is little scope to convert the existing area to fruit cultivation because our first requirement is to have sufficient food. Therefore, the major area for expansion will be marginal degraded arid and semiarid land. Drought-hardy fruit plants that can withstand biotic and abiotic stresses and salinity will play a major role, as they can be grown on these lands successfully.

High-density orcharding results in early bearing, helping to minimize weed problems. However, the productive life of an orchard is reduced due to dense canopies that do not allow sunlight penetration, resulting in gradual decline. This problem can be overcome by removing plants in alternate rows. Other methods that can be used to overcome this problem include training and selective pruning. The productivity of almost all fruits in India is lower than in other fruit-growing countries of the world. To overcome this problem, pomegranate high-density orcharding in cultivar Ganesh has been standardized under Maharashtra conditions. To obtain higher production per unit area, a maximum number of plants were accommodated per hectare. High-density plantation at 5 × 2.2 m under semiarid conditions resulted in a 2.5 times higher yield than did the normal spacing of 5 × 5 m in a 6- to 7-year-old orchard.

	Yield q/ha.	
Spacing (m)	1981	1982
5 × 2	66.65	85.69
5 × 3	49.76	61.96
5 × 4	36.30	36.35
5 × 5	27.46	36.64
CD at 5 %	11.15	25.27

5.16 Canopy Management

Manipulation of tree vigor and the maximum utilization of sunlight results in increased productivity and quality. The basic principle of canopy

management is maximum utilization of light. Avoiding the growth of a microclimate conducive to diseases and pests helps in cultivation operations. Furthermore, the inter space can be utilized for raising annuals as intercrops.

5.16.1 Training

The pomegranate plant is bushy in nature and throws a considerable number of shoots near ground level. Retaining all these shoots at the base increases the crowding of the tree frame and the incidence of shoot borers and diseases. Considering these factors, keeping three to four stems from the base was found to be satisfactory for maintaining good productivity as well as proper health of the plant.

Training is done only to give shape to the tree. At the time of planting, all the side shoots are removed. Young plants are allowed to grow into a bush with a number of main shoots arising at the ground level. Then, they are properly trained to form a single stem with a number of well-distributed scaffold limbs. The plant is topped at a height of 60–70 cm, and the side shoots (4 to 6 in number, well distributed along the main stem) are allowed to arise from about 40–50 cm from ground level. As and when the plant becomes too thick, very low branches are thinned out and removed. Trellises provide support to the branches to avoid the breaking of branches. Training is done systematically during the initial 3–4 years of plant growth. This helps ensure plants are uniform in the orchard. After 3–4 years of age, plant growth is tremendous. Therefore, training is necessary to control growth, avoid criss-crossing of twigs, and to allow air and light to the canopy. Sometimes non-bearing twigs and water shoots, along with dried and diseased twigs, must be pruned. If pruning is not carried out manually, it can be achieved by applying 1,000 ppm spray of Lihosin once, 2,3,5-triiodobenzoic acid (TIBA) 500 ppm twice, or maleic hydrazide 500 ppm twice. These sprays can reduce plant growth and does the job of pruning.

5.16.2 Pruning

Farmers in Maharashtra have adopted manual as well as chemical pruning to rest the plant and subsequently initiate bahar. Even though no regular pruning is recommended, it has recently been practiced by some farmers to improve fruit size. Pomegranate fruiting occurs on 1-year-old spur. Fruit that set on the terminal branches do not attain a good size. To avoid this, the terminal branches are pruned (15–20 cm).

Systematic work on this aspect was initiated at CHES Vejalpur, where manual pruning was carried out. Pruning in pomegranate was attempted to initiate new growth on 5-year-old plants. The plants were pruned in the second half of May. Two types of pruning were attempted: (1) heavy (removing 5–7 kg of fresh weight per plant; and (2) light (removing 2–3 kg of fresh wood per plant). Under rain-fed conditions, sprouting started 3–4 weeks after pruning. However, the subsequent flowering was delayed.

The mean fresh and dry weight of biomass removed in heavy pruning per plant was 5.67 and 2.92 kg per plant, respectively, and 2.90 and 1.65 kg per plant in light pruning. New shoot growth, as evidenced by an increase in shoot length, diameter, fresh and dry weight revealed that heavy pruning resulted in higher shoot growth than did light pruning and control (no pruning). Similar trends were also recorded in leaf growth (Tables 5.20 and 5.21).

Although fruit set was significantly higher in controls (no pruning), fruit retention was higher with heavy pruning, ultimately giving a higher yield per plant. There was an increase of about 7.36 q/ha (16.95 %) in yield, giving an additional income of Rs. 3,680/ha at Rs 500/q. Similarly, fruit weight and fruit diameter showed significant increases, which may have resulted in increased yield per plant.

In pruning of pomegranate cultivar Ganesh plants, subsequent growth started 1 month later. Leaves and shoots were sampled for the 4th and 5th month. The percent NPK content in shoot and leaf revealed that leaves had higher nitrogen but there was not much difference in terms of phos-

Table 5.20 Effect of pruning on new growth (fresh and dry weight of shoot)

	Shoot fresh wt. (g)		Shoot dry wt. (g)		Shoot length (cm)		Shoot dia. (mm)		Pruned wood/plant	
Treat.	4/10	22/11	4/10	22/11	4/10	22/11	4/10	22/11	Fresh Wt. (kg)	Dry wt. (kg)
Heavy pruning	6.37	10.04	3.16	4.75	66.33	70.83	4.51	4.98	5.67	2.90
Light pruning	4.51	6.57	2.14	3.23	56.16	60.66	3.76	4.28	2.90	1.65
Control	1.58	2.49	0.70	1.22	26.83	30.5	2.42	2.95	–	–
CD at 5 %	0.51	0.73	0.29	0.47	8.50	9.04	0.26	0.23	–	–

Table 5.21 Effect of pruning on new growth and nutrient composition

	Leaf fresh wt. (g)		Leaf dry wt. (g)		N (%)		P (%)		K (%)	
Treatment	4/10	22/11	4/10	4/10	4/10	22/11	4/10	22/11	4/10	22/11
Heavy pruning	8.78	11.27	4.07	4.61	2.94	2.42	0.18	0.13	0.850	0.712
Light pruning	6.12	8.21	2.70	4.02	2.91	1.52	0.16	0.13	0.698	0.66
Control	2.39	4.87	1.16	0.98	2.58	1.81	0.14	0.18	0.782	0.84
CD at 5 %	1.02	0.68	0.53	0.72	–	–	–	–	–	–

Table 5.22 Effect of pruning on yield and yield parameters

Treatment	Fruit set no.	Fruit retention no./plant	% retention	Yield kg/ plant	Yield q/ha	Fruit wt (g)	Fruit length (mm)	Fruit dia. (mm)
Heavy pruning	67.8	52.0	85.54	12.7	50.0	169.33	65.21	71.33
Light pruning	75.7	63.5	88.75	10.4	41.6	158.33	58.88	61.05
Control	114.5	54.3	68.39	10.86	43.4	147.00	57.98	63.05
CD at 5 %	20.3	6.8	06.16	–	–	14.45	NS	7.72

Table 5.23 Effect of pruning on NPK content of shoot

	N (%)		P (%)		K (%)	
Treatment	4/10	22/11	4/10	22/11	4/10	22/11
Heavy pruning	1.97	1.06	0.18	0.11	0.894	0.95
Light pruning	1.52	1.48	0.14	0.11	0.764	0.97
Control	1.81	1.52	0.18	0.13	0.834	0.77

phorus and potassium content. The NPK content in both leaf and shoot decreased just before initiation of flowering, probably due to diversion of nutrition, which may explain why the nitrogen and phosphorous was reduced but potassium content increased. Nitrogen content was higher in heavily pruned shoots in both leaf and in new growth, and it was least in control (Tables 5.22 and 5.23).

5.16.3 Fruit Thinning

Fruit thinning is a tool that horticulturists can use to reduce the burden of the plant and avoid the use of stored food material at one time. The sink source relationship plays an important role in managing the crop load. Fruit thinning helps in maintaining the sustainability of production over the years, particularly in fruit trees with a long

life span. By reducing the number of fruit, the crop load can be evenly distributed all over the plant, thereby avoiding the breaking of branches and improving the exposure of fruits to sunlight, which helps improve fruit development.

