High-tech Pomegranate Production Practices for Export Quality Pomegranate Production and Value Addition

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ISBN: 978-93-91668-12-9

Citation: Marathe R.A., Mallikarjun M. H, Manjunatha N, Dr. Venkata Rao B. (2022). ***High-tech Pomegranate Production Practices for Export Quality Pomegranate Production and value addition.*** Hyderabad: National Institute of Agricultural Extension Management (MANAGE) & ICAR- National Research Centre on Pomegranate.

Published for Dr.P.Chandra Shekara, Director General, National Institute of Agricultural Extension Management (MANAGE), Hyderabad, India by Dr.Srinivasacharyulu Attaluri, Program Officer, MANAGE and printed at MANAGE, Hyderabad as e-publication.

TOPICS OF TRAINING LECTURES

Chapter 1

Pomegranate: A crop for doubling farmer's income

Agriculture is the backbone of the Indian economy contributing more than one-fifth to the gross domestic product (GDP) and providing livelihood support to about two-thirds of the country's population. India has done fairly well in terms of the total production of horticultural crops. In 2018-19, India's total fruit production was 9796.7 thousand Metric tons from 6597 thousand ha area. Among various fruit crops, Pomegranate is one of the most important horticultural crops.

Punica granatum L. is the only species cultivated from the genus Punica. The fruits from this plant are consumed as a fresh fruit after peeling or consumed after processing such as pure juice, minimally processed fresh arils, Ready-to-serve beverages, virgin seed oil, cookies, squash, ice cream, jam, jelly, syrup, wine, anardana, mouth wash, mouth freshener, tea etc. It is a very popular fruit often considered a symbol of fertility and prosperity. Pomegranate is considered to be native to Iran and the Himalayas. It is the most historic fruit tree domesticated for its innumerable health benefits. Pomegranate cultivation today is a highly lucrative and remunerative agriculture business in India. The alluring monetary return per unit area from this crop has resulted in a steady increase in area, production and export of pomegranate during the last two decades. Numerous studies on the health benefits of pomegranates confirmed that most of the plant parts like leaves, flowers, fruit, peel and roots contain various bioactive phytochemicals with antimicrobial properties. These important phytochemicals play a role in reducing diabetes, blood pressure and cancer, and are important components of cosmetic products like anti-ageing cream, soap etc. As a result, increased public awareness about the consumption of pomegranate led to a substantial increase in its demand at the global level.

It is widely cultivated throughout India, Iran, China, Turkey, USA, Spain, Azerbaijan, Armenia, Afghanistan, Morocco, Egypt, Uzbekistan, the Middle East, Pakistan, Tunisia and Israel, dry regions of Southeast Asia, Peninsular Malaysia, the East Indies and tropical Africa. India is the world's leading country in pomegranate production. The statistics on acreage and production of pomegranate are not available with Food and Agriculture organization at the global level, however, the estimated global cultivated area under pomegranate is around 3 lakh ha and production of 3.0 million tones. Among the pomegranate-growing countries, India holds the 1st position in terms of both areas under cultivation and total pomegranate production. In India, pomegranate is extensively grown in Maharashtra, Karnataka, Andhra Pradesh, Gujarat and Rajasthan are picking

up fast in Himachal Pradesh and Madhya Pradesh. Small areas are under cultivation in Tamil Nadu, Mizoram, Odisha, Nagaland, Lakshadweep, Jharkhand and Jammu and Kashmir. As per recent advance estimates for the year 2019-2020 by National Horticultural Board (NHB), total pomegranate cultivation in India spreads over an area of 2.83 lakh hectares with a record production of 31.46 lakh MT of fruits. Out of which, India exported 67.89 thousand metric tons fetching 6885 million rupees in foreign exchange. In addition, its cultivation also provides livelihood to more than 2.5 lakh families in arid and semi-arid regions of India. Maharashtra is the largest producer occupying 2/3rd of the total area in the country followed by Gujarat, Karnataka, Andhra Pradesh, Rajasthan, Telangana and Himachal Pradesh.

This large expansion in the area is attributed to the pomegranate's versatile adaptability to a wide range of climatic conditions, hardy nature, and low water requirement gives this crop an edge over the others in the drier regions of the world. Pomegranate's good response to high tech-horticultural practices, high yield, higher returns on investment, magical therapeutic values and increasing demand for table and processed products as well as high export potential have made this crop a very popular fruit in tropical and subtropical regions of the world.

This ancient crop that once had no major biotic problems except fruit borer, today is facing a multitude of stresses. Among them, bacterial blight, wilt disease, anthracnose, root-knot nematode, shot hole borer, thrips, and fruit borer are the most important pests and diseases faced by the pomegranate farmer while fruit cracking, Aril browning, sunburn/sunscald are few of the major abiotic stresses leading to huge losses in quality and quantity of pomegranate. To reap maximum benefits from pomegranate cultivation, complete know-how of the crop starting from the selection of planting material to post-harvest processing and value addition is necessary; this training manual is an endeavor in this direction.

Chapter 2

Orchard establishment, canopy management and impact of high-density planting in pomegranate

The pomegranate can adapt itself to a wide range of climate and soil conditions. It, however, performs best under semi-arid/arid conditions. Climatic conditions, soil type and other factors responsible for profitable yields should therefore be taken into consideration before establishing a pomegranate orchard.

A. Site Selection, Climate and Soil:

- Arid and semi-arid regions receiving low annual rainfall below 1000 mm (preferable around 560 mm) with a long, hot and dry summer and mild winter are suitable for quality fruit production.
- Select well-drained land with a moderate slope (3-5%).
- Light soil having a pH range of 6.5-7 is most suitable for pomegranate but under well-managed conditions, it can tolerate pH up to 8.5.

B. Farm Planning:

If the farm where the new pomegranate orchard is to be established is new, the following points need to be taken care of while planning:

- 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 and water supply.
- A provision of buildings including office, implement shed, godown-cum-store, and packing shed, pump houses, water harvesting ponds *etc.* should be made on the farm.
- Keep fencing and wind break arrangements around the farm.
- Plant two rows of wind break plants in a triangular system. The wind breaks selected should be such that, they give good protection from wind and require minimum maintenance. Suitable wind break like Karonda (*Carissa carandas*), Jamun (*Syzygium* sp.), bougainvillaea, Shisam (*Dalbergia sissoo*), Silver Oak (*Grevillea robusta*) *etc*. should be planted around the boundary.

C. Planting System:

Square or rectangular planting systems (Fig. 1) can be followed in pomegranate. Planting should be done in pits if the soil is not deep and is rocky or gravely up to 1m depth. However, if soil depth is up to 1m or more pits are not essential and planting can be done in trenches.

Fig. 1: Rectangular Planting System

D. Pit-digging and Filling

- Dig pits of 1m x 1m x 1m or make trenches of 0.75 m width x 0.75 m depth along the rows depending on soil condition.
- Pits/trenches (Fig 2) are dug about a month or more before planting and kept open for at least 1 month so that it is disinfected by intense solar radiation. The heat of April and May is most beneficial for pit sanitization.

Pits

Trenches

Fig. 2: Planting Methods

- The bottom and sides of the pits/trench should be treated with carbaryl dust 50g/pit or 5 l solution having 0.4% (4ml/l) chlorpyriphos 20EC. Bleaching powder (a.i.33% Cl) @ 100g/pit also can be used.
- Fill the pit/trench with a 1:1 proportion of soil, sand/ murrum.
- Prepare a mixture of manure and bio-fertilizers as given in Table 1.

Table 1: Mixture for 1 acre (around 300 plants)

Component	**Quantity/acre**
FYM (Well decomposed)	3.5 t
Vermicompost	300 kg
Neem cake	300 kg
Trichoderma formulation	1 kg
Phosphate Solubilising bacteria (PSB)	1 kg
Azotobacter formulation	1 kg
Pseudomonas flourescens	1 kg
Azospirillum formulation	1 kg
Paecilomyces formulation	1 Kg

Mix all ingredients, make 1 ft height heaps of any length of your convenience under the shade, moisten with water, and cover with a polythene sheet for 10 days. Rake it once every day. Apply 10 to 12 kg/plant and mix into the top 50 cm layer of soil.

E. Time of Planting

Planting should be done during the spring season (February-March) or July-August depending on the availability of irrigation water. Before taking the planting material to the main field spray the plants with copper oxychloride (COC)@ 2.5g/l) or Kocide @ 1.5-2g/l.

F. Spacing

In general, 4.5m x 3.0 m (740 trees/ha.), is optimum for cv. 'Bhagwa'. However, spacing of 5m x 4 m (500 trees/ha) and 5m x 5m (400/ha) can be followed for more spreading varieties like Ganesh. There is an immense possibility for hedge row planting (Fig. 7) with 4.5m x 2m (1110 trees/ha) that can improve productivity and facilitate mechanization. But closer spacing is not recommended if specific disease and pest problems are prevalent. After 8 years, alternate plants from the hedge row may be removed or restrict tree growth by proper training and pruning to avoid overcrowding and enhance productivity.

G. Staking

Young plants need support to keep the plant straight and bear the load of growing shoots. Use 50-75cm long bamboo or wooden sticks and tie the main limbs at one or two places with coconut or jute strings to avoid bending and breaking the plant.

H. Orchard Sanitation

- Maintain strict orchard sanitation
- Keep the orchard free from weeds, which may be latent carriers or multiplication ground for several diseases including bacterial blight pathogens and insect pests.
- Do not leave dead drying infected plant parts (leaves, flowers, fruits & twigs) in orchards nor dump them near the orchard, nor throw them in irrigation channels. The orchard should be swept clean to collect all fallen plant parts and burnt.
- Dust bleaching powder (a.i.33% Cl) every 3 months @ 100-150g/plant or drench @ 25 kg/1000 l water/ha on ground below the canopy in the basin of tree. This will reduce the disease and pest inoculum on leftover plant debris if any in the orchard.
- Pruning tools – secateurs *etc.* should be sterilized after handling each infected tree with sodium hypochlorite (2.5%).

I. After care

Young plants take 2 to 3 months for proper establishment. Subsequently, regular irrigation, weeding, hoeing, training, pruning, fertilizer application, and plant protection measures should be followed.

4a. CANOPY MANAGEMENT IN POMEGRANATE

Canopy management refers to designing the plant as per need using inherent plant characteristics by a given set of conditions & resources to perform the plant maximum. The inherent plant characteristics include growth behaviour, flushing patterns, dormancy pattern and bearing behaviour.

The horticultural techniques for modification of the tree canopy

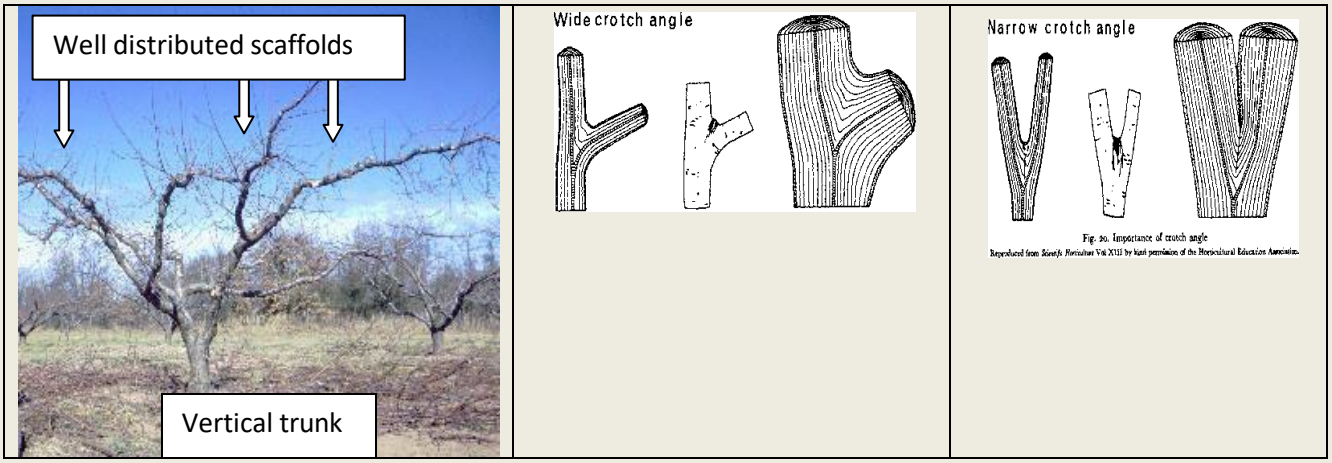
- Pruning (removal of unproductive braches of fruit tree)
- Training **(**aim to shape or build a strong framework of the trees to support maximum crop when the plant reaches the bearing stage)
- HDP **(**High-density planting**)**

- Influence of rootstock **(**RS**)** on canopy
- Orientation of row and branch
- Nutrition

Aims of canopy management

A. Establish a strong tree framework

- Upright vertical trunk
- Well distributed scaffolds
- Wide crotch angles



B. Facilitate management of the tree and crop

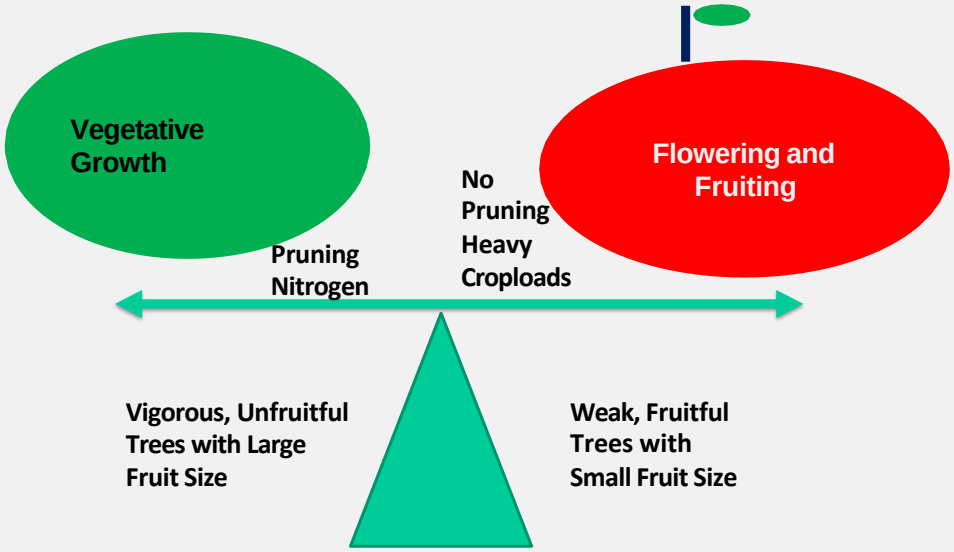
- Height of primary scaffolds ***(***Access to tree base for Irrigation, herbicides and fertilizers***)***
- Distribute scaffolds well ***(***Good coverage of spray chemicals***)***
- Tree uniformity ***(***Mechanization possible***)***
- Tree size ***(***Small trees are easier to work***)***

C. Harvest sunlight efficiently

- Maximize surface area of orchard covered by canopy
- Limit canopy depth

D. Maintain productivity

- Maintain light distribution in canopy
- Remove unproductive wood
- Maintain good vegetative/fruit balance



The balance between vegetative growth and cropping is heavily influenced by pruning, nitrogen and cropload.

Principles of canopy management

Canopy management is the manipulation of tree canopies to optimize the production of quality fruits. The canopy management, particularly its components like tree training and pruning, affects the quantity of sunlight intercepted by trees, as tree shape determines the presentation of leaf area to incoming radiation. An ideal training strategy centers around the arrangement of plant parts, especially, to develop a better plant architecture that optimizes the utilization of sunlight and promotes productivity. Light is critical to the growth and development of trees and their fruits. The green leaves harvest the sunlight to produce carbohydrates and sugars which are transported to the sites where they are needed – flower buds, flowers and fruits. Better light penetration into the tree canopy improves tree growth, productivity, yield, and fruit quality. The density and orientation of planting also impact light penetration in an orchard. Generally, in close planting, quicker shading becomes a problem. An east-west row orientation results in more shading as compared to the western and southern orientation of trees. Strong bearing branches tend to produce larger fruits. The problem of a fruit grower is initially to build up a strong and balanced framework of the trees, then equip them with appropriate fruiting. Obviously, pruning in the early years has to be of a training type to provide strong and stocky framework with well-spaced limbs or any other desired shape.

Some of the basic principles in canopy management are:

- Maximum utilization of light.
- Avoidance of built-up microclimate congenial for diseases and pest infestation.
- Convenience in carrying out the cultural practices.
- Maximizing productivity with quality fruit production.
- Economy in obtaining the required canopy architecture.

Tools and equipment's for canopy management

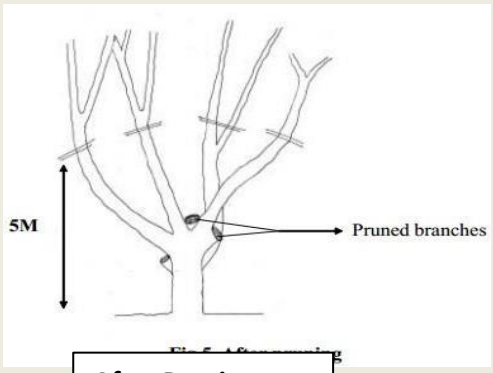
Canopy management involves pruning and lopping of branches. Pruning done through manual methods are cumbersome. However, different pruning tools are available to make this operation simple and easy nowadays. Following tools / equipment's can be used based on the need.

1. Secateurs

Used to prune small twigs and terminal shoots of mango. Twigs around 1 to 1.5 cm diameter can be cut easily.

2. Pruning saw

Used to prune small branches of 1 to 2 inches' diameter.



After Pruning

Before pruning

Canopy management in pomegranate

Understanding the growth habit and phenological stages of a tree is most important aspect for canopy management. Pomegranate grows like a shrub or small tree has a tendency to develop multiple trunks with a bushy appearance. Depending upon variety and agro-climatic conditions, it can grow up to 5 m or more. Even semi-dwarf varieties of pomegranate have been reported but their evaluation has to be done in warmer regions of India. Most of the varieties of pomegranate are deciduous but in Deccan Plateau, they are evergreen or partially deciduous. Though, some evergreen varieties shed their leaves in higher elevations and colder climates. 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. Over time large trees with increased shading inside the canopy are formed which allow most of the fruits to appear on the tops and outsides. Pomegranate bears fruits on both older wood (2-3 years old and elder) as well as on the current season`s growth. Depending upon the agro-climatic condition, in general, 2-3 flowering seasons have been observed in India and plant tends to flower and fruit throughout the year but in a commercial orchard, only one crop should be taken. It is better during early pruning before blossoming to remove about 50% of the current season's shoot and shorten the remaining current season`s growth a little so they will not flower. Encourage fruiting on older branches/shoots. The density and orientation of plants or branches have an impact on light penetration in the orchard. The closer the planting, the poorer will be light penetration. The fruits appearing on strong bearing branches tend to produce larger fruits with a clean surface. Strong scaffold branches tend to transport water and nutrients more efficiently throughout the growing season. This aspect should be understood very well and apply water and nutrients judiciously to have a balance between vegetative and reproductive phases/stages.

Thus, pruning should be done in such a way to encourage new strong growth. The tree exhibits

apical dominance; consequently, the top bud suppresses the shooting of buds below it. Therefore,tip pruning is required, especially in pre-bearing trees (1-2 years old). The best time for pruning is normally after harvest and before bud break. Pomegranate varieties have spreading and erect tree structures so their pruning styles will vary accordingly. This is a general phenomenon, when crop load is heavy, that the branches and limbs tend to break more easily by a strong wind. Overall, the tree branches tend to be longer, thinner, and more flexible. Thus, there should be regular attempts to shorten these branches and encourage fruiting within 75 cm inside from the outer surface of the tree. The tree usually tends to produce strong, vigorous upright water shoots having thorns. These sprouts exhaust the energy of the plant, especially in the early years. Thus, these shoots need to be removed as early as possible. However, sometimes the water shoots/sprouts can be used effectively to replace old productive structural limbs while rejuvenating trees. This has been observed that after severe pruning and nutrient application, the trees produce more suckers from the stem at ground level which need to be removed regularly. To obtain more fruiting the plant must be pruned every year to either a single trunk or the more desirable multiple trunks (stems). However, in warmer areas single stem training system may be more desirable for strong plant architecture and quality fruit production but this training system needs more skill.

4b. PRUNING IN POMEGRANATE

Pruning refers to the removal of parts of a tree, especially shoot, roots, limbs, and buds or nipping away of the terminal parts to make a tree more productive, bear quality fruits, enhance the longevity of the tree, make a manageable tree shape and finally to get maximum return from the orchard per unit area basis. Pruning trees soon after planting restores the balance between the root system and the above-ground part. In general, three pruning stages pre-bearing, bearing and senile (low productive) are observed in pomegranates. Accordingly, pruning operations should be followed.

Tip pruning:

- in pre-bearing trees (1-2 years old)

Shoot pinching:

- Pinching or light cutting back of shoots
- rapid but temporary accumulation of carbohydrates and flower bud forming hormones near the uppermost bud on the shoot and particularly in the leaves near this bud
- desirable in pomegranate to regulate the current season growth

Skirting:

- Removal of the lower tree branches

Topping:

- Practiced in low productive old orchards (12-15 years) for rejuvenation

Factors need to be considered before pruning

- monitor pests/pathogens on re-growth, particularly inside the canopy;
- healthy trees suffering from crowding or shading will respond the best;
- dead wood should be removed – this can carry disease and increase blemish;
- skirt trees for improved irrigation and pest and disease control;
- Sterilization of pruning equipment to reduce the spread of disease.

Rejuvenation pruning

Chapter 3

Different pomegranate varieties and their geographical suitability for quality pomegranate production

Punica granatum L. (Pomegranate) is the only cultivated species found in the genus 'Punica' with two subspecies *chlorocarpa* and *porphyrocarpa*. It is consumed as fresh fruit as well as in processed forms such as pure juice, Ready-to-serve beverage, minimally processed fresh arils, wine, seed oil, cookies, ice cream, anardana and mouth freshener etc. Based on this, pomegranate varieties are categorized into edible (table, value-added & anardana types) and ornamental types.

Presently, >20 cultivated varieties of pomegranate are reported in India. Among these, 'Bhagawa' is the most popular commercial variety in the country which occupies >80% of the pomegranate area, followed by 'Phule Bhagawa Super', 'Ganesh', 'Phule Arakta', 'Mridula' and 'Ruby' (Table 1). There are some other varieties or local types which are known in different parts of the country i. e., Alandi, Karadi, G-137, P-13, P-16, P-23, P-26 (Maharashtra); Madhugiri, Jyoti, KRS, Bassein Seedless (Karnataka); Dholka (Gujarat), Jallore Seedless, Jodhpur Red, Jodhpur White, Jodhpur Local (Rajasthan), Kandhari (Himachal Pradesh), Yercaud-I, CO-1, Vellodu (Tamil Nadu) and Chawla, Nabha, Country Large Red (Haryana). These varieties are sweet flavoured with low-very high acidity, medium-large fruits of yellow with a red tinge to dark red fruits, light pink to deep red arils and very soft to very hard seeds (Table 2, Fig. 2). Recently, 'Solapur Lal' and 'Kandhari Seedless' varieties were released for table purposes (Fig. 2). A brief description of the most important cultivars is given in Table 2.

Table 1: Pomegranate varieties are grown in India

Sl. No.	State	Varieties
1.	Maharashtra	Bhagawa, Phule Bhagawa Super, Ganesh, Phule Arakta, Mridula, G-137
2.	Karnataka	Ruby, Bhagawa, Jyoti, Phule Bhagawa Super,
3.	Gujarat	Dholka, Bhagawa
4.	Andhra Pradesh	Bhagawa, Ruby
5.	Madhya Pradesh	Bhagawa, Ganesh
6.	Rajasthan	Jallore Seedless, Jodhpur Red, Jallore Red, Bhagawa
7.	Himachal Pradesh	Bhagawa, Kandhari, Daru (Wild) types
8.	Jammu & Kashmir	Bhagawa, Daru (Wild) types
9.	Tamil Nadu	Bhagawa, Ganesh, CO-1, Yercaud-1

Ornamental types of pomegranate cv. 'Nana' (dwarf pomegranate) and 'Double Flower' (large attractive flowers) are being exploited for natural decoration purposes (Fig. 1). Pomegranate is also known to grow wildly in the northern states (Himachal Pradesh, Jammu & Kashmir and Uttarakhand) of India. They are called 'Daru', having small to medium-sized fruits with highly acidic arils and hard seeds, which are found very useful for anardana preparation (an acidulant product used in culinary preparations) (Fig. 1). Earlier highly acidic cultivars like 'Goma khatta' and 'Amlidana' were identified for anardana use; while 'Phule Anardana' and 'Solapur Anardana' varieties were recently released in the country (Fig. 2).

Yellow Nana

Ganesh Ornamental type

Ornamental Type

Fig.1: Naturally occurring Ornamental and Wild pomegranates

IC-444208

IC-318753

Wild Pomegranate

Table 2: Characteristic features of important pomegranate varieties

Sl. No.	Germplasm	Fruit size	Fruit rind colour	Aril colour	Taste	Seed hardness	Maturity (days)	Avg. fruit yield (kg/tree)	Varietal description
TABLE/PROCESSING VARIETIES									
1	Bhagawa	Medium	Red	Red	Sweet	Soft	170-180	25-30	Suitable for long distance market as it has a medium thick rind and better keeping quality.
2	Phule Bhagawa Super	Medium	Red	Red	Sweet	Soft	165-170	28-33	Matures in about 2 weeks earlier than Bhagawa. High yielder with better fruit quality.
3	Solapur Lal	Medium	Red	Red	Sweet	Medium hard	160-165	30-36	The biofortified variety is rich in iron, zinc and anthocyanin. High-yielding variety matures in 165 days. Suitable for table & juice purposes.
4	Kandhari Seedless	Medium	Red	Red	Sweet-acidic	Soft	-	30-35	Better keeping quality, less cracking and suitable for long distance transportations
5	Ganesh	Large	Yellow with red tinge	Light Pink	Sweet	Soft	150-155	28-33	Large fruit size, sweet arils, popular in domestic markets
4	Phule Arakta	Medium	Deep Red	Dark Red	Sweet	Very Soft	135-140	21-26	Early maturing (140 days) than "Bhagawa" (180 days) with very soft seeds

6	Mridula	Medium	Deep Red	Dark Red	Sweet	Very Soft	135-140	21-26	Early maturing (140 days) than "Bhagawa" (180 days) with very soft seeds
7	Ruby	Medium	Red	Red	Sweet	Soft	170-175	23-28	Bright red fruits with red sweet arils suitable for the domestic market
8	Dholka	Large	Red	Light Pink	Sweet	Medium soft	150-160	32-36	Sweet arils, suitable for processing purposes
9	Jallore Seedless	Large	Yellow with red tinge	Light Pink	Sweet	Medium soft	143-148	24-28	Large fruit size and sweet arils
10	Yercaud-1	Medium	Pink	Pink	Sweet	Very Hard	130-140	26-32	Early maturing (140 days) than "Bhagawa"(180 days) with high TSS
11	Jyoti	Large	Yellow with red tinge	Light Pink	Sweet	Soft	155-167	30-35	Large fruit size, very sweet arils, suitable for table and processing purposes
ORNAMENTAL TYPE									
12	Yellow Nana	Small	Yellow	Light yellow	Sour	Hard	-	-	The dwarf pomegranate variety produces profuse yellow-coloured miniature flowers and fruits with highly acidic arils
ANARDANA TYPE									
13	Solapur Anardana	Medium	Red	Red	Sour	Soft	145-155	28-34	High yielding variety with high Titrable acidity of 4.8%, suitable for anardana purpose.

14	Phule Anardana	Medium	Red	Red	Sour	-	-	18-22	High titrable acidity suitable for anardana purpose

Fruit Size grade (Based on average fruit weight): Small: < 200g; Medium: 200-300g; Large: >300g

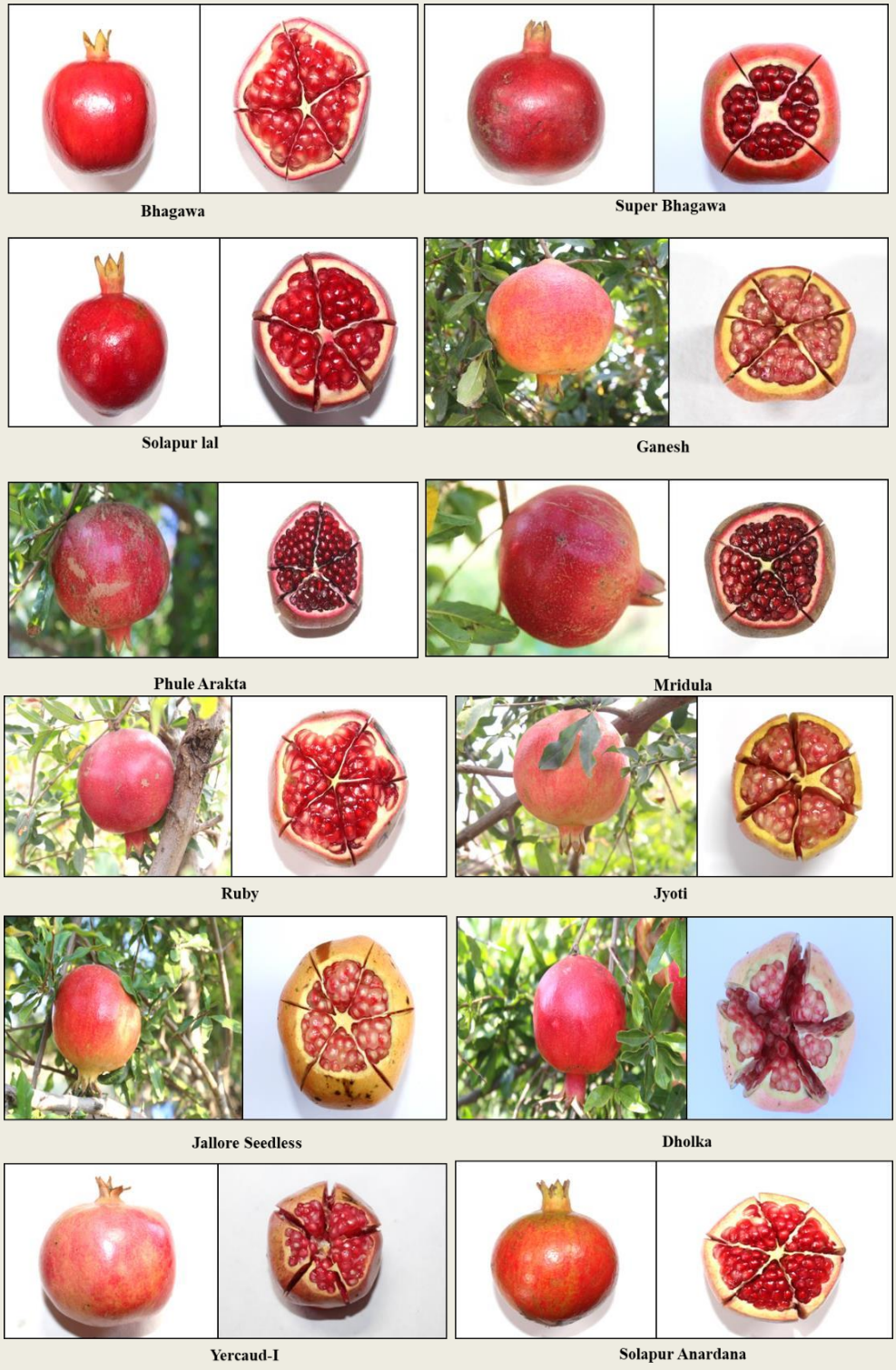


Fig 2: Important Commercial cultivars of Pomegranate

Chapter 4

Recent advances in crop regulation for quality pomegranate production

Once the orchard has been established, the plants need to be well-taken care of for vigorous healthy growth, and avoidance of pests and diseases. Proper and timely management of cultural practices, nutrients, diseases, insects and other pests along with physiology+ical disorders results in good plant growth, and increase orchard life with high productivity. Regular monitoring of the orchard is, therefore, of utmost importance to take needful action for proper orchard management.

A. Care of a Pre-bearing Orchard (First two years of planting):

- One month after planting spray with Streptomycin sulphate 90% + Tetracycline hydrochloride 10% (Streptocycline) @ 0.5 g/L + Copper Oxychloride 50% WP @ 2.5 g/L in bacterial blight affected areas and only Copper Oxychloride in blight disease free areas. Alternate the above sprays with freshly prepared Bordeaux mixture (1%). Similarly, Copper Oxychloride + Streptocycline sprays have to be replaced with 2-bromo-2-nitropropane-1, 3-diol (Bronopol 95%) @ 0.5 g/L + Captan 50% WP @ 3 g/L. Other need-based fungicides like Carbendazim @ 1 g/L, or Mancozeb @ 2.5 g/L *etc.* can also be used.
- Spray interval should be one month in disease-free orchards. In orchards where blight incidence is observed spray schedule interval should be 15 days during dry periods and 7-10 days during rainy days.
- In orchards having blight infestation, one spray of Streptocycline @ 0.5 g/L + COC @ 2.5 g/L after the rain is mandatory.
- If fungal leaf spots appear, spray the Mancozeb 63% WP + Carbendazim 12% WP @ 2 g/L or Chlorothalonil 75% WP @ 2.0 g/L or Hexaconazole 5% EC @ 1 ml/L. Repeat the spray at 15 days interval if required.
- For sucking pests particularly thrips which attack new flush growth, spray Azadiractin 1% (10000 ppm) @ 3 ml/L or Thiamethoxam 25% WG @ 0.5 g/L. or Acetamiprid 20% SP @ 0.3 g/L or Chlorantraniliprole 18.5% EC @ 0.75 ml/L or Imidacloprid 17.8% SL @ 0.3 ml/L or Flonicamid 50% WG @ 0.75 – 1 g/L or Spinotoram 12% SC @ 0.75 ml/L

or Spinosad 45% SC @ 0.5 ml/L or Cyantraniliprole 10.26% OD @ 0.7-0.9 ml/L. Repeat the spray at 15 days interval or as and when needed with other insecticide to avoid resistance development.

- For mite infestation during dry spell, spray Fenzaquin 10% EC @ 1.5 ml/L or Fenpyroximate 5% EC @ 0.5 ml/L or Spiromesifen 24% EC @ 0.5 ml/L or Dicofol 50% WSP @ 1 g/L or 18.5% EC @ 2.5 ml/L or Wettable Sulphur 80% WP @ 3 g/L in rotation.
- For leaf eating caterpillars spray of Chlorantraniliprole 18.5% EC @ 0.75 ml/L Indoxacarb 14.5% SC @ 0.75 ml/L or Spinotoram 12% SC @ 0.75 ml/L or Spinosad 45% SC @ 0.5 ml/L or Cyantraniliprole 10.26% OD @ 0.7-0.9 ml/L has to be taken.
- Follow recommended training and pruning procedures to manage optimum canopy.
- Never prune during rainy days.
- Follow 3 - 4 stem-based training after 6 - 9 months of growth.
- Remove all shoots up to 30 - 60 cm above ground depending on plant height.
- Remove water sprouts, cross branches, dead, dry, infected branches and twigs.
- Little thinning and pruning of old wood /spur should be done.
- Avoid too heavy pruning, confine pruning during the dormant stage to the previous year's growth.
- Allow a set of new shoots to develop every year on all sides of the tree.
- Disinfect the secateurs with 2.5 % sodium hypochlorite after pruning each tree.
- Monitor regularly for blight and wilt symptoms.
- In case of observance of foliar symptoms of blight, recommended sprays have to be commenced. If blight symptoms are observed on stems, prune and remove infected twigs as and when the symptoms are noticed.
- Prune about 2 inches below the infected area. Bordeaux paste (10%) is applied to the cut ends after pruning. Oil-based pastes (COC paint or Chaubatia paste) should be preferred for pasting the cut ends in the rainy season.
- If wilt symptoms are observed, check roots for cause and treat the plants accordingly.
- Any plant severely infected with blight or wilt has to be removed, burnt and replaced with a new disease-free plant after taking necessary remedial measures.

- All sanitation measures should be followed strictly.
- Fertilizer application should be based on soil test and leaf analysis values.
- The orchard must not be allowed to bear fruits for initial two years to improve the growth of plants and better canopy development.

B. Care of Established Orchard (After Second Year):

In bacterial blight-prone areas, only *hasta bahar* or late *hasta bahar* crops must be regulated. In bacterial blight-free areas, growers may take *ambe or mrig bahar* convenient to them. Only one crop in a year is recommended. The date-wise schedules for all the three *bahars* are given on the NRCP website (https://nrcpomegranate.icar.gov.in), however, those who take weekly sprays can follow the *mrig bahar* schedule (Annexure 3) in any season, after changing dates accordingly.

I. Rest period:

- A rest period of 3 - 4 months is recommended for better plant health, vigour and reduction of pathogen inoculum load if any.
- Apply the recommended dose of manures and fertilizers during the rest period.
- Sprays of Bordeaux mixture 1% altered with COC 50% WP @ 2.5 g/L or Copper hydroxide 77% WP @ 2 g/L are mandatory at 15 days interval in general. If the rest period falls during rainy season (for *hasta/*late *hasta bahar* crop) sprays at 15 days interval of Bordeaux mixture 1% alternated with sprays of streptocycline (100%) @ 0.5 g/L + COC 50% WP @ 2.5 g/L or 2-bromo-2-nitropropane-1, 3-diol (Bronopol, 95%) @ 0.5 g/L + Captan 50% WP @ 3 g/L need to be practiced to keep inoculum load at minimum.
- After 20-30 days of chemical fertilizer application, apply any or combination of bioformulations along with manure. Bioformulations like *Aspergillus niger* AN 27 (renamed IRAG07) or Mycorrhiza (*Rhizophagus irregularis*/*Glomus irregularis*) or *penicillium pinophilum* or *Trichoderma viride* or *T. harzianum*, *Pseudomonas fluorocence or paecilomyces lilacinus* @ 1 kg/acre is recommended. Each bioagent (except Mycorrhiza) should be multiplied separately under shade. Mixed 1 kg of bio-formulations with 1 ton of well-decomposed manure. Prepare a 1-foot high bed for each formulation using well-decomposed manure, mix bioformulation, maintain 50-60% moisture in these beds, cover it with gunny bags to maintain humidity and

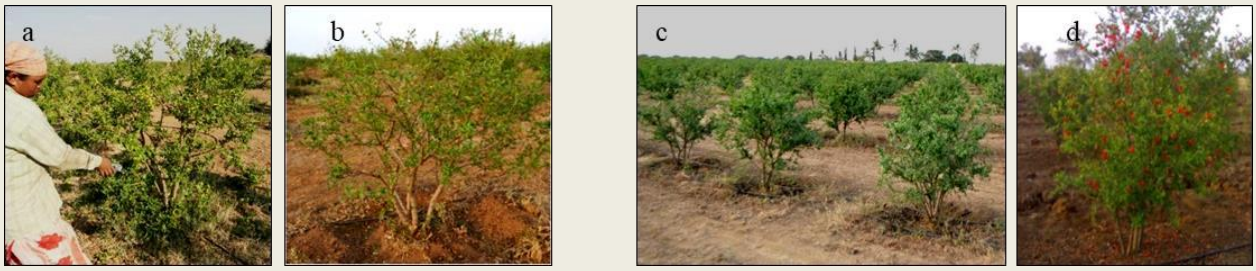
rake/mix the soil every 2-3 days. Incubate for 10-15 days, at the time of application mix Mycorrhiza and apply @ 1 kg of bioformulation/acre of plants along with manure. Application of these bioagents twice a year (once after the harvest of previous season fruits during the rest period and second at crop regulation) in the soil helps in improving nutrient uptake, plant growth and biochemical resistance to diseases and also checks pomegranate wilt.

- After fertilizer application, start light (15-20 litres) irrigation twice (light soil) or once (heavy soil) every 7-8 days. The irrigation should be just enough for nutrient uptake in soil and increase storage in the plant.
- **Pesticide sprays** should be carried out at 15 days intervals. (i) Copper oxychloride 50% WP @ 2.5-3 g/L or Copper hydroxide 77% WP @ 2 g/L or 1% Bordeaux mixture (freshly prepared) will check both bacterial and fungal diseases. Still, if any fungal disease is observed then one or two sprays of mancozeb or any other fungicide can be taken. For any specific disease, chemicals from the Adhoc list may be used.
- If the rest period falls during rainy season (for *hasta*/late *hasta bahar* crop) spraying of Streptomycin sulphate 90% + Tetracycline hydrochloride 10% (Streptocycline) @ 0.5 g/L + Copper Oxychloride (COC) 50% WP @ 2.5 g/L in bacterial blight affected areas and only COC in disease free areas. Alternate the above sprays with freshly prepared Bordeaux mixture (1%). Similarly, COC + Streptocycline sprays have to be replaced with 2-bromo-2-nitropropane-1, 3-diol (Bronopol, 95%) @ 0.5 g/L + Captan 50 % WP @ 3 g/L. (ii) Insecticide sprays may be taken as per need depending on pest observed. Azadirachtin 1% (10000 ppm) @ 3 ml/L once a month may be taken as preventive insecticide. If foliar pest infestation observed is high then only take spray with any of the following- Lambda cyhalothrin 5% EC @ 0.5-0.75 ml/L or Indoxacarb 14.5% SC @ 0.75 ml/L or Cyantraniliprole @ 0.75 ml/L or Thiamethoxam 25% WG @ 0.5 g/L along with sticker @ 0.3–0.5 ml/L. Drenching with Thiamethoxam 25% WG @ 10 g/10 L water is recommended if shot hole borer pests are observed in the orchard.
- Farmers facing wilt and nematode problems may follow the Wilt advisory on the NRCP website.

- Remove the water shoots regularly.

II. Pruning and *bahar* regulation:

- Prune twice (Figure 1) a year to maintain proper canopy and fruit set.
- Main pruning just after harvest of previous season fruits.
- Light (upper 10-15 cm) pruning at flower regulation.



a & b) Main pruning just after harvest c & d) Light pruning for flower regulation

Figure. 1: Pruning in pomegranate

- In orchards where severe bacterial blight infection is noticed, go for heavy pruning (Figure 2) immediately after harvest and remove as far as possible all stems with fresh blight infection.

Figure 2: Heavy pruning in the severe blight-affected orchard

- Prune about 2" below the infected area. Apply Bordeaux paste (10%) to the cut ends after pruning. Oil-based pastes [COC paint made by mixing 500g COC + 1 L linseed oil or

Chaubatia paste prepared by mixing 1 kg red lead (non-setting grade) + 1 kg Copper carbonate + 1.25 L linseed oil) are preferred for pasting during rainy seasons.

- Any severely infected plant must be uprooted, burnt and replaced with a new disease-free plant or cut from the base 2-3 inches above ground level. New well-growing sprouts have to be trained for new disease-free plants.
- In disease-free orchards, practice need based on pruning after the rest period.
- Spray Bordeaux mixture (1%) immediately after pruning.
- After the rest period, defoliate the trees with ethrel 39% SC (2-2.5ml/L depending on soil moisture conditions) + DAP @ 5 g/L. Mix suitable recommended insecticide if some insect attack is observed at the time of defoliation.
- Do light pruning after leaf fall and spray Bordeaux mixture (1%) immediately after pruning.
- Collect all fallen leaves and burn them for good orchard sanitation or decompose them for organic manure**.** Drench with bleaching powder 25 kg/1000 L water/ha

III. Nutrient management: Apply manures and fertilizers

IV. Water management:

- **Avoid excess irrigation.** Drip irrigation with four drippers placed in four directions needs to be employed.
- **Irrigate the crop immediately after fertilizer application** in the case of soil application with light irrigation initially and then irrigate at regular intervals.
- Irrigate the plants depending on the water requirement of the plant in different seasons

V. Plant protection:

- To get disease-free quality produce follow the IDIPM schedule given

Chapter 5

Recent advances in propagation methods in pomegranate

I. Basic steps for getting disease-free elite planting material

- The selected mother plants should be maintained by the ICAR-NRCP/IIHR/NBPGR/IIHR/NBPGR/another institute. Relevant genetic/molecular markers should be established for maintaining their varietal identity and purity.
- The progeny orchards should be established from mother plants in different areas free from bacterial blight**.** This should be regularly monitored by a team of experts from ICAR and SAUs of respective regions.
- Approved/certified nurseries must obtain standardized planting material (air layers/hardwood cuttings/ tissue culture saplings) from the respective progeny orchards
- Suspected propagating material has to be tested through diagnostic symptoms, ooze tests, microscopy and also isolation. PCR-based diagnostics are not foolproof for bacterial blight (a non- systemic disease), however, can be used for testing wilt pathogens.
- The soil used for nursery raising needs to be sterilized through (i) solarisation or (ii) using Formalin (5%).
- To prepare 100kg of potting material mix 50 kg soil and 50 kg compost, sterilize then add consortium having 1 kg each of various bioformulation, neem cake. Also, incorporate 200g of VAM culture. Planting should be done after 8 days of mixing the above ingredients.
- Apply Bordeaux paste (10%) to the cut ends of the mother plant and air layered cuttings.
- Place planting material under 50% shade net. Sprays of Bordeaux mixture (1%) altered with 2-Bromo- 2-nitropropane -1,3-diol (0.5 g/l) + Copper hydroxide (1.5-2g/l) or COC (2.5 g/l) should be taken. Interval should be 15 days during the rainy season and 20-30 days in the winter and dry seasons.
- If fungal leaf spots appear use the combi-product like 'Companion' having mancozeb 63%WP+carbendazim 12%WP @ 2g/l or chlorothalonil 75WP (2.0g/l). Repeat the same at 15 days intervals if required.
- For sucking pests, especially thrips which are a problem in nursery plants spray Thiamethoxam 25WG @ 0.3g/l. Repeat the same at 10-15 days intervals or as and when required. Alternate with Acetamiprid 20SP@ 0.3g/l or Imidacloprid 17.8SL @0.3ml/l to avoid resistance development.
- Diseases and pests in nursery plants that need to be checked:
    - Bacterial Blight leaf spots and nodal blight
    - *Cercospora* leaf spots **(**common**)**
    - *Alternaria* leaf spots
    - *Phytophthora* blight
    - Wilt –*Ceratocystis fimbriata, Macrophomina, Rhizoctonia, Fusarium,*
    - Sucking pests - Thrips **(**most common pest**)**

- Caterpillars **(**occasional pest**)**
- Nematode **(**Root knot nematode**)**

II. Nursery sanitation

- The nursery should be kept clean. Collect all fallen plant parts and burn/put them in a compost pit.
- Drench bleaching powder (a.i.33% Cl) every 3 months @ 25 Kg/1000 l water/ha on ground.
- Pruning tools – secateurs etc if used should be sterilized after handling each plant with sodium hypochlorite (2.5%).
- Keep nursery free from weeds, which may be latent carriers or multiplication ground for several diseases, nematodes and insect pests.

A. Nursery Certification

- Nurseries in non-traditional areas where there is no disease at present should be promoted**.**
- Nursery certification programmes need to be made effective and streamlined**.**
- Issue of the phytosanitary certificate should be mandatory**.**
- Periodical inspection of the specified/nurseries should be mandatory for the presence of any disease/insect pests before the planting material is lifted. Nurseries should be inspected every 3 months for at least 2 years and found free throughout should be given license/certificate**.**
- This may be supervised by the certifying authorities in collaboration with experts from ICAR institutes- NRCP, IIHR *etc.* /SAUs in the region before issuing the phytosanitary certificate.
- Nursery sites must be about 1 km away from commercial pomegranate plantation and 100 feet away from plants not certified by the Department as being free from bacterial blight and wilt, unless and until propagation is done under highly sanitized protected structures.

B. Recommendations for Propagation through Tissue Culture

- Mother plant with the proven horticultural trait, obtained from a reliable source and in a healthy state should be used for excision of explants.
- It should be ensured that the mother plants should be kept under protected structures/insect-proof shade nets and monitored regularly for any visible symptoms

of infection.

- All the plant protection and phytosanitary measures should be regularly followed to keep mother plants healthy.
- Shoot tips or meristem portion or axillary bud with nodal segments should be used as explants and other explants which follow an indirect regeneration pathway should be avoided to reduce the chances of occurrence of somaclonal variations.
- The number of multiplication cycles should be limited to 5-6 to reduce the chances of somaclonal variations

(a) Hardwood (b) Sanitization with antibiotics and fungicides followed by tretament with NaOCl (1%) for 10 min. (c) IBA treatment (d) planting in cocopeat-sand/cocopeat mixture (e) sprouted cuttings transferred to polybags (f) root system of saplings from hard wood cuttings

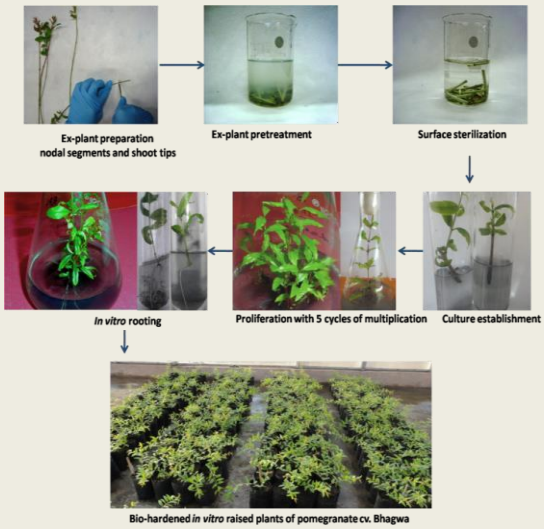
- Biohardening/biopriming of tissue culture-raised plants should be carried out using various plant beneficial microbes like arbuscular mycorrhizal fungi to improve the field performance of *in vitro* raised plants. At least 3 to 4 months of hardening should be done to reduce field mortality.
- Clonal fidelity testing of *in vitro* raised plants should be carried out using molecular tools to detect variability if any.
- As there is no reported economical damage due to viruses in pomegranate so virus indexing may be kept optional.

F. Recommendations for Propagation through Hardwood Cutting

Prefer pruned wood immediately after the rest phase of the pre-monsoon period, which gives a high success rate

- Take 6–18-month-old shoots for the hardwood cuttings for high success. Lateral shoots, which usually flower and fruit heavily should not be used for making cuttings.
- Stem cuttings ranging in length from 18-20 cm and thickness 0.6-1.2cm perform best.
- Before planting it is desirable to sanitize the cuttings by giving a 5-minute dip in 2-bromo-2-nitro-1,3-diol@ 500mg/l + Carbendazim @ 1.0 g/l (or Bavistin® @ 2g/l) dissolved in lukewarm or hot water at 45-48 º C to get rid of non-systemic surface pests and disease

pathogens. This has to be followed by treatment with surface sterilizing agents like NaOCl (2.0 %) for 10 min.



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- Dip the lower part (half the length) of stem cuttings for 30 sec. to 5 min. in a solution of indole-3-butyric acid (IBA) @2.5-5.0g/l for inducing roots in stem cuttings (IBA needs to be dissolved in a small volume of ethanol or 1 N NaOH then volume should be made up with lukewarm water).
- Plant cuttings in a mixture of cocopeat and sand (4:1, v/v) or cocopeat alone for faster rooting in polyhouse/shade net.
- Well rooted cuttings should be transferred after 45 -60 days to nursery bags having pre-sterilized Sand: Soil: FYM mixture in 1:1:1
- At the time of transfer, place premultiplied (in FYM) beneficial microflora formulation containing, *Pseudomonas fluorescens*, AMF, *Aspergillus niger* AN27 in the root zone.
- Plant in the field after 45 days of growth in bags. Before shifting to the field keep for 1 week in a 50% shade net for acclimatization.

G. **Recommendations for Propagation through Air Layering**

- Regular monitoring and spray of mother plants with antibiotics and fungicides
- The upright branches of 0.8-1.5 cm diameter are girdled 2-3cm in length and @ 2000-3000 ppm IBA (in the form of paste using talc) is applied on the upper part of the cut to get success.
- Treat the roots of air-layered saplings after separation with copper oxychloride (COC) @3g/l or Bavistin 2g/l to protect against soil borne diseases at the seedling stage and plant them in the standard size polyethylene bags filled with above potting mixture.

3a. PRODUCTION OF QUALITY PLANTING MATERIAL IN POMEGRANATE

Quality planting material is a key to success for proper orchard establishment and optimum production in pomegranate**.** Traditional propagation methods need to be confluence with modern propagation techniques and logistics to fulfill the ever-increasing need of elite planting material in required quantity**.** On an average the yearly estimated demand for pomegranate planting material is 5-6 million and this demand is increasing with quite a good pace**.** This ever-increasing demand of pomegranate can only be met when conventional and non-conventional methods of pomegranate propagation can be exploited at commercial scale with need-based modifications by involving modern propagation technologies**.** Pomegranate is commercially propagated through stem cutting, air layering and recently by *in vitro* propagation. Air-layering is commonly used for propagation of pomegranate in the Deccan Plateau and hardwood cutting in the rest of India. Few Indian firms have come up with the tissue culture raised pomegranate planting

material but endeavor is still on to produce biohardened and better field performing pomegranate plants using tissue culture technique in an economic manner.

The utilization of *in vitro* propagated plants should be made mandatory for expansion of pomegranate to non-traditional areas, so as to avoid spread of pathogens like *Xanthomonas axonopodis* pv. *punicae* to new areas through infected planting material. Bio-hardening of *in vitro* raised plants utilizing plant beneficial microbes and placing their formulations in rhizosphere and phyllosphere of *in vitro* raised plants, ascertain the improved field performance by virtue of their improved morphological, physiological and biochemical functioning. However, there is an urgent need to develop package of practices and sanitation measures for *in vitro* raised pomegranate orchards to realize complete benefit of this technology. Recently, systematic efforts for standardization of grafting technique and identification of suitable rootstocks to overcome problems of biotic and abiotic stresses have been initiated by this Centre.

Propagation

Most of the fruit crops are propagated through clonal or vegetative methods of propagation to avoid any variation in the planting material arising due to cross pollinated nature of fruit crops**.** Clonal propagation is also helpful in maintaining performance and genetic constitution of planting material exactly similar to the mother plant**.** In Deccan plateau air layering is the most common method of propagation and is practiced during June-August**.**

A. Air Layering:

In major pomegranate-growing areas of the Deccan Plateau of India, air-layered plants (Fig. 1) are used for establishing pomegranate orchards. The upright branches of 0.8-1.5 cm diameter are girdled (2-3cm) in length and rooting hormone 2000-3000 ppm IBA is applied on upper part of the cut. The girdled stems are wrapped with *Sphagnum* (peat moss) and covered with a small polyethylene strip. Coir/Jute thread or string is used for tying. Well rooted layers are detached from the mother plants from the lower girdle within 75-90 days and planted in nursery or kept in polythene bags for planting in orchard. The optimum time for air-layering is June-August.

Air Layering

B. Stem Cutting

Cuttings can be propagated round the year using pruned wood in polyhouses under high humidity. Pruned wood of rest period gives higher success rate. This is very useful for farmers who wish to take yield and simultaneously multiply superior pomegranate plants using pruned wood. This is a farmer's friendly and less labour-intensive method. Following points should be kept in mind for multiplication through hardwood stem cuttings (Fig.2).

- Prefer pruned wood immediately after rest phase of pre monsoon period, which gives high success rate

- Time of planting of stem cuttings in nursery and field conditions affects rooting and subsequent survival. In general, hard wood cutting taken immediately after rest period or pruned wood of rest period gives high cutting success.
- Hard wood cutting planted during June-August and November-February gave high cutting success under Solapur conditions.
- Take 6–18-month-old shoots for the hardwood cuttings for high success.
- Lateral shoots, which usually flower and fruit heavily should not be used for making cuttings.
- Stem cuttings ranging in length from 20-25cm and thickness 0.6-1.2cm should be used for making cuttings.
- Before planting it is desirable to sanitize the cuttings by giving 15 minutes dip in 2-bromo-2-nitro-1,3-diol@ 500mg/l + Carbendazim @ 1.0 g/l dissolved in lukewarm or hot water at about 45º C to get rid of non-systemic surface pests and disease pathogens.
- Dip lower part (half the length) of stem cuttings for 1 to 5 min. in a solution of indole-3-butyric acid (IBA) @2.5-5.0g/l for inducing roots in stem cuttings.
- Plant cuttings in a mixture of cocopeat and sand (4:1, v/v) or cocopeat alone for faster rooting in polyhouse/shadenet.
- Well rooted cuttings should be transferred after 45 -60 days to nursery bags having pre-sterilized Sand: Soil: FYM mixture in 1:1:1
- At the time of transfer, place premultiplied (in FYM) beneficial microflora formulation containing, *Pseudomonas fluorescens*, AMF, *Aspergillus niger* AN27 in the root zone.
- Plant in field after 45 days of growth in bags. Before shifting to field keep for 1 week in 50% shade net for acclimatization.

C. Grafting

In many fruits crops identification of promising rootstocks and their utilization in the production process through grafting has significantly influenced the fruit industry. Standard grafting technique (Fig 3) and suitable rootstocks are required to mitigate the challenges of climate resilient horticulture with special reference to increased soil salinity, drought and other insect pests and diseases for commercial cultivation of pomegranate. NRCP has standardized wedge grafting technique. Presently, wilt is an emerging threat to the pomegranate industry in its major growing areas. Non-availability of wilt tolerant rootstocks is a major impediment for its mitigation. Research on suitability of rootstocks is the need of the hour to mitigate the challenges under climate resilient horticulture with special reference to increased soil salinity, drought, insect pests and diseases in commercial cultivars of pomegranate.

- Wild varieties should be used as rootstock and desirable variety 'Bhagwa', ‘Ganesh’ *etc*. as scion. Grafting success up to 90% can be achieved if done in January-February under Solapur conditions with mild winters.
- Rootstocks of 1-1½ years old should be decapitated (headed back) at 25-30cm above the ground level. Split beheaded rootstock to about 5cm depth through center of the stem with a sharp knife. Take six to twelve months old scion of 15-20cm length having 0.7-

1.0cm diameter from a terminal shoot, make the base wedge shape and insert in the vertical split of the beheaded rootstock.

- Tie the grafts with polethylene strips and cover with 20-25cm long polethylene tube tied with thread at its base.
- The grafts are watered and kept under shed to protect from direct sunlight. In general, scion sprouting starts between 8 and 12 days after grafting and after a few days of sprouting (12-15 days), the polythene tubes are removed.
- Wedge grafting during January under Solapur condition gave 90 % graft success. However, grafting can be done throughout the year under green house conditions.

Fig 3. Planting material prepared through grafting

D. Patch Budding

This method is recently standardized by ICAR-NRCP, Solapur and can be very effectively utilized after identification of promising rootstocks. It opens the avenue for *in situ* budding. More than 90 per cent success has been achieved when Bhagwa scion bud was budded on wild pomegranate root stocks during November to February under Solapur conditions. One year old rootstock and a patch bud of 20 mm x 10 mm containing some wood portions have been found ideal for patch budding. The patch of bark containing the bud is cut from the bud stick in the same manner in which the bark patch is removed from the rootstock. Two transverse cuts through the bark one above and other below the bud are made, then two vertical cuts are made on each side of the bud so that bark piece should be about 20 mm long x 10 mm wide. After the bud patch is removed from the bud stick it must be placed immediately on the rootstock or bud should be kept dipped in 0.1 % Carbendazim solution to avoid loss of moisture from the bud and microbial contamination till budding. The patch from the bud stick should fit snugly at the top and bottom into the opening in the rootstock. Polythene tape or polythene strips of 200 gauze thickness is used for covering budded portion to enhance budding success by maintaining high moisture at the budded portion (Fig. 4.). The preliminary trials gave encouraging success to the tune of more than 90 per cent when Bhagawa scion was budded on wild rootstocks.

Fig. 4.

E. *In vitro* Propagation (Tissue Culture)

Conventionally, pomegranate is propagated through air layering and hardwood cuttings which do not ensure production of disease-free planting material, moreover, success for these vary with season and maturity of the wood. The gaining popularity and up surging demand for quality planting material can't be fulfilled alone by conventional propagation methods and *in vitro* propagation has to be explored as an alternative tool to fulfill the demand of good quality disease free planting material in large number. Shoot tips, axillary buds, hypocotyls (may lead to variations) and nodal segments have been used as explants in pomegranate. Callus can also be taken for regeneration and production of entire plant. Generally, leaf segments, petals, hypocotyl and cotyledons are used for callusing. However, micropropagation through callusing may result abnormalities or sometimes creation of variability through enhanced possibility somaclonal variations, hence preferred only when other explant types are either not responsive or available Ex. coconut, datepalm, oilpalm. Preparative and explant plant pretreatment stage comprised of donor/mother plant selection and treatments, excision and treatments of explants *(*2-3 cm long and 20-25 days old nodal segments*)* with various antibiotic, fungicidal and surface sterilizing agents to avoid any microbial contamination and ensure good culture establishment Shoot proliferation of established culture occur through stimulation of branching, growth of side shoots and vertical splitting of elongated multinodal shoots. After 5-6 cycles of multiplication, sufficiently long shoots *(*3-4 cm*)* are transferred to rooting medium. Well rooted plantlets are hardened *in vitro* initially and then *ex vitro.* These *in vitro* raised plants are initially free from any kind of infection. The *in vitro* raised plants of pomegranate should be exactly similar to the mother plant from where explants had been excised, provided multiplication cycles are judiciously standardized with optimum level of growth regulators and there is non-occurrence of somaclonal variations which is a rare phenomenon in case where explant is nodal segment or shoot tip.

Biohardening:

After 45 days of acclimatization, plant beneficial microbes (biohardening agents) are introduced in the root zone the plants. The soil and other carrier based Arbuscular Mycorrhizal Fungi (AMF) cultures (*Glomus intraradices Glomus mossae*, *Glomus manihotis*, etc.) and other plant beneficial microbes can be used for biohardening of *in vitro* raised plantlets under glasshouse conditions.

Plant beneficial microbial formulations are placed in the root zone or/and phylloplane of plants at the time of their transfer to sterile potting mixture in nursery bags. These biohardening agents not only improve availability of nutrients by increasing root biomass but also help in improving immunity of plants system through induced systemic resistance. Biohardening agents like AMF helps in improving the phosphorus nutrition and growth of the host plant, which may result in an increased resistance to various stresses**.** They increase root surface area for water and nutrients uptake. The use of AMF as biohardening agent helps in more branching of plant roots as the mycorrhizal hyphae grow from the root to soil enabling the plant roots to contact with wider area of soil surface, hence, increasing the absorbing area for water and nutrients of the plant root system. Therefore, plants with mycorrhizal association will have higher efficiency for nutrients absorption, such as nitrogen, phosphorus, potassium, calcium, magnesium, zinc and copper and also increased plant resistance to drought. Besides, nutrient augmentation these microbes are responsible for anatomical changes in the root system, microbial changes in the rhizosophere and enhanced plant defense responses by altering the host's signaling pathways. Plant beneficial microbes like AMF plays critical role in increasing activity of hydrolytic enzymes, enhancing the levels of pathogenesis related proteins and accrual of phytoalexins in the plant system.

- **Advantages**
- Availability of elite, disease free planting material in bulk.
- Synchronized flowering and fruiting of *in vitro* raised pomegranate plants make them more suitable for mechanized cultivation.
- Precocity, higher uniformity, better quality and yield.
- Disease free planting material for extension of pomegranate to non-traditional areas.
- *In vitro* propagation is highly successful in most of the high value crops and has vast scope in pomegranate.
- **Disadvantages**
- Cost intensive and high skill requiring technology.
- Intensive care is required by *in vitro* raised plants to realize its full potential in term of yield and quality.
- Needs proper standardization of package of practices for commercial cultivation.

Chapter 6

Physiological disorders in pomegranate impact of use of plant growth-promoting hormones for quality pomegranate production

Pomegranate area under cultivation, production and export from India have increased significantly since last three decades. Pomegranate fruit contains numerous seeds covered by juicy, sweet/acidic, red/pink/whitish, and translucent aril. Arils are comprised of almost 78% juice and 22% seeds, and they constitute about 52% of total fruit (w/w). The fresh juice contains almost 85.4% moisture along with substantial concentrations of total soluble solids, total sugars, reducing sugars, phenolics, anthocyanins, ascorbic acid and proteins. Pomegranate is a nutritious fruit that is also being used because of its high medicinal value since ages. Though it is a high-yielding horticultural crop, but there are few physiological issues linked to its cultivation, which directly affect quality and yield. Physiological disorders are different from other disorders as they are not caused by living organisms, but by non-living, abiotic situations and cause a deviation from normal growth. Major physiological disorders that bother pomegranate farmers/growers are fruit cracking, sunscald, aril browning, chilling injury and husk scald.

Fruit cracking is one of the major physiological disorders in pomegranate. Cracked fruits are unmarketable for the fresh market and also are unsuitable for the juice industry when cracks are deep and arils are exposed. Major cause of fruit cracking is soil moisture imbalance at fruit growth stage. Prolonged drought cause hardening of pomegranate peel, heavy irrigation at this stage leads to an asymmetric increase in aril turgor pressure that is much higher than peel turgor pressure causing cracking. The water potential of the fruit produces the cracking force, and the cell wall and other structures when fail to resist this pressure, cracks appear on the peel. The biomechanical properties of peel play important role in sustaining inner pressure and resisting fruit cracking. These properties are affected by calcium content and pectin value, cell wall structure and its' component, quantity and volume of intercellular spaces etc. Many morphological characteristics viz. physical properties and thickness of the cuticle, number of hypodermal layers, fruit shape and size affect sensitivity to cracking. Two types of cracking are observed in pomegranate viz. physiological and pathological (Figure 1). Pathological fruit cracking appears mainly due to bacterial blight disease.

Figure 1: Symptoms of physiological and pathological Cracking

Among different elite horticultural practices, growth regulators have been advantageously used in the recent time to enhance fruit quality and production. Worldwide, management approaches tried till date in pomegranate includes foliar sprays and soil application of various plant growth hormones, micronutrients and biostimulants. The major treatments used are sprays of a mixture containing salicylic acid, magnesium sulfate, chelated zinc, boric acid and calcium chloride; irrigation at two-week intervals along with mulching with dried grasses and spray with boric acid potassium nitrate and magnesium sulfate; boron; borax and zinc sulfate along with mulching;

boric acid; tryptophan, irrigation at 14 days along with borax application; fruit bagging along with sprays of kaolin and calcium chloride, calcium nanoparticles, controlled irrigation along with zinc sulfate, sprays of kaolin and humic acid; sprays of spic cytozyme and biozyme; paclobutrazol (Singh et al 2020). These strategies reduced fruit cracking in the range of 44 to 90%. Among these treatments, borax (0.75%) along with irrigation at 14 days interval reduced the fruit cracking to the maximum extent.

Pomegranates are more prone to sunburn due to terminal bearing nature. Moreover, the thin branches bend with the increasing weight of fruits that directly expose fruits to sunlight. Though quality traits such as attractive aril colour, small/soft seeds in aril, sweetness etc. can be seen only when the fruit is cut open, the first thing that attracts the consumer in the market is the appearance of the fruits. The fruits that contain clean skin, free from any cracks, russeting, sunburn and discoloration attract the consumers the most. In pomegranate, sunscald is a major problem that decreases its marketability due to poor appearance. Prolonged high temperatures during fruit growth and maturation stage results in cell death leading to necrosis of tissues. Figure 2 shows the sunscald/sunburn symptoms.

Figure 2: Symptoms and severity of sun scald

For management of sunscald, fruit bagging, use of shades/screens to cover plants, controlled irrigation, coating with reflectants viz. kaolin, calcium carbonate and lime water has been tried. Kaolin coating is reported to allow the passage of beneficial radiation required for photosynthesis and reflects harmful radiations. Calcium carbonate protects fruits by reflecting harmful infrared and ultraviolet radiation without hindering leaf stomata and photosynthesis. Ascorbic acid and gibberellic acid sprays have also shown some beneficial effects to prevent sunscald in pomegranate. The incidence of sunburn can be so high to cause losses of more than 30% of harvested fruits. Regulation of soil/plant water status, transpiration rate and fruit surface wax status are important parameters to reduce sunburn. Effect of bagging on fruit quality is shown in figure 3.

Figure 3: Effect of bagging on fruit appearance

Aril browning, also called internal breakdown, critically affects fruit quality and is characterized by soft, light creamy, brown, dark blackish/ brown and slightly flattened arils. These arils are

generally deformed and possess an unpleasant odour when the fruit is cut open. This disorder cause desiccation, wrinkling and development of internal spaces in the arils. Aril browning starts with a tiny dark dot on the seed that slowly expands to the whole aril and in some cases, white streaks appear on the arils. Fruits with such arils are unsuitable for consumption. These affected arils exhibit higher sugars, respiration rates, pyruvic acid, acidity, malondialdehyde and higher activity of superoxide dismutase, peroxidase, phenyl ammonia lyase, pectin methylesterase and polyphenol oxidase. Brown arils contain lower starch, ascorbic acid, phenol, anthocyanin compared to healthy arils. Some reports linked aril browning with mineral deficiency as brown arils contained lower calcium, boron and copper than healthy arils. Peel of affected fruits is reported to contain lower concentration of copper, potassium, magnesium and manganese compared to peel of healthy fruits. Major concern with this disorder is that the fruits show no symptoms externally and hence cannot be separated before packing, causing serious problems in export trade. The intensity of this disorder can be more than 50% in some cases causing severe losses. Studies have shown that during the early stage of fruit development, differences in concentration of plant growth hormones viz. auxin and gibberellins lead to the development of seeds with variable sink strength. At this stage, the moisture content in weak sinks or seeds is reduced causing loss of viability (Figure 4). Low moisture content in such arils leads to loss of membrane integrity causing activation of polyphenol oxidase enzyme and oxidation of phenols. This indicates that a pre-harvest management strategy is required at the fruit setting and 50% fruit maturity stage as no treatment can be effective once the fruits are mature.

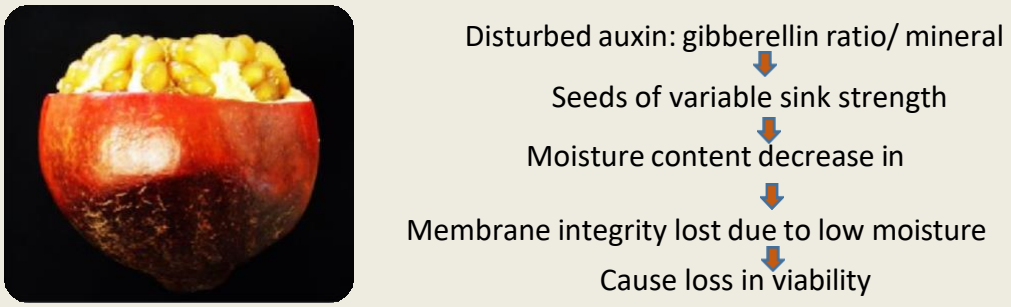

Figure 4: Possible mechanism of aril browning

Foliar application of salicylic acid and sodium nitroprusside has been reported to decrease the aril browning significantly. Pruning intensity reduced aril browning in susceptible cultivars. Covering fruits to protect them from direct light increases humidity around the fruit which is reported to increase browning. Better flow of calcium is important to prevent browning. Pruning of shoots increases light penetration that aid transport of calcium and boron to fruits resulting in lesser browning. Along with proper pruning, sprays of calcium and boron on fruits during initial growth stages and harvesting at proper maturity also reduce aril browning incidence. Further studies are required to understand the complete mechanism behind aril browning, so that proper management can be carried out. To develop suitable management practices to overcome all these physiological disorders, complete knowledge on the processes involved and key genes responsible for these disorders is required. Water, nutrient and canopy management can be some of the important cultural practices that can reduce the physiological disorders.

Storage of pomegranate at temperatures lower than 5°C for 2 months induce chilling injury. Being chilling sensitive, pomegranates develop surface pitting on the peel and brown discoloration of locular septa separating the arils, and when severe, the arils may also be affected (Figure 5). For short storage i.e 2-3 months storage temperature at 5°C can be used however, for long-term storage i.e up to 5 months 7.2°C is more suitable. Treatments of fruits with polyamines

viz. putrescine and spermidine; and plant growth hormones viz. jasmonic acid and salicylic acid showed chilling tolerance. Likewise, conditioning at 38°C hot air or 45-55°C hot water also enhanced chilling tolerance in pomegranate. However, these treatments are partially effective and could not completely eliminate the chilling injury symptoms. To control chilling injury, fruit exposure to temperatures below 5°C (41°F) should be avoided. Intermittent warming during storage, or modified atmosphere packaging can help to prevent this disorder.

Figure 5: Symptoms of chilling injury

Husk scald is storage related disorder that affects fruit quality during and after cold storage. It occurs mainly during long-term cold storage of pomegranates. It differs from chilling injury and its symptoms appear as superficial browning of peel (Figure 6). It develops as brown discoloration from stem end of fruit and does not affect arils and locular septa. This disorder decreases the marketability of pomegranate as fruits appear defective even if the arils are of good quality. These defective fruits are more prone to fungal diseases. Husk scald is aggravated at temperatures higher than 5°C, that is recommended for pomegranates to avoid chilling injury. Husk scald increases when fruits of low-temperature storage are exposed to room temperature. However, it can also occur at storage temperature of more than 10°C. For husk scald, late harvested fruit is less susceptible than earlier harvested fruit during storage. Low temperature treatment of fruits by pre-storage at 15°C for 10 days before transfer to cold storage is an effective treatment. Controlled atmosphere storage with a combination of 5 kPa O_2 and 15 kPa CO_2, has been shown to extend pomegranate postharvest life for up to 5 months at 7°C.

Figure 6: Symptoms of Husk scald

Chapter 7

Adavanced biotechnological approaches for quality pomegranate production

Biotechnology is one of the fastest growing areas in science that made a great development in various fields such as agriculture, medicine, pharmacy, industry and environment science. Biotechnology applies scientific and engineering principles to living organisms in order to produce products and services of value to society. Pomegranate (*Punica granatum* L.) is an economically important perennial crop, with high nutritional, medicinal and ornamental importance. Maharashtra is the major pomegranate producing state, where numbers of Pomegranate varieties are under cultivation with more or less phenotypic dissimilarities in various regions. This has created confusion about the real identity of these varieties among farmers, in addition these heavy economic losses witnessed by bacterial blight and fusarium wilt. Therefore, to overcome these constraints deployment of advanced biotechnological tools is very important in pomegranate which can effectively boost the precise of evaluation and conservation of germplasm resources, genetic mapping and marker assisted breeding of exportable grade fruit quality traits at institute level for developing improved new pomegranate varieties.

DNA markers can aid in resolving the varietal identification disputes for commercially grown cultivars of India. Markers also help in clonal fidelity testing of micro-propagated plantlets for distribution of true to type disease free pomegranate planting materials to the farmers. In order to strengthen the traditional breeding in pomegranate, currently plenty of genomics tools and techniques are available. With respect to structural genomics, three genome sequences are reported in pomegranate using next generation sequencing technologies (NGS). Among these, Tunisia genome represented the high-quality with chromosomal level assembly. In parallel, in India the pomegranate variety cv. Bhagawa has been sequenced at our institute using four NGS technologies to assemble reference quality genome.

Apart from this, currently the availability of genome and transcriptome sequences have provided an unprecedented opportunity for development of large-scale informative markers like simple sequence repeat markers (SSRs), expressed sequence tag-SSRs (EST-SSRs) and single nucleotide polymorphism (SNPs) markers and microRNA-SSRs (miRNA-SSRs) in pomegranate. These represents an important marker repository for construction of high-density genetic maps along with precise phenotyping platforms would facilitate for quick identification of genes/QTLs for fruit quality traits. The regular deployment of these genomic tools into pomegranate breeding programmers in the form of markers assisted selection (MAS) would greatly facilitate in accelerating for breeding exportable grade fruit quality traits in pomegranate.

Chapter 8

Conservation and utilization of pomegranate genetic resources for quality pomegranate production

Plant genetic resources or germplasm or genetic stores or restores or totality of genes. PGR have played key roles in achieving some of these goals so far especially food security, poverty alleviation, environmental protection and sustainable development. Thus, their conservation which entails sustainable exploitation of plant diversity so that current and future generations of humans will benefit from it should be encouraged. The basis for rational conservation actions is a good knowledge of the current situation and its dynamics. This lecture is sought to create sufficient awareness on the importance of conserving and utilizing PGR in the light of advances and contemporary changes in the practice. The term 'Genetic material' means any material of plant, animal, microbial or other origin containing functional units of heredity. The value of any functional units of heredity can be captured in two dimensions: which is the genetic structure per se can be utilised; or the information encapsulated in the nucleotide sequence of the genetic material can be read (Schei and Tvedt, 2010). That is PGR refer to all the types of yams, almonds, cotton, coffee, etc. According to IPGRI (1993), PGR include the following categories of plants:

i) Cultivated varieties (cultivars) in current use;
ii) Newly developed varieties;
iii) Obsolete cultivars;
iv) Primitive cultivars (land races);
v) Wild and weedy relatives of cultivated varieties and
vi) Special genetic stocks (including elite and current breeders' line and mutants).

Plant genetic resources pool is valueless and can determine useful traits that people can conserve, characterize, evaluate, and use to meet their needs. These resources are not simply the genes encoded in DNA, but also the expressions of the genes that farmers and scientists have recognized and selected. Genetic diversity created in the farmers' fields over millennia is complemented by the diversity present in wild relatives of crops. Plant genetic resources for food and agriculture (PGRFA) include the traditional crop varieties and their wild relatives, modern cultivars, breeding lines and genetic stocks which provide food, feed for domestic animals, fiber, clothing, shelter, medicine and energy.

Roles of Plant Genetic Resources

In order to grasp the importance as well as current challenges in the conservation and utilization of PGR, there is need to outline some benefits of PGR.

1) Development of new variations through genetic modification techniques.
2) Transfer of a genetic trait, such as a gene for pesticide resistance taken out of one species and put into another.
3) Production of recombinant cell lines and transgenic plants.
4) Use of in vitro nucleic acid techniques, including recombinant deoxyribonucleic acid (DNA); and direct injection of nucleic acid into cells or organelles
5) Use of fusion of cells beyond the taxonomic family.

6) Sequencing genes or genomes (e.g. identification of genes coding for useful traits; molecular systematics for understanding evolutionary relations; genotyping of plants for identification and DNA barcoding of plants for identification; environmental genomics)
7) Phenotyping of the characteristics of plants, animals and micro-organisms for ecological and other studies and purposes
8) Experimental evaluation of heritable characteristics
9) Creation of collections of reference specimens in repositories such as museums and herbaria
10) Isolation of a compound from genetic material for the purpose of characterization and evaluation.

Types of conservations

The CGIAR maintains large depositories of germplasm at its various centres include large numbers of accessions from public national collections in many countries.

There is a wide range of motivations for maintaining the diversity of species in general. There are two broad approaches to PGR conservation and these are:
1) In situ conservation and
2) Ex situ conservation.

Effective ex situ storage aims to complement in situ preservation in maintaining the existing gene pool especially for future agricultural production. In many countries this is practiced through a national conservation programme set-up, usually as a combination of the in situ, ex situ in vitro and ex situ, in vivo methods for conservation programmes and collections of long-term storage of cryo-preserved genetic material.

In situ conservation: Demands the establishment of nature or biosphere reserves, national parks, or special legislation to protect endangered species. UNEP (1992) defined it as the conservation of ecosystem and natural habitats, and the maintenance and recovery of viable population of species in their natural habitats or where they have developed their distinctive properties.

Ex situ conservation: Ex situ conservation is the conservation and maintenance of samples of living organisms outside their natural habitat, in the form of whole plants, seed, pollen, vegetative propagules, tissue or cell cultures. Vavilov was the first to recognize the value of genetic diversity and created first modern seed bank in St Petersburg. (Base, active, working collections)

They are also taken as main centres of conservation of plant resources from their extinction as well as:
1) Repository of plants of a country and also of selected exotic species and serve as a "safe abode" for the rare and endemic plants.
2) Accommodation for germplasm collection of selected economic, ornamental and medicinal plants and their wild progenitors.
3) Promotion of educational programmes and research in experimental botany and ornamental horticulture
4) Generate awareness about value of trees and about curious, beautiful and interesting plants with delightful landscaping and display.
5) For the introduction of economically exploitable species and
6) Data bank for information and documentation on holdings in botanic gardens of the country

or region.

Wild resources

In India, naturally growing wild pomegranates are found in Northern parts especially in Western Himalayan regions which included Jammu and Kashmir, Himachal Pradesh and Uttarakhandstates. Locally they are called as 'Daru', which were known to be exist in nature over long periods of with better climatic adaptability and resistance to pests and diseases. These wild plants are known to produce small fruits of highly acidic juice with hard seeds in comparison to cultivated types. Dried arils of 'Daru' pomegranate are used in the *anardana* (acidulant product) preparation as a souring agent in Indian food (Pruthi and Saxena, 1984). Apart from these countries, a well scattered population of wild pomegranate is identified in Kandahar, Baikh, Farag, Kapisa, Samangan, Nagharhar and Heart regions of Afghanistan. In addition, some of the promising landraces with good quality are known to exist in Kandahar and Farah provinces. In Pakistan, Khyber Pakhtunkhwa (Chitral, Dir and Kurrum regions), Baluchistan andsouth Waziristan parts are also witnessed to have wild pomegranates which grow naturally in forest areas.

Germplasm collection and conservation

More than 500 pomegranate cultivars with diverse characteristics are known in the world. Of which only 50 varieties are being commercially cultivated (IPGRI, 2001). This could be because of less utilization of the available genetic diversity in pomegranate, which drastically reduced the variability in the modern cultivars. With the available large genetic diversity in the wild forms of pomegranate it becomes extremely important to conserve them along with cultivated types to maintain as well as broaden the genetic base for future genetic improvement program in pomegranate.

Several efforts have been initiated to collect, conserve and evaluate pomegranate germplasm at international level. Wild, semi-wild and cultivated accessions of pomegranate are currently conserved in the germplasm collections of 26 pomegranate-growing countries. Among these, the largest pomegranate collection is at Turkmenistan Experimental Station of Plant Genetic Resources, Garrygala, Turkmenistan (1117 accessions) followed by N. I. Vavilov Research Institute of Plant Industry, St. Petersburg, Russia (800 accessions) and Iranian National Pomegranate Collection, Yazd and Saveh, Iran (770 accessions). In India, pomegranate germplasm accessions are being conserved in at least 12 centers. ICAR-National Research Center on Pomegranate, Solapur, Maharashtra holds the largest collection of >300 accessions, followed by Indian Institute of Horticultural Research, Bangalore, Karnataka (265 accessions) (https://www.iihr.res.in/division-fruit-crops, 2020); ICAR-National Bureau of Plant Genetic Resources, New Delhi (>200 accessions) (Unpublished) and ICAR-Central Institute of Arid Horticulture (ICAR), Bikaner, Rajasthan (154 accessions) (https://ciah.icar.gov.in/reserch_highlights.php, 2020). Besides these, Punjab Agriculture University, Abohar, Punjab; Mahatma PhuleKrishiVidhyapeeth, Rahuri, Maharashtra; SardarkrushinagarDantiwada Agricultural University, Sardarkrushinagar, Gujarat; ICAR-Central Arid Zone Research Institute (ICAR), Jodhpur, Rajasthan; Dr.Y.S.R. Horticultural University, Venkataramannagudem, West Godavari District, Andhra Pradesh; Central Institute

of Temperate Horticulture, Jammu and Kashmir; Sri Karan Narendra Agriculture University, Jobner, Rajasthan (KVK Navgaon, -Alwar) and CCS Haryana Agricultural University, Bawal, Haryana are the other centres which are involved in pomegranate germplasm collection and conservation in the country.

List of major institutes involved in pomegranate germplasm collection in the world

Sl. No.	Institute name
1.	Kabul University, Kabul, Afghanistan
2.	Agricultural university of Tirana, Albania
3.	Fruit Trees Division, Agricultural Research Institute, Nicosia, Cyprus
4.	French Agricultural Research Centre for International Development at Capesterre Belle Eau, France
5.	University of Horticulture and Food Industry, Budapest, Hungary
6.	ICAR-National Research Center on Pomegranate, Kegaon, Solapur, Maharashtra, India
7.	ICAR-NBPGR (National Bureau of Plant Genetic Resources), Regional Stations Shimla (Himachal Pradesh), Bhowali (Uttarakhand) and (Jodhpur), Rajasthan, India
8.	ICAR-Indian Institute of Horticultural Research, Bangalore, Karnataka, India
9.	ICAR-Central Institute of Arid Horticulture (ICAR), Bikaner, Rajasthan, India
10.	Mahatma PhuleKrishiVidyapeeth Agricultural University, Rahuri, Maharashtra, India
11.	SardarkrushinagarDantiwada Agricultural University, Sardarkrushinaga, Gujarat, India
12.	Iranain National Gene Bank, Mahdasht Road, Karaj, Iran
13.	Agricultural and Natural Resources Research Center of Markazi Province, Arak, Iran
14.	Department of Plant Breeding, Science and Research Branch, Islamic Azad University, Tehran, Iran
15.	Agriculture and Natural Resources Research and Education Center of Yazd, Yazd, Iran
16.	Pomegranate Research Station, Saveh Agriculture Research Center, Saveh, Iran
17.	Unit of Deciduous Fruit Tree Sciences, NeweYa'ar Research Center, Agricultural Research Organization, Israel
18.	Institute of Agricultural Sciences, Verona, Italy
19.	National Fruit Breeding Station, Alcobaça, Portugal
20.	NI Vavilov Research Institute of Plant Industry, St. Petersburg, Russia
21.	Alternafruit SA (Pty) Ltd., Wellington, South Africa
22.	Chiang Mai, Bangkok, Thailand
23.	Tunisian national germplasm collection of pomegranates, Zerkin, Tunisia
24.	Alata Horticultural Research Institute, Erdemli-Mersin, Turkey
25.	Turkmenistan Experimental Station of Plant Genetic Resources, Garrygala, Turkmenistan
26.	The Nikita Botanical Gardens of the Ukraine Academy of Agrarian Sciences, Yalta, Crimea, Ukraine
27.	The National Clonal Germplasm Repository, Tree Fruit & Nut Crops & Grapes, USDA, ARS, UC Davis, Davis, California, USA

28.	Richard R. Schroeder Uzbek Research Institute of Fruit Growing, Viticulture, and. Wine Production, Tashkent, Republic of Uzbekistan, Uzbekistan

Germplasm diversity

Pomegranate adaptability to a wide range of climatic conditions in different geographical locations has created an ample amount of genetic variability with in the genus. Even the plants raised through sexually (seed) are known to exhibit good amount of variation due to its often cross-pollination nature. A wide range of phenotypic variability for tree, leaf, flower and fruitmorphological, physiological and biochemical traits; variety of reaction to biotic and abiotic stresses; different climatic behaviors have been reported in different countries.

In India, a good diversity of pomegranate in the form of wild (Western Himalaya) and evergreen cultivars has been reported. Singh and Singh, (2006) reported the presence of high diversity in wild pomegranates of Himachal Pradesh for number of fruits per tree, fruit weight (g), number of arils per fruit, Total Soluble Solids (°Brix) and titrable acidity (%). Notable variability was also recorded in Uttarakhand collections for plant height, leaf and fruit size, stem, rind and aril colour, number of thorns and their size, TSS, acidity, etc. (NRCP, 2007). Wide genetic variability in 33 indigenous accessions of pomegranate collected from Kashmir Valley was reported for ten characters *viz*., fruit yield/ tree, fruit length, fruit diameter, fruit weight, fruit volume, appearance, total aril weight, fruit rind colour, fruit size and rind weight. In a recent population divergence study, comprising of pomegranate collections of Jammu & Kashmir, Shimla (Himachal Pradesh), Bhowali (Uttarakhand) indicated that fruit weight (g) character has a maximum (43.67%) contribution for the genetic differences among the genotypes. The population structure analysis of 88 Indian pomegranate collections using SSR markers gave the hint of close association of cultivated pomegranates with the wild-types that grow naturally in Jammu and Kashmir. Patil *et al*., (2020a) also demonstrated a high level of genetic differentiations or low level of gene flow among 42 diverse pomegranate genotypes using class I hypervariable SSRs.Among cultivated types, >20 cultivated varieties of pomegranate are reported. These varieties are sweet flavored with low-very high acidity, medium-large fruits of yellow with red tinge to dark red fruits, light pink to deep red arils and very soft to very hard seeds. These varieties are developed or released for table, processing and anardana purposes.

Iranian cultivars are known for late ripening, medium to large size fruits with thick red rind and red arils. Some are early in maturity (in August) which is considered to be good for the export. Late maturing cultivars are harvested till December (Verma*et al*., 2010). The collection includes all sweet, sweet-sour and sour varieties. Simple sequence repeats markers analysis of 738 pomegranate (*Punicagranatum* L.) accessions, representing 23 provinces of Iran, separated the accessions into 8 main groups based on their geographical origin providing evidence for wide variability in the Iranian National Pomegranate Collection (Alamuti*et al*., 2012).

Martinez-Nicolas *et al*., (2016) evaluated fifty-three pomegranate collections of Spain for 31 morphometric characteristics in order to determine their degree of polymorphism. The cluster analysis showed the cultivar discrimination based on their geographical origins. They described that the traitsrelated to fruit and seed size, juice's acidity and pH had the highest discrimination

between the Spanish accessions.

Way forward

Building sustainability in terms of PGR conservation and utilization should be on the agenda of international as well as national conferences. There is need to improve conservation science to impact on monitoring erosion, vulnerability and developing indicators of diversity can guide against extinction and promote utilization. Pomegranate is an age old fruit crop found to be exists in different agro-climatic and edaphic conditions. An ample amount of genetic variability is recorded for various pomological characteristics among the existing pomegranate cultivars of the world. However, being single cultivated species of 'Punica' genus, attempts need to be made to widen its genetic base through pre-breeding programmes by utilizing its wild progenitor or wild forms. It will help to overcome the major production constraints like insect pests, diseases, physiological disorders and abiotic stresses in pomegranate. Redundancy among the pomegranate accessions is another issue needs to be tackled for more precise assessment of the germplasm diversity and its utilization in crop improvement programmes. Generation of whole genome sequence information of most diverse pomegranate accessions could be made using advances Next Generation Sequencing platform for better knowledge on the crop diversity.

Chapter 9

Recent adavances in water management for export quality pomegranate production

Pomegranate is grown mainly in arid or semiarid regions with limited irrigated water sources; hence water management is an important technique for efficient utilization of available water for maximum production. The water requirement of pomegranate crop depends on age, season, location and management strategies.

A. Water Management Techniques

Covering the soil/ground below plant canopy with inorganic or organic mulches (Fig. 1) during dry months after the rainy season conserves soil moisture and saves irrigation water, creates favorable conditions for plant growth, development and efficient crop production. Prevents the direct evaporation of moisture from the soil, increases soil temperature during winters, reduces soil compaction and fruit production is earlier. Organic mulches in addition increase water and nutrient retention capacity, improve soil oxygen, root growth and also supply nutrients on decomposition.

Inorganic Plastic Mulch

Organic mulch

Fig. 1: Different types of mulches in pomegranate

I. Types of drip irrigation system (Fig. 2.)

- **Sub-surface drip irrigation:** Sub-surface drip irrigation system, the drippers and lateral lines are laid below the ground level in the plant root zone.

Surface drip irrigation: Surface drip irrigation system, the drippers and the lateral are laid on the soil surface. Based on the types of laterals or the emitting devices used, the drip irrigation systems can be classified as:

On line drip irrigation system: On line drip irrigation system in which the drippers or emitters are fixed on the lateral pipes by punching suitable holes on the drip lateral pipes at locations specific to the crop being irrigated. Single dripper 15 cm away from plant may be used till 6-12 months, 2 drippers till 2-3 years and 4-6 drippers on 2 laterals after 3rd year depending on plant height and spread (Fig. 3).

Sub-surface drip On line drip In line drip

Fig 2: Drip Irrigation Systems

Single lateral with one dripper Single lateral with two drippers

Two laterals with four drippers

Two laterals with six drippers

Fig. 3 Drip irrigation system in pomegranate

In line drip irrigation system: In line drip irrigation system drippers are factory installed within or on the drip lateral at regular intervals. This is suitable for close spaced crop.

II. Water requirement

The water requirement of pomegranate in different stages and seasons is given in Tables 1-3.

Table 1 . Water to be applied (lit/day) for one to five years old pomegranate tree during *Mirg bahar*

Months	MW	1st	2nd	3rd	4th	5th	Months	MW	1st	2nd	3rd	4th	5th
June	23	3	5	6	8	11	2nd week of September to October	39	2	9	16	25	31
	24	3	5	6	8	13		40	2	8	15	24	30
	25	3	5	7	11	16		41	2	8	16	24	30
	26	3	5	8	13	17		42	3	9	16	25	32
July to 1st week of September	27	3	6	9	15	20		43	3	9	18	27	34
	28	3	6	10	16	22		44	3	9	17	26	33
	29	2	7	11	18	23	November to 2nd week of January	45	3	9	17	26	33
	30	2	7	10	17	23		46	3	8	16	25	32
	31	2	7	12	19	25		47	3	8	15	24	30
	32	2	8	13	21	27		48	3	7	15	23	29
	33	2	8	14	22	29		49	3	7	14	23	29
	34	2	8	14	23	29		50	3	6	13	21	27
	35	2	8	15	25	31		51	3	6	13	21	26
	36	2	9	16	25	32		52	3	6	12	20	25
	37	3	9	17	26	33		01	3	5	12	19	24
	38	2	8	16	24	31		02	3	6	12	20	26

Table 2. Water to be applied (lit/day) for one to five years old pomegranate tree during *Hasta bahar*

Months	MW	1st	2nd	3rd	4th	5th	Months	MW	1st	2nd	3rd	4th	5th
	36	2	3	4	5	6		52	2	8	16	24	30

Septem-ber	37	2	3	4	6	9	4th week of Decemb er to 2nd week of February	01	2	8	15	23	29
	38	2	4	5	8	11		02	2	8	16	24	30
	39	2	4	6	10	13		03	3	9	16	25	31
1st week of October to 3rd week of December	40	2	4	7	11	15		04	3	10	18	28	35
	41	2	5	8	13	18		05	3	10	19	29	37
	42	2	6	9	15	20		06	3	10	20	31	39
	43	2	7	11	18	24		07	4	11	21	33	41
	44	2	7	12	19	25	3rd week of February to March	08	4	11	23	35	44
	45	2	8	13	21	28		09	4	12	24	37	47
	46	2	8	14	22	29		10	5	12	24	39	49
	47	2	8	14	23	30		11	5	12	25	39	49
	48	2	8	15	24	31		12	6	12	25	41	52
	49	2	9	16	25	32		13	6	12	25	41	52
	50	2	8	16	24	30		14	6	12	25	41	52
	51	2	8	16	24	30		15	6	12	26	43	54

Table 3. Water to be applied (lit/day) for one to five years old pomegranate tree during *Ambia bahar*

Months	**MW**	**1st**	**2nd**	**3rd**	**4th**	**5th**	**Months**	**MW**	**1st**	**2nd**	**3rd**	**4th**	**5th**
January	1	2	3	3	5	6	3rd week of April to 2nd week of June	17	5	19	35	54	68
	2	2	3	4	5	8		18	6	20	36	56	70
	3	2	4	5	8	11		19	6	19	36	56	70
	4	2	5	7	11	15		20	6	19	36	56	70
	5	2	6	8	13	18		21	6	19	35	54	67
February to March	6	3	7	10	17	23		22	5	18	33	51	65
	7	3	8	12	20	27		23	4	14	27	42	53
	8	3	9	15	25	33		24	4	12	24	37	47
	9	4	11	18	30	39	3rd week June to 1st week of August	25	4	11	22	33	42
	10	4	12	21	34	45		26	4	10	19	30	38
	11	4	13	24	38	50		27	4	9	18	29	37
	12	4	15	28	44	57		28	4	8	17	27	34
	13	5	16	30	48	60		29	3	7	15	25	32
	14	5	17	32	49	62		30	3	6	13	22	27
	15	5	18	33	51	64		31	3	6	13	21	27
	16	5	19	35	54	68		32	3	6	13	21	27

III. Precautions for trouble free irrigation

- Additional flushing must be conducted at the end of the irrigation season

- Flushing the manifold and mainline ends flushing laterals to remove sediments that accumulate at the drip lateral ends
- Clean filters at regular intervals based on the water quality and content
- Check pressure at each of the system's stations, head, valves, laterals, beginning and end
- Checking the lateral flow in random drippers
- Leaks can occur unexpectedly as results of insects, animals or farming tools. So, monitor lines for any physical damage regularly.

Easy way to know water requirement of your crop

Water requirement depends on several factors- climate and weather, soil type, organic content, plant age, plant size, plant stage and crop load, hence, will vary from orchard to orchard. Therefore, best and easy way to standardize water for your orchard is:

1. Irrigate the crop say for 1 hour.
2. Next day after 24 hrs check soil moisture at 15-20 cm depth in root region by taking soil from this region in your fist and close your fist to compress the soil.

(a.) If it remains loose and does not compress to form mould : Water is deficient: irrigate the crop

(b.) If it forms a mould, throw it on the ground:

(i) If it loosens after falling- water is perfect; irrigate next day after checking

(ii) If it remains in mould without much dispersing- water is excess: No irrigation is required, check regularly and irrigate accordingly.

Chapter 10

Integrated nutrient management practices for sustainable pomegranate production

Nutrients affect pomegranate plant growth, health, fruit yield and quality. With each harvest considerable amounts of macro and micro-nutrients are being removed which need to be replenished on regular basis. Nutrients also play important role in increasing shelf life of produce thereby minimize post-harvest losses. Hence, maintaining soil health is necessary for sustainable production.

A. Diagnosing Nutrient Requirement of the Plant

After each harvest nutrient content in plant and availability of nutrients in orchard soil should be assessed for undertaking fertilization schedule to be followed in pomegranate. The leaf nutrient standard and nutrient doses recommended for pomegranate are given in Table 1 and 2 respectively.

Table 1: Leaf nutrient standard for pomegranate

Nutrient	**Diagnosis and Recommendation Integrated Systems (DRIS) Norms**				
	Deficient	**Low**	**Optimum**	**High**	**Excess**
Nitrogen (%)	<0.54	0.54-0.90	0.91-1.66	1.67-2.04	>2.04
Phosphorous (%)	<0.09	0.09-0.11	0.12-0.18	0.19-0.21	>0.21
Potassium (%)	<0.20	0.20-0.60	0.61-1.59	1.60-2.26	>2.26
Calcium (%)	<0.13	0.14-0.76	0.77-2.02	2.03-2.65	>2.65
Magnesium (%)	<0.03	0.03-0.15	0.16-0.42	0.43-0.55	>0.55
Sulphur (%)	<0.10	0.10-0.15	0.16-0.26	0.26-0.42	>0.42
Iron (ppm)	<34	34-70	71-214	215-286	>286
Manganese(ppm)	<15	15-28	29-89	90-119	>119
Zinc (ppm)	<8	8-13	14-72	73-94	>94
Copper (ppm)	<7	8-28	29-72	73-94	>94
Yield (t/ha)	**<13.7**	**13.7-15.5**	**15.6-18.8**	**18.9-20.6**	**>20.6**
Note: < : Less than; >: More than					

B. Macronutrient Deficiency Symptoms

The deficiency symptoms of important major nutrients are described below and shown in Fig 1.

I. Nitrogen: The older mature leaves gradually change from normal green appearance to pale green. The older leaves become uniformly yellow. The young leaves at the top of the plant become pale and smaller in size. Branching is reduced in nitrogen deficient plant. The yellowing in nitrogen deficiency is uniform over the entire leaf including veins.

II. Phosphorus: Phosphorus deficiency symptoms are not very distinct and thus difficult to identify. Phosphorus deficient leaves show some necrotic spots, generally chlorosis starts from leaf tip followed by necrosis, giving leaf tip burn symptoms. Plants are dwarfed or stunted, with reduction in leaf expansion and number of leaves. Leaves have a darker green color. In older

leaves under very severe deficiency condition, a brown netted veining of the leaves may develop. There is less and delayed flowering.

III. Potassium deficiency: The first symptoms are marginal interveinal chlorosis followed by dry leathery tan scorch and necrosis on recently mature leaves. The symptoms progress towards midrib. The veins remain green and the leaves tend to curl and crinkle. Symptoms may also develop on young leaves under extreme deficient condition. Fruit size gets reduced.

IV. Calcium deficiency: Deficiency symptoms occur in the young parts of the plant. Growing tips become twisted and deformed. Deficiency symptoms start as a narrow necrotic border at the leaf margin that moves in steps towards the petiole attachment. Very slow growing plant. The chlorosis of leaves initiates with purplish colouration of the interveinal area.

V. Magnesium deficiency: The first symptom of magnesium deficiency is a yellowish green blotch near the base of the leaf between the midrib and the outer edge. The yellowing enlarges until only the tip and base of the leaf remain green as an inverted V-shaped area on the midrib. With acute deficiency, leaves may become entirely yellow-bronze and eventually drop.

VI. Sulfur deficiency: The visual symptoms of sulfur deficiency are very similar to the chlorosis found in nitrogen deficiency. However, in sulfur deficiency the yellowing is much more uniform over the entire plant including young leaves. The leaves show overall chlorosis while still retaining some green color. The veins show a very distinct reddish color on the underside of the

leaves and the petioles have more pinkish tone. With advanced sulfur deficiency, brown lesions and/or necrotic spots develop along the petiole and the leaves tend to become more erect and often twisted and brittle.

<table>
<tr><td> 
</td><td>  </td><td>  </td></tr>
<tr><td>Nitrogen</td><td>Phosphorus</td><td>Potassium</td></tr>
<tr><td colspan="3">  </td></tr>
<tr><td colspan="3">Calcium</td></tr>
<tr><td>  </td><td colspan="2">  </td></tr>
<tr><td>Magnesium</td><td colspan="2">Sulphur</td></tr>
<tr><td colspan="3">Fig 1 : Macronutrient deficiency symptoms</td></tr>
</table>

Macro Nutrient Management

- Fertilizer should be applied during March to October to ensure greater absorption by the root.
- Well decomposed organic manure in slurry form enhances nutrient uptake by the plant.
- Adequate level of nitrogen is required for vegetative growth, flowering and fruit yield.
- One fourth of the recommended nitrogen and full dose of phosphorus and potassium should be applied soon after harvest to be stored and used early in the following season. Rest should be applied after bloom/fruit set in two /three equal splits at one month interval.
- Potassium also plays important role in determining yield, fruit size and quality. Post bloom foliar application of potassium nitrate (1.48-2.25 kg K_2O/acre) increases fruit size, yield and reduces fruit cracking.

- Triple super phosphate (TSP) or di-ammonium phosphate (DAP)are preferred source of P in calcareous soil but in highly calcareous soil under drip irrigation P may be applied in the form of single super phosphate (SSP) as basal band fertilization combined with soluble P as KH_2PO_4 with the irrigation water.

Table 2: Quantity of Different Fertilizers to be Applied Per Tree Depending on Age and Source

Age of Plant (Yrs)	FYM (Kg)	Nitrogen (g/tree)			Phosphorus (g/tree)					Potassium (g/tree)	
		N Req.	Source		P_2O_5 Req.	Source				K_2O Req.	Source
			Urea	CAN		TSP	SSP	DAP			MOP
			46% N	25% N		43% P	16% P	46% P	#18% N		60% K
1	10	250	540	1000	125	290	780	271	50	125	210
2	20	250	540	1000	125	290	780	271	50	125	210
3	30	500	1090	2000	125	290	780	271	50	125	210
4	40	500	1090	2000	125	290	780	271	50	250	420
5 & above		625	1360	2500	250	580	1560	544	100	250	420

Note: Doses are total requirement/year, should be reduced depending on available nutrients in the specific orchard soil in different regions.
Quantity to be to be subtracted from Urea/CAN dose if DAP is source of phosphorous.

- Before onset of monsoon fertilizers and manures should be applied in trenches made around the canopy line (Fig.2.a) but in other application fertilizers and manures should be put under the dripper (Fig. 2.b.) placed on canopy line.

(a) Trenches around canopy line

(b) Under drippers placed on canopy line

Fig. 2: Fertilization Application

Micronutrient management

Micronutrients assume significance in pomegranate production. Micronutrients have ability to:

- Improve quality, size, color, taste and earliness, thereby enhancing their market appeal.
- Improve input use efficiency of NPK fertilizers and water.
- Provide disease resistance, thereby reducing dependence on plant protection chemicals.
- Increase post-harvest/shelf life of produce and minimizing losses.
- Prevent physiological disorders and increase marketable yield.

Micronutrient can be managed by giving 3 foliar sprays during crop season. First spray each of ZnSO4 @ 0.3%, MnSO4 @ 0.6%, Boric Acid (17% B) @ 0.6% or Solubor (20% B) @ 0.5% should be given before flower and bud initiation i.e. 15-20 days after defoliation when new flush of leaves has come. The second and third spray of $ZnSo_4$ @ 0.3% and Mn So_4 0.6% should be given at 30 to 60 days after full bloom. The deficiency symptoms are given in Table 3 and Fig 3.

Table 3: Factors contributing to micronutrient deficiencies, deficiency symptoms and management strategies.

S. No.	Micronutrient	Factors contributing to deficiency	Deficiency Symptoms	Management Strategy
3	**Boron**	• Coarse texture soil Leaching • Dry soil condition	• Growth ceases at the growing point and poor development of roots. • Premature shedding of male flowers and impaired pollen tube development leading to poor fruit setting. • Cracking and distorted growth of fruit.	• Identify deficiency symptoms • If deficiency symptoms observed, spray solubor (20% B) or boric acid (17% B) @ 0.05-0.1% B during pre bloom period and followed by two post bloom application, one at 7-10 days after petal fall and other at 30 days after petal fall. • Never spray B during fruit maturity period to prevent fruits from abnormal ripening. • Apply annually borax (11%B) or Solubor or Granubor (15%B) @ 0.56-1.12 kg B per ha depending on deficiency of B in soil.

5	**Copper**	• High soil pH • High phosphate level • High soil organic matter content	• Abnormal and stunted leaf development • Stunted shoot growth with die back • Poor flowering and fruit setting • Production of small fruit with poor quality	• Identify deficiency symptoms • If deficiency observed, spray Cu @ 0.2% copper sulfate either alone or neutralized with fresh hydrated lime during post harvest period and /or during pre-bloom stage • Mixing of hydrated lime should be so regulated so as to maintain the pH at 7.0. • Apply copper-based fungicides according to the product directions for disease control.
2	**Iron**	• High soil pH • High phosphate level in soil • Poor soil drainage	• Leaf chlorosis on rapidly growing water sprouts	• Properly identify deficiency symptoms. • If deficiency symptoms observed, apply Fe chelates (Fe- EDDHA) through fertigation @ 3-5 mg /litre but it must be supplemented with repeated foliar sprays of Fe- chelates (Fe-DTPA) @ 0.3-0.5% during late summer-early dormant period. • Use various surfactants like detergent surf and humactants (0.2% $CaCl_2$) to enhance effectiveness of foliar spray. • Spraying of citric acid @ 2g /litre can also release Fe immobilized within the plant on high pH soil by changing apoplastic pH.

4	**Manganese**	• High soil pH • Highly leached soil • Presence of nitrifying organisms	• Appearance of light green mottle between the main veins. • A band of darker green left bordering the main veins while the inter-veinal chlorotic areas become pale green or dull yellowish in colour.	• Identify deficiency symptoms • If deficiency symptoms exist, spray manganese sulfate @ 0.40 to 0.60% depending on the severity of deficiency at 7-10 days after petal fall. • spraying of fungicide, mancozeb also supplement readily available Mn to tree
1	**Zinc**	• High soil pH • High phosphate level • High soil organic matter content	• Reduced leaf and shoot growth. • Reduction in flowering and fruit setting. • Production of small size fruit.	• If deficiency observed in standing crop, apply chelated zinc (EDTA-Zn) @ 2.5-7.5 g /plant through soil and later on through foliar sprays. • For foliar sprays use zinc sulphate @ 0.30 to 0.50% either alone or neutralized (adjusted pH to 6.5-7.0) with fresh hydrated lime during rest period as post-harvest application, but the most effective time for application is before bud opening. • Add silicon-based surfactant and diluted urea solution (0.02%) to increase spray effectiveness and to reduce leaf damage.

Copper

Iron

Manganese

Zinc

Fig. 3 : Micronutrient deficiency symptoms

D. Organic Manures: The use organic manures like farm yard manure, poultry manure, vermicompost are important for overall plant health for sustainable production. These decrease bulk density, improve soil porosity, water holding capacity, organic carbon and pH of the soil. Organic amendments also result in higher microbial population. It results in increased organic carbon and availability of all major and micronutrients. Vermin-compost is rich in macro and micronutrients, vital plant promoting substances, nitrogen fixers and humus forming microorganisms. Using organics, at least twice a year- once just after harvest and again at flower regulation should be practiced. At least one third nutrient requirement should be given through organics.

Fertilizer application schedule			
S. No.	**Days after Defoliation**	**Stage**	**Operation**
1.	0-7	Defoliation	• Defoliate with Ethrel **(**1.5-2ml/l**)** +DAP5g/l • Remove weeds and suckers • Apply 25-30 kg FYM of 15-20 kg FYM + 2 kg vermin-compost + 2kg neem-cake per plant + Phorate10G @ 25g/plant or Carbofuran 3G @ 40g/plant in wet soil in a ring around the plant • Give light irrigation immediately after manures application

2.	8-14	85-100 **%** leaf fall	• Remove fallen leaves and debris from the orchard and burn • Drench soil with bleaching powder **(**33**%** Cl**)** @ 25Kg/1000 liters/1 ha
3.	15-21	First flush of leaves	Irrigate
4.	22-28	Flower initiation	Foliar application of planofix @ 22**.**5 ml per 100 lit waters Foliar application of micronutrient mixture @ 1-2 kg ha^{-1}
5.	29-49	100**%** Flowering	
6.	50-63	Fruit set starts	Remove weeds Fertigate N**:** P**:** K**:** 00**:**52**:**34 Mono-Potassium Phosphate @ 12 kg/ha/application -Give 3 applications at 7 days**'** interval through irrigation Apply Gypsum @ 250 g /plant and $MgSO_4$ @ 125 g/plant followed by thorough mixing with the soil and watering Irrigate regularly
7.	64-70	Fruit setting	
8.	71-126	Fruit set 100**%** Fruit enlargement	Fertigate N**:** P**:** K**:** 00**:**52**:**34 Mono-Potassium Phosphate, urea and 0-0-50 @ 12, 19**.**25 and 26 kg/ha/application respectively -Give 6 applications at 7 days**'** interval through irrigation Foliar application of micronutrient mixture @ 1-2 kg ha^{-1} Two foliar application of gibberellic acid @ 50 ppm at 15 days**'** interval Drench soil with bleaching powder **(**33**%** Cl**)** @25Kg/1000 liters/1 ha in last week of Aug**.** or first week of Sep**.**
9.	127-140	Fruit enlargement +Aril colour development	Apply Gypsum @ 250 g /plant and $MgSO_4$ @ 125 g/plant followed by thorough mixing with the soil and watering Fertigate N**:** P**:** K**:** 00**:**52**:**34 Mono-Potassium Phosphate, urea and 0-0-50 @ 2**.**5, 21 and 20**.**5 kg/ha/application respectively -Give 8 applications at 7 days**'** interval through irrigation Three foliar application of 0-52-34 @ 10 g/lit and two foliar application of manganese sulphate @ 6 g/lit at 10 days**'** interval • Remove weeds and suckers
10.	141-184	Fruit enlargement &development	
11.	185-199	Fruit Maturity	

			• Irrigate
12.	200-214	Fruit Maturity 1 month before harvest	Fertigate N**:** P**:** K**:** 00**:**52**:**34 Mono-Potassium Phosphate, urea and 0-0-50 @ 6, 25 and 2 kg/ha/application respectively -Give 10 applications at 3 days' interval through irrigation Give moderate Irrigation Harvest mature fruits
13.	215-230	Fruit ripening	
Operations During Rest Period			
14.	**-**	Rest	Do heavy pruning to remove blight affected and old dry branches Drench soil with bleaching powder **(**33**%** Cl**)** @25Kg/1000 liters/1 ha Apply 20-25 kg FYM or 13-15 kg FYM + 2kg vermin-compost + 2 kg neem-cake per plant Apply 1/3rd dose of N and K_2O and half dose of P_2O_5 followed by light Irrigation
15.	**-**	Rest	Light Irrigation
16.	**-**	Stress	Stop Irrigation

Note:

1. Irrigate depending on soil type, plant age and stage and weather conditions
2. Apply nitrogen, phosphorus and potash depending on plant age as given in section on Nutrient management

Recent advances in management of diseases of pomegranate for export quality pomegranate production

Pomegranate is affected by large number of diseases, disorders and insect pests. Correct and early diagnosis is a key to successful management. Key symptoms of the diseases or disorders and management practices are described here. Step wise and crop stage wise 'Integrated Disease and Insect Pest Management Schedule (IDIPM)' has been given in Annexure 3 which can be used for any crop season, however, modifications in the present schedule will be placed on ICAR-NRCP website nrcpomegranate.icar.gov.in. The schedules have been made, taking into consideration, MRLs and PHI given in the Annexure 4.

A. Diseases

Bacterial Blight Disease (BBD)/Oily spot disease (*Xanthomonas axonopodis* pv. *punicae*)
Symptoms (Figure 1):

- The appearance of water-soaked spots on under surface of leaf which, later turn blackish brown irregular spots of different size, with a clear regular chlorotic/yellow halo against light confirms the bacterial blight infestation on leaves.
- Similar water soaked or brownish black spots also appear on Lemon sized fruits or bigger fruit cracks or split opens due to BLB infection.
- The bacterial ooze comes out after rains/spray/dew, which feels sticky to hands and after drying gives white shiny encrustation on the surface of blight lesion.
- On stems, water soaked grey/black lesions develop on nodes; these later develop into cankers of different size.
- Planting material made from bacterial blight affected orchards develops stem/nodal blight infection just above soil surface.
- Symptoms do not develop on flowers and roots. On roots blight symptoms may develop only on exposed roots under blight affected plant.

Bacterial blight symptoms on Leaves

Bacterial blight symptoms on fruits

Bacterial blight symptoms on stems and Nodal blight in planting material (right)

Figure 1: Various symptoms of pomegranate bacterial blight on different plant parts

Predisposing factors: Temperatures between 25 – 30^{o} C + RH above 50%, rain, wind, application of higher nitrogen doses than recommended, micronutrient deficiencies and too many unwanted sprays favour rapid bacterial blight development.

Management: Orchards where blight has been detected or present in severe proportions or orchards which are disease free but in neighbour of blight affected orchard should follow the

schedule strictly (Annexure 3). Six easy and economical steps described below have been found very effective in controlling bacterial blight. Apart from those different strategies have been described below:

Six easy and economical steps to manage bacterial blight: Any bacterial disease in plants can be managed effectively only through bacterial blight resistant variety and no chemical gives complete/absolute control. In the absence of blight resistant variety in pomegranate and constraints in breeding due to tight linkage of genes for big size fruits with its susceptibility to bacterial blight, integrated management is being recommended which includes, planting new orchards with bacterial blight free planting material, balanced plant nutrition with sufficient organics and beneficial organisms, avoiding rainy season crop if disease is observed, orchard sanitation, avoiding too many/unwanted sprays and chemical sprays at 7 - 10 days interval depending on season. Several farmers have benefitted using the IDIPM schedules and ICAR-NRCP Advisories. The 'Six Step' schedule to manage Bacterial Blight Disease (BBD) is for the farmers taking ***mrig bahar*** and **late *mrig bahar*** crop of pomegranate and facing loses due to BBD. It needs to be taken in community approach, wherein all the orchards in a locality having bacterial blight should follow the schedule simultaneously. If followed properly and by all farmers in community the pathogen will be eradicated and farmers can take the rainy season crop successfully. The major steps are given below.

I. **Main Pruning:** Soon after harvesting of fruits in the end of December to middle of February, main pruning should be done, removing crowded branches, damaged and dry branches so that proper light penetration and aeration is there. Secondary and tertiary branches with BBD cankers should be cut 2 - 4 inches below the cankers and cut end should be pasted with 10 % Bordeaux paste. Cankers on main stem should be pasted with Bordeaux paste. Also apply 10 % Bordeaux paste on stem up to 1.5 - 2 feet from ground. All BBD affected stems and fruits should be destroyed or buried in soil for decomposition.

II. **Rest period fertilizer dose and disease/insect pest protection**: Apply rest period dose of fertilizer according to the age of the plant. For plants of 2 years and above apply:

   a) 20 kg of well decomposed farm yard manure **or** 15 kg of manure + 2 kg of Vermicompost + 1 - 2 kg of neem cake per plant **or** well decomposed poultry manure 7 kg + 2 kg of neem cake per plant.

   b) Nitrogen 205 grams (446 grams neem coated urea) + Phosphorus 50 grams (315 grams single super phosphate) + Potash 152 grams (254 g Murate of potash or 304 g sulphate

of potash) per plant.

c) After 20 - 30 days of chemical fertilizer application, apply any or combination of promising bioformulations along with manure. Bioformulations like *Aspergillus niger* AN 27 (renamed IRAG07), Mycorrhiza (*Rhizophagus irregularis*/*Glomus irregularis*) and *penicillium pinophilum* @ 1 kg/acre. (Use of *Trichoderma viride* or *T. harzianum* or *Pseudomonas fluorocence* or *paecilomyces lilacinus* @ 1 kg/acre is optional) Each bioagent (except Mycorrhiza) should be multiplied separately under shade. Mix 1 kg of bioformulations with 1 ton of well decomposed manure. Prepare 1 feet high bed for each formulation using well decomposed manure, mix bioformulation, maintain 50 – 60 % moisture in these beds, cover it with gunny bags to maintain humidity and rake/mix the soil every 2 - 3 days. Incubate for 10 - 15 days and apply @ 1 kg of bioformulation/acre of plants along with other manures. At the time of application, also mix Mycorrhiza in this enriched compost. Application of these bio agents twice a year (once during the rest period and second at crop/bahar regulation) in the soil helps in improving nutrient uptake, plant growth and biochemical resistance to diseases, also checks pomegranate wilt and nematode infestation.

   (a) After fertilizer application, start light (15-20 litres) irrigation twice (light soil) or once (heavy soil) in every 7 - 8 days. Keep the pomegranate orchard in the rest period for 2 to 4 months. The irrigation should be just enough for nutrient uptake in soil and increase storage in the plant.

   (b) **Pesticide sprays** should be carried out at 15 days interval. (i) Copper oxychloride 50 % WP @ 3 g/L or Copper hydroxide @ 2 g/L or 1 % Bordeaux mixture (freshly prepared) will check both bacterial and fungal diseases. Still if any fungal disease is observed then one or two sprays of mancozeb or any other fungicide can be taken. For any specific disease, chemicals from the adhoc list may be used (ii) Insecticide sprays may be taken as per need depending on pest observed. Azadirachtin 1 % (10000 ppm) @ 3 ml/L once a month may be taken as preventive insecticide. If foliar pest infestation observed is high, then only take spray with any of the following- Lambda cyhalothrin 5 % EC @ 0.5 - 0.75 ml/L or Indoxacarb 14.5 % SC @ 0.75 ml/L or Cyantraniliprole @ 0.75 ml/L or Thiamethoxam 25 % WG @ 0.5 g/L. If shot hole borer pests are observed drench with Thiamethoxam 25 % WG @ 10 g/10 L water.

(c) Farmers facing wilt and nematode problem may follow Wilt advisory on NRCP website.

III. **Put crop on stress during hottest months for natural defoliation:** Stop the irrigation from mid/end March to put crop on stress till 100 % natural defoliation occurs. After complete defoliation, remove the blight cankers visible on the branches by cutting the branch 2 - 4 inches below the canker using secateurs and burn it outside the orchard.

IV. **Expose defoliated stems to solar radiation:** Expose defoliated naked stems to solar radiation for 15 - 20 days before crop initiation to kill bacteria in the nodes **(**this is the latest modification and key step to eradicate the bacteria blight pathogen). Monitor this period critically. As soon as 1 - 2 cm tip drying of branch/stems is observed, first irrigation is to be given and farmer should not wait for 20 days.

V. **Light pruning and fertilizer application:** Go for light pruning of top 8 - 10 inches of branches. Remove the cankers if any as mentioned above. Go for pasting with 10 % Bordeaux paste as detailed in step I.

VI. **Follow crop season fertilizer and IDIPM spray schedule:** Applying crop season fertilizer dose and irrigation.

a. During crop season apply humic acid and sulphur 80 % @ 20 - 30 g per plant depending on soil pH (if soil pH is above 8 use 30 g per plant) along with recommended fertilizer applications.

b. After 20 - 30 days of chemical fertilizer application, apply bioformulations *Aspergillus niger* AN 27 (renamed IRAG07), Mycorrhiza (*Rhizophagus irregularis*/*Glomus irregularis*) and *Penicillium pinophilum* @ 1 kg/acre. Use of *Trichoderma viride* or *T. harzianum* or *Pseudomonas fluorocence* @ 1 kg/acre is optional). Apply these bioformulations after multiplying in manure as described above in para II.c.

c. Give 4 sprays of micronutrient mixture @ 2 g/L and salicylic acid @ 300 ppm (30 g in 100 litre) at 1 month interval starting pre-flowering stage.

d. Take sprays of recommended fungicides and insecticides @ 7 - 10 days interval as per plot requirement for quality production.

e. If the field is infested with Root-knot nematode, go for soil drenching with fluopyrum 38.48 % SC @ 2 ml/ 2 L/plant or Fluensulfone 2 % Gr @ 10 gram/dripper (Maximum dose should not exceed 40 gram/plant) at crop initiation.

f. Harvest fruits when mature and ripe.

g. All blight affected orchards in the community should follow the same schedule for promising results.

Pictorial Six Steps in the management bacterial blight of pomegranate:


Step I - Main Pruning: After harvesting of fruits from December to February, main pruning should be done removing the secondary and tertiary branches with BBD cankers. All BBD affected stems and fruits should be destroyed or buried in soil for decomposition.


Step II – Rest period: After the main pruning is done, recommended dose of rest period fertilizers should be applied and sprays for disease/insect pest protection should be taken at regular intervals.


Step III – Stress induction: Stop the irrigation from mid/end March to put crop on stress till 100% natural defoliation occurs. Remove the BBD cankers visible (if any) on naked branches.


Step IV - Expose defoliated stems to solar radiation: Expose defoliated naked stems to solar radiation for 15-20 days before crop initiation to kill bacteria in the nodes. Monitor this period critically. As soon as 1-2 cm tip drying of stems is observed, first irrigation is to be given and farmer should not wait for 20 days.


Step V- Light pruning and fertilizer application: Light pruning of top 8-10 inches of branches should be done removing the cankers if any as mentioned above. Go for pasting with 10% Bordeaux paste as detailed in step I.


Step VI - IDIPM spray schedule: follow IDIPM schedule recommended by ICAR-NRCP for good pomegranate harvest.

(b) Integrated Management:

- Avoid *mrig bahar* (rainy season) crop and shift to *hasta bahar* crop for at least 2 - 3 years
- Give balanced plant nutrition:
- Add humic acid and sulphur 80 % @ 10 - 30 g/plant depending on p^H, for reducing soil pH. Apply FYM (30 - 40 Kg/plant), vermicompost (2 - 3 Kg/plant), poultry manure (0.5 -1.0 kg/plant) and neem cake (3 Kg/plant).
- Give 2 soil applications of bioformulations (*Aspergillus niger* AN 27) @ 1 kg/acre and Mycorrhiza [*Rhizophagus irregularis* Syn. *Glomus irregularis* @ 1 Kg/acre), once at flower regulation and second soon after harvest.
- Give recommended potash and phosphorous doses during rest and crop regulation period. Apply nitrogen in split doses after lemon size fruit stage.
- Give 4 sprays each of micronutrient mixture @ 2 g/L (must have zinc sulphate and Manganese sulphate) and salicylic acid @ 300 ppm (30 g in 100 litre) at 1 month interval starting at pre-flowering stage.

i. Follow all sanitation measures:

- Remove fallen plant debris and put them in a pit and cover with FYM and soil for decomposing/burn - do not dump them in or near orchards nor throw them in irrigation channels.
- Wet upper 0.5 - 1.0-inch soil on ground below the canopy with solution of bleaching powder (a.i. 33% Chlorine) @ 25 Kg/1000 liters water/ha every 3-4 months especially after pruning.
- Disinfect pruning tools – secateurs *etc.* after handling each plant with sodium hypochlorite (2.5 %) or any other disinfectant and keep orchard free from weeds.

iv. Practice proper pruning and training:

- If stem infections are severe, practice heavy pruning immediately after harvest and remove all stems with blight infection. Prune about 2 - 3 inch below the infected area.
- Apply Bordeaux paste (10 %) to the cut ends after pruning. Oil based pastes [COC paint made by mixing 500 g COC + 1 L linseed oil are preferred for pasting during rainy seasons or mix oil @ 50 ml/L paste.

v. **Take recommended sprays**

- **During crop season** spray Bordeaux mixture (0.5 % except 1 % just after pruning), altered with Streptocycline (Streptomycin sulphate 90 % + Tetracycline hydrochloride 10 %) @ 0.5 g/L or 2-bromo, 2-nitro propane-1, 3-diol (Bronopol 95%) @ 0.5 g/L mixed with copper-based formulations like copper oxychloride or copper hydroxide 53.8 % @ 2 – 2.5 g/L. Depending on fungal problems present in the orchard, copper-based formulations may be replaced with appropriate fungicides.
- Sprays may be taken **at 7-10 days interval depending on season and crop stage**. Apart from recommended sprays during crop season, **prophylactic sprays** should be taken after harvest during rest period and also after planting a new orchard till fruiting is taken. Spray with Bordeaux mixture (1 %) altered with Bronopol @ 0.5 g/L mixed with copper-based formulations like copper oxychloride or copper hydroxide @ 2 -2.5 g/L at 15 - 20 days interval depending on disease present in the orchard/neighbouring orchards and weather conditions**.** If orchards in rest period and have leaf blight infection, one spray of Streptocycline @ 0.5 g/L may be taken in alteration with Bordeaux mixture and Bronopol. **If it is a bacterial blight free area then sprays of streptocycline or bronopol are not required**.
    - **Emergency sprays**:
        - 1 - 2 sprays at 4 days interval soon after 5 – 10 % blight infection observed on fruits restricts further blight spread.
        - Streptocycline @ 0.5 g/L + 2-bromo-nitropropane-1, 3-diol (Bronopol 95%) @ 0.5 g/L + Copper hydroxide 53.8 % WP @ 2.0 g/L + spreader sticker @ 0.5 ml/L solution.
        - Streptocycline @ 0.5 g/L + 2-bromo-nitropropane-1, 3-diol (Bronopol 95%) @ 0.5 g/L + Carbendazim 50 % WP @ 1.0 g/L + spreader sticker @ 0.5 ml/L solution.

vi. All precautions should be strictly followed for getting good results.

- New orchards should be planted with disease free planting material and first bearing should be taken after at least, two preferably three years. Note that planting material made from bacterial blight affected orchard carries latent infection. The blight bacteria remain safe in the nodes and injuries on stem. These bacteria activate under favourable conditions

to cause stem/nodal blight infection just above soil surface from where infection spreads on foliage and then to other plants.

- Provide balanced nutrition including organic manures, biofertilizers, inorganic fertilizers and micronutrients to plants, follow rest period of 3 - 4 months and take only 1 crop in a year to improve plant vigour and resistance.
- Take only need based sprays at recommended doses, too many sprays increase the disease.
- Before starting any spray, remove and burn affected fruits or put them for decomposing in a pit. Insecticides, fungicides or micronutrient sprays required, should be combined with bactericidal sprays depending on compatibility to reduce number of sprays.
- During crop period soon after the rains - when plant surfaces dry up - additional spray with a bactericide should be taken without fail.
- Always (rains or no rains) mix good quality non-ionic spreader sticker with sprays except with Bordeaux mixture.
- Bordeaux mixture should always be prepared fresh and used on the same day.

1. Wilt

Symptoms

- Plants with yellowing/drooping/drying of leaves/nutrient deficiency type symptoms in some of the branches or entire plant.
- Observe the roots and split open the roots and lower portion of the stems, if you observe
- The brown/grey/black discolouration of wood is observed on the roots of wilted plant, this type of symptoms results from infection of *Ceratocystis fimbriata* fungi (Figure 2). It is the most prevalent fungus associated with pomegranate wilt in India. In early stages of infection, inner root shows yellow wood with alcoholic smell. Plants dye one after the other over a period in a row or vicinity generally is due to spread of *C. fimbriata* through water, intercultural operations like weeding, fertilizer application, farm implements or by farm animals like poultry birds.

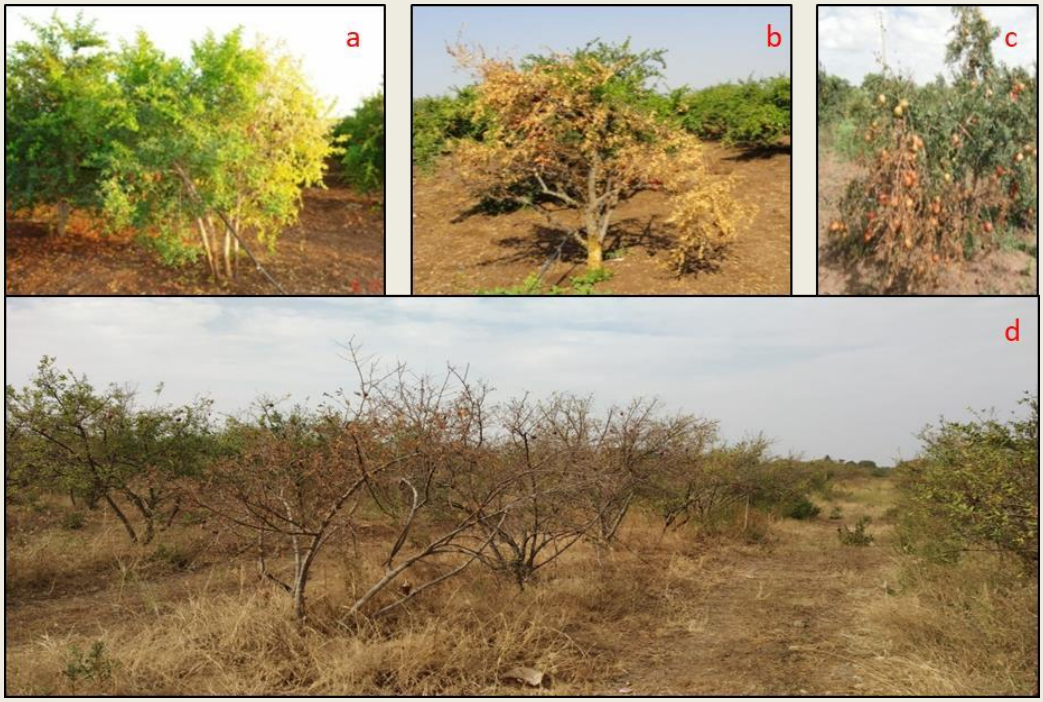

Figure 2: Wilted plants due to *Ceratocystis fimbriata* fungus. a) Initial yellowing of leaves. b & c) drying of one branch as disease progress d) wilting of plants in line.

- Fungi species like *Sclerotium* or *Macrophomina* cause grey/black root rot and generally observed where moisture is high around root zone.
- Collar rot/canker on stem at soil level (can also spread below and above soil level); caused due to infestation of *Phytophthora nicotianae* var. *nicotianae* or *Rhizoctonia* sp. symptoms can also extend up to the root causing root rot (Figure 3).

Figure 3: Root rot and collar rot by a) *Sclerotium* b) *Rhizoctonia* c) *Macrophomina* d) *Phytopthora* fungi.

- White wash /mesh like fungal growth on the root surface is due to *Rhizoctonia* sp. This is generally observed when beds are raised after plants grow and soil is heaped around the stem.

- In case the xylem/centre pith is brown/red in colour, these symptoms can be attributed to another fungi *i.e.*, *Fusarium* sp. Though, it is not a major cause of wilt in many pomegranate areas.
- Presence of pin holes on inner wood/outer surface, are due to shot hole borer. These shot hole borers generally attack weak plants and are also attracted to metabolites produced by *Ceratocystis fimbriata* (Figure 4).

Figure 4: Symptoms due to minor wilt pathogens e) *Fusarium* wilt f) & g) Pin/Shot hole borer

- Knots/galls on the pomegranate roots confirm the infestation of root-knot nematode.
- **Survival and Spread:**

- Wilt fungus *C. fimbriata* can survive in the soil and in infested plant debris for several years (5 - 7 yrs). Wilt caused by root-knot nematode is reported from all type of soils but more severe in sandy loam soil with more aeration.
- Majority of wilt pathogen including fungus and nematodes spreads through infected planting material to new areas while intercultural operations like weeding, manure application, farm machinery and pruning tools, root grafts, flooding/runoff irrigation water and insects like shot hole borer can spread the pathogens within and nearby orchards.

Management:

1. The planting material i.e. sapling and the potting mixture in which sapling is planted should be free from wilt pathogens like fungi, nematodes and insects. Use of solarized/ sterilized soil (potting mixture) for saplings eliminates almost all soil borne pathogens. Planting samplings on raised beds increases aeration and reduce wilt incidence in the pomegranate orchards.

2. Soil solarization for 6 weeks in the hottest month (April - May) using 50 - 75 LLDPE (Linear Low Density Polyethylene) sheet kills the soil borne pathogen. Prepare the plot selected for planting, irrigate it and cover with the LLDPE sheet for better results (Figure 5).

Figure 5: Soil solarization before planting using LLDPE sheet during hottest summer months

3. Apply promising bioformulations such as *Aspergillus niger* AN27 (IRG 07) and Mycorrhiza [*Rhizophagus irregularis* Syn. *Glomus irregularis*], @ 1 kg/acre and *Trichoderma harzianum* or *T. viride* or *Pseudomonas* spp.or *Paecilomyces* spp. etc., right from planting, every 6 months. These serve as best preventive measure for all types of wilt pathogens.
4. Grow green manure crops like dhaincha (*Sesbania aculeata*) and sunhemp (*Crotalaria juncea*) during rainy season and incorporate in soil before flowering.
5. Apply boron depending on soil test value.
6. On observing first symptoms of wilt first ascertain the cause/s. If it is due to **fungal pathogens *Ceratocystis, Fusarium***, etc. in the orchard treat soil with only one of the following most promising protocols:
   a) 1st drenching with Propiconazole 25 EC @ 2 ml/L + Chlorpyriphos 20 EC @ 2 ml/L. After 30 days of first application; 2nd drenching with A*spergillus niger* AN 27 (IRG 07) @ 5 g/plant with 2 Kg FYM/plant followed by 3rd drenching of Mycorrhiza [*Rhizophagus irregularis* Syn. *Glomus irregularis*] @ 25 g/plant with 2 Kg FYM/plant 30 days after 2nd drenching.

or

b) Three drenchings at 20 days interval with Propiconazole 25 EC @ 2 ml/L + Chlorpyriphos 20 EC @ 2 ml/L. Use 5 - 10 L solution/plant.

or

c) 1st and 3rd drenching with Fosetyl Al 80 % WP @ 6 g/plant, 2nd and 4th drenching with Tebuconazole 25.9 % w/w EC @ 3 ml/plant. Make solution volume 10 L with water for each drenching.

d) Drenching with Metalaxyl 8 % + Mancozeb 64 % @ 2 - 2.5 g/L will be beneficial if *Phytophthora* is causing any loss.

7. To avoid residues in fruits drenching should be done immediately after harvest in rest period. Irrigate the plants well, one day before treatment. After chemical drenching irrigation should be stopped for 2 days.
8. For controlling **shot hole borer** (*Xyleborus* spp.) which is associated with wilt disease, 10 litres preparation (paste) containing red soil (4 kg) + Chlorpyriphos 20 EC (20 ml) + Copper oxychloride 50 WP (25 g) needs to be applied on stem surface from plant base up to 2 ft. from second year onwards. Pasting should be done twice a year; once soon after the harvest and once at defoliation, before crop regulation. Shot hole borer attacks weak plants, hence keep plant vigour through recommended nutrition and proper irrigation during as well as after crop period. Prune out affected branches and do no dump in or near orchard.
9. Once the wilt disease is detected in the orchard, dig the 3 - 4 feet long trench between healthy and diseased/wilted plant. The partial wilt affected plants showing initial symptoms should be immediately treated with suitable agrochemicals. The plants showing more than 25 % dry branches or completely dead plant should be removed and brunt and should not be kept dumped as woodpile. While removing wilted plant from the orchard, due care should be taken not to spread the infected root samples and soil to nearby plants.
10. Soil solarization or formalin should be used to disinfect such pits after removing the diseased (wilt affected) plants. For this, 1 foot deep and 2X2 feet pit should be made at the place where trunk has been removed. Formaldehyde solution (37 – 41 % formalin) half a liter of the solution is required for 10 liter of water per pit. The solution should be made at the site of pit and poured immediately. Before starting, one should cover whole

body, use mask, gloves and eye protection as formalin is poisonous to humans. After adding the formalin into the water, quickly pour it in the pit and cover it with plastic and soil so that vapor generated from the solution should not escape in the atmosphere. Keep the pit coved for 1 week. After 1 week, remove the plastic cover and rake the soil for next 10 - 15 days, till the smell for formalin is completely gone. The pit can be used for planting new sapling (Figure 6).

11. As soon as the initial symptoms of the wilt visible in the orchard, drenching should be taken in the root areas around the main trunk and 2-3 plants in all four sides using recommended agrochemicals.

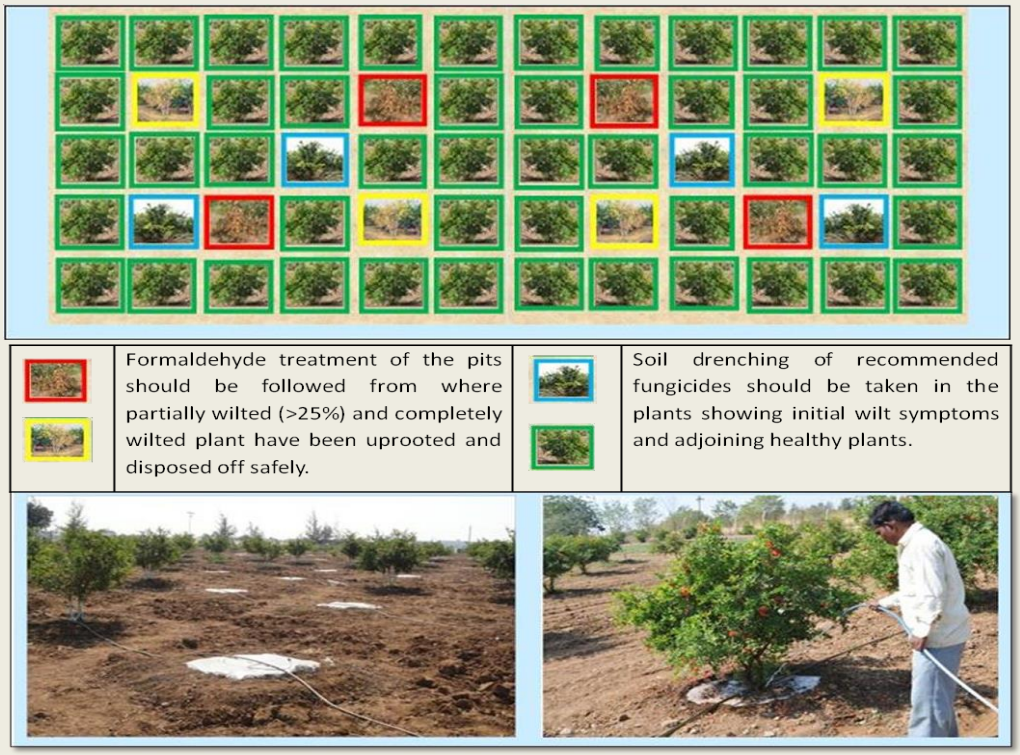

Figure 6: Soil treatment of wilt affected plot.

12. Pruning tools should be disinfected after each use; plants cut ends painted with 10 % Bordeaux paste. *Azadirachta indica* (neem) oil may be added @ 50 ml/L in the paint during rainy season. Pruning should be avoided during monsoons/rainy days. Affected plants within the buffer zone should be treated with a systemic fungicide; neighboring asymptomatic apparently healthy plants should also be treated with appropriate systemic

fungicides. Plants with more than 25% canopy loss should preferably be uprooted and burnt for better wilt management.

2. **Fungal Spots and Rots**

Symptoms

The fungal pathogens cause leaf and fruit spots and rots. The major fungal diseases are discussed here.

***Cercospora* spots:** *Cercospora punicae* spots on leaves are reddish brown 1 - 4 mm with no or inconspicuous diffused halo sometimes. Dark brown/black, discrete or coalesced, round to angular spots of various sizes surrounded with diffused yellow halo on coloured varieties (Figure 7). The spots are without cracks and have no stickiness; this distinguishes it from bacterial blight. Temperatures of 20 - 30°C and humidity above 60% for long duration's favours rapid disease development.

Figure 7: Symptoms of *Cercospora* spots on leaves (left and on fruits (right)

Fruit Scab: Fruit Scab is caused by fungus *Elsinoe* (*Sphaceloma*) *punicae*. Rough raised brown spots of various sizes give russet appearance to fruit skin. Flowers and fruits when affected are distorted (Figure 8). Temperatures of 22 - 28°C, humidity around 45 - 65% with rain and wind favours disease development.

Figure 8: Scab symptoms on pomegranate fruits

Anthracnose (on Fruit): Hard dark black to brownish black spots of no proper shape or size, cover fruit surface to varying extent. *Colletotrichum* sp. is associated with these symptoms (Figure 9).

Figure 9: Symptoms of anthracnose on fruits caused by *Colletotrichum*

Colletotrichum* rot**: The disease is caused by ***Colletotrichum gloeosporioides. Mostly fruits start discolouration from calyx end sometimes round-irregular spots are also observed on fruit surface. The discoloured area becomes reddish brown to black and is hard dry. The infected area covers half to full fruit within a week under favourable conditions. The rot extends beyond rind into the arils which disintegrate and are dark grey/brown black colour but not watery. Temperatures of 25 - 30°C and high humidity favour disease development **(Figure 10).**

Figure 10: Pomegranate fruit rot caused by *Colletotrichum*

Alternaria heart rot: The heart rot is caused by *Alternaria alternata*. Infection takes place at flowering and develops later. Temperature range of 25 - 30°C favour heart rot development. There are no external signs of heart rot, however, due to disintegration of arils the fruits may appear softer on application of slight pressure and in later stages become light weight. Rot is revealed only when the fruit is opened. The arils inside the fruit turn brown-black. Greyish black fungal growth/sporulation may be observed in rotten fruits on the rotten arils (Figure 11a). The rind is generally not attacked. Slight rind discolouration may be seen in severe cases or when secondary rot fungi are associated.

Aspergillus rot: The pathogen results in brownish soft rots, with a depressed centre in later stages blackish sporulation of the fungus can be seen inside and sometimes on surface. The affected skin surface turns light coloured at later stage. The fungus generally may grow inside without any external symptoms for some time. The rind and underlying pulp become soft, but fruits retain their shape unless externally damaged (Figure 11b).

Penicillium rot: This pathogen generally starts on the wounds and produces light tan-coloured mushy soft rots, with bluish green mould growth in later stages (Figure 11c).

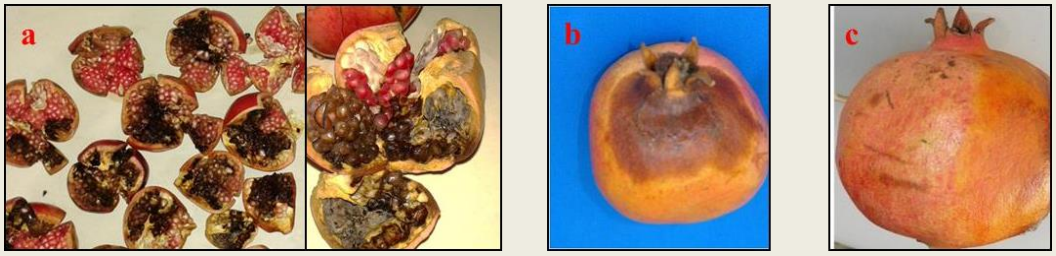

Figure 11: Symptoms of fruit rots on pomegranate fruits. (a) *Alternaria* Heart rot; (b) *Aspergillus* fruit rot and (c) *Penicillium* fruit rot.

***Phomopsis* rot:** Dark blackish brown dry hard rot with distinct sharp edge, generally starting from calyx end and spreading towards stem end of fruit. When flowers and young fruits are affected, they drop. On bigger fruits yellowish brown to black spots appear all over the fruit.

Some other rots like Rhizopus spp. produce irregular brown watery rot with rapid tissue disintegration. Water may ooze out from infected fruits. *Sclerotium* rots appear on any surface generally from injury, are brownish to dark brown are soft watery and white fungal growth on surface at latter stages. Entire fruit rots in short time under ambient temperatures. In general, most of the rots can be identified after fungal sporulation.

***Phytophthora* blight/rot:** The pathogen *Phytophthora spp.* affects seedlings, foliage as well as fruits particularly during warm rainy season, when humidity is high and temperatures between 25 -30°C. The affected seedlings show damping off and wilt symptoms, whereas, leaves and young twigs give typical blighted appearance. The fungus also attacks flowers and fruits at all stages and also causes fruit rot (Figure 12). Light brown tan colour mushy rot later turning darker, which is neither hard nor very soft, generally appears first in fruits near ground level and spreads rapidly with white sporulation in humid conditions. The fungus survives in soil as thick walled chlamydospores for long periods.

Figure 12: *Phytophthora* blight (Left); *Phytophthora* fruit rot (right)

Management:

- In orchards, where fungal spots, rots or *Phytophthora* blight make yearly appearance and adversely affect fruit quality or marketable yield, change flower regulation time from rainy to winter season.
- Maintain orchard sanitation by removing plant debris, pruning of dead dry branches, wetting upper 0.5 - 1.0 inch of ground after rains and pruning, with 2.5% bleaching powder (33.3 % Cl) @ 25 Kg/1000 litre water/ha and sterilization of pruning tools with 2.5% sodium hydroxide.
- Most of the fungal spot and rot fungi are present on plant surfaces in latent form, on getting suitable conditions they cause infection, hence preventive sprays with suitable chemicals at recommended doses, starting from flowering at 7 - 14 days interval depending up on season and nature (systemic/non systemic) of fungicides give good control.
- During rest period, Bordeaux mixture (1%) alternated with copper or other economical fungicides at 15 days period helps reduce the inoculum load of pathogens for next crop season.
- Leaf and fruit spots as well as rots caused by different fungal pathogens are effectively managed by the sprays of Mandipropamid 23.4 % SC @ 1 ml/L or Propiconazole 25 % EC @ 1 ml/L + Azoxystrobin 23 % SC @ 1 ml/L or Azoxystrobin 20 % + Difenoconazole 12.5 % SC @ 2 ml/L or Chlorothalonil 50 % WP + Metalazxyl M 3.75 % @ 2 ml/L or Bordeaux mixture @ 0.5 % or Copper Oxychloride 45 % + Kasugamycin 5 % WP @ 2.5 g/ L or Zineb 68 % + Hexaconazole 4 % WP @ 2.5g/ L or Tricyclazole 18 % + Mancozeb 62 % WP @ 2.5 g/ L or Chlorothalonil 75 % WP @ 2 g/L or Propiconazole 25 % EC @ 1 ml/L
- Combination treatments of Carbendazim (0.1 %) + Mancozeb (0.2 %) and Benomyl (0.1 %) + Mancozeb (0.2 %) also improve fruit quality and yield. Anthracnose and calyx end rot of pomegranate caused by *C. gloeosporioides* can be effectively checked with combi sprays of Tricyclazole 18 % + Mancozeb 62 % WP @ 2.5 g/L. The combi products with one systemic and one contact fungicide effectively arrest further spread of disease during favourable weather conditions. For *Phytophthora* rot, take sprays of Metalaxyl 8 % + Mancozeb 64 % WP @ 2.5 g/L followed by a spray of fosetyl-Al 80 % WP @ 2.0 g/L or Cymoxanil 8 % + Mancozeb 64 % @ 2 g/ L.
- In case of high incidence and favorable weather, take 2 - 3 combination sprays at 7 - 10 days interval depending on weather conditions.

Chapter 12

Integrated nematode management in pomegranate

Pomegranate is facing a multitude of biotic stresses and wilt complex is the most important biotic stress faced by the pomegranate grower after bacterial blight. Wilt disease has been reported from Maharashtra, Karnataka, Andhra Pradesh, Gujarat, Rajasthan and Tamil Nadu (Jadhav and Sharma, 2009). Several pathogens are reported to be associated with pomegranate wilt disease; the fungus *Ceratocystis fimbriata* and root knot nematode, *Meloidogyne incognita* are identified as the major causal organisms for wilt disease of pomegranate. Along with the root knot nematode, other plant parasitic species like *Rotylenchulus*, *Aphelenchus* and *Helicotylenchus* were also reported from pomegranate orchards.

Symptoms of root knot nematode infestation:

*M***.** incognita is a polyphagous parasite and has very broad host range i.e more than 3000 hosts which includes cultivated plants and weeds**.** General nematode infested plant shows symptoms of nutrient deficiency, yellowing of leaves and stunted growth. It is also observed that sometimes luxuriantly growing plants show reduced or no flowering for long periods (more than 1 year) due to heavy infestation of root knot nematode, *Meloidogyne incognita* (Figure 1). With increase in the population of nematode due to rapid reproduction rate, feeder roots are damaged resulting in less nutrient uptake from the soil. This root damage causes losses in terms of quality (small sized fruits) and quantity (less number of fruits per plant). The knots/galls on the pomegranate roots confirm the infestation of root-knot nematode (Figure 2). Root damage also helps in invasion of pathogenic fungi like *Ceratocystis fimbriata* and *Fusarium oxysporium* which causes wilt of pomegranate. Root-knot nematode is the second major cause of wilt disease in pomegranate after *C. fimbriata*.

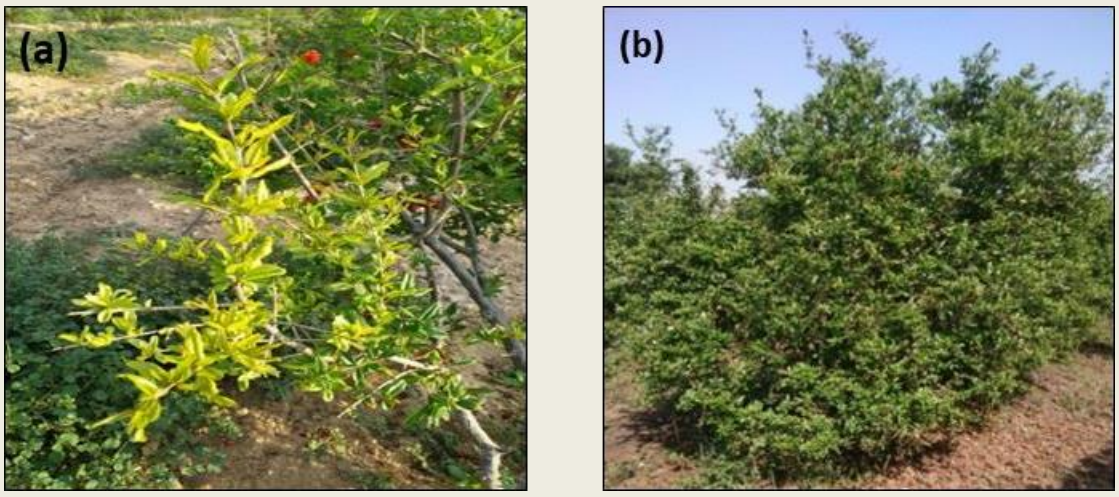

Figure 1: General symptoms of Root-knot nematode on Pomegranate a) Pomegranate plant showing the symptoms of nutrient deficiency. b) Fully grown plants without flowers.

Figure 2: Root-knot nematode symptoms on the pomegranate roots. (a-c) heavily infested pomegranate roots with galls on old and new roots. (d) New galls on young pomegranate roots (adjacent to drippers) on plants in the field and (e) Roots of planting material with heavy nematode infestation.

Wilt Complex: Root knot nematode, *Meloidogyne* spp. along with the fungus *Ceratocystis fimbriata* forms the wilt disease complex. In the orchards having wilt disease, the symptoms start with yellowing of leaves followed by gradual wilting one or more branches culminates into death infected plants (Figure 3). Surveys conducted by NRCP in recent years have shown heavy losses ranging from 20 to 80 percent due to wilting and death of plants. About 85% of the total wilt infected orchards surveyed, have both root knot nematode and fungi *C. fimbriata* together. It is also observed that nematode infestation increases the severity of wilt disease by providing easy sites for fungal infection as well as reducing the plants innate immunity. Few farmers facing the wilt problem uprooted their orchards in a span of 3-4 years and shifted to other crops. In 2020, farmers from Maharashtra and Karnataka have reported spread of wilt disease in their orchards due to consistent rains during the crop season.

Life cycle of root-knot nematode, *Meloidogyne incognita*

The life cycle of root knot nematode consists of 6 life stages (Egg, 4 juvenile stages and adult stage). Within the egg, nematode juvenile undergoes 1st moulting and hatches as second stage juveniles (J2s) from eggs. These eggs hatch freely in presence of moisture and the J2s search roots of their host for the penetration. These J2s penetrate just behind the root cap, moves towards

the vascular cylinder and select the cell near to vascular cylinder for feeding. Once the feeding starts, nematode lose its mobility becomes sedentary. The 3rd (J3) and 4th (J4) stages on root knot nematode does not feed and moults in quick succession leading to development of pear-shaped white adult female. The *M. incognita* reproduces by parthenogenesis. Males are vermiform and not required for reproduction. The females after maturity secrete gelatinous matrix and lays about 200-400 eggs inside the gelatinous matrix. Under the optimum temperature condition (27-30˚C), the nematode can complete its life cycle (egg to egg) in 3 to 5 weeks' time (Figure 4). Due to perennial nature of crop, the nematode can complete several (10-14) generation in a year leading to rapid population build-up.

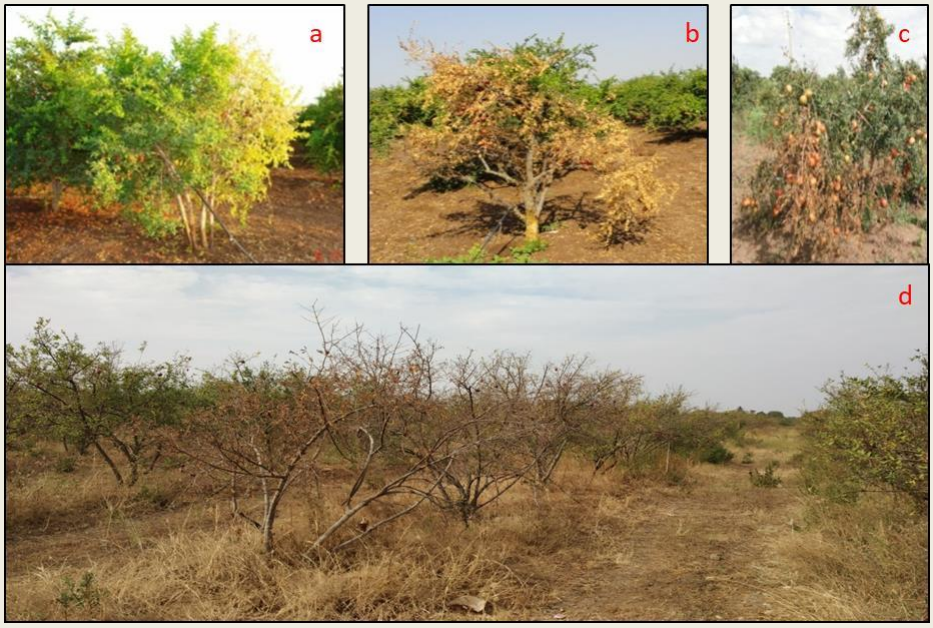

Figure 3: Symptoms of wilt disease in pomegranate associated with the *Ceratocystis fimbriata* (major cause) and root-knot nematode, *Meloidogyne incognita* infestation. a) Initial yellowing of leaves. b & C) drying of one branch as disease progress d) wilting of plants in line.

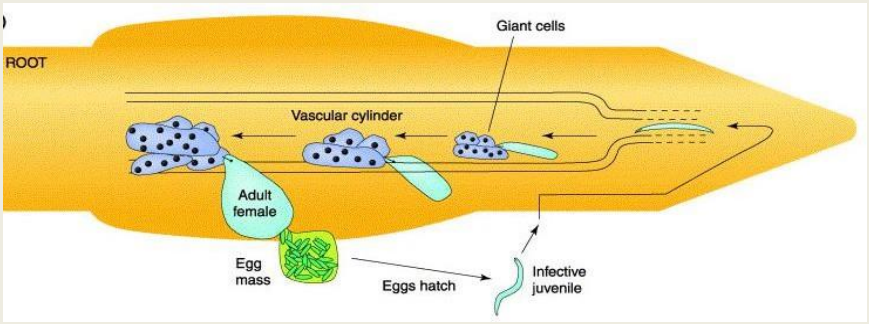

Figure 4: The life cycle of root-knot nematode, *M. incognita* (illustrated from Williamson and Gleason, 2003).

Survival and spread:

- The root knot nematode is very susceptible to heat and water stress and die quickly under harsh conditions in the absence of host. When inside the roots of the host plant, it is well protected from outside weather vagaries as well as from antagonistic/ bio control organisms. It can survive and multiply and infect the same/ new roots of the same plant or nearby plant roots by passive movement mainly though water.
- Infected planting material is the major and primary source of spread of root-knot nematode in new localities even to other states. States like Gujarat and Rajasthan where pomegranate is new crop; nematode problem became severe due to planting of infected saplings material from other places.
- The intercultural operations like manure application, farm machinery, flooding/runoff irrigation water can spread the nematode within and nearby orchards.

Management:

- The planting material *i.e.* sapling and the potting mixture in which sapling is planted should be free from root knot nematode. Use of solarized/ sterilized soil (potting mixture) for saplings eliminates almost all soil borne pathogens. Planting samplings on raised beds increases aeration and reduce wilt incidence in the pomegranate orchards.
- Soil solarization for 6 weeks in the hottest month (April-May) using 50-75 LLDPE (Linear Low-Density Polyethylene) sheet kills the soil borne pathogen including nematodes. Prepare the plot selected for planting, irrigate it and cover with the LLDPE sheet for better results (Figure 5).
- If the wilt disease is caused due to *C. fimbriata* fungi, it is advised to follow the wilt management advisory published online on ICAR-NRCP website.
- Growing of Sun hemp (*Crotalaria juncea*) as green manure crop which also acts as resistant trap crop, where nematode can penetrate the roots of sun hemp but fails to multiply.

Figure 5: Soil solarization before planting using LLDPE sheet during hottest summer months

- Apply any or combinations of the promising bioformulations such as *Aspergillus niger* AN27 (IRG 07), Mycorrhiza (*Rhizophagus irregularis*/*Glomus irregularis*) and *penicillium pinophilum* @ 1 kg/acre. (Use of *Trichoderma viride* or *T. harzianum*, *Pseudomonas fluorocence, paecilomyces lilacinus* @1 kg/acre is optional) Each bioagent (except Mycorrhiza) should be multiplied separately under shade. Mixed 1 kg of bioformulations with 1 ton of well decomposed manure. Prepare 1 feet high bed for each formulation using well decomposed manure, mix bioformulation, maintain 50-60% moisture in these beds, cover it with gunny bags to maintain humidity and rake/mix the soil every 2-3 days. Incubate for 10-15 days;
- After multiplying the bio-agents separately, mix Mycorrhiza @ 1 kg/acre just before application and apply the bioformulated mixture @ 10-20 gram/plant.
- Application of these bio agents twice a year (once on start of rest, second at crop regulation) in the soil helps in improving nutrient uptake, plant growth and biochemical resistance to diseases, also checks pomegranate wilt.
- If the incidence of root-knot nematode is high, first go for chemical nematicide to reduce the root knot population below the damage threshold. Farmers can use the granular nematicide Fluensulfone 2% GR. In order to use the granular nematicide, make a small pit (5-10 cm) under the dripper and apply the granular chemical @ 10 gm per dripper (Maximum dose should not exceed 40 gm/plant); cover it with the soil and start watering.

- Drenching can also be done with another nematicide like fluopyrum 34.48% SC @ 2 ml/plant. Plants should be sufficiently watered day before drenching. Mix 2 ml of the nematicide in two litre of water and pour 500 ml per dripper (4 drippers/plant) or 1000 ml per dripper (2 drippers/plant).
- These nematicides can be used either in the rest period or in the beginning of bahar season. Use of these nematicides can be handy in keeping the nematode population under check.
- The planting of African marigold (*Tagetes erecta)* varieties like 'Pusa Narangi Gainda' and 'Pusa Basanti Gainda' (Figure 6) in the space between pomegranate plants for 3-5 months for the effective results.

Pusa Narangi Genda Pusa Basanti Genda

Figure 6: African marigold varieties recommended for intercropping in pomegranate for the management of root-knot nematode, *M. incognita*.

- Application of well decomposed organic manure, vermicompost, neem cake along with green manuring crops like sesbania or sun hemp and above mentioned bioformulations can manage the menace of root-knot nematode in pomegranate.

Chapter 13

Integrated management of insect pest of pomegranate

A. Insect and other Pests

1. Fruit borer (*Deudorix isocrates*):

The adult female lays shining white eggs singly on calyx, buds, flowers, young and maturing fruits. On hatching, the caterpillar bores into fruit and feed on the arils; the round holes can be seen on bored fruits, from which larval excreta comes out continuously (Figure 1). The damage caused by fruit borer attracts other saprophytic fungi, bacteria and beetles. The total life cycle of the borer is completed in 1-2 months. The damage of fruit borer is seen throughout the year irrespective of the *bahar* and severe during the *Mrig bahar*.

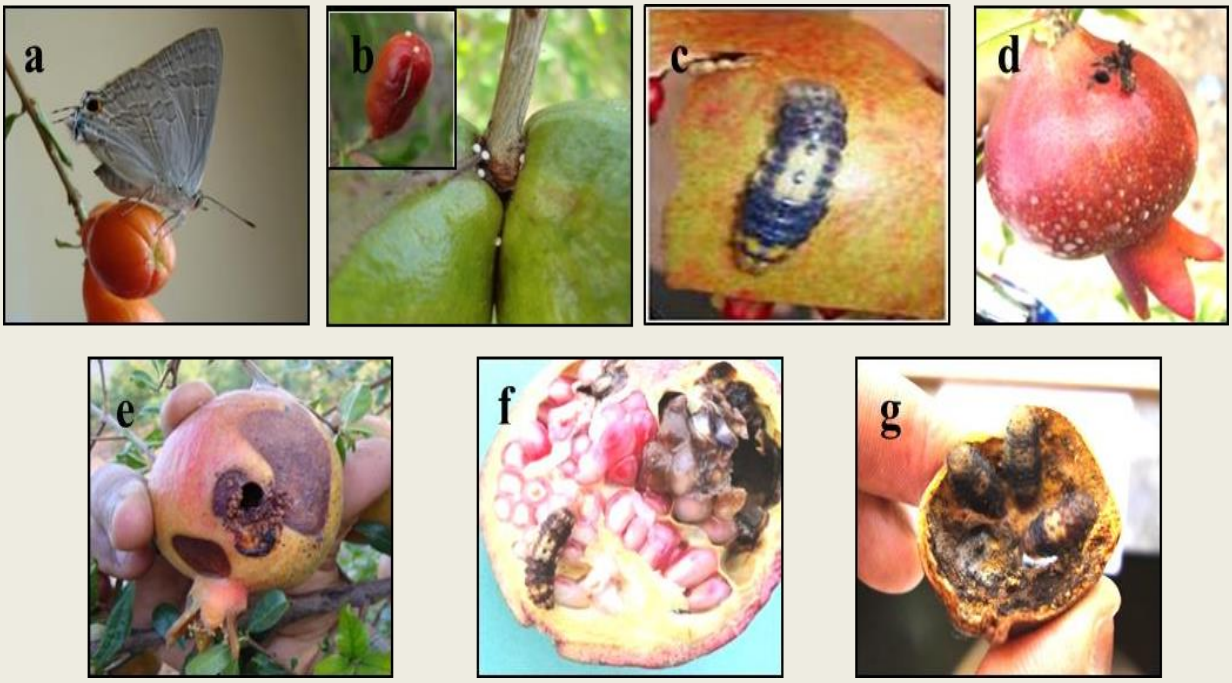

Figure 1: Nature and symptoms of damage of pomegranate fruit borer. a) Adult female laying eggs; b) singly laid eggs on buds and fruits; c) caterpillar on fruit; d & e) fruit borer damaged fruit with excreta outside f) caterpillar feeding on arils inside the fruit g) Fruit borer pupa inside the damaged pomegranate fruit.

Management:

- Do not plant alternate host crops like guava, sapota, aonla and tamarind in or around the pomegranate orchard and keep orchard clean and weed free.
- Clipping off calyx cup of flowers immediately after pollination helps in reducing the load of fruit borer eggs on the fruits and further damage.

- Bagging 30-40 days old fruits with poly Propylene non-woven white bags or butter paper bags to avoid the egg laying by adult and boring by fruit borer larva.
- Removal and destruction of all the damaged fruits periodically up to final harvest**.**
- Release of *Trichogramma chilonis* @ 2.5 lakhs/ha four times at 10 days' interval reduces fruit borer infestation.
- At flower bud initiatiom and flowering, one spray of freshly ground neem seed extract 50 g/L or with 3 % neem oil and second spray with azadirachtin 1500 ppm @ 3**.**0 ml/L after 15 days of first spray**.**
- After flower initiation, spray any of the following insecticide like deltamethrin 2.8 EC @ 1.5 ml/L or Cyantraniliprole 10.26 % OD @ 0.7 ml/L or Chlorantraniliprole 18.5 % EC @ 0.75 ml/L or Spinosad 45 % SC @ 0.5 ml/L or Indoxacarb 14.5 % SC @ 0.75 ml/L or Cypermethrin 25 % EC @ 1.0 ml/L or Flubendiamide 19.92 % w/w + Thiacloprid 19.92 % w/w @ 0.5 ml/L.
- Above mentioned chemicals need to used alternatively at 10-15 days**'** intervals up to harvest subject to the presence of the pest and PHI of the insecticide**.**

3. **Pomegranate stem borer (*Coelosterna spinator*):**
   Stem borer, once considered minor pests of pomegranates now its assuming major status and *Coelosterna spinator* is normally found associated with pomegranate. Adult female lays eggs on stems and on hatching, grubs bore and make tunnel into the heartwood of the tree. The adult emerges from infested plants during July to September through a round hole made by chewing wood (Figure 2). Adult beetles are active during the day and feed by gnawing the green bark of shoots. It normally completes one generation per year and longevity of beetles is 45 to 60 days. Presence of saw dust like pellets under the tree indicates the damage caused by the grub. Leaves of damaged branches turn yellow and subsequently get weakened, which badly affect the growth of trees.

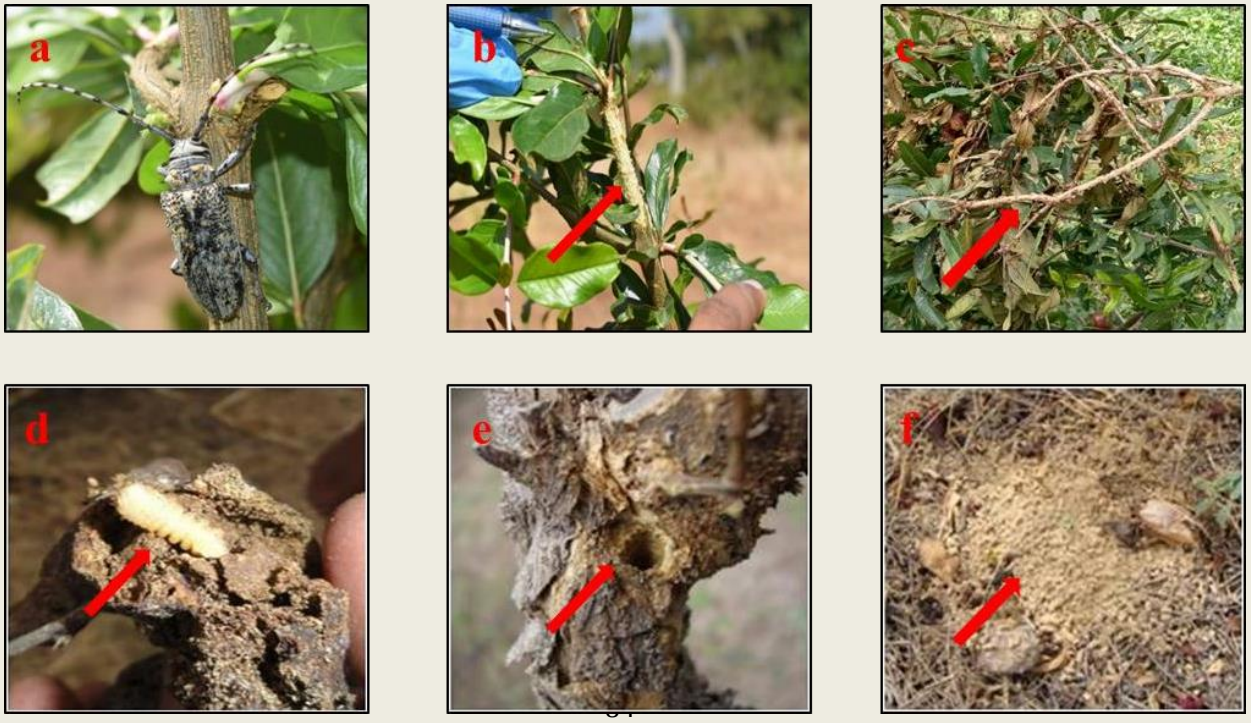

Figure 2: Nature and symptoms of damage of stem borer *Coelosterna spinator* a) Stem borer adult beetle; b) damaged symptoms; c) drying of damaged plant/branch; d) Stem borer grub; e) Dried plant with hole; f) Saw dust pellets on the ground.

Management:

- Avoid the plants becoming weak due to poor nutrition, attack by other insect etc.
- Pruning of dead branches during pre-monsoon and before taking *bahar*.
- Hand picking and killing of adults in kerosene water from July to September.
- Mechanical killing of eggs and first instar grubs hiding in the slits with the help of a sharp knife or by inserting a hooked wire down the hole.
- Do not heap the dead or uprooted wood within or near orchards destroy by burning.
- Adult beetle can be attracted and get killed by installing the light traps with 200 watts' bulb immediately after the first showers by keeping the kerosene/insecticide mixed water below the bulb.
- Stem pasting (Figure 3): Prepare the paste using 10 litres of water + Red soil (4 kg) + Chlorpyriphos 20 EC (20 ml) + Copper oxychloride (25 g) It should be applied from plant base up to 1-2 feet above from second year crop onwards, twice in a year (before and after taking the bahar).
- Stem injection with Dichlorvos 76 EC @ 8-10 ml/L has to be applied with the help of squeeze bottle/ Syringe till the tunnel is filled and then closing with the wet mud.

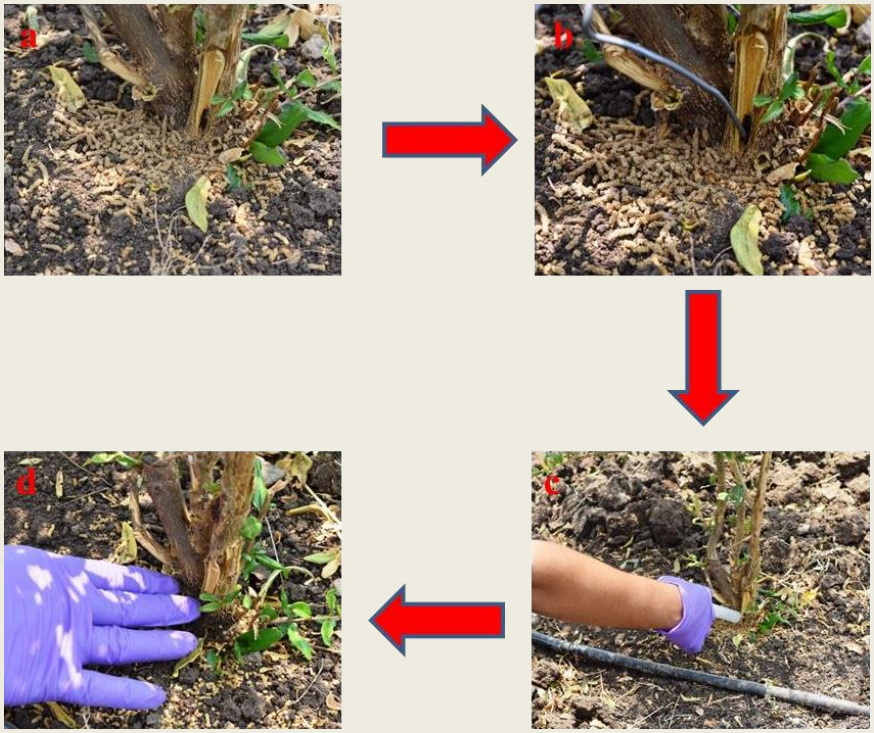

Figure 3: Schematic representation of treatment for pomegranate stem borer a) Stem borer grub damage b) Cleaning of damaged hole with wire c) Injecting of damaged hole with DDVP d) Covering of injected hole with wet mud.

3. Shot-hole borer (*Xyleborus fornicatus*):

Shot-hole borer is becoming most serious pests of pomegranate orchards grown under heavy soils. This pest is very difficult to control due to its well concealed habitats. Shot-hole borer infestation is a combined attack of the beetle and the ambrosia fungus and the attack leads to death of the pomegranate plant (Figure 4 & 5). It remains active throughout the year with higher activity during the post-monsoon period.

Figure 4: Early symptoms of damage of shot hole borer associated in pomegranate

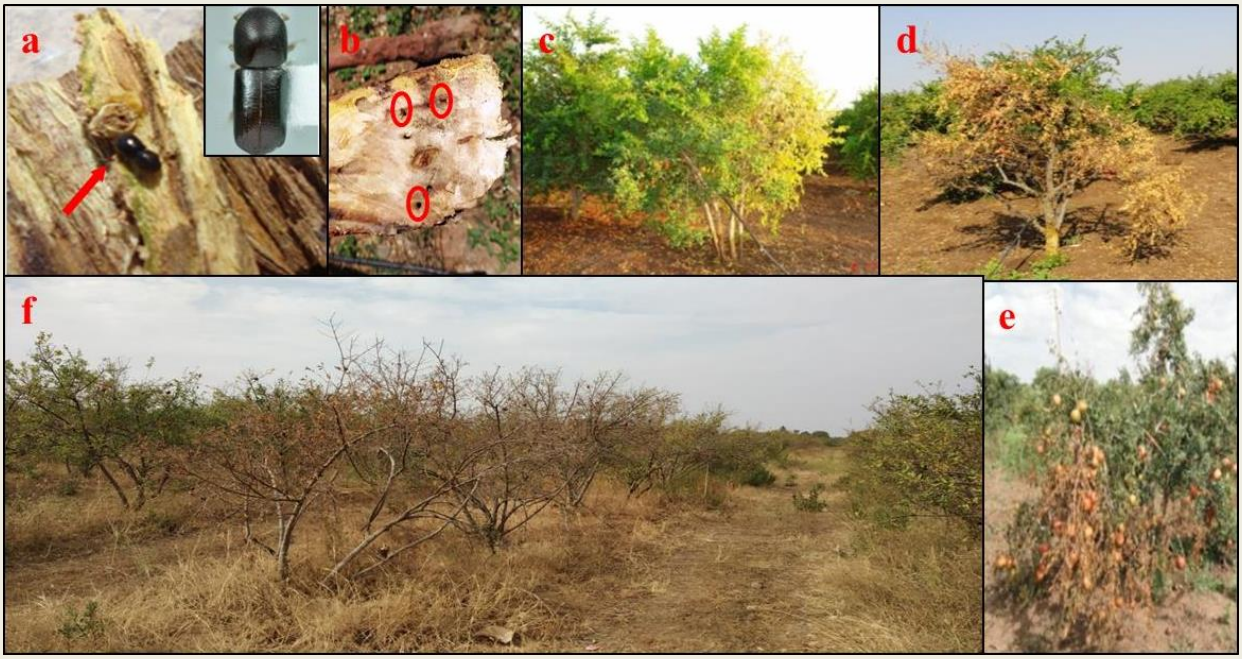

Figure 5: Nature and symptoms of damage of shot hole borer associated symbiotic fungi

a) Adult of shot-hole borer b) holes on the stem visible after cross section c) Early stage of wilting

d & e) Wilting advanced stage f) complete wilting of plants in row.

Management:

- Early detection, pruning of the affected parts and destroy by burning or burial.
- Avoid alternate host crops like castor from vicinity of orchards.
- Do not heap dead or uprooted wood within or near orchards; destroy by burning or burial.
- Light traps can be used to catch the adult beetles.
- Stem pasting: Prepare the paste using 10 litres of water + red soil (4 kg) + chlorpyriphos 20 EC (20 ml) + copper oxychloride (25 g). It should be applied from plant base up to 1-2 feet above from second year crop onwards, twice in a year (before and after taking the bahar).
- Soil applications of granular systemic insecticides and use of fungicide to destroy both the ambrosia and other pathogenic fungi.

4. Bark eating caterpillar/ Wood borer Moths (*Inderbela* sp.)

Bark eating caterpillars are polyphagous pest and found associated with trees and shrubs of neglected orchards with peak activity from September to October. Two species, *Inderbela quadrinotata* (Walker) and *Inderbela tetraonis (*Moore*)* are serious pests. Larva bores a tunnel downwards in to the wood. Several holes can be seen on the trunk at the joints of the branches. Holes or zigzag tunnels are bored by the caterpillar on the tree trunk and it feeds inside the bark. Around the affected portion wood dust and excreta pellets can be found hanging in the form of a web. Beneath fresh webbing, brownish larvae can be seen. Severe infestation may damage the whole stem/plant Wood dust and faecal matter hangs in the form of a web around the joints of branches with main stem or on the main stem directly (Figure 6). The tunnels cause weak points on the tree, where breakage occurs, affecting the vitality of the trees.

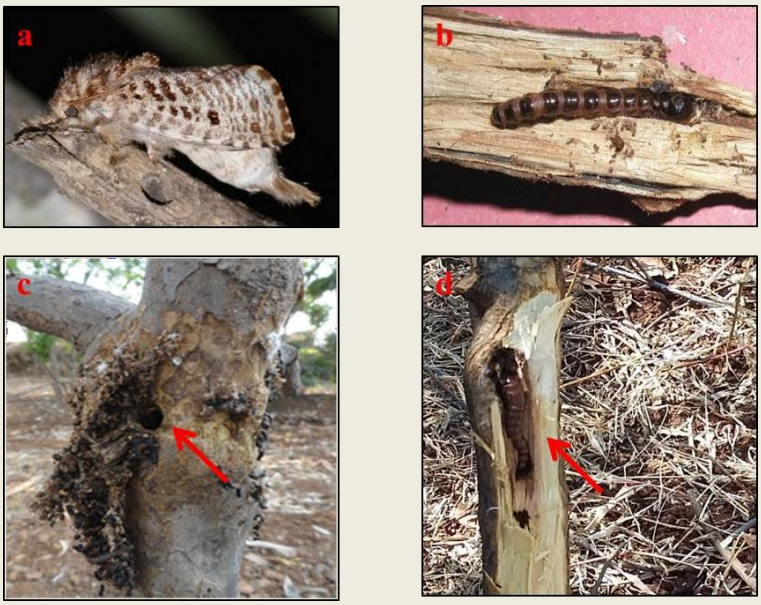

Figure 6: Nature and symptoms of damage of bark eating caterpillar

a) Adult moth of Bark eating caterpillar; b) Larva c) Excretory pellets with bored hole; d) Larva with galleries inside the stem.

Management:

- Keep the orchard clean and make the regular inspection for early detection.
- Kill the larvae by poking the hooked wire into damaged hole.
- Prune plants without mechanical injury and dispose of the dead and pruned plant material by burning.
- Inject the paradichlorobenzene in the tunnel, and seal it with the mud.
- Stem pasting: Prepare the paste using 10 litres of water + red soil (4 kg) + chlorpyriphos 20 EC (20 ml) + copper oxychloride (25 g). It should be applied from plant base up to 1-2 feet above from second year crop onwards, twice in a year (before and after taking the bahar).
- Stem injection with dichlorvos 76 EC @ 8-10 ml/litre has to be applied with the help of squeeze bottle/ Syringe till the tunnel is filled followed by closing it with the wet mud.
- Do not pour petrol or kerosene into the holes as these products are very damaging to the bark and wood of the tree and the tree will take at least three times longer to recover.

5. Fruit piercing moths (*Eudocima matrna* / *E. fullonia* / *E. homaena)*

Three different species of fruit sucking moths remain active from August to October and attack only the fruits of *Mrig bahar* crop of pomegranate. Adult males and females of moth pierce the fruits at night; with time, these damaged fruits become soft owing to secondary infections from different fungi and bacteria. Punctured holes on fruits with oozing fruit juice can be noticed from pierced fruits. Later these fruits drop under the plants. Number of pierced holes may vary from 1 to 30 per fruit (Figure 7).

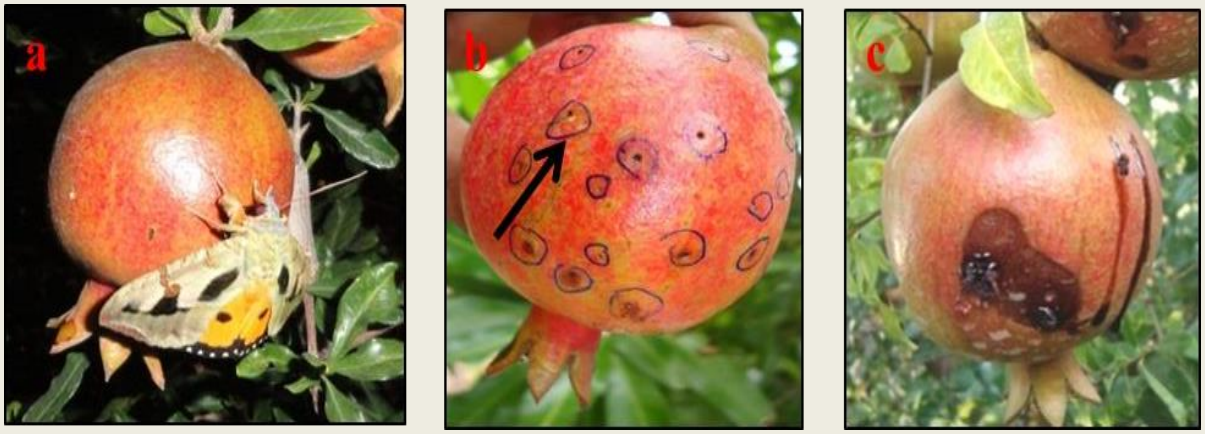

Figure 7: Symptoms and nature of damage of fruit sucking moth in pomegranate

a) Adult Moth piercing the fruit **b)** Fresh feeding holes **c)** Oozing of fruit juice from pierced fruits.

Management:

- As the activity of fruit sucking moth remains from August to October avoid taking *Mrig Bahar* crop in pest endemic areas.
- Destroy alternate hosts like *Tinospora* spp., *Cocculus* spp., *Lantana camara* and Castor from and around the field.
- Do not remove the pierced fruits as moths again visit the damaged fruits. Thus, other fresh fruits get protected. However, take some fungicide spray to avoid growth of fruit rot pathogens.
- Collect and destroy moths using torch in the night.
- High voltage fluorescent bulb installation around the orchard will help to deter the moths.
- Maturing papaya crop around the pomegranate orchard will serve as alternat host crop and avoids the damage to main crop.
- Ripened banana/papaya fruits injected/dipped with insecticide hanged in bucket traps around the pomegranate crop will attract moths and fed moths will get killed.
- Bagging fruits with poly propylene non-woven white bags or butter paper bags one week before the moth incidence.

6. Leaf Eating Caterpillar:

These caterpillars voraciously eat the leaf lamina leaving only midribs on the entire leaves of the branches. The milky brown caterpillars can be are seen feeding on the defoliated branches. The caterpillars of one species have long tufts of hairs all over body and can cause extreme itching, skin irritation when touched.

Management:

- The caterpillars should be collected and destroyed mechanically. Prophylactic sprays of Chlorpyriphos 20 EC @ 2.5 ml or Cypermethrin @ 0.5 ml per liter of water are advisable. The same sprays can also be taken after initiation of insect infestation.

7. Hairy caterpillar (Figure 8)

Bored sepals of buds, eaten sepals of flowers and nibbled rind of fruits and bark of soft stems can be noticed. Black and brown hairy caterpillar can be seen at affected sites.

Management:

The caterpillars should be collected and destroyed mechanically. Prophylactic sprays of contact insecticides like Indoxacarb 14.5% SC @ 0.75 ml/L or Cypermethrin @ 0.5-1.0 ml/L of water are advisable. The same sprays can also be taken after initiation of insect infestation.

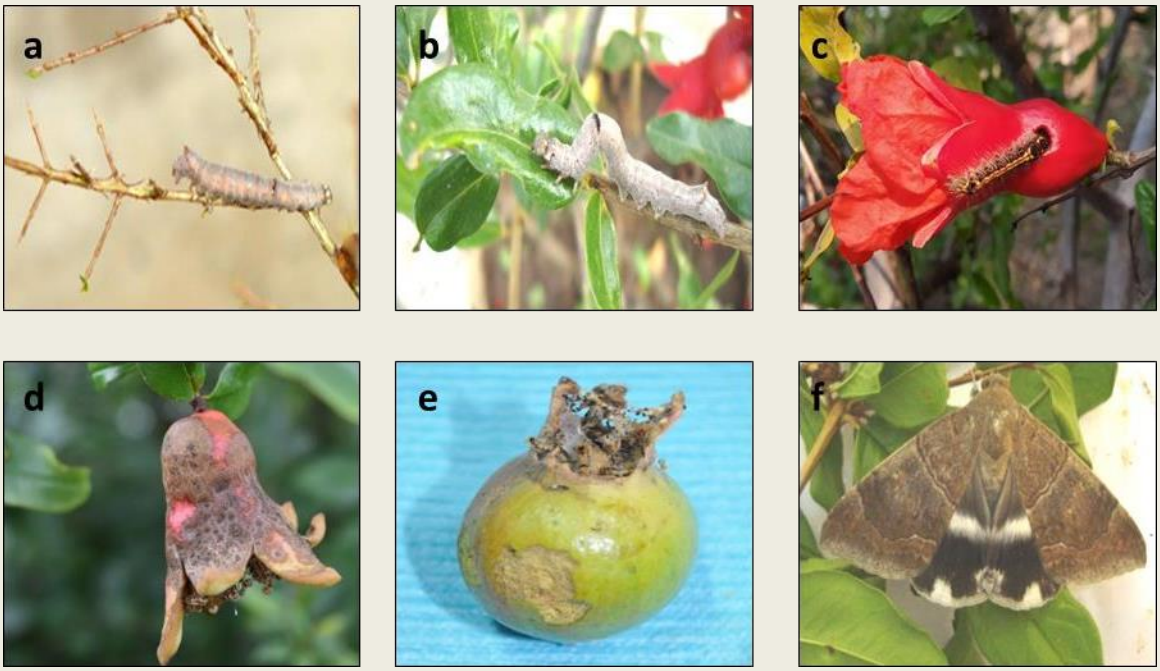

Figure. 8: Symptoms and nature of damage of Leaf eating caterpillar in pomegranate

2. Sap sucking insects of pomegranate and their management

The sap sucking insects like aphids, thrips, mealy bugs, white flies and mites are described below**.**

Thrips (*Scirtothrips dorsalis* and *Rhipiphorothrips cruentatus*):

Thrips infestation can be seen on the pomegranate plants throughout the year. Presence of thrips can be seen by tapping the tender shoots on white paper. Affected leaves curl upwards and downwards. The tip of the tender growth gets dried. Scrapping marks on buds and fruits can be noticed easily (Figure 9).

Figure. 9: Damage symptoms thrips on different parts of the pomegranate plant. a) On new flesh of leaves; b) Curling symptoms; c) scrapping scar on the flower; d) symptoms on tender fruit; e) scrapping symptoms on developing fruit.

Management:

- Do not cultivate alternate hosts crops like chilly, onion, garlic, brinjal and tomato in and around the pomegranate.
- Remove affected, dried tender shoots as and when seen**.**
- Install the sticky traps prior to flowering @ 16-20 traps /acre
- Sprays of Neem oil @ 3 ml/ L + Karanj oil @ 3 ml/ L water may be taken prior to flowering as prophylactic spray or on observing the pest or their damage symptoms.
- Two sprays of any chemicals enlisted below can be used in alteration. Acetamiprid 20 % SP @ 0.3 ml/L or Flubendiamide 19**.**92 % w/w + Thiacloprid 19**.**92 % w/w @ 0.5 ml/L or Spinosad 45 % SC @ 0.3 - 0.5 ml/L or Thiacloprid 21.7 % SC @ 0.3 - 0.75 ml/L or Thiamethoxam 25 % WG @ 0.5 - 0.75 ml/L Cyantraniliprole 10.26 % OD @ 0.7 - 0.9 ml/L or Imidacloprid 17.8 % SL @ 0.5 ml/L water can be sprayed at flowering and fruit setting stage subjected to the presence of thrips**.**
- Sprays need to be taken in the evening time to avoid the direct effect on the honeybees and natural enemies. If the population of natural enemy is abundant in the field, the spray time may be extended.

Aphids (*Aphis punicae*):

Aphids are observed in spring and autumn. Climatic conditions containing High humidity and low-moderate temperatures favors multiplication. Whitish green aphids can be noticed on tender foliage, buds, flowers and fruits, which might be accompanied with black exuviae (Figure 10)**.** Sticky honey like semisolid also found on upper surface of leaves on which sooty mold grows**.**

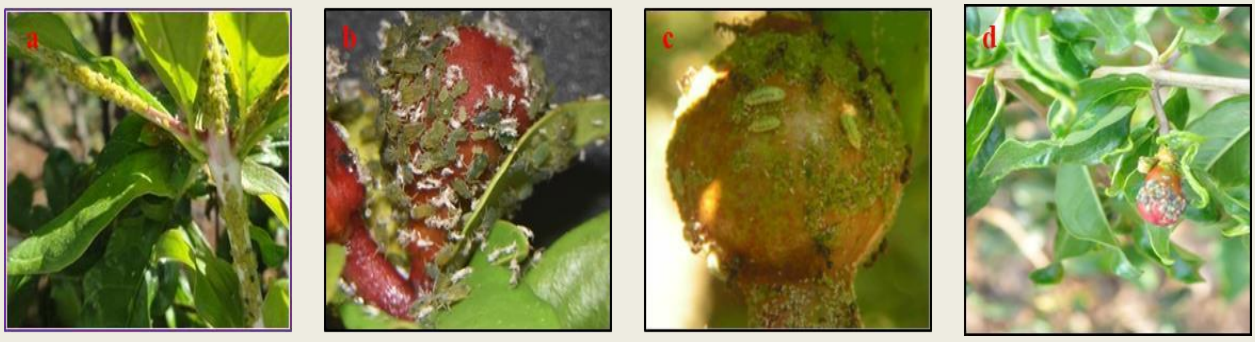

Figure 10: Infestation of Aphids on different parts of the plant with curling symptoms a) On new leaves b) Flower buds c) Tender fruits d) Curling symptoms.

Management:

- Do not grow ornamentals plants which are host to aphids.
- Spray Neem oil + Karanj oil (3 + 3 ml/L water) or Spinosad @ 0.3 ml/L or dimethoate 0.6 - 1 ml/L deltamethrin @ 1.5 ml/L or dichlorvos @ 0.5 ml/L or may be taken prior to commencement of winter season as prophylactic spray or on observing the aphids.
- If predators like syrphids and coccinellids are found, delay spraying and in some cases, natural enemies can sufficiently suppress the aphids.
- In severe conditions, spray Acetamiprid 20% SP @ 0.3 ml/L or Spinosad 45 % SC @ 0.3 -0.5 ml/L or Thiacloprid 21.7 % SC @ 0.3 - 0.75 ml/L or Thiamethoxam 25 % WG @ 0.5 - 0.75 ml/L or Cyantraniliprole 10.26 % OD @ 0.7 – 0.9 ml/L or Imidacloprid 17.8 % SL @ 0.5 ml/L water, subjected to the presence of aphids.
- Sprays need to be taken in the evening time to avoid the direct effect on the honeybees and natural enemies.

Mealybugs:

White waxy cottony appearance on tender foliage buds and fruit is seen; if infestation is severe it looks like a white lime is sprinkled on plant parts**.** Leaves and tender shoots show characteristic curling symptoms. Discoloration or rot can occur where the mealy bugs deposit honeydew (Figure 11). The infestation may lead to fruit drop. Following eight species of mealybugs are recorded from pomegranates in India

1. Oriental mealybug, *Pseudococcus lilacinus* (Ckll)
2. Citrus mealybug, *Planococcus citri* (Risso)
3. Coffee mealybug, *Planococcus lilacinus* (Ckll.)
4. Stripped mealybug, *Ferrisia virgata* (Ckll.)
5. Cotton mealybug, *Phenacoccus solenopsis* (Tinsley)
6. Vine mealybug, *Planococcus ficus* (Signoret)
7. Spherical Mealybug, *Nipaecoccus viridis* (Newstead)
8. Jack Beardsley mealybug, *Pseudococcus jackbeardsleyi* (Gimpel and Miller)

Figure. 11: Different species of mealy bug infesting on different parts of the pomegranate plant. a) *Ferrisia virgate* b) *Phenacoccus solenopsis* c) *Planococcus lilacinus* d) *Pseudococcus jackbeardsleyi* e) *Nipaecoccus viridis damage* f) Symptoms on fruits washing.

Management:

- Avoid intercropping with crops like cotton, okra, potato, tomato, chili, capsicum and related species which are good host crops of mealy bugs.
- Remove wild hosts in the surroundings**.**
- Avoid high humidity especially in nursery plants**.**
- Timely sprays of recommended insecticides should be taken with chemicals like Buprofezin 25 % SC @ 1 - 1.5 ml/L or Thiamethoxam 25 % WG @ 0.5 - 0.75 ml/L or Chlorpyriphos 20 EC @ 2.0 ml/L or Azadirachtin 1500 ppm **(**0.3**%)** with fish oil rosin soap clears the infestation.

Ash Whitefly (*Siphoninus phyllariae*):

This whitefly feeds on the lower surface of leaves. White appearance of lower leaf surface and flying insects can be seen after disturbing the twigs on infested plants**.** Affected parts distort and dry (Figure 12)**.** Under moist conditions, sooty mold can develop on the honeydew.

Figure 12: Nature and damage symptoms Ash whitefly on pomegranate leaves a) Ash whitefly b) severe infestation on the leaves c) growth of sooty mould on leaf surface due to honeydew secretion.

Management:

- Spraying water with high volume sprayer by focusing the nozzle towards the under surface of leaves helps in washing out the honeydew, eggs, larvae, pupae and adult whitefly. This should be followed by spraying Triazophos 40% EC @ 1.5 ml/L or Lamda cyhalothrin 5% EC @ 0.5 ml/L or Pongamia oil 3 ml/L. The sprays can be repeated at an interval of 8-10 days if needed.
- White flies can be trapped by hanging bright yellow sticky traps coated with adhesive at the height of the crop canopy.

1. Mite pests of pomegranate:

Two species of mites namely, False spider mite, *Tenuipalpus punicae* and *Aceria granati* infest the pomegranate crop. These are very small (0.2 - 0.3 mm long) and reddish in colour. It is most active during dry spell. Adult and nymphs feed on the lower leaf surface by scrapping leaf and sucking the liquid contents. They can be easily identified due its red colour. If you press your thumb against the surface of infested leaves your thumb turns red. Shiny white/silvery patches can be seen on the undersurface of affected leaves which may further curl and fall.

Management:

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

- Earrly detection and taking of prophylactic measures are necessary during dry period.
- For mite infestation during dry spell spray Fenzaquin10% EC @ 2 ml/L or Fenproximate 5 % EC 0.5 - 0.6 ml/L or Phasalone 35 % EC @ 2.0 ml/L or Spiromesifen 240 SC (22.9 % w/w) @ 0.4 – 0.7 ml/L or NSKE 5 % in rotation when required.

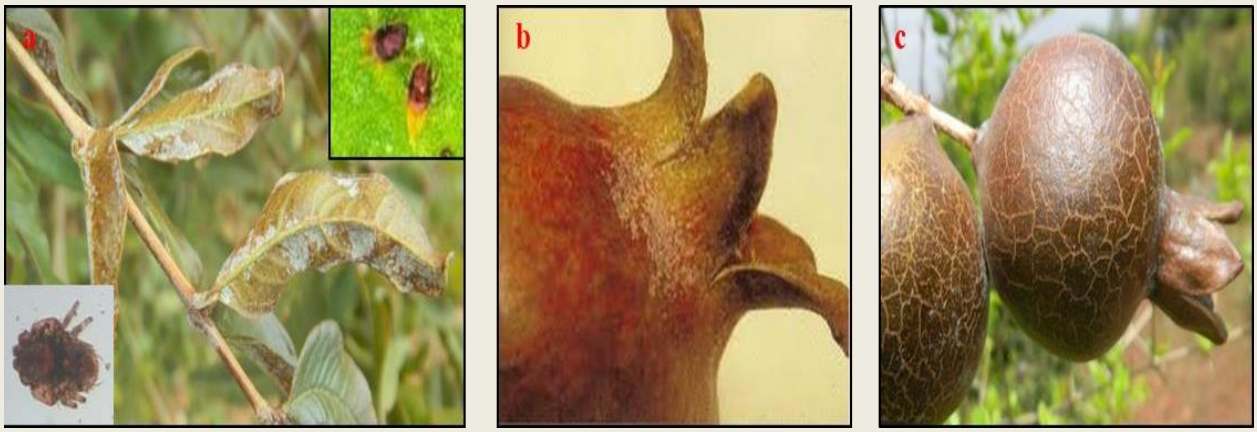

Figure 13: Symptoms of mite infestation on pomegranate. a) Leaf infestation b) Infestation on fruits.

Chapter 14

Pomegranate phytochemicals and its importance in the human dier and helath

Pomegranate (*Punica granatum* L.) is a fruit-bearing deciduous tree that belongs to the family Lythraceae. It most likely originated from Iran and Afghanistan. Wild pomegranates grow in Armenia, where they are considered as one of the most valuable nutritional, medicinal and ornamental plants in the country. The pomegranate plant, fruit, and their anatomical segments including flowers, fruit rind, leaves, bark, seeds, and roots encompasses a variety of biomolecules including phenolics, hydrolysable tannins, anthocyanins, flavonoids, and a wide range of essential micronutrients. The unique biochemical profile of the fruiting body and its major fractions attribute strong antioxidative, anti-inflammatory, apoptotic, and antimutagenic properties to curtail chronic maladies. Prophylactic properties of pomegranate are of broad spectrum and are anticipated to mitigate microbiological and parasitic pathogenesis, gastric damage, cardiovascular disease, type 2 diabetes, several types of cancers, renal illnesses, liver complications, infertility, osteoarthritis, oral and dental health, and skin melanoma.

The consumption trend of fruit and associated structures is diversely alike fresh or dried arils, fresh or fermented juice, powdered extracts, rind powder tablets, capsules and soft gels, and extracts-based ointments and decoctions. Pomegranate fruit waste including peel and seeds provides substantial number of phytonutrients that can be exploited for their potent health benefits. The mechanistic properties of pomegranate fruit and peel extracts such as antioxidant, antimicrobial, flavoring, and colorant may also be implicated as a natural additive in the food industry for quality enhancement and food preservation. In addition, pomegranate seed oils and rind extract deliberate photoprotective effect and can be utilized in cosmo care products. The peel powders also have biosorption capacity for heavy metal from water and are capable of acting as phyto-remediating agent to ensure cost-effective waste water treatment and decontamination of chromium, nickel, and zinc contamination. A plethora of research has been conducted on health-promoting and food features of pomegranate and its anatomical fractions as in the last two decades.

Phytochemicals in the Pomegranate:

The chemical composition of the fruits differs depending on the cultivar, growing region, maturity, cultivation practice climate, and storage circumstances. About 50% of the total fruit weight corresponds to the peel, which is an important source of bioactive compounds such as phenolic, flavonoids, ellagitannins, and proanthocyanidin compounds, minerals, mainly potassium, nitrogen, calcium, phosphorus, magnesium, and sodium, and complex polysaccharides. The edible part of the pomegranate fruit 50% consists of 40% arils and 10% seeds. Arils contain 85% water, 10% total sugars, mainly fructose and glucose, and 1.5% pectin, organic acid, such as ascorbic acid, citric acid, and malic acid, and bioactive compounds such as phenolics and flavonoids, principally anthocyanins. The seed cover of the fruit contains delphinidin-3-glucoside, cyanidin-3-glucoside, delphinidin 3,5-diglucoside, cyanidin-3,5-

diglucoside, pelargonidin-3,5- diglucoside, and pelargonidin-3-glucoside with delphinidin 3,5-diglucoside being the main anthocyanin in pomegranate juice. 12 to 20% of total seed weight of pomegranate comprises seed oil and is self-possessed with more than 70% of the conjugated linolenic acids.

The fatty acid component of pomegranate seed oil comprises over 95% of the oil, of which 99% is triacylglycerol's. Minor components of the oil include sterols, steroids, and a key component of mammalian myelin sheaths, cerebroside. Interestingly, punicic acid, which is a conjugated isomer unique to pomegranate oil, constitutes 70–76% of the seed oil. Phenolic compounds, together with flavonoids, anthocyanin, and tannins, are the main group of antioxidant phytochemicals that are important due to their biological and free radical scavenging activities. Phenolic acids, flavonoids, and tannins are present in different parts of pomegranate fruit and this may be one of the reasons why many of the studies demonstrated that combinations of pomegranate extracts from different parts of the fruit were more effective than a single extract. In a comparative analysis, anthocyanin from pomegranate fruit were found to possess higher antioxidant activity than Vitamin-E α-tocopherol, β-carotene, and ascorbic acid.

Nutritive value of pomegranate fruit/100 g edible portion:

Nutrients	**Value/100 g**	**Lipids (fatty acids)**	**Value/100 g**
Water (%)	77.93 (80.97)	Saturated (g)	0.12
Energy (kcal)	83 (68)	Monounsaturated (g)	0.09
Protein (g)	1.67 (0.95)	Polyunsaturated (g)	0.08
Carbohydrate (g)	18.70 (17.17)	Cholesterol (mg)	-0.0
Lipid (fat) (g)	1.17 (0.30)	Phytosterol (mg)	-17
Dietary fibre (g)	4.0 (0.6)		
Ash (g)	0.53 (0.61)		

Minerals	**Value/100 g**
Calcium (mg) 10.0 (3.0)	10.0 (3.0)
Selenium (μg)	0.5 (0.6)
Iron (mg)	0.30 (0.3)
Manganese (mg)	0.12 (-)
Magnesium (mg)	12.0 (3.0)
Copper (mg)	0.16 (0.70)
Phosphorus (mg)	36.0 (8.0)
Zinc (mg)	0.35 (0.12)
Sodium (mg)	3.0 (3.0)
Potassium (mg)	236 (259)

Principal phytochemicals of different parts of pomegranate like peel, root, bark, flower, leaves:					
Pomegranate peel	Pomegranate juice	Pomegranate root & bark	Pomegranate flower	Pomegranate leaves	Pomegranate seed

Gallic acid Ellagic acid Punicalin Punicalagin Caffeic acid Ellagitannins Pelletierine alkaloids Luteolin Kaempferol Quercetin	Simple sugars Aliphatic Organic acids Gallic acid Ellagic acid Quinic acid Flavonols Amino Acids Minerals EGCG Ascorbic acid	Ellagitannins Piperidine alkaloids Pyrrolidine alkaloid Pelletierine alkaloids	Gallic acids Ursolic acid Triterpenoids Fatty acids	Reducing sugars Sterols Saponins Flavanoids Tannins Piperidine alkaloids Flavone Glycoside Ellagitannins	Punicic Acid Oleic acid Palmitic acid Stearic acid Linoleic acid Sterols Tocopherols Sex steroids 3,3-Di-O-methylellagic acid 3,3,4-Tri-O-methylellagic acid

Health Benefits of Pomegranate and Its Fractions

Pomegranate role in maintaining oral hygiene:

Orodental health is mostly affected by plaque-forming biofilms and cariogenic bacteria that seek habitat in oral cavity. Several chemotherapeutic agents including chlorhexidine, bisbiguanides, and fluorides containing mechanical floss and gels have been formulated to ensure orodental hygiene. However, long-term use of such chemotherapeutic agents develops resistance in bacterial strains and promotes tooth staining. Such a situation calls for the development of herbal products as an alternative therapy to orodental chemotherapeutic agents Pomegranate polyphenols have strong tendency toward inhibiting growth of plaque-forming bacteria including Streptococcus sanguis and Pseudomonas aeruginosa. Use of pomegranate mouthwash effectively reduced gingivitis gum bleeding and periodontitis gum infection in comparison with 0.2% chlorhexidine standard mouth rinse. Topical application of oral gel containing 10% pomegranate extracts relieves pain and reduces time for wound healing in aphthous stomatitis disorder.

Wound healing properties of pomegranate accessions:

Wound healing is a distinct process of biochemical and cellular events that involves immediate inflammation after injury to achieve homeostasis, tissue granulation, and collagen formation that imparts tensile strength in the remodelling phase of skin regeneration. Pomegranate pericarp and epicarp are historically used in folk medicines for their ameliorative effects in various ailments including excised and incised wound healing.

Cosmo care properties of pomegranate:

The skin is the most targeted and exposed site for pathogenesis from exogenous factors especially ultraviolet radiations UVA and UVB and microbiological infections. Exogenous factors like UV radiations induce genotoxicity and oxidative stress consequently creating skin disorders including immunosuppression, skin carcinoma, sunburn, and photo aging. Pomegranate a mystical fruit famed as a pharmacy unto itself owing to its polyphenolic compounds, hydrolysable tannins, and organic acid fractions has a tonic effect in skin care

1. **Pomegranate Perspective Potential in Improving Fertility:**

   Pomegranate juice significantly improves changes in female sex hormone levels and reduces symptoms of polycystic ovarian syndrome. Oral administration of isoflavonoid rich extracts of pomegranate rind to the animal models at 0.5 g/kg increased

fertility through improved sperm count, sperm motility, and sperm quality.

2. **Pomegranate Promotes Cardiac Health:**
   Global estimates predict death toll due to cardiac complication to be 40% by the year 2020. Several epidemiological studies correlate inverse relation between adherence to relatively high intake of plant polyphenols and incidence of cardiovascular diseases CVD. Healthy heart features are attributed predominately by the pomegranate ellagitannins especially punicalagin isomers α and β. Pomegranate hydrolysable ellagitannins after being converted to ellagic acid are further metabolized into certain types of urolithins by intestinal microbiota. Studies on pomegranate consumption and association with improved cardiac health correlate urolithins as one among the known ellagitannins metabolites that stand responