POMEGRANATE GROWING MANUAL

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Foreword

Pomegranate (Punica granatum L.) is an economically important commercial fruit plant species belonging to family Punicaceae. It is a good source of protein, carbohydrate, minerals, antioxidants, vitamins A, B and C, also been used in controlling heart diseases, cancer, diarrhea, hyperacidity, tuberculosis, leprosy, abdominal pain, fever etc. There has been enormous increase in pomegranate acreage, production and export over the past decades owing to its immense medicinal/therapeutic values and higher profit earning from the produce. India has become the largest producer and consumer of pomegranate in the world. However, the productivity is only 6.57 t/ha, which is significantly low as compared to other pomegranate growing countries like Spain and the USA. The lack of awareness on scientific management practices for pomegranate has been one of the hindrances in realizing the production potential of this crop in the vast tract of arid and semi-arid region. Moreover there is great demand for literature on complete package of practices from various stakeholders involved in pomegranate production.

The scientists of NRCP have made an endeavor in bringing out a complete package of practices for pomegranate covering wide range of topics from the history of pomegranate cultivation to propagation, establishment and maintenance in the form of manual based on their long-standing experiences in various aspects of pomegranate. This compiled information, recommendations, guidelines, illustrations in the book will be of very useful platform not only for growers but also for planners, researchers and students. I am confident that the practical information provided in this book will engender a greater pomegranate growing culture in India, especially in arid and semi-arid regions of tropical and sub-tropical zones. This in turn may benefit local household nutrition, improve rural socio-economic condition and widen export opportunities.

I implore my profound gratitude to all the scientists who contributed in bringing out a valuable publication in the form of pomegranate growing manual which will be very useful not only for pomegranate growers but also for the researchers, students, developmental agencies and industry.

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Preface

Pomegranate is in great demand for fresh fruit consumption and export in the national and international markets; hence, all round emphasis is to enhance its production and productivity. India occupies the first position in the world with respect to pomegranate area (1.25 lakh ha) and production (8.21 lakh tonnes). Maharashtra is the leading state in India with 0.99 lakh ha area and 5.56 lakh tonnes production followed by Karnataka, Andhra Pradesh and Gujarat. Its productivity is however, very low (6.57 t/ha) in the country compared to some important pomegranate growing countries like Spain (18.5 t/ha) and the USA (18.3 t/ha). National Research Centre on Pomegranate (NRCP), since its inception, has made significant progress in germplasm enhancement, plant protection and crop production, but consistent efforts are needed to disseminate and commercialize production technologies among the growers so as to enhance production and improve the productivity of pomegranate, especially in Deccan Plateau. Keeping in view the increasing demand of literature on pomegranate from pomegranate growers, researchers and other stakeholders, a pomegranate growing manual has been prepared for the benefit of all concerned. The manual covers almost all aspects of pomegranate with special emphasis on propagation, orchard establishment, canopy management, crop regulation, nutrient and water management, intercropping, weeding and moisture conservation, fruit quality enhancement, fruit maturity and harvesting, postharvest management and crop protection. The cultivation practices covered in this manuscript are based on the research experience of pomegranate researchers and published literature.

The authors are thankful to Dr. S. Ayyappan, Secretary DARE & Director General, Dr. H. P. Singh, Deputy Director General (Hort.) and Dr. S. Rajan, ADG (Hort.) of ICAR, New Delhi for their keen interest, motivation and guidance to promote pomegranate cultivation in India. This was indeed, a driving force for preparation of this manuscript. We also owe our sincere gratitude to Dr. V. T. Jadhav, Director, NRCP for his consistent encouragement, suggestions and moral support in publishing the manual. Sincere thanks are due to Dr. K. K. Sharma, Pr. Scientist, Dr. N. V. Singh, Scientist, Dr. K. D. Babu, Sr. Scientist, Dr. A. Maity, Scientist and Mr. Anshul Lohakare, Research Associate for providing their critical inputs in improving the manuscript. Other staff of NRCP also deserve appreciation for their valuable help. Finally, knowledge, experience and difficulties shared by pomegranate growers from time to time are thankfully acknowledged.

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**Importance and taxonomy**

Pomegranate (*Punica granatum* L.) is one of the oldest known edible fruits and is capable of growing in different agro-climates, ranging from tropical to temperate regions of the world. However, its major cultivation is confined in tropical and sub-tropical regions. It is presumed that pomegranate was domesticated in the Middle East about 5000 years ago. Interestingly, it is considered to be one of the first five domesticated edible fruit crops along with fig, date palm, grape and olive. The scientific name *Punica granatum* is derived from the name *Pomum* (apple) *granatus* (grainy) or seeded apple. Pomegranate belongs to Punicaceae family contains a single genus *Punica* of two species, *Punica granatum* L. and *P. protopunica* Balf. f. The species *P. granatum* has two sub-species viz. Chlorocarpa and Porphyrocarpa. Since time immemorial, it has been embedded in human history and utilized for fruit, pharmaceutical and nutraceutical values. Despite this, its cultivation was limited and considered as a minor fruit crop in several countries including India. In the recent past, its wide range of significance in human health, nutrition and livelihood security has been recognized that triggered heavy demand for fruit consumption in India and the western world too.

**Global area, production and export**

Presently, Morocco, Tunisia, Egypt, Israel, Syria, Lebanon, Turkey, Greece, Cyprus, Italy, France, Spain, Portugal, Iran, Iraq, India, China, Afghanistan, Bangladesh, Myanmar, Vietnam, Thailand, Kazakhstan, Turkmenistan, Tajikistan, Armenia, Georgia, the USA, Mexico, Argentina, Chile, Australia and Brazil are some countries growing pomegranate in the world for table use and as an ornamental plant in East Asia. Among these countries, India, Iran, China, the USA and Turkey are the five major producers of pomegranate. The current total annual world production of pomegranate fruit is estimated to be around 15 lakh tonnes. It is estimated that > 1.2 lakh tonnes pomegranate fruit are exported from Iran, India, the USA, Spain, Tunisia etc. to different countries. Now, India has occupied first position in the world with
respect to pomegranate area (1.25 lakh ha) and production (8.21 lakh tonnes). However, Maharashtra is the leading state in pomegranate area (0.99 lakh ha) and production (5.56 lakh tonnes) followed by Karnataka, Andhra Pradesh and Gujarat. India has very low productivity (6.57 t/ha) compared to Spain (18.5 t/ha) and the USA (18.3 t/ha). Iran occupies first rank in pomegranate export with an annual export of 60,000 tonnes followed by India (33,415 tonnes). India has the lowest share (3.0%) in export compared to other pomegranate exporting countries. Interestingly, the export of pomegranate from India increased about 5 fold in 2009-10 over 2002-03, indicating a bright future for export in years to come. At present, the major pomegranate importing countries from India are UAE, the Netherlands, Saudi Arabia and Bangladesh.

**Composition**

The edible portion (arils) is about 45-61 per cent of total fruit weight of pomegranate which includes about 60-85 per cent juice and 15-25 per cent seeds; peel forms 33-40 per cent of the fruit. The arils in improved varieties of pomegranate are bold, fleshy and very juicy. However, the taste of the pulp varies from sweet and aromatic to sour and insipid. The edible part of the fruit contains considerable amounts of acids, sugars, vitamins, polysaccharides, polyphenols and important minerals. The flavour of fruit juice is influenced by the amount of organic acids (citric, malic, oxalic, succinic and tartaric) present. Though citric acid is the predominant organic acid found in the juice. Interestingly, most of the cultivated varieties of pomegranate in India have acidity below 0.6 per cent. However, fruits of wildly growing pomegranate in Western Himalayas have very high acidity (3.4-4.8%) and are used for preparation of *anardana*. As far as sugar fractions are concerned, glucose (5.46%) and fructose (6.14%) are predominant sugars in the juice with almost no sucrose. In fact, the quality of pomegranate juice is mainly assessed by its sugar and acid contents. Acidity decreases and soluble solids (mainly sugars), pH and red colour intensity of the juice increase with the fruit maturation and ripening. At present, consumer’s preference is more for fruits having red skin with red arils.
Anthocyanin pigments are found to be responsible for the red colour of pomegranate skin (rind), arils and juice. These anthocyanins are labile compounds that are easily susceptible to degradation during storage and processing. The other phenolic compounds in pomegranate include ellagic acid derivatives and hydrolysable tannins (punicalagin, punicalin). Besides, the fruit is a good source of antioxidant.

**Medicinal properties and other uses**

Every part of pomegranate, including the root and trunk bark, wood, sprouts, leaves, flowers, fruit, rind and seeds have economic value. Its seed oil can be used for producing enamels and oilcake for feed meal and some sorts of medical compounds. Fruit and its different parts contain about 153 phytochemicals like ellagic acid, catechin and procyanidins, fatty acids and triglycerides (linoleic acid, palmitic acid, punicic acid, tri-O-punicylglyceriol), sterols and terpenoids (betulinic acid, estrone, stigmasterol, testosterone), flavonols etc. that have been associated with a reduced risk of chronic human diseases. Because of these properties, it is recognized as a strong therapeutic agent and considered as an important medicinal fruit crop. There are several potentially active phytochemicals like sterols and terpenoids in the seeds, bark and leaves; alkaloids in the bark and leaves; fatty acids and triglycerides in seed oil; simple gallyol derivatives in the leaves; organic acids in the juice, flavonols in the rind, fruit, bark and leaves; anthocyanins and anthocyanidins, catechin and procyanidins in the juice and rind. Now, there is ample scope to treat several human diseases like coronary heart diseases, cancer (skin, breast, prostate and colon), inflammation, hyperlipidemia, diabetes, cardiac disorders, hypoxia, ischemia, aging, brain disorders and AIDS with biologically active ingredients isolated from different parts of pomegranate plant. However, pomegranate is commercially grown for its sweet acidic fruits, which are mainly used for dessert purposes and extraction of juice. There is good demand of pasteurized juice. The juice is also popular for culinary purpose. It is mainly used to prepare grenadine, extracts, liquors, wines, jelly etc. In fact, consumption of fresh arils is also
increasing in domestic and international markets. Besides, the wild fruit is used for citric acid production and its byproducts can be used to produce alcohol, tannin, waxes etc. Even the flowers and rind are good sources of natural dye.

**Origin and distribution**

Evidences are available that pomegranate originated in Iran and its surrounding areas. Earlier, N.I. Vavilov described its origin in the Near East. Long back, it was cultivated in ancient Egypt, in early Greece and Italy, and Iraq. Over time, it spread to Asia (Turkmenistan, Afghanistan, India, China etc.), North Africa and Mediterranean Europe. Domestication process of pomegranate might have started independently in various regions during different periods. Ancient sailors and traders introduced it in Greece and the areas surrounding the Mediterranean Sea, as far west as Spain and Portugal and then to the New World. According to an estimate pomegranate was introduced into India and China over the Silk Route. Probably in the first century AD, it was introduced in the Indian Peninsula from Iran. Still wild forms of pomegranate are found in Transcaucasia and Central Asia from Iran and Turkmenistan to Northern India.

**Climate and soil**

Pomegranate is cultivated throughout the world in different micro-climatic zones of sub-tropical and tropical regions. In Western Himalayas, it grows up to 1600-3330 m above mean sea level. Contrary to this, good quality pomegranate fruits are produced in Deccan Plateau between altitudes of 270 and 900 m above mean sea level. It is well known that arid regions have vast potential for its intensive cultivation and quality fruit production with assured irrigation. In the sub-temperate regions of India (Western Himalayas), seedling types of trees locally known as *Daru* come up naturally in abundance. It is very common and gregarious in gravel and boulder deposit of dry ravines in the outer Himalayas. These hardy deciduous seedling trees are growing since long time and they have climatic adaptability and resistance to insect pests and diseases.
Its cultivation has been noticed on heavy clay, clay loam, chestnut, loamy, loamy-pebble soils, sandy loam soils rich with humus, black soils, light humus soils with pebble inclusions, yellow soils, alluvial soils, on seaside sands, gravel talus, dry rocky hills, alkali soils, lime rich soils as well as on limestone rich lands of arid hills. However, the best soils for pomegranate cultivation are considered to be fertile, rich with humus, deep, medium density having good drainage, especially alluvial soils can produce the best quality fruits with good colour development. Though, it can be grown well in slightly saline soils as it is found to be a saline tolerant fruit crop. Pomegranate can tolerate salinity up to 6.0 dsm⁻¹ and sodicity up to 6.8 exchangeable sodium per cent. Accumulation of salts, in excess of 0.5 per cent of the soil mass causes dying off of growing roots. Water soluble salts like sulphates and chlorides and exchangeable sodium have negative effect on root formation. It can tolerate soil salinity due to the ability of its root system which can accumulate the majority of toxic salts present in the soil and thus prevent their intensive flow out to the above ground parts. Pomegranate tissues are reported to accumulate sodium, chlorine and potassium if irrigated with saline water. It has been reported that the plant can tolerate saline water up to concentration levels of 40 mM NaCl and above this concentration, the growth parameters are severely affected. Intensive absorption of toxic sodium ion, reduces the content of potassium and phosphorus, protein and phospho-organic compounds, nitrogen supply from the soil and utilization of phosphorus compounds as a result the content of chlorophyll, carotenoids, sugars and tannin substances are reduced in the plant.

Pomegranate is a light loving plant and reacts negatively to excessive shading. But direct sunlight and considerable heating often causes harmful effect on fruits leading to sun-burns. The optimal conditions for pomegranate cultivation include high insolation, the sum of active temperatures of 4000-4600°, annual precipitation of 18-55 cm and mild winters. However, best quality fruits are produced in arid regions having a long, hot and dry summer. It can easily withstand temperatures up to 45-48°C in combination with dry hot winds.
Propagation

Vegetative methods of propagation, especially air-layering and stem cutting are common. However, in major pomegranate growing areas air-layering is most popular.

1. **Air-layering**: The upright branches of 0.8-1.5 cm diameter from healthy trees are selected, girdled 2-3 cm in length and rooting hormone (IBA 2000-3000 ppm) is applied on upper part of the cut. The moist rooting medium (sphagnum moss) is wrapped over the cut portion using desirable size of black polythene strip (200-300 gauge) and both the ends of the polythene strip are tied with coir/jute thread or string. The type of media used for layering plays role in rooting and survival of layers. In general, sphagnum moss is used as a substrate for air-layering, but soil, sand and cow dung manure in a 2:1:1 proportion has also been reported as a suitable media for preparation of air-layers. In general, rooting takes place between 30-40 days and well rooted layers are detached from the mother plants within 75-90 days. These air-layers after 70-80 per cent defoliation can be planted in nursery or polythene bags containing soil, sand and well rotten FYM in 1:1:1 ratio. The optimum time for air-layering is June-August. Well developed layered plants should be used for establishment of pomegranate orchards.

2. **Stem cutting**: Multiplication of pomegranate by stem cuttings is a common practice in major parts of the world. Although pomegranate is considered to be difficult-to-root by stem cuttings, it has been proved that it can successfully be propagated under green house with mist facility. Hardwood, semi-hardwood and softwood stem cuttings are used for propagation, but hardwood stem cutting is most suitable. The wood younger than 6 months and older of 18 months is found unsuitable for making stem cuttings. Similarly, hardwood lateral shoots, which usually flower and fruit, are also unsuitable for propagation. In general, 20-25 cm long and 0.6-1.2 cm thick cuttings found to be suitable for propagation. Usually,
use of plant growth regulators (PGRs), especially auxins improves rooting in stem cuttings. Basal cuttings are better for rooting than sub-apical ones. The quick dip method is mostly preferred over the prolonged dip method for the treatment of stem cuttings. In the quick dip method, 30 second to 5 minute treatment is beneficial for inducing roots in the cuttings. Indole-3-butyric acid (IBA) at 2000-3000 ppm with the quick dip method (1 min dip) is optimum for higher rooting and field survival (Fig. 1). Though, a lower concentration of IBA (100 ppm) in the prolonged dip method (24 hrs) with hardwood cuttings is also proved to be beneficial. High rooting success has been recorded when cuttings are planted in November. The optimum time for raising of stem cuttings is July-August or January-March in different agro-climatic conditions.

Orchard establishment

1. Planning: Establishment of an orchard is long term investment and hence needs thorough planning. Well drained land with moderate slope (3-5%) should be selected for establishment of an orchard. There should be no water stagnation in the orchard. A well laid out internal network of main, cross roads and paths is essential for efficient movement of workers and machinery. The farm should have adequate electricity supply with assured irrigation facility. Required numbers of buildings including office, implement shed, godown-cum-store, packing shed, pump houses etc. should be constructed at convenient locations preferably in the centre to ensure sufficient supervision and watch and ward. However, for development of these infrastructures below 10 per cent of the total farm area should be allotted. A provision of fencing and wind break should be made along
with the farm boundary. Two to three years before planting of pomegranate, suitable wind break (single or double rows) like caronda (*Carissa carandas*)/jamun (*Syzygium* sp.)/casuarina/silver oak (*Grevillea robusta*) should be established along the boundary. However, wind break row(s) facing east direction should not grow very tall.

2. Planting system, spacing, pit-digging and time of planting: As far as planting system is concerned square or rectangular planting system (*Fig. 2*) can be followed. Planting distance should be decided depending upon soil type, soil depth, climatic condition and variety. Pits of 1 m x 1 m x 1 m or 0.75 m x 0.75 m x 0.75 m are dug at a spacing of 4.5 m x 3.0 m, especially for cv. Bhagawa depending upon soil type and depth. This can accommodate about 740 trees/ha.

However, wider spacings like 5 m x 4 m (500 trees/ha) or 5 m x 5 m (400 trees/ha) can be followed for varieties like 'Ganesh' having vigorous growth. Even there is scope for hedge row planting (*Fig. 3*) in pomegranate with 5 m x 2 m (1000 trees/ha) or 5 m x 3 m (666 trees/ha) spacings which can improve productivity and facilitate mechanization. Although closer spacing in long run may invite disease and insect pest problems. Therefore, after 6-8 years, alternate plants from the hedge row may be
removed or tree growth be restricted by proper pruning to avoid over crowding and enhancing production.

Pits are dug about a month prior to planting and kept open for at least 1 month, so that it is disinfected by intense solar radiation. Drench with 0.15 per cent carbendazim and 0.2 per cent chloropyriphos @ 4-5 litre/pit on the bottom and sides of the pits just before filling pits. Fill the pits with a mixture of soil, sand/murrum, silt and clay in equal proportion when planting is done on rocky/gravely lands. In each pit mix the following manure and bio-fertilizer in the top soil (30-50 cm) and then fill the pits.

<table>
<thead>
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<th>FYM</th>
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<tr>
<td>Vermi-compost</td>
<td>2 kg</td>
</tr>
<tr>
<td>Neem cake</td>
<td>1.5 kg</td>
</tr>
<tr>
<td><em>Trichoderma</em> formulation</td>
<td>25 g</td>
</tr>
<tr>
<td>Phosphate solubilising bacteria</td>
<td>25 g</td>
</tr>
<tr>
<td><em>Azotobacter</em> formulation</td>
<td>25 g</td>
</tr>
<tr>
<td><em>Pseudomonas fluorescens</em> formulation</td>
<td>25 g</td>
</tr>
<tr>
<td><em>Azospirillum</em> formulation</td>
<td>25 g</td>
</tr>
</tbody>
</table>

After filling the pits, watering is done to allow soil to settle down. Well developed cuttings/air-layered plants preferably 5-12 months old raised in polythene bags should be used for planting. While planting, one should be careful that the earth ball does not break. Light irrigation is given immediately after planting. And then give regular irrigation through drip irrigation system. Planting should be done during spring season (February-March) subject to the availability of irrigation water; otherwise July-August is an ideal time of planting in different parts of the country.

3. Staking: Just after planting some support is required to keep the plant straight and to bear the load of growing shoots as the branches and stem tend to break due
to strong wind. Seventy five cm to 1 m long bamboo or wooden sticks should be used for staking. And tie the plant at one or two places with coconut or jute strings to avoid bending and breaking of the plant (Fig. 4).

![Fig. 4. Staking with bamboo sticks](image)

**Varieties**

More than 50 varieties/genotypes are available in India but hardly 20 of them are cultivated in different regions. However, some promising varieties have been recommended for cultivation (Fig. 5). Out of these 'Bhagawa', 'Ganesh', 'Mridula', 'Ruby', 'Phule Arakta', 'Kandhari' and 'Jalore Seedless' are popular among the farmers. Though, at present 'Bhagawa' is the leading variety. The salient features of some cultivars/varieties of pomegranate are described below.

1. **Bhagawa**: The 'Bhagawa' variety of pomegranate known by different names viz., 'Shendari', 'Ashtagandha', 'Mastani', 'Jai Maharashtra' and 'Red Diana' is a heavy yielder and possesses desirable horticultural traits. The fruit matures in 180-190 days after blooming (anthesis) with an average fruit yield of 20-25 kg/tree. Bigger fruit size, sweet and glossy red rind with bold red arils, thick skin makes it suitable for distant market.

2. **Ganesh**: It a selection from 'Alandi'. Its fruits are medium in size with yellow smooth surface and red tinge. The seeds are soft with pinkish arils. 'Ganesh' has revolutionized the cultivation of pomegranate in Maharashtra, but after release of 'Bhagawa' its acreage has decreased in India and now it is holding 2nd position after 'Bhagawa'. It is a medium maturing variety. The fruits mature in about 150 days after blooming.
3. **Mridula**: It is a seedling selection from an open-pollinated progeny raised from the F₁ progeny of a cross 'Ganesh' x 'Gul-e-Shah Red'. Its fruits are medium-sized, rind smooth with dark red colour. It has blood-red arils with very soft seeds, juicy and sweet in taste. It is significantly superior to other commercially grown cultivars. Fruits mature in 140-150 days.

4. **Phule Arakta**: The variety is a medium yielder and possesses desirable fruit characters. The fruits are medium in size, sweet with soft seeds, blood red arils and possess glossy attractive dark red skin. It is quite suitable for processing purpose owing to its dark red fruit juice.

5. **Ruby**: It is a hybrid from a 3-way crosses between 'Ganesh' x 'Kabul' x 'Yercaud' and 'Gulesha Rose Pink' which has soft and red arils with good flavour. The variety was developed at Indian Institute of Horticultural Research (IIHR), Bengaluru. The plants are prolific-bearer providing uniformly red fruits.

6. **Kandhari**: Fruit is medium in size, rind red, aril fleshy pink or red with sweet, slightly acidic juice and soft seeds.

7. **P-26**: It is a seedling selection from 'Muskat' and is superior to 'Ganesh' in yield and fruit weight. Its fruits are large-sized, rind yellowish-green with red tinge; fleshy pinkish-white aril with moderately hard seeds and sweet juice.

8. **Jyoti**: It is a selection from mixed seedling population of 'Bassein Seedless' and 'Dholka'. The fruits are medium to large in size having attractive yellowish-red rind and fleshy creamy aril. The fruits are very sweet and soft-seeded with good taste.

9. **Dholka**: Fruit is medium in size, rind reddish yellow, fleshy pinkish-white aril with sweet juice and soft seeds.

![Image](image_url)

**Fig. 5. Some promising varieties of pomegranate**
Canopy management

The world wide trend is developing for improving productivity of fruit crops with appropriate canopy management practices. In some fruit crops like apple, pear, peach, avocado, grape etc., canopy management brought significant transformation in their productivity levels. In fact, canopy in a tree refers to its physical composition comprising the stem, branches, twigs and leaves. But, the canopy density is determined by the number and size of leaves. Moreover, canopy architecture has significant impact on fruit production which is determined by the number, length and orientation of branches and shoots. In any fruit crop, for optimum fruiting and quality fruit production, the canopy management of the tree is prerequisite that deals with the development and maintenance of their structure in relation to the size and shape. The basic idea of canopy management is to manipulate the tree vigour and use maximum available light and temperature to increase productivity, fruit quality and also to minimize the adverse effects of the weather. Pomegranate is a light loving plant thus enough light should be available in the tree canopy for quality fruit production. The green leaves trap the sunlight to produce carbohydrates which are then transported to the sites (buds, flowers, fruit etc.). Restricting the build-up of micro-climate congenial for the development of diseases and insect pests and convenience in carrying out the cultural operations are also important considerations in canopy management. However, balance between vegetative and reproductive growth must be maintained giving emphasis to have less wood and more fruit on plant canopy (Fig.6).

Fig. 6. Balanced growth for quality fruit production
1. **Tree growth and structure**: Pomegranate is a shrub or small tree that tends to develop multiple trunks and has a bushy appearance. Depending upon variety and agro-climatic conditions, it can grow up to 5 m. However, in natural condition it grows up to 7 m. Even dwarf and semi-dwarf varieties of pomegranate have been reported. Most of the varieties are deciduous and in Deccan Plateau, the trees are evergreen or partially deciduous. Though, some evergreen varieties shed their leaves in higher elevations and colder climate. The young branches from the vegetative growth of the recent years are numerous and thin. In general 3-4 growth flushes in a year are noticed. Each new flush is added onto the previous growth flush, resulting in a drift of the young bearing wood to the outsides of the tree canopy (Fig. 7). Over the time large trees with increased shading inside the canopy are formed which allow most of the fruits appear on the tops and outsides.

The density and orientation of plants have impact on light penetration in the orchard. The closer the planting, the poorer will be light penetration. Strong bearing branches tend to produce larger fruits and they also transport water and nutrients more efficiently throughout the tree. Thus, pruning should aim to encourage new strong growth. The tree exhibit apical dominance; consequently, the top bud suppresses the shooting of buds below it. Therefore, tip pruning is needed, especially in pre bearing trees (1-2 years). The best time to prune is normally after harvest and before bud break.

Pomegranate has spreading and erect tree structures for these, pruning styles will vary. When crop load is heavy, the branches and limbs tend to break more easily by strong wind. Overall the tree branches tend to be longer, thinner and more flexible. Thus, attempts should be made to shorten these branches.
and fruiting should be encouraged inside of the tree. The tree usually has a tendency to produce strong, vigorous upright water shoots having thorns. These shoots are generally unproductive and should be removed as early as possible. However, sometimes these water shoots/sprouts can be used effectively to replace old unproductive structural limbs while rejuvenating trees. However, after severe pruning and nutrient application, the trees produce more suckers from the stem at ground level which need to be removed regularly.

2. Training System:

a) Multi-stem training system: Earlier, training and pruning was not a common practice in pomegranate but due to fast growth of this industry in recent years, the awareness for training and pruning has been created among the growers, especially in Deccan Plateau. But, multi-stem training system has some disadvantages that it complicates many cultivation practices such as pruning, spraying, removal of unwanted growth (suckers) and fruit harvesting. Looking into fruiting behaviour and growth of the trees, open center or vase shaped training system can be followed to develop suitable framework for optimum growth, flowering and fruiting. Well grown up air-layered saplings of 5-6 months old should be planted and trained in multi-stem training system. For this purpose, 3-4 healthy suckers may be allowed and other suckers arising from the ground level should be removed regularly. Within 2 years after planting, such suckers will develop proper canopy. In multi-stem training system, 3-4 strong stems with 6-8 strong fruiting branches (thick ones) may be allowed to produce good quality fruits from fourth year (Fig. 8).
b) **Single stem training system**: Recently, single stem training system in pomegranate has already been started in some countries like the USA and Israel because of its many advantages over multi-stem training system. It has been reported earlier that pomegranate is highly susceptible to stem borer and shot hole borer so not much emphasis was given on this training system in India. However, nowadays some effective insecticides are available that can manage these pests. In this system, well developed single stem saplings of one year old should be used for planting. Cut the plants back to 50-65 cm at planting and allow to develop 3-4 symmetrically spaced scaffold limbs by pinching back new shoots, the lowest at least 25-30 cm above the ground (**Fig. 9**). Shorten scaffold limbs to about 60% of their length. Remove interfering branches and sprouts leaving 2 or 3 shoots per scaffold branch (limb). Thus, a total 6-9 strong fruiting branches (thick ones) will develop. Prune to produce stocky, compact framework in the first 2 years of growth. Surprisingly, in Israel, single trunk up to 30 cm (stem) with 3-4 main branches (limbs) in vase shape training up to 3.5-4 m is a common practice in modern orchards. Properly irrigated and fertigated orchards trained in this way often produce > 30 tonnes fruit/ha. Undoubtedly, there seems to be scope for promotion of single stem training system in India as the canopy architecture in this system develops very well which is suitable for higher productivity and easy farm operations.
3. Pruning stages:

a) Young tree formation: Pruning normally starts when the trees are 6-15 months old. At this stage pruning is used to develop structural framework of trees. The aim is to have 3-4 main limbs with the lowest branch starting at 25-30cm above the ground (single stem training system) or 3-4 stems (multi-stem training system). The trees should not be allowed to bear fruits for initial 2 years to improve the growth of plant and better canopy development.

b) Maintenance pruning of bearing trees: A more regular programme of pruning starts from third year onwards with the following basic objectives.

- To remove dead, diseased, broken and weak or old branches
- To remove crossed over branches or branches in the wrong place
- To reduce tree height and width
- To open up the tree canopy to improve light and air penetration
- To remove unwanted re-growth or strong suckers or suckers arising from the ground level
- To manipulate tree form, shapes and growth
- To manipulate flowering, fruit set and crop load
- To rejuvenate old trees
- To improve spray coverage

c) Rejuvenation pruning of old/bacterial blight affected trees: This type of pruning is normally undertaken on old trees which are still healthy with the aim of reinvigorating the tree to improve cropping potential. With this type of pruning major limbs (thick fruiting branches) are normally removed to encourage replacement with new young branches. This type of pruning should be undertaken over a number of years depending upon orchard condition and age. Typically trees are pruned initially on one side so that some crop yield is retained; the other side is then pruned 1-2 years later. Even severely bacterial blight infected orchards can be rejuvenated by proper pruning and orchard management practices. Since bacterial blight is the major problem in pomegranate, severe pruning of infected branches and scooping of stem
cankers with knife and application of Bordeaux paste 10 per cent thereon can help managing such orchards. Very high fruit yield (16 t/ha) of pomegranate was recorded after rejuvenation of bacterial blight infected orchard in Solapur district (Fig. 10).

4. **Pruning techniques:**
   a) **Topping:** This type of pruning is done manually or mechanically in bearing orchards to reduce tree height. This is most desirable in hedge row planting (Fig. 11). This should be done in premonsoon period (mid May-June) or in winter (December-January) preferably after fruit harvesting. However, topping in late spring or summer may result in unwanted vigorous upright growth and thus it should be avoided during this period. Pruning of 40-60 cm growth, depending upon the age and thickness of the branches, encourages vegetative growth which can help accumulation of reserve food materials in the plant for better flowering and fruiting in the next season. However, after topping sufficient organic manure and fertilizer should be applied in the soil.

Fig. 10. Profuse fruiting after rejuvenation of bacterial blight infected trees (cv. Bhagawa, 6 year old)

Fig. 11. Topping and skirting in pomegranate
b) Skirting: Removal of the lower tree branches up to a height of between 0.5-1m from the ground is termed as skirting. This improves under tree access for irrigation, weeding, fertilizer application etc. Even it also reduces the damage of certain insect pests and diseases. Topping and skirting should be done simultaneously after harvesting.

5. Pruning tips:
- Pruning should be a regular part of tree management.
- Pruning (15-25 cm) of terminal portion of a branch lowers down the total flower production and developed fruits get strong support on the branches (Fig. 12) during fruiting.
- Fruit size and yield of higher grade fruits are more with higher pruning intensity.
- Pruning minimises the bending of branches and staking.
- Sterilise pruning equipment with a sterilising solution of 3 per cent sodium hypochloride after each tree to reduce the spread of diseases, especially bacterial blight.
- Heavy pruning should not be carried out in hot weather as such pruning at the wrong time can result in excessive vegetative growth.
- The heavier you prune the longer it takes for the tree to recover for flowering and fruiting.

Fig. 12. Fruit bearing on strong branches or twigs after proper pruning
Crop regulation

1. Flowering and fruiting behaviour: The flowers may be solitary (single) or grouped in twos and threes at the ends of the branches. Generally, cross-pollination occurs by insects that increases the fruit set. However, wind pollination has insignificant role. Flowering time varies according to geographical situation and cultivars. In tropical climate, pomegranate flowers almost throughout the year whereas in subtropics, it flowers once a year. Under tropical condition, flower bud differentiation takes place at varied times. Time span between the start of the flower bud elongation and anthesis varies between 14 to 28 days depending on the variety and climatic conditions. But, in subtropical climates of the northern hemisphere, flowering occurs from the last week of March till the second week of May. In subtropical central and western India, there are 3 distinct seasons of flowering. In major pomegranate areas of Deccan Plateau, the flowering is regulated in three distinct seasons i.e. Ambe bahar (January-February flowering), Mrig bahar (June-July flowering) and Hasta bahar (September-October flowering). Ambe Bahar is most commonly preferred by the growers because of high yield as compared to other flowering seasons. In Karnataka, flowering is observed in June-August for 80-87 days but flowering in March and September extended over 22 to 30 days only. In Punjab, only one flowering season is observed from April-June. Under Delhi conditions, depending on cultivar, the flowering may occur once a year or twice. In temperate climate of Himachal Pradesh, the flowering takes place during middle of April. In Bihar, flowering occurs twice during February-March and July-August. Therefore, understanding of flowering behaviour in different regions is must for crop regulation.

Three kinds of flowers viz., hermaphrodite (female and male), male and intermediate forms occur on the same tree (Fig. 13). The calyx of the hermaphrodites is urceolate (pitcher-like) with a broad, well developed ovary. Male flowers are smaller with a companulate (bell-shaped) calyx and a rudimentary ovary. The intermediate forms exhibit various degrees of ovary degeneration. Fruits arising from such flowers drop early or if they reach maturity
they are mis-shaped. Hermaphrodite flowers are usually homostylosus or pin eyed (i.e. the stigmas are on the same level or higher than the anthers) and male flowers are thrum eyed (i.e. the stigmas are beneath the level of the anthers).

However, many exceptions to this rule apparently exist. The per cent of hermaphrodites out of the total number of flower on a pomegranate tree depends on the cultivar, the flowering season and other unknown environmental factors. In the beginning of the main flowering season this percentage is higher than at the end of the season. In several cultivars, 25 to 60 per cent hermaphrodite flowers, 20 to 47 per cent male flowers and 14 to 24 per cent intermediate forms have been reported in India but their ratios vary according to cultivars. Fruit yield, however, depends on number of hermaphrodite flowers as positive correlation is found between the bearing capacity and the percentage of perfect flowers. Though, it has a very specific flowering habit that the flower buds do not open at night. Maximal opening rates were found between 11 am and 2 pm, though the exact time depends on climate, flowering period and cultivars. In fact, for the opening of flower buds, an optimum temperature is reported to be between 37°C and 38°C. It has been reported that fruit retention increased from about 30 per cent during early flowering to about 80 per cent during full bloom and/or late flowering. However, flowers produced 4 to 5 weeks after the onset of blooming gave the highest fruit set (90%) with the best fruit quality.

2. Bahar treatment: This is an important operation in pomegranate in which plants are given rest by stopping water that causes artificial stress. Consequently, proper
flowering and fruiting occur. In general, a rest period of 3-4 months is necessary for a prolific harvest. Therefore, only one crop should be taken in a year. Three main bahars have been noticed in Deccan Plateau each has its own advantages and disadvantages as summarized below.

<table>
<thead>
<tr>
<th>Bahar</th>
<th>Flower initiation month</th>
<th>Harvesting month</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ambe</td>
<td>January - February</td>
<td>June - August</td>
<td>More flowering and high yield</td>
</tr>
<tr>
<td>Mrig</td>
<td>June - July</td>
<td>November-January</td>
<td>More prone to diseases and insect pests; fruit quality is not very good; it should be avoided in areas receiving more rainfall during July-September.</td>
</tr>
<tr>
<td>Hasta</td>
<td>September - October</td>
<td>February - April</td>
<td>Flowering good; fruit colour and quality best; less diseases and insect pests as fruits mature in cold season; fetches higher market price; preferred for export.</td>
</tr>
</tbody>
</table>

Considering the severe problem of bacterial blight, Hasta bahar is recommended in blight affected areas. However, in other areas, it can be taken depending on water availability and market demand. The crop is evergreen in Deccan Plateau. Hence, it has to be forced into rest by giving stress before flower initiation. Irrigation is stopped at least 30-35 days before defoliation (during bahar treatment) in light sandy soil and 40-45 days or even 2 months before defoliation in sandy loam soil. In the last period of stress, defoliation is done using ethrel 2-2.5 ml/litre and just after defoliation (80-85% leaf fall), light pruning (15-25 cm) is done (Fig. 14). After stress period, the fallen leaves are collected and burnt. And land is ploughed or shallow digging is done. Just after completion of pruning operation, a light irrigation is given and then recommended doses of manure and fertilizer are
applied and regular normal irrigation is started at prescribed interval. Excess irrigation at this stage should be avoided otherwise flowering will be affected adversely. The tree responds readily to irrigation and produces new flush (Fig. 15). Generally, flowering occurs within 30-75 days after first irrigation (Fig. 16). Initially more male flowers appear and subsequently, hermaphrodite flowers appear and produce fruits (Fig. 17). Judicious irrigation should be given at this stage (fruit setting). Only healthy and properly developed fruits should be retained on the tree canopy. Regular plant protection measures should be followed throughout the cropping season.

Fig.14. Defoliation followed by light pruning (15-25 cm) in pomegranate

Fig.15. New flushes appear on the tree between 8 and 12 days after first irrigation

Fig.16. Profuse flowering on trees after bahar treatments

Fig.17. Heavy fruiting after bahar treatment
Nutrient management

Although pomegranate grows well in soils of low fertility, its productivity and fruit quality can be enhanced by adequate supply of nutrients. In fact, balanced nutrition is needed both to the young and bearing trees for better growth and optimum fruit production. It is observed that most of the roots are distributed in top 60 cm of soil and within 1 m of the stem. Accordingly, nutrients should be applied in the root zone depending upon the age of the tree. In general, 33.6 kg N, 6 kg P, 52.2 kg K, 13.6 kg Ca, 2.0 kg Mg and 4.4 kg S, 55 g Fe, 28.5 g Mn, 78 g Zn and 38.8 g Cu are removed if 30 tonnes of fruit yield/ha is taken. Thus, replenishment of these nutrients in soil is of paramount significance for sustainable production. Both macro and micro-nutrients are needed for proper growth, development and productivity of pomegranate, when grown as a commercial crop. There is a need to promote site specific nutrient application in pomegranate for enhancing the nutrient use efficiency. In the recent past, leaf nutrient standards have been developed for pomegranate trees (Table 1) which may be useful for the growers. Even nutrient deficiency symptoms can be diagnosed by observing the deficiency symptoms on leaves (Table 2). And thus after leaf analysis, nutrients may be supplied to the trees either through soil or foliar sprays. Now, trend is also developing to apply soluble fertilizers (fertigation) through drip irrigation system which is the need of hour as fertigation has some advantages like it improves availability of nutrients and their uptakes by roots, application is restricted to wetted area where root activity is most intensive, loss of nutrients by leaching is minimum, soil compacting is prevented, weed population is reduced and labour and fertilizer cost is minimised. It has been reported that up to 75 per cent of recommended rate of fertilizers on 20-40 per cent wetted area basis can be given through fertigation. However, perfect fertigation schedule for pomegranate in different agro-climatic conditions has to be developed to promote precision farming.
Table 1: Leaf nutrient standards for pomegranate

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Observed Range</th>
<th>Deficient</th>
<th>Low</th>
<th>Optimum</th>
<th>High</th>
<th>Excess</th>
</tr>
</thead>
<tbody>
<tr>
<td>N (%)</td>
<td>0.40 - 2.20</td>
<td>&lt; 0.54</td>
<td>0.54-0.90</td>
<td>0.91-1.66</td>
<td>1.67-2.04</td>
<td>&gt;2.04</td>
</tr>
<tr>
<td>P (%)</td>
<td>0.08 - 0.33</td>
<td>&lt; 0.09</td>
<td>0.09-0.11</td>
<td>0.12-0.18</td>
<td>0.19-0.21</td>
<td>&gt;0.21</td>
</tr>
<tr>
<td>K (%)</td>
<td>0.20 - 2.05</td>
<td>&lt; 0.20</td>
<td>0.20-0.60</td>
<td>0.61-1.59</td>
<td>1.60-2.26</td>
<td>&gt;2.26</td>
</tr>
<tr>
<td>Ca (%)</td>
<td>0.06 - 2.40</td>
<td>&lt; 0.13</td>
<td>0.14-0.76</td>
<td>0.77-2.02</td>
<td>2.03-2.65</td>
<td>&gt;2.65</td>
</tr>
<tr>
<td>Mg (%)</td>
<td>0.16 - 0.49</td>
<td>&lt; 0.03</td>
<td>0.03-0.15</td>
<td>0.16-0.42</td>
<td>0.43-0.55</td>
<td>&gt;0.55</td>
</tr>
<tr>
<td>S (%)</td>
<td>0.04 - 0.70</td>
<td>&lt; 0.10</td>
<td>0.10-0.15</td>
<td>0.16-0.26</td>
<td>0.26-0.42</td>
<td>&gt;0.42</td>
</tr>
<tr>
<td>Fe (ppm)</td>
<td>25 - 297</td>
<td>&lt; 34</td>
<td>34-70</td>
<td>71-214</td>
<td>215-286</td>
<td>&gt;286</td>
</tr>
<tr>
<td>Mn (ppm)</td>
<td>14 - 99</td>
<td>&lt; 15</td>
<td>15-28</td>
<td>29-89</td>
<td>90-119</td>
<td>&gt;119</td>
</tr>
<tr>
<td>Zn (ppm)</td>
<td>7 - 44</td>
<td>&lt; 8</td>
<td>8-13</td>
<td>14-72</td>
<td>73-94</td>
<td>&gt;94</td>
</tr>
<tr>
<td>Cu (ppm)</td>
<td>21 - 86</td>
<td>&lt; 7</td>
<td>8-28</td>
<td>29-72</td>
<td>73-94</td>
<td>&gt;94</td>
</tr>
<tr>
<td>Yield (t/ha)</td>
<td>20 - 87</td>
<td>&lt; 13.7</td>
<td>13.7-15.5</td>
<td>15.6-18.8</td>
<td>18.9-20.6</td>
<td>&gt;20.6</td>
</tr>
</tbody>
</table>


Table 2: Deficiency symptoms of some important nutrients on pomegranate leaves

<table>
<thead>
<tr>
<th>Deficiency symptoms</th>
<th>Diagnosis of nutrient deficiency symptom</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Nitrogen</strong></td>
<td>Restricted plant growth; first symptom appears on lower and mature leaves; yellowing seen uniformly on whole leaf; subsequently, whole leaves turn yellow starting from tip downwards; leaves become stiffer in strength; plants flower early with more hermaphrodite flowers; at advanced stage leaves become light brown followed by drying up from the tip.</td>
</tr>
</tbody>
</table>
**Phosphorous**: Stunted plant growth; first symptom appears on younger leaves; leaves become slender, elongated and smaller in size; leaf margins turn upwards and get tunnel like shape; yellowing of leaf starts from tip only other part remains green; in advanced stage total leaf becomes yellow followed by appearance of chlorotic spots which later on turns dark brown; veins of the leaves also turn yellow.

**Potassium**: First symptom appears on older leaves; many brown spots appear on dorsal side of leaves along the leaf margin starting from tip; leaf margin becomes yellow followed by scorching appearance.

**Calcium**: First symptom appears on younger leaves; inter-veinal yellowing starts from leaf tip, advanced from margin towards midrib, veins remain green during initial stages and in later stages become yellow; pinkish tinge appears on the yellow portion of the leaf; yellow portion of leaves turn dark brown in color and half of the leaf from the tip dry up.

**Magnesium**: Leaf margin and vein appear light green in colour; grey patches appear on the side margin of the leaves, subsequently covers whole leaf; leaves show drying up sign; the colour of dry leaves is grey while in case of Ca it is dark brown.

**Sulphur**: Deficiency symptoms first appear on middle leaf; leaf veins become light green in colour; yellowing starts on the middle of leaf around the mid rib; inter-veinal area turns yellow in color and whole leaf becomes yellow.

**Iron**: Deficiency symptoms first appear on younger leaves; inter-veinal chlorosis followed by complete yellowing and subsequently drying of leaf.
1. Application of manure and fertilizer in non bearing trees: Recommended dose of manure and fertilizer (Table 3) should be applied to non bearing trees (1-3 years) in three split doses coinciding with growth flushes during January, June and September. The manure and fertilizer should be applied in shallow trenches/small pits at 30-45 cm away from the main stems below the tree canopy at 8-10 cm depth and it should be covered immediately after application (Fig. 18). If deficiency of micronutrients is observed in the tree, based on leaf analysis (Table 2) the required nutrients may be applied through foliar spray(s) or soil application(s) through slurry (25 g each of zinc sulphate, borax, manganese sulphate and iron sulphate).

Table 3: Manure and fertilizer requirement of pomegranate

<table>
<thead>
<tr>
<th>Age of tree (Year)</th>
<th>FYM (kg)</th>
<th>Nitrogen (g)</th>
<th>Phosphorus (g)</th>
<th>Potash (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10</td>
<td>250</td>
<td>125</td>
<td>125</td>
</tr>
<tr>
<td>2</td>
<td>20</td>
<td>250</td>
<td>125</td>
<td>125</td>
</tr>
<tr>
<td>3</td>
<td>30</td>
<td>500</td>
<td>125</td>
<td>125</td>
</tr>
<tr>
<td>4</td>
<td>40</td>
<td>500</td>
<td>125</td>
<td>250</td>
</tr>
<tr>
<td>5 and above</td>
<td>40</td>
<td>625</td>
<td>250</td>
<td>250</td>
</tr>
</tbody>
</table>


2. Application of manure and fertilizer after fruit harvest: The plants are exhausted to a considerable extent after fruit harvesting. Then it becomes necessary to promote vegetative growth by proper pruning and nutrition. Hence, after harvesting of the crop, pruning and nutrient application should be done with the
3. Application of manure and fertilizer after bahar treatments (crop regulation): Now, remaining 2/3rd recommended dose of the manure and fertilizer (Table 3) should be applied in split doses after defoliation and pruning. First split dose consisting of full dose of FYM, 1/3rd dose of N and K, full dose of P and additional dose of neem cake @ 1 kg, vermi-compost 1 kg with phorate 20 g and biofertilizers @ 25 g each of Azotobacter and phosphorus solubilizing bacteria (PSB)/tree should be applied as basal dose just after first irrigation and remaining two split doses of N and K at 3-4 weeks intervals. Apply manure and fertilizer in shallow circular trenches/small pits (8-10 cm depth) at 45-60 cm away from main stems below tree canopy and cover with top soil and give irrigation (Fig.19).

It is more appropriate to apply nutrients based on soil and leaf analysis. However, based on leaf analysis of pomegranate (cv. Bhagawa), the optimum concentrations of different nutrients have been worked out as nitrogen 2.5 per cent, phosphorus 0.2 per cent, potassium 1.47 per cent, calcium 1.3 per cent, magnesium 0.75 per cent, sulphur 0.18 per cent, iron 199 ppm, manganese 196 ppm, zinc 55 ppm and boron 76 ppm. Accordingly, nutrients should be maintained in the leaves.
Moreover, Zn, Fe, B and Mn have been reported to be more limiting micro-nutrients in pomegranate. So composite nutrient sprays of 0.4 per cent ferrous sulphate + 0.3 manganese sulphate + 0.3 per cent boric acid + 0.3 per cent zinc sulphate before flowering, during flowering or fruit setting should be done to increase yield and quality of fruits. In fact, integrated nutrient management approach found to be better option for nutrient supply in pomegranate. Preferably 1/3rd dose of nutrients required by the plants should be applied as organics (manures), 1/3rd through inorganics (fertilizers) and remaining 1/3rd through fertigation (soluble fertilizers). Beneficial effect of calcium nutrition through fertigation has been noted. Thus, one month before fruit harvesting, schedule two drip irrigation applications of calcium nitrate 12.5 kg/ha/application at 15 days interval.

**Water management**

Although pomegranate enjoys heat and thrives well in arid and semi-arid areas, it still needs regular irrigation throughout the dry season to get optimal yield and fruit quality. However, at the same time it is sensitive to even slight water deficit or excess water that affects tree growth adversely. In fact, from commercial point of view, it should not be considered as a drought tolerant plant and irrigation should be scheduled so as not to stress the plant. The most sensitive phase of a plant growth cycle occurs during pollination and fertilization; it is critically important not to incur water deficits in these phases. Further water deficits, at fruit maturity and ripening stages, will likely result in splitting of fruits and such fruits will be unsuitable for the fresh market. Therefore, irrigation management is highly essential in pomegranate in order to get higher yield and better fruit quality. Moreover, water requirement varies in different seasons and growth stages. For Mrig bahar crop, first irrigation needs to be given during mid-May followed by regular irrigation until the onset of monsoon. In post-monsoon period, copious and regular irrigation is essential for better development of fruits. However, for other bahars (seasons), regular irrigation is must through out the cropping period. At present, drip irrigation (Fig. 20) is common in major pomegranate growing areas which can save up to 66 per cent of water.
Fig. 20. Drip irrigation is highly efficient system of irrigation in pomegranate compared to surface irrigation. Besides water saving, yield can be increased up to 30-35 per cent by this method. Even application of water equivalent to 20-40 per cent wetted area in non-bearing and bearing trees of pomegranate is optimum. Thus, drip irrigation system with 2-4 online drippers/tree should be followed in the non-bearing and bearing orchards depending upon age of the tree. For up to 3 year old trees, 2 drippers/tree may be enough to provide required irrigation to the plant. While from 4th year onwards 4 drippers/tree may be better. Even fertigation can be done through drip irrigation. In general, for non-bearing trees, about 5-25 litres/tree/day and 20-65 litres/tree/day for bearing trees are needed. However, quantity of water will depend upon age of the tree, variety, soil type, season, stage of crop etc. In general, irrigation should be given regularly on daily or alternate day basis during fruiting period. Although, everyday moisture level in the root zone should be checked and accordingly, frequency of irrigation should be decided. Excess irrigation should always be avoided as its roots are highly prone to rotting which may invite wilt and nematode problems in the orchards. Therefore, judicious irrigation should be provided to the trees.

Even, use of mulches (organic and inorganic) can improve water use efficiency under drip irrigation system. Water requirement (Table 4) has been determined for pomegranate based on 100 years data on cumulative pan evaporation under 4.5 m x 3 m spacing (740 trees/ha) that may be followed. However, bahar wise water requirement for 4th and 5th year onwards is given in Table 5, which may be beneficial for enhancing water use efficiency in pomegranate (cv. Bhagawa).
### Table 4: Water requirement of pomegranate (litres/day/tree)

<table>
<thead>
<tr>
<th>Month</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5 and above</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>2.70</td>
<td>7.59</td>
<td>20.93</td>
<td>29.90</td>
<td>38.87</td>
</tr>
<tr>
<td>February</td>
<td>2.83</td>
<td>10.39</td>
<td>28.66</td>
<td>40.95</td>
<td>53.23</td>
</tr>
<tr>
<td>March</td>
<td>2.96</td>
<td>11.10</td>
<td>31.08</td>
<td>44.40</td>
<td>57.72</td>
</tr>
<tr>
<td>April</td>
<td>3.24</td>
<td>12.15</td>
<td>34.02</td>
<td>48.60</td>
<td>63.18</td>
</tr>
<tr>
<td>May</td>
<td>3.40</td>
<td>12.75</td>
<td>35.70</td>
<td>51.00</td>
<td>66.30</td>
</tr>
<tr>
<td>June</td>
<td>1.99</td>
<td>7.69</td>
<td>21.95</td>
<td>31.35</td>
<td>40.75</td>
</tr>
<tr>
<td>July</td>
<td>1.54</td>
<td>5.94</td>
<td>16.94</td>
<td>24.20</td>
<td>31.46</td>
</tr>
<tr>
<td>August</td>
<td>1.33</td>
<td>5.13</td>
<td>14.63</td>
<td>20.90</td>
<td>27.14</td>
</tr>
<tr>
<td>September</td>
<td>1.33</td>
<td>5.13</td>
<td>14.63</td>
<td>20.90</td>
<td>27.17</td>
</tr>
<tr>
<td>October</td>
<td>1.57</td>
<td>6.07</td>
<td>18.90</td>
<td>27.00</td>
<td>35.10</td>
</tr>
<tr>
<td>November</td>
<td>1.80</td>
<td>6.75</td>
<td>18.90</td>
<td>27.00</td>
<td>35.10</td>
</tr>
<tr>
<td>December</td>
<td>1.68</td>
<td>6.30</td>
<td>17.64</td>
<td>25.20</td>
<td>32.76</td>
</tr>
</tbody>
</table>


### Table 5: Water requirement of bearing tree of pomegranate (cv. Bhagawa) in different bahars at various stages

<table>
<thead>
<tr>
<th>Crop stage</th>
<th>Ambe bahar</th>
<th>Mrig bahar</th>
<th>Hasta bahar</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Month</td>
<td>Age wise water requirement in litres/day/tree</td>
<td>Month</td>
</tr>
<tr>
<td>I 4th year</td>
<td>January</td>
<td>8</td>
<td>June</td>
</tr>
<tr>
<td>II 5th year</td>
<td>February-March</td>
<td>31</td>
<td>39</td>
</tr>
<tr>
<td>III 4th year</td>
<td>April-July</td>
<td>48</td>
<td>55</td>
</tr>
<tr>
<td>IV 5th year &amp; above</td>
<td>August</td>
<td>24</td>
<td>33</td>
</tr>
</tbody>
</table>

I- New leaf initiation (30 days); II- Blooming and fruit set (60 days); III- Fruit development and maturity (120 days); IV- Harvesting (30 days)
**Intercropping**

In the early stage of establishment of pomegranate orchard till bearing, the inter-space should be economically utilized preferably with leguminous crops. Since it is mainly grown in arid and semi-arid regions, where water scarcity is observed, some suitable intercrops can be taken mainly in rainy season. Therefore, low-growing vegetables, pulses or green manuring crops etc. may be grown in pre-bearing orchards for additional income (Fig. 21) or to improve the soil fertility. The choice of the intercrops will depend upon the *bahar* to be taken and irrigation facilities available or amount of rainfall and its distribution pattern. Even, fruit crops like sapota, mango, custard apple, lime, sweet orange, guava etc. may be included in pomegranate based farming system (Fig. 22).
**Weeding and moisture conservation**

Weed management is an important operation in pomegranate. Since regular irrigation is given in pomegranate, which encourages growth of weeds that compete with trees for water and soil nutrients. In addition, weeds can host a wide range of damaging pomegranate pests and might disturb efficient pest control.

Black polythene mulch or organic mulches such as sawdust, banana trash, paddy husk, sugarcane trash etc. may be used for soil moisture conservation and weed control. Use of mulches reduces water consumption by 20-25 per cent and also reduces weed population by about 20 per cent. Regular manual weeding is must, especially after fertilizer application. However, some small weeding tools and implements are available which may also be used for weeding. Besides, several herbicides have also been found beneficial for management of weeds. Oxyfluorfen and simazine (triazine) as pre-emergence herbicides can control wide spectrum of annual broad leaf weeds and grasses (Fig. 23). Even Glyphosate, a nonselective post-emergence herbicides (total killer), is also effective in controlling all kinds of weeds in pomegranate orchards. However,
extensive use of these herbicides may result in tree damage; therefore, proper care should be taken while using the herbicides. The recommended dose of herbicides should be used for weed management. Always avoid use of higher doses of weedicides.

**Fruit quality enhancement**

Fruit quality with respect to size, sweetness, colour development, shelf life, occurrence of cracking and spoilage by insects and diseases in different cultivars vary with season and cultivation practices. These aspects can be managed with suitable cultural practices. Among these thinning of fruits at appropriate stage is very important. Proper thinning of fruitlets during the selected *bahars* (seasons) to an optimum number helps developing good size fruits (Fig. 24). On an average 60-80 fruits should be retained on fully grown up trees in order to produce export quality fruits. Avoid excess fruiting which exhausts the tree that may cause low or irregular fruiting in the next season.

In *Ambe bahar*, the aril and rind colour development is enhanced when fruits are harvested during July-August (Fig. 25) in Maharashtra owing to prevalence of moderate temperature (< 30°C). Similarly, fruits ripening during December-February also develop very good colour. Therefore, crop regulation (*bahar* treatments) should be done in such a way that the fruit is ready in these months. However, fruits available during December-March are preferred for export. In fact, in North India the fruit quality with respect to colour and sweetness is better in *Mrig bahar* than *Ambe bahar*. This indicates that mild temperature during fruit maturation and ripening is essential for better colour development of fruit skin and arils. Potassium application through foliar sprays or drip irrigation during last stage of fruit maturation or early...
ripening stage also improves fruit colour. Even covering of fruits with butter paper bags has been found to improve the rind colour and protection from insects and diseases.

Fig. 25. (A) Good colour development in cv 'Ganesh' and (B) 'Bhagawa'during rainy season

Physiological disorders and their management

Among the abiotic disorders, fruit cracking, sun scald/sunburn and internal breakdown or blackening of arils are very common in pomegranate. These disorders are associated with several factors like environmental, edaphic, nutritional, hormonal, varietal, cultural etc.

1. Fruit cracking and splitting: This is a general phenomenon in fruit crops that fruits are splitted or cracked. However, cracking is a general term applied to certain physical disorders of fruits that are expressed as fractures in cuticle or skin. These fractures may be microscopic or easily seen, some times extending deep into inner flesh as well defined cavities. Splitting is an extreme form of cracking in which the cracks penetrate deep into the flesh. As high losses as 75 per cent have been reported in pomegranate (Fig. 26). Cracks or splits provide open wounds that facilitate rapid moisture loss and excessive shriveling, which lowers fruit quality and storage life. Fruit cracking occurs in practically all pomegranate growing areas but degree of crop loss varies in different regions. It is a serious problem in Rajasthan and Northern India. As high as 63 per cent cracking has
been reported in pomegranate in the spring crop (January-June), 34 per cent in the winter crop (October-March) and only 9.5 per cent in the rainy season crop (July-December) in Rajasthan. Apart from biotic fruit cracking caused by bacterial blight, it is also associated with improper irrigation, environmental factors and nutritional deficiency, especially boron, calcium and potash. Besides, high temperature during the drought period causes desiccation of the plants and consequently the fruit skin become hard and less elastic. The heavy rains accelerate the growth processes and expansion of internal tissues resulting in cracking of the inelastic fruit skin. The cracking is more evident when the fruits are at maturity stage. It has been observed that during drought period, strengthened tissues (skin) lose their ability to divide and enlarge. If after a dry spell, water supply is greatly increased, the meristematic tissues quickly resume growth but not the strengthened tissues. Owing to differential growth rates; harder tissues rupture.

The genetic character of a variety has role in fruit cracking. Some exotic varieties viz., 'Shirvan', 'Burachni', 'Apsheronskii Krasnyi', have been reported to be resistant to fruit cracking under sub-tropical conditions. Even some cultivars tend to split in much earlier stages of fruit development. Cultivar 'Bhagawa' is found to be a
less cracking type in India owing to its thick rind. However, for management of fruit cracking, several horticultural practices have been recommended. Spraying with some chemicals like 150-250 ppm GA\textsubscript{3}, 0.2 per cent boron, 1 per cent KNO\textsubscript{3}, or MgSO\textsubscript{4}, 5 per cent pinolene (an antitranspirant) 4-5 weeks before harvest, micronutrients, regular irrigation through drip irrigation and mulching reduce fruit cracking in pomegranate. In fact, regular water supply through drip irrigation system at fruit development, maturity and ripening stages reduces fruit cracking in pomegranate. Because of this fact, in major pomegranate growing areas of Deccan Plateau, fruit cracking is not a major problem. Hence, regular irrigation during cropping season is the best option to minimise fruit cracking in pomegranate.

2. Sun scald: In Deccan region, pomegranate fruits are damaged owing to high solar radiation. In case of sun scald (sunburn), the fruit skin turns brown or bronze colour (Fig. 27). Generally, the fruits facing sunlight are more affected during April to June by solar radiation. In fact, solar radiation between 220 J/cm\textsuperscript{2} and 324 J/cm\textsuperscript{2} is highly correlated with fruit surface temperatures. And fruit surface temperatures that cause sunburn are reported to vary between 41°C and 47.5°C. There has not been reported any variety in India having sun scald resistance. However, in Israel early cultivars such as Akko and Shani-Yonay are noted to be less susceptible to sun burn. Usually, high temperature along with excessive light, drought, and low relative humidity are responsible for sun scald injuries. In some parts of Deccan Plateau farmers follow severe pruning consequently fruits are exposed to sun light leading severe sun scald problems. It has been reported that spraying of refined Kaolin over the whole canopy and fruits four times at 2-3 week intervals at 5 per cent (first spray) and other three at 2.5 per cent reduced sun burn damage by reducing leaf and fruit surface temperatures and improved fruit colour. However, sun scald damage on fruits can be reduced by proper training and pruning.
3. **Internal breakdown**: Aril browning or blackening (internal breakdown) is a common phenomenon in Indian pomegranate varieties grown in Maharashtra and its adjoining areas. In this malady, the arils become brown (Fig. 28) and somewhat flattened rather than plumb. Even, the aril colour development is arrested and flavour is abnormal. The fruit is apparently healthy but after cut open its arils look abnormal (brown or blackish). It originates commonly during growth in some seasons. In variety 'G-137', the incidence of internal breakdown develops 150 days after anthesis and its intensity increases when the fruits are left on the tree for more than 165 days. The incidence of browning increases with increase in weight of fruit from 150 to 200 g (26.60%) to more than 350 g (60%). Chemical analysis of pomegranate fruit revealed that TSS, acidity, ascorbic acid, total sugars, reducing sugars, calcium, phosphorus and the enzyme catalase were low whereas non reducing sugars, starch, tannins, nitrogen, potassium, magnesium, boron, polyphenoloxidase and peroxidase enzymes were high in affected arils of cvs Ganesh and P-23 than in healthy ones. It has been noticed that 'Bhagawa' has less problem of internal breakdown. As a precautionary measure, fully ripen fruits should not be retained on the tree for more periods and adequate nutrients should be supplied to the bearing trees. Though, the exact cause of this malady is yet to be ascertained.

![Fig. 28. Symptoms of internal breakdown on arils (grains)](image-url)
Fruit maturity and harvesting

In general, the fruit ripens 5-8 months after fruit set, depending on the variety. Most of the pomegranate varieties reach full ripeness between 125 and 180 days after flower opening in different agro-climatic conditions. Pomegranate fruit has a typical characteristic of non-climacteric fruits. Thus, in order to ensure the best eating quality, the fruit should be picked at the fully ripened stage. The major maturity indices in pomegranate are TSS, acidity and fruit colour. Generally, sweet varieties contain acidity below 1 per cent while sweet-sour ones 1-2 per cent. The fruits of 'Bhagawa', 'Mridula' and 'Ganesh' are ready for harvest when TSS ranges between 14.5° brix and 15.5° brix and acidity between 0.35 per cent and 0.45 per cent. Thus, based on these maturity indices fruits can be harvested. Time of harvesting influences the storage life of fruits. In order to have better fruit quality and prolonging shelf life, the fruits should be harvested either early in the morning or in the evening hours with the help of clippers from the base of the fruit.

Yield and economics

Pomegranate is a highly remunerative crop in Deccan Plateau. On an average fruit yield of 15-20 t/ha can be obtained from a well maintained orchard (5-6 years old) which may fetch a net return of Rs.2.50-3.50 lakhs/ha.
Improper handling of pomegranate fruits leads to high spoilage losses (25-30%) However, with due care during various stages of handling operations such losses can be minimised.

**Handling**

Handling deals with many operations right from harvesting to marketing and these operations vary for domestic and international marketing. Fully matured fruits are picked manually and assembled at grading platform for on farm grading and packing. In general, for export purpose the fruits should be harvested with clippers and placed in picking bags or plastic crates for transport to the packing house. Then the fruits are sorted to eliminate those with severe defects like scuffing, cuts, bruises, splitting and decay. And the remaining fruits are separated according to the magnitude of the physical defects. The fruits with moderate defects are used for processing into juice and those with slight or no defects are marketed fresh. The latter fruits are washed, air dried to remove surface moisture, fungicide treated, waxed, divided into several size grades and packed in shipping containers. Various ways to immobilize the fruits within the shipping containers have been suggested to reduce incidence and severity of scuffing and impact bruising during handling. Packed fruits are cooled by forced-air cooling at 7°C and kept at the same temperature with 90-95 per cent relative humidity (RH) during storage and subsequently the packed fruits are transported for marketing.

1. **Transportation of fruit from field to pack-house:** After harvesting, the fruits should be transported immediately to pack house and precaution should be taken that the natural colour and shine of the fruit are maintained while transportation and unloading.

2. **Sorting and grading:** Diseased and insect damaged fruits should be discarded while sorting the fruits. Sound fruits according to standard grades should be kept separately for marketing. Grading is done based on fruit weight, size and rind colour and following grades are common. Generally, 12A grade fruits are
preferred in Southern and Northern India. However, grading can be done by mechanical graders also.

<table>
<thead>
<tr>
<th>Grade</th>
<th>Weight (g)</th>
<th>Skin colour</th>
<th>Skin quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Super sized</td>
<td>&gt;750</td>
<td>Good attractive bright red colour</td>
<td>No spots on skin</td>
</tr>
<tr>
<td>King sized</td>
<td>500-750</td>
<td>Attractive red colour</td>
<td>Spot free</td>
</tr>
<tr>
<td>Queen sized</td>
<td>400-500</td>
<td>Bright red</td>
<td>Spot free</td>
</tr>
<tr>
<td>Prince sized</td>
<td>300-400</td>
<td>Fully ripe bright red</td>
<td>Spot free</td>
</tr>
<tr>
<td>12 A</td>
<td>250-300</td>
<td>Fully ripe red colour</td>
<td>Spot free</td>
</tr>
<tr>
<td>12 B</td>
<td>250-300</td>
<td>Fully ripe red colour</td>
<td>Some spots</td>
</tr>
</tbody>
</table>

3. **Packing**: The fruits are packed according to market needs. Corrugated fiberboard boxes are used for packaging due to their light weight and easy in handling. In a single box, 4-5 queen sized fruits, 12 prince sized or about 15-18 of 12A or 12B grades may be packed. The white colour boxes with 5 piles are used for export purpose and red colour ones with 3 piles are preferred for domestic markets. Mainly three kinds of boxes viz. 13” x 9” x 4”, 15” x 11” x 4” and 14” x10” x 14” are prepared for packing. And cut pieces of waste paper are utilized as cushioning material while packing of fruits. After proper packing of fruits in the boxes according to different grades, the boxes are ready for marketing.

4. **Storage**: The fruits are very susceptible to water loss resulting in shrivelling of the rind. The relative humidity has major impact on improving the storability of pomegranate fruits under different storage conditions. At low humidity, the skin desiccates readily and the rind becomes dark and hard with poor marketability. Physiological activities like respiration and ethylene production rates in pomegranate fruits are increased with an increase in temperature and these activities influence the storability of the fruits. In fact, high temperature with low RH causes more water losses from the fruit. In general, a RH of 90 to 95 per cent has been reported to be congenial for storage of the fruits. Even, use of plastic liners and waxing can reduce water loss, especially under conditions of lower RH.
The fruits are susceptible to chilling injury if stored longer than 1 month at temperatures between their freezing point (-3°C) and 5°C, or longer than 2 months at 5°C. However, it has been proved that the minimum safe temperature for postharvest handling of pomegranate fruits is between 5 and 8°C, depending on the variety and growing condition. Some heat treatments (hot water dips, forced hot air and vapour) can induce tolerance to low temperature, reducing chilling injury and thus increasing shelf life. Some studies have shown a reduction in incidence of chilling injury symptoms by conditioning before storage, intermittent warming during storage, or modified atmosphere packaging.

Recently, controlled atmosphere (CA) storage with 5 per cent O₂ + 15 per cent CO₂ at 7°C and 90-95 per cent RH was reported to be optimal for storage of pomegranate. Even, use of polyethylene bag wraps significantly reduces weight loss and improves appearance of the fruit under CA storage. Now, modified atmosphere packaging; involves the usage of special bags (Xtend®) having small pores has been developed. These bags result in the development of 5 per cent O₂ and 12 to 14 per cent CO₂ within the bag surrounding the fruit. The Xtend® packaging reduces weight loss from 7 to 3.5 per cent, reduces the scald from 38 per cent to 21 per cent and reduces crown decay when fruits stored at 6°C for 16 weeks. Using either the Xtend® packaging technique or CA conditions of 2 per cent O₂ + 3 per cent CO₂ at 6°C permitted storage of pomegranate fruit for 4-5 months with acceptable commercial quality. However, it is advocated to use suitable anti-fungal chemicals prior to storage.

**Postharvest disease management**

The fungal species of genus *Botrytis, Cladosporia, Phomopsis, Rhizopus* and *Sphaceloma* have been found to be associated to cause decay in pomegranate fruits. However, gray mold caused by *Botrytis cinera* and rot caused by *Penicillium implicatum, Rhizopus arrhizus* and *Alternaria solani* have also been reported to cause decay during storage of pomegranate fruits. *Botrytis cinera*, is the primary limiting
factor for long-term storage. To prevent development of fungicidal resistance in these pathogens, a combination of sanitation treatments with chlorine and fungicides dip is recommended before cold storage. A combination of waxing with antifungal treatments has been suggested to extend the shelf life and the quality of pomegranate in cold storage and ambient conditions. Appropriate postharvest disease management strategies need to be followed to minimise physical damage during fruit harvesting and postharvest handling. However, maintaining optimal temperature and relative humidity throughout postharvest handling of the fruits are prerequisites. \( \text{CO}_2 \)-enriched atmospheres are fungistatic and inhibit growth of \textit{Botrytis cinera}. Use of Fludioxonil as a postharvest fungicide is effective in controlling this fungus. Dipping treatment with aqueous Topsin-M (0.1%) and Bavistin (0.05 to 0.1%) is found to inhibit the growth of \textit{Aspergillus niger}. Pre-treatment of pomegranate fruits with hot water at 45°C was shown to reduce chilling injury and electrolyte and K leakage. Heat treatment has also been reported to be effective in maintaining the nutritive and functional properties of pomegranate fruit after a long period of storage.
Pomegranate is prone to different diseases and insect pests; however, their distribution varies in different geographical regions. At present, bacterial blight and wilt are the most threatening diseases affecting pomegranate cultivation, causing enormous losses (50-80%) to growers in different regions. Besides, fungal leaf and fruit spots, *Phytophthora* blight and fruit rots are also emerging as new threats to this crop, if not managed timely with recommended management practices. Similarly, among insect pests, fruit borer (*Anar* butterfly), fruit sucking moth, thrip, aphid, stem borer, shot hole borer, nematode etc. are of major concern.

**Important diseases and their management**

1. **Bacterial blight:** It is caused by a bacterium *Xanthomonas axonopodis* pv. *punicae*. The bacterial blight is also known as nodal blight or black spot; in Maharashtra it is commonly known as oily spot or *Telya*.

   **Symptoms:** The bacterial blight symptoms can be observed on all aerial plant parts *(Fig. 29)*. On leaves initially small regular to irregular greyish black water soaked spots appear on the under surface, which increase in size and turn dark brown to black, surrounded by a yellow halo. On twigs water soaked spots turning black-brown start around the nodes. The lesions enlarge and spread on the twig leading to girdling and cracking of the nodes on slight pressure. On fruits infection starts with scattered round water soaked spots which later turn brown to black. The spots enlarge, coalesce and develop small cracks of various shapes, in severe cases entire fruit splits open.

![Necrotic spots with yellow halo on leaves](image1)

![Nodal blight on young twig](image2)

![Necrotic lesions with cracks on fruits](image3)

**Fig. 29. Symptoms of bacterial blight**
**Epidemiology:** In established orchards stem cankers, dormant buds and plant debris are major sources of primary inoculum. The secondary spread of bacterium is mainly through rain/spray splashes, irrigation water, pruning tools, human activities and insect vectors. Temperatures between 28°C-35°C, humidity ≥ 80 per cent, light drizzles and more number of rainy days play important role in rapid disease development.

**Management:**

- Resistant varieties/transgenic lines can only be the long term solution. In the absence of any resistance source, integrated management schedule should be followed. This includes change of crop season, balanced plant nutrition, orchard sanitation, and judicious spray schedule of recommended pesticides.
- The progeny orchards should be established from mother plants free of bacterial blight.
- New orchards should be established with certified disease free planting material or tissue culture saplings.
- Apply Bordeaux paste (10 %) to the cut ends of the mother plant and air layered cuttings.
- Monthly sprays of streptocycline (0.5 g/l) + COC (2.5 g/l) altered with bronopol (0.5 g/l) + COC (2.5 g/l) in bacterial blight affected areas and only COC in disease free areas should be taken till plants are ready for planting in the orchard.
- Before taking the planting material to the main field spray the plants with COC (2.5 g/l) + streptocycline (0.25 g/l).
- One month after planting, spray with streptocycline (0.5 g/l) + COC (2.5 g/l) in epidemic areas and only COC in disease free areas. Take alternate sprays of Bordeaux mixture (1%). Alternately, COC + streptocycline sprays have to be replaced with 2-bromo-2-nitropropane-1,3-diol (Bronopol) @ 0.5 g/l + captan @ 3 g/l. When fruiting is taken COC can be replaced with suitable systemic fungicides in alternate sprays.
- In orchards having blight, one spray of streptocycline (0.5 g/l) or bronopol (0.5 g/l) + COC (2.5 g/l) after the rain stops is mandatory.
• If blight symptoms are observed on stems, prune and remove infected twigs. Prune about 5cm below the infected area. Apply Bordeaux paste (10%) to the cut ends after pruning. Oil based pastes like COC paint (1kg COC + 750-1000 ml linseed oil) or Chaubatia paste (1 kg red lead + 1 kg Copper carbonate + 1.25 l linseed oil) should be preferred for pasting the cut ends in the rainy season.
• All plant debris should be collected and burnt, orchard sanitation should be strictly maintained.
• In bacterial blight prone areas only hasta bahr or late hasta bahr crop should be taken.

2. Wilt: It is mainly caused by the fungus, *Ceratocystis fimbriata* other fungi which are occasionally found associated with wilt are *Fusarium oxysporum, Rhizoctonia soloni* and *Macrophomina* sp. Shot hole borer and nematodes alone or in association with *C. fimbriata* also result in wilting of the plant.

**Symptoms:** Yellowing of leaves on some branches, followed by drooping and drying of leaves are the external signs (Fig. 30). If it is in bearing stage dried fruits can be seen hanging on dry branches of tree. The entire tree dies in few months or a year. The stem roots when cut open lengthwise or in cross-section shows dark greyish-brown discoloration of wood (Fig. 31). Wilt symptoms are also observed when fungi like *Fusarium oxysporum*, block the xylem or *Rhizoctonia soloni* result in girdling of stem and *Macrophomina* sp. destroy the feeder roots and result in root rots.

![Fig. 30. Yellowing, drooping and drying of branches in wilt affected plant](image1)

![Fig. 31. Greyish-brown discoloration of wood in C. fimbriata wilt](image2)
**Epidemiology**: Shot hole borer and nematodes help in spreading the pathogen. The disease is more severe in heavy and moist soil. The disease develops in spring or early summer seasons and bearing trees are more vulnerable. Rain is also conducive for the wilt development.

**Management**:
- Plant pomegranate in sandy loam soil with proper drainage and not in heavy soils.
- The soil used for nursery raising needs to be sterilized through solarisation. It can be done by covering moist soil with 25-75 µm thick linear low density transparent polyethylene (LLDPE) sheets for 6 weeks during hot summer months.
- Treat the roots of air layered cuttings with copper oxy-chloride 50 WP (COC) @ 3 g/l or Dithane M-45.
- Dust the pits with bleaching powder (a.i. 33 % Cl) @ 100 g/pit before filling with soil.
- On observing first symptoms of wilt in the orchard, immediately drench soil with chlorpyriphos 20 EC (2.5 - 4.0 ml/l) + carbendazim 50 WP (2.0 g/l) or propiconazole 25 EC (2 ml/l) @ 5-8 litre solution/tree. Repeat drenching 3-4 times at 20 days interval.
- The wilted plants should be uprooted and burnt immediately; should not be piled in orchard.
- Developing resistant root stocks will give complete control.

3. **Fungal spots**: Various fungi are known to cause leaf and fruit spot, while leaf spots are easily controlled by fungicidal spray schedules, fruit spots need special attention.

**Symptoms**:
- **Anthracnose**: It is caused by *Colletotrichum gloeosporioides* and produces brown, black, hard, corky spots of various shapes and sizes (*Fig. 32*).
- **Scab**: It is caused by *Sphaceloma punicae*. It produces spots of various shapes and sizes from small rough, raised spots to large brown spots covering entire fruit
surface with russet appearance. Sometimes, spots with light centre and dark edge also yield *Sphaceloma punicae* on isolation. In advance stages these spots may become corky (Fig. 33).

![Fig. 32. Anthracnose](image)

![Fig. 33. *Sphaceloma* fruit spots various types](image)

c) *Cercospora spots*: It is caused by fungus *Cercospora punicae*. On leaves the spots are irregular reddish brown small spots which may be few to numerous (Fig. 34). On fruits the spots look much like that of oily spot disease but do not have cracks (Fig. 35). The differences between the symptoms of *Cercospora* and bacterial blight are described as under.

<table>
<thead>
<tr>
<th>Symptoms</th>
<th><em>Cercospora spots</em></th>
<th>Bacterial blight spots</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leaf</td>
<td>Reddish brown numerous, irregular spots</td>
<td>Dark brown to black regular to irregular spots, generally few.</td>
</tr>
<tr>
<td>Fruits</td>
<td>Dark black discrete spots of various size without cracks.</td>
<td>Brownish black spots without cracks and may coalesce to form larger spots.</td>
</tr>
</tbody>
</table>
d) **Alternaria spots**: It is caused by a fungus *Alternaria alternata*. Spots on leaves are isolated, irregular, round, blackish-brown and enlarge to cover large area (Fig. 36). Sometimes the affected leaves give blighted appearance. The affected leaves turn yellow, dries and fall down. Sometimes fruits are also affected. 

**Epidemiology**: Leaf and fruits spots are favored by high temperature, humidity and stress.

**Management**: 
- At flower initiation spray the crop with carbendazim 50 WP (0.1 %) or mancozeb 75 WP (0.25%), or copper oxy-chloride 50 WP (0.25%) or thio-phanate methyl 70 WP (0.15%) and repeat at 15-20 days interval depending on environmental conditions and disease severity. For scab sprays of thio-phanate methyl 70 WP (0.15%) are essential.

4. **Fruit rots**: Most fungal rots in pomegranate are caused by fungi such as *Phytophthora, Colletotrichum, Phomopsis, Aspergillus, Penicillium* and *Rhizopus*. In pomegranate, most of the rot causing pathogens enter through calyx or stem end.

**Symptoms**:

a) **Phytophthora rot**: The pathogen *Phytophthora nicotianae* causes light brown tan colour rot of fruits hanging near ground level, which may later become darker in colour (Fig. 37). The rot generally starts from calyx and spread covering entire fruit within 2-3 days. White cottony growth may be seen in later stages. *Phytophthora* blight affects seedlings, foliage as well as fruits in particular.

b) **Colletotrichum rot**: Fruits start discoloration from calyx end and sometimes from sides. The discolored area becomes reddish brown and is dry. The infected area covers half to full fruit within a week (Fig. 38).
c) *Penicillium* rot: The rot generally starts on an injury or from calyx end. Light soft colour rot covers large areas with greenish sporulation of the fungus in later stages (Fig. 39).

**Epidemiology:** All rots are favored by hot humid conditions and rains.

**Management:**
- For *Phytophthora* rot spray the crop at disease appearance with metalaxyl 8 per cent + mancozeb 64 per cent WP (0.25%) or mancozeb 75 WP (0.25%) or dimethomorph 50 WP (0.1 %). For other rots, sprays of carbendazim 50 WP (0.15%) altered with mancozeb 75 WP (0.25%)/ thio-phanate methyl 70 WP (0.15%) should be taken starting from flower initiation.

**Important insect, mites, nematodes and their management**

Several insects and other pests are known to attack pomegranate crop at different growth stages, however only few are known to cause economic losses if not managed timely. Important among these are fruit borer, fruit sucking moths, shot hole borer and thrips. The infestation levels of these insects vary with respect to space and time.

1. **Fruit Borer (*Deudorix isocrates*):** It is the most important insect pest distributed all over India (Fig. 40). The adult males are glossy bluish and brownish violet; in case of females a conspicuous orange patch on the forewings is seen. The adult female lays eggs on bud, flower and young fruits. The damage of fruit borer is seen throughout the year irrespective of the bahar.
**Signs and symptoms**: Pencil size bored holes can be seen on fruits from which larval excreta comes out continuously ([Fig. 41](#)). The injury caused by fruit borer attracts bacteria, fungi and beetles which induce rot in the fruits producing foul smell, such damaged fruits then drop.

**Management**:
- The affected fruits should be collected and destroyed.
- Spray deltamethrin 2.8 EC @ 1.5 ml/l or methomyl 40 SP @ 1.0 ml/l or azadirachtin 1500 ppm @ 3.0 ml/l at 15 days intervals commencing from initiation of flowering up to the harvesting subjected to the presence of fruit borer.

2. **Fruit sucking moths** (*Othreis materna, O. fullonia and O. homoena*) : Fruit sucking moths ([Fig. 42](#)) might remain absent in an area of fruit crop for years, then suddenly attack the orchards overnight. This unusual behaviour is the result of migration from outbreak sites, sometimes far away from the orchards where the damage is already done. The moth is large, robust with big eyes and remains active from August to October. The mouth parts of the moth are strong enough to penetrate skin of fruit. Feeding occurs at night and damaged fruits become soft owing to secondary infections with rot causing fungi and bacteria.
Signs and symptoms: Punctured holes on fruits with oozing fruit juice can be noticed (Fig. 43). Later the fungal and bacterial infections occur causing premature ripening and dropping of fruits.

Management:
- Destroy alternate hosts like *Tinospora* spp. and *Cocculus* spp.
- Collect and destroy moths using torch in the night.
- Keep poison bait (95% molasses/jaggery + 5% malathion) in the big flat earthen pots and install Compact fluorescent lamp (CFL) bulb over it. Moths get attracted toward the earthen pots and fall down in it.

3. Stem borer (*Zeuzera* sp.) and Shot hole borer (*Xyleborus* sp.): The grubs of stem borer bore into the cambium then girdle the stem or branch causing death of the tree. In case of shot hole borer, the damage is caused by adults, which construct galleries in the crown and underground portion of stem (Fig. 44). Once the female makes contact with a host, it begins boring an entrance hole. These pests are very difficult to manage owing to their concealed habitat.

Signs and symptoms: In case of stem borer, a single bored hole on the middle of tree trunk can be noticed from which wood dust comes out. However, adults of shot hole borer make several pin holes (Shot holes) on crown and underground portion of stem from which wood dust and excreta comes out (Fig. 45).
Management:

- Do not pile dead or uprooted wood within or near orchards because beetles breed on it and attack nearby orchards, burning and destroying is the best practice.
- Drench soil around the main trunk with chlorpyriphos 20 EC @ 2.5 ml/l using 2-3 l solution per tree.
- Clean the bored holes with the help of a hooked wire which helps killing the grubs and adults.
- Cotton swab soaked in petrol or kerosene or dichlorvos 76 EC solution (20 ml/10 l of water) should be inserted into the holes or 2 ml dichlorvos solution can be poured into bored holes with the help of syringe then seal the holes with mud.
- For discouraging the oviposition and boring by these pests, 10 litre preparation containing red soil (4 kg) + lindane (25 g) + chlorpyriphos (20 ml) + copper oxychloride (25 g) can be applied on plant base from second year onwards of the crop before and after taking the bahar.

4. Bark eating caterpillar (Indarbela sp.): It is a polyphagous insect that feeds on a range of trees. The caterpillar bores into the stem and feeds on the bark of the tree at night. Several holes can be seen on the trunk at the joints of the branches. Neglected and ill-managed orchards witness heavy infestation of this pest. The tunneling causes weak points on the trees where breakage occurs affecting the vitality of the trees badly.

Signs and symptoms: Wood dust and faecal matter hangs in the form of a web around the affected portion. The damage causes a reduction in growth rate of the trees as well as provides entry points for secondary infestations by other insects and pathogens.

Management:

- The webs around the affected portion should be cleaned.
- Cotton swab soaked in petrol or kerosene or dichlorvos 76 EC solution (20 ml/10 l of water) should be inserted into the holes and sealed with mud.
- Spray methomyl 40 SP @ 1 ml/l on tree trunk.
5. **Thrips (Scirtothrips dorsalis):** *S. dorsalis,* always prefers feeding on new growth of plants. This species is pale yellowish in colour and seen with two black stripes on the body. It affects all the three bahars of the pomegranate. Nymphs and adults lacerate and suck the contents of buds, flowers, leaves, and fruits.

**Signs and symptoms:** Affected leaves curl upwards and downwards. The tip of the tender growth dries and looks like herbicide injury. Scrapping marks on buds and fruits can be noticed easily ([Fig. 46](#)). On tapping the affected twigs on white paper thrips can be seen moving.

![Dried tips of tender growth](image1.png)  ![Scrapping on buds](image2.png)  ![Scrapping on fruit](image3.png)

**Fig. 46. Thrips damage on leaves, bud and fruit**

**Management:**
- Remove and destroy affected plant parts.
- Spray thiamethoxam 25 WG @ 0.3 g/l or acetamiprid 20 SP @ 0.3 ml/l or acephate 75 SP @ 1 ml/l at flowering and fruit setting stage.

6. **Aphids (Aphis punicae):** Aphid is a serious problem on new flush of pomegranate ([Fig. 47](#)). They are yellowish green in color. Nymphs and adults suck the sap from tender shoots, leaves, flowers, buds and fruits. It excretes sweet semisolid (honeydew) which attracts fungal growth. High humidity favours the multiplication of aphids.

![Infestation of aphids on tender leaves](image4.png)

**Fig. 47. Infestation of aphids on tender leaves**
Signs and symptoms: The affected leaves show chlorotic patches. The black sooty mold and sticky honey like excretion can also be seen on tender parts of plants. Yellowish green aphids can be seen attached to tender parts.

Management:
- Spraying with dimethoate 30 EC @ 2 ml/litre or acetamiprid 20 SP @ 0.5 ml/l or imidacloprid 17.8 SL @ 0.5 ml/l at 15 days interval effectively manage the aphid population.

7. Mealybug: Planococcus spp., Ferrisia spp. and Phenacoccus solenopsis (Fig. 48) are known to attack pomegranate. Females are oval with waxy coatings all over the body and males are winged. Nymphs and adults suck the sap from the leaves, buds, flowers and fruits resulting in yellowing of leaves, shedding of buds and tender fruits.

Signs and symptoms: White waxy coating of mealybug is seen on affected parts. Leaves show characteristic curling symptoms much like a viral infestation. Black sooty mold develops on excreted honeydew. The infestation may lead to fruit drop. The market value of heavily infested fruits is reduced considerably (Fig. 49).

Management:
- The plants in the vicinity of the orchard acting as alternate hosts for the mealybugs should be destroyed.
- Spray chlorpyriphos 20 EC @ 2 ml/l or monocrotophos 36 EC @ 1.5 ml/l or malathion 50 EC @ 2 ml/l with fish oil rosin soap.

8. White fly (Siphoninus phillyreae): The adult ash white fly is a pale whitish with slightly mottled wings. The winged adults fly with irregular motion like tiny moths when disturbed. A winged female lays eggs on the underside of the leaves. When the nymphs emerge they do not move far and feed on the plant sap by
Signs and symptoms: White colonies of white flies can be seen on the under surface of leaves. Curling/yellowing of leaves and black sooty mold can be seen on tender leaves. Heavy infestations cause leaf wilting, early leaf drop and may lead to smaller fruits.

Management:
- Spraying water with high volume sprayer helps in washing out the white flies followed by spray of triazophos 40 EC @ 1.5 ml/l.

9. Mites (Tenuipalpus sp. and Tetranynchus sp.): Mites are not insects they are tiny spiders, red or brown in colour and remain most active during dry spell. Adult and nymphs feed on the lower leaf surface by scrapping leaf and sucking the liquid contents. They can easily be identified due to its red colour, if you press your thumb against the surface of infested leaves your thumb turns red.

Signs and symptoms: Shiny white or brown patches can be seen on the undersurface of affected leaves (Fig. 51) which may further curl and fall.

Management:
- Spray dicofol 50 WSP @ 1 g/l or sulphur 80 WP @ 2 g/l; repeat the spray after
fortnight if mite population does not decline.

- Do not neglect the orchards during the off period and must provide irrigation frequently to avoid dryness.

10. **Root-knot nematode (Meloidogyne spp.)**: Adult female lays hundreds of eggs which pass through an embryonic stage, four juvenile stages and an adult stage. Juvenile hatches from eggs as vermiform second stage juvenile, which is free living and invades the new host roots. It takes about three months to complete life cycle. Root-knot nematodes can be spread by water or by soil which clings to the farm equipments or through infested planting materials.

**Signs and symptoms**: Infested plants reveal pale green or yellowish leaves with reduced plant growth and eventually resulting in wilting and death of the plants *(Fig.52)*. The feeder roots of plants show galls towards its tips *(Fig.53)*.

**Management**:

- **Soil solarization**: It heats the top 8 inches of soil and kills nematodes.
- **Healthy seedlings**: Be sure that seedlings are free of nematode before planting in orchard.
- **Organic manure**: Manuring soil with organic matter introduces microbes which can act against nematodes.
- **Intercropping**: Marigold *(Tagetes erecta)* suppresses the nematodes with antagonistic phytochemical exudates.
- **Neem cake**: Apply Neem cake @ 5-10 kg per plant. It repels/discourages nematodes from feeding.
- **Chemical control**: Apply phorate 10 G @ 15-25 kg/ha or carbofuran 3 G @ 40-60 kg/ha.


Profuse bearing in single stem training system
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