Therefore, work was initiated at CHES Vejalpur under semiarid rain-fed conditions. Fruit weight showed maximum increase over control (79.92 %) when 25 fruits per plant were retained; this decreased to 69.08 % with 50 fruit, and 41.60 % with 75 fruits per plant. However, there was no change in percent juice content and acidity of fruits. TSS content was maximized when a lower number of fruits per tree were retained (17.08 °Bx), showing a decreasing trend as the number of fruits per plant increased. It was observed that keeping 75 fruits per plant produced the maximum yield per plant (11.41 kg) compared with control (10.24 kg). However, thinning to 25 fruits resulted in a yield reduction by 54.98, and thinning to 50 fruits resulted in a yield reduction to 12.56 %. Fruit thinning produced good size 'B' grade fruit, fetching higher market prices. Overall, keeping 50 fruits per plant was found to be an economically viable preposition for farmers as the economic returns were highest (Rs. 10,670/-) compared with control (Rs. 4,692/-), Hiwale (2009) (Table 5.24).

Rate of sale according to grade:	*Cost of cultivation* – Rs. 3,500/-,
B grade- Rs. 5/kg- 400/q,	*Cost of thinning*– 3 labor /ha @Rs. 50 = Rs. 150/-
C grade- Rs. 3/kg- 300/q,	*Small fruits* – Rs. 2/kg- 200/q.

5.17 Rejuvenation of Pomegranate Orchards

Old orchards become non-productive due to the incidence of pests, diseases, and neglect. It is a general tendency of farmers in India to neglect such orchards. In pomegranates, when the survey was conducted, it was observed that 25 % of the old orchards became unproductive due to loss of vigor in the plant, a heavy incidence of pests and diseases and a deepening of the water table. There is still scope to review production from these orchards through intensive care. Rejuvenation can be achieved via mechanical measures, chemical measures, and by training and pruning of plants. Work carried out on non-selective pruning at CHES Vejalpur has shown encouraging results. A 15-year-old orchard that was showing signs of decline, mainly due to drying of old branches, resulting in sparse flowering and fruiting, was used for the study. To overcome the situation, non-selective pruning of the orchard was undertaken. The plants were headed back to 30, 60, 90, and 120 cm above ground level in the month of April; plants that were not pruned acted as controls. The cut ends were sprayed with chlorpyriphos 3 ml/L with bavistin 1 g/L to control the incidence of termites and various other pests and diseases. New sprouts emerged 20–25 days after pruning. The number of new sprouts per plant was reduced to 8–10 by allowing two to three healthy sprouts per branch to balance the framework of the plant. Upon onset of monsoon,

Table 5.24 Effect of thinning of fruit on yield and physico-chemical characteristics of pomegranate cultivar Ganesh

Thinning	Yield/ plant (kg)	Fruit wt. (g)	Fruit length (mm)	Fruit dia. (mm)	Aril skin ratio	Juice (%)	TSS °Bx	Acidity (%)	Yield (q/ha)	Gross income (Rs.)	Net return (Rs.)
25 fruit	4.61	197.74	66.26	65.86	1.66	74	17.08	1.82	18.44	7,336	3,726
50 fruit	8.95	185.82	63.22	61.89	1.77	73	16.16	1.84	35.80	14,320	10,670
75 fruit	11.41	155.62	61.74	60.02	1.87	73	16.0	1.79	45.64	13,692	10,042
Control	10.24	109.9	56.16	56.82	2.32	72	15.8	1.82	40.96	8,192	4,692
CD at 5 %	0.474	10.59	2.11	N.S.	0.01	NS	0.080	NS	–	–	–

Hiwale (2009)

the growth of the plant increased, and after 1 year the plant height was on a par with that of control plants. In due course, the plant growth slowed down due to diversification of food material to flowering and fruiting. Mean shoot diameter also increased at a faster pace after the initial setback. Plant spread was almost equal to that of the controls after 3 years of growth, i.e. non-significant differences were recorded in various treatments.

The fruit set in the initial year was reduced in the first year of pruning (19 per plant), which surpassed the controls in the second year (101 per plant) in plants pruned to 30 cm from ground level. They outperformed controls in the following years. Similar trends were recorded in terms of the number of fruit retained per plant. The maximum number of fruit was retained in plants pruned to 30 cm from ground level (Table 5.2). Yield (kg per plant) in the first year after pruning was reduced to 1.14 kg (81.18 % reduction) in plants pruned to 30 cm from ground level. However, the yield per plant surpassed that of controls in the second year, and the trend continued thereafter. The increase was to the tune of 16.96, 32.94, and 26.10 % in the 2nd, 3rd, and 4th years of pruning to 30 cm level (Tables 5.25, 5.26, and 5.27).

Pruning plants to 30 cm from ground level was the most effective method to rejuvenate the old pomegranate orchard, and can be recommended as standard practice in rejuvenating old orchards (Hiwale et al. 2006).

Table 5.25 Growth parameters of rejuvenated pomegranate cultivar Ganesh

					Plant spread			
	Plant height (m)		Stem dia. (mm)		NS (m)		EW (m)	
Treatment/year	1999	2001	1999	2001	1999	2001	1999	2001
T1 cutting 30 cm	2.68	2.42	21.23	30.94	2.39	2.55	2.43	2.73
T2 cutting 60 cm	2.61	2.66	23.88	32.67	2.61	2.51	2.66	2.62
T3 cutting 90 cm	2.68	3.34	17.18	34.03	3.46	2.72	3.46	2.72
T4 cutting 120 cm	2.7	3.42	17.56	32.81	3.34	2.29	3.48	2.32
T5 control	3.13	3.56	32.73	35.96	3.68	2.54	3.66	2.63
CD at 5 %	**2.93**	**0.35**	**2.62**	**7.13**	**0.26**	**NS**	**0.35**	**NS**

Hiwale et al. (2006)

Table 5.26 Fruit set and retained/plant

	No. fruit set/plant				No. of fruit retained/plant			
Treatment/year	1999	2000	2001	2002	1999	2000	2001	2002
T1 cutting 30 cm	19.0	101	89.2	53.00	7.6	52.4	60.8	51.8
T2 cutting 60 cm	50.8	92.2	88.8	140.75	16.2	44.4	52.0	74.4
T3 cutting 90 cm	63.4	70.8	82.2	42.75	20.0	35.4	38.4	34.6
T4 cutting 120 cm	72.8	48	64.8	48.25	22.0	29.0	35.0	46.4
T5 control	83.4	90.6	93.2	90.75	40.4	44.8	46.4	59.0
CD at 5 %	**5.97**	**21.05**	**27.33**	**47.62**	**2.74**	**4.58**	**5.43**	**11.16**

Hiwale et al. (2006)

Table 5.27 Percent retention and yield kg/plant

	% retention				Yield kg/plant			
Treatment/year	1999	2000	2001	2002	1999	2000	2001	2002
T1 cutting 30 cm	40.0	51.88	68.16	97.73	1.14	7.86	9.12	11.16
T2 cutting 60 cm	31.89	48.16	58.56	52.86	2.43	6.66	7.80	7.77
T3 cutting 90 cm	31.54	50.00	46.72	80.93	3.02	5.25	5.76	6.33
T4 cutting 120 cm	30.22	60.42	54.01	96.16	3.10	4.35	5.46	6.96
T5 control	48.44	49.45	49.78	65.01	6.06	6.72	6.86	8.85
CD at 5 %	–	–	–	–	**0.39**	**0.69**	**0.92**	**0.48**

Hiwale et al. (2006)

5.18 Staggering of Crops

Staggering pomegranate plants is practiced with a view to regulating crop load on the plant, which helps in the availability of the fruit for a longer period, helping the farmer fetch remunerative prices in the market. It also helps avoid gluts in the market that lead to distress sales. The relationship between source and sink can be regulated, which helps improve fruit development. Pomegranates flower and fruit throughout the year if irrigation is provided. Taking of particular bahars leads to gluts in the market. This results in distress sales by farmers, as fruit crops are obviously perishable in nature. To avoid this, staggering the pomegranate crop was attempted to find the best time to allow flowering during various months of the year so that maximum production with the best-quality fruits can be obtained. The pomegranate was allowed to flower during different months of the year in 5-year-old plants of cultivar Ganesh by withholding irrigation and releasing it during the specified period to initiate flowering. The best crop was obtained when September flowering was allowed, because the fruit development coincided with maximum moisture availability and cool climate, leading to a lower incidence of insect pests and reducing cracking, thereby improving the fruit quality (Table 5.28).

Flowering in September was observed to produce the maximum yield per plant. Aril seed ratio increased and softness of seed decreased with this period. Time of flowering significantly influenced TSS and acidity: TSS increased with an increase in time of flowering, while acidity showed a decline. The best fruits were obtained with September flowering under rain-fed conditions with one or two supplementary irrigations. Similar observations were recorded by Sonwane and Desai (1989).

Reducing the fruit load per plant results in the production of fruits of superior size, which then fetch premium prices at market. Also, in the pomegranate, where the production of hermaphrodite flowers is higher and results in higher fruit

Table 5.28 Staggering in pomegranate

Month	Fruit length (mm)	Fruit Dia. (mm)	Fruit wt. (g)	Yield/plant (kg)	Aril seed ratio	100 seed wt (g)	TSS °Bx	Acidity (%)
August	67.4	78.10	134.20	9.83	1.89	1.54	16.18	0.44
September	70.99	70.24	151.68	11.83	2.70	1.89	17.64	0.35
October	70.92	70.70	141.88	9.98	3.03	1.96	16.72	0.37
November	70.75	71.05	141.66	2.88	3.28	2.36	18.12	0.34
CD at 5 %	2.11	N.S.	2.91	2.35	2.51	0.17	1.03	0.07

Anonymous (1999)

set, the thinning of fruits can be adopted as regular practice. Appropriate fruit load helps in proper distribution of food and maintenance of sustainability of production. Work at CHES Vejalpur on cultivar Ganesh in hasta bahar indicated that thinning fruits to 25 per plant resulted in larger-size fruits than all the other treatments applied but yield was significantly reduced. However, retaining 75 fruits per plant produced uniform medium-sized fruits with much reduction in yield per plant. The returns were higher than with other treatments.

5.19 Crop Regulation–Chemical Regulation

Fruit and leaf abscission have been reported with the application of alar at 500–3,000 ppm, which induced flower and fruit drop. However, chemical regulation is currently avoided, as most chemicals involved have been reported to be harmful and are either banned or are no longer manufactured.

The main purpose of crop regulation is to force a tree to rest and to induce profuse flowering during the regained season. For instance, the pomegranate has three flushes of flowering: mrig (June–July), hasta (September–October), and ambe (December–January) bahar. The methods used for imposing bahar can be broadly classed into cultural and chemical. The common cultural method is to withhold irrigation or use root exposure and root pruning, etc. In terms of chemical methods, most of the growth retardants and growth regulators can be used to impose the bahar treatment. The pomegranate naturally flowers in mrig bahar, which depends upon monsoon and is difficult to regulate. But withholding irrigation can regulate hasta and ambe bahar. Thus, imposition stress leads to leaf drop and cessation of growth before the bahar. Later, reducing the stress slowly will lead to profuse flowering and fruit set. At CHES Vejalpur, Raturi and Hiwale (1991) worked on pomegranate cultivar Ganesh under rain-fed conditions and reported that it is possible to raise a successful hasta bahar crop. Hand thinning was used to remove mrig bahar flowering. Comparative studies on mrig and hasta bahar indicated that the fruit set, retention, and yield per plant were highest in hasta bahar. The fruit of the bahar are available when there is no pomegranate glut in the market and therefore can fetch remunerative prices. The quality of fruit skin color and TSS was also superior, while the incidence of pests and diseases was lowest. Fruit borer infection in mrig bahar was recorded at up to 18.83 %, whereas in hasta bahar it was just 8.92 % (Table 5.29).

5.19.1 Improving Fruit Skin Color

When temperatures are high during the ripening period, the skin color of the Ganesh variety normally becomes dull and pale, and fruit lose market value. When there is excess nitrogen, irrigation, and magnesium in the soil, the skin color becomes light and dull. Therefore, when fruits are maturing and turning their color, the application of potassium helps improve the fruit color. Color of the aril and skin are due to

Table 5.29 Effect of cropping season on fruit, retention, and yield of pomegranate cultivar Ganesh

	% fruit set		% fruit retention		Yield/plant (kg)	
Cropping season (Bahar)	88–89	89–90	88–89	89–90	88–89	89–90
Mrig	3.90	3.99	39.97	47.63	3.18	5.16
Mrig + hasta	5.04	5.43	42.49	55.46	4.52	7.37
Hasta	8.12	9.26	54.06	65.81	5.82	10.25
CD at 5 %	1.26	0.79	9.43	5.55	1.01	2.18

Table 5.30 Root distribution pattern (fresh and dry weight g/plant)

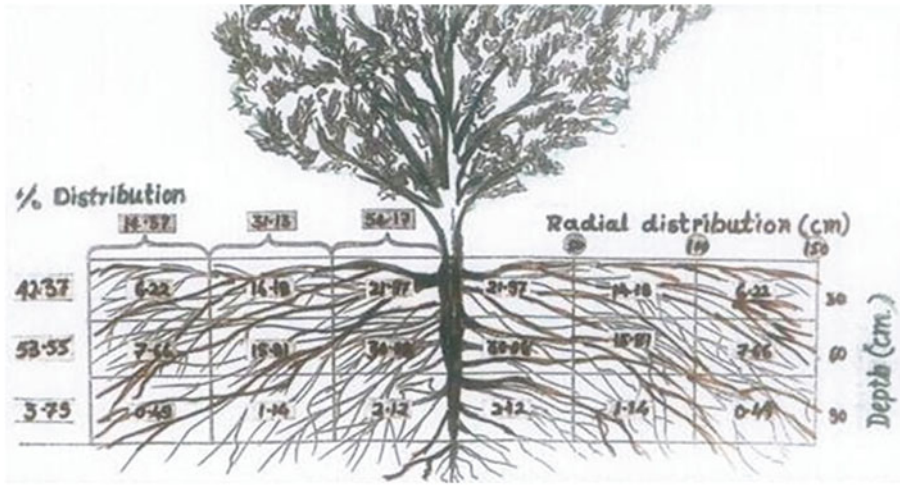
	Depth of	0–50		50–100		100–150		Total	
Type of root	soil (cm)	Fresh wt.	Dry wt.	Fresh wt.	Dry wt.	Fresh wt.	Dry wt.	Fresh wt.	Dry wt.
Thin (>3 mm)	30	190	114	250	173	101	67	541	354
Medium (>7 mm)	30	282	162	185	122	90	50	557	334
Thick (>15 mm)	30	202	118	–	–	–	–	202	118
Thin (>3 mm)	60	272	213	216	153	138	100	526	466
Medium (>7 mm)	60	364	304	164	101	97	73	625	478
Thick (>15 mm)	60	287	228	105	40	–	–	392	268
Thin (>3 mm)	90	–	–	–	–	–	–	–	–
Medium (>7 mm)	90	–	–	–	–	–	–	–	–
Thick (>15 mm)	90	65	37	35	21	15	9	115	67
Grand total		1,662 (54.17)	1,176	955 (31.12)	610	441 (14.37)	299	3,068	2,085

Figures in parentheses are percent values

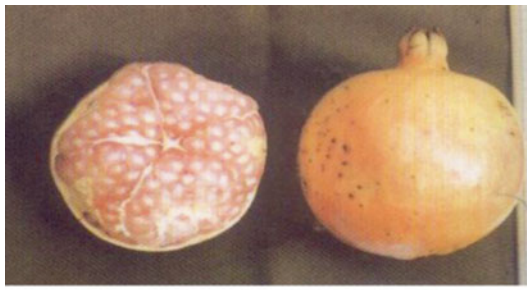
anthocyanin pigment (Du et al. 1975). Low temperatures stimulate anthocyanin synthesis and activity of the enzyme phenyl aniline ammonia lyase (PAL), which is directly related to anthocyanin synthesis (Akoi and Katayama 1970 and Hyodo 1971). A spray of potassium dihydro orthophosphate 1–2 g in 1 L of water, two sprays of 500 ppm lihosin, two sprays of 500 ppm of ethrel during the color-breaking stage, along with cytozyme100 ml +100 g potassium dihydro orthophosphate in 100 l of water, improve the skin color to reddish.

5.20 Root Distribution

Root distribution acts as a guide for the application of fertilizers as well as irrigation. Root distribution varies according to the type of soil and method of propagation. No such work had been carried out in India on the pomegranate. Therefore, studies were initiated to study root distribution patterns of air-layered 6-year-old pomegranate cultivar Ganesh. The active root zone was very shallow and was spread within the plant canopy. The root distribution pattern in air layers of pomegranate cultivar Ganesh under semiarid rain-fed conditions revealed that the root system is shallow in nature, as little root activity was recorded below a soil depth of 60 cm. Maximum root activity, on a fresh and dry weight basis, was observed at a radial distance of 0–30 cm from the tree trunk (54.17 %); at a distance of 30–60 cm it was 31.12 %; at a distance of 60–90 cm it was 2.12 %. However, in terms of soil depth, maximum root activity was observed at a soil depth of 30–60 cm, and 42.69 % activity was found at a soil depth of 0–30 cm. The least root activity (3.74 %) was observed at a soil depth of 60–90 cm (Hiwale et al. 2009) (Table 5.30).



Spatial root distribution in pomegranate Cv. Ganesh



Ganesh

5.21 Intercropping

Pomegranate occupies the recommended spacing (6 m×6 m) after 8 years; however, the trees start bearing at 4 years and, until then, inter-cropping can be carried out with fodder such as berseem and lucerne, crops such as cowpea and green gram, and vegetables such as cucurbits, cabbage, cauliflower, beans, peas, tomato, carrot, onion, radish, potato, and brinjal. However, inter-crops should be regulated so that their cultural care does not interfere with the bahar regulation.

5.22 Post-harvest Technology

The pomegranate has a low respiration rate and a non-climacteric respiratory pattern. Freshly harvested pomegranate fruits of cultivar Ganesh were treated with wax coupled with carbendazim (0.1 %) and stored at room temperature (22–24 °C with 52–82 % relative humidity) as well as in cold storage. Results indicated that fruits could be stored for up to 75 days in cold storage as against 30 days at room temperature (Waskar et al. 1999). Chilling injury can be overcome by intermittent warming. Storing pomegranates at 2 °C with intermittent warming was optimum for minimizing chilling injury and maintaining the quality of the fruit up to 13 weeks (Artes et al. 2000). Controlled atmospheric storage of pomegranate fruits indicated that the color value of the juice was significantly increased in fruit stored at 10 % O_2, 5 % CO_2 (Artes et al. 1996). The pomegranate fruit reached its horticultural maturity when its soluble solid content reached 15 %. The maturity period of 105–140 days from fruit set can be used as a criterion for fruit maturity (Hayes 1953). However, Kulkarni et al. (2005) reported that harvesting of fruit on the 100th day from fruit set was crucial to prevent browning during storage.

5.23 Value Addition

With increases in area and production of fruit, steps need to be taken to develop industries to add value to a crop; if this does not occur, a glut in the market results and the crop becomes

uneconomical, leading to either distress sales or removal of orchards. Pomegranate fruit is known for its value-added products such as juice, jelly, anardana, anar rub, rind power, etc., which can be easily prepared at the field level. Fruits are mainly used as fresh fruit or juice.

5.23.1 Fruit Juice

Pomegranate varieties with dark red arils are preferred. The juice can be extracted by two methods: (1) keeping the skin intact and removing the lower portion, the fruit is separated into four parts and the juice is extracted via a juice extractor; (2) the skin is removed, arils are separated, and juice is extracted. Juice is preserved with the addition of potassium metabysulphite and storing it in cold temperatures in steel or glass bottles/vessels. A temperature of 77 °C for 33 s is recommended for pasteurization of fruit juice. This process eliminates *Aspergillus niger* and lactic strains. Color stability was maintained at temperatures up to 80 °C for 30 min, after which a slight color reduction was observed. Pasteurized juice showed comparable quality to unpasteurized juices (Rage and Pai 1999). The pomegranates were frozen at –40 °C, either with or without sugar and stored at –18 °C for 9 months (Bilsil and Cevic 1997). Clarification of pomegranate juice via ultra filtration resulted in a better retention of ascorbic acid (2–5 % loss), high yield (97.8 %), and better quality than conventionally clarified juices (Iboyaima et al. 1993). Effective stabilization of color in juice stored at room temperature can be achieved with polyvinylpyrrolidone (PVP) and trypsin (Khrameeva et al. 1987).

5.23.2 Pomegranate Syrup

Pomegranate syrup is prepared by taking one-quarter fruit juice and raising the sugar to 60–64 %. The syrup can be stored under normal conditions for about 3–4 months, and is served by mixing water in appropriate proportions according to taste.

5.23.3 Pomegranate Nectar

Fresh pomegranate juice can be preserved for a long time by increasing the sugar content to 20–30 %.

5.23.4 Juice Concentrate

Juice is converted to powder form either by freeze drying or by drying on a conveyer belt and is vacuum packed in polythene bags.

5.23.5 Pomegranate Chutney

Wild pomegranate (Anardana type) found in Himachal Pradesh can be used to prepare chutney. The product was dried in a mechanical cabinet at 65 °C for 10–14 h. Samples were packed in polythene pouches and stored at 37 °C. The quantity of green chilies added increased the vitamin C content, total sugars, and PH, while protein levels and acidity decreased. Chutney had a shelf life of more than 6 months.

5.23.6 Carbonated Pomegranate Beverages

The pomegranate beverages were prepared with different levels of juice (5, 10, 15, and 20 %). Drinks were formulated to a pH of 3.14–3.16 and acidity of 0.24 % and stored for 80 days at ambient temperatures. The beverage with 10 % pomegranate juice and initial content of 11.78 % sucrose, 1.3 % reducing sugar, and 1.0 mg ascorbic acid was the best (Riaz and Elahi 1992).

5.23.7 Pomegranate Wine

Pomegranate wine is one of the important products with which it is possible to absorb the glut of this fruit in the market, simultaneously providing a healthy drink and creating job opportunities. Around 500 ml of juice can be obtained from 1 kg of pomegranate fruit, from which

400–450 ml of wine can be prepared through fermentation with the addition of yeast.

5.23.7.1 Methodology

Preparation of starter: A spoonful of standard wine yeast *Saccharomyces ellipsoids* no.101 maintained on yeast extract peptone dextrose (YEPD) agar was transferred to a test tube containing 5 ml of YEPD broth and incubated overnight at 25 °C. After 22 h, it was shaken well in an incubator at 120 rpm, which is used for inoculation after activating the yeast cell at 40 °C for 1.5 h.

5.23.8 Anardana

Wild pomegranate seeds and aril are sun dried and commercially marketed as 'anardana', which is used as a condiment (Sharma and Sharma 1990). Chemical characteristics such as high juice content and sugar/acid ratio, more intensive color, and less tannin content are good attributes for a better quality of anardana. To improve color stability by preventing oxidation of the anthocyanin, a mixture of glucose and citric acid is used as stabilizer at a ratio of 1.0:0.20:0.003 of juice to glucose to citric acid (Gafizov et al. 1990).

In Himachal Pradesh, making anardana is a household activity and it is mainly used as a substitute for tamarind and mango slices. It is also used in the garnishing of ice cream, fruit salad, chutney, and panmasala. There is huge demand for the product in North India. The culled fruits can be used for preparation of anardana. Anardana can be prepared from varieties with acidity of 7.8–15.4 %; the Russian types are especially suitable. The varieties under large-scale cultivation have acidity of just 0.3–0.5 %, which can be used with the addition of 5 % citric acid to the arils. The total expenditure for the preparation of 1 kg anardana is around Rs. 60.

Mahajan et al. (1992) processed wild pomegranate for the preparation of anardana with three thermal treatments: deep sand roasting of whole fruits for 5 min; dry roasting on a heater; and blanching in boiling water for 5 min. The first method was found to be the best. Three drying techniques were also tried: solar drying; conventional sun drying; and via a hot air dehydrator. Solar drying was the best. Hussein et al. (2004) analyzed pomegranate Whole fruit remove as seed powder samples, and seed powder samples as suggested standard grades for sensory evaluation.

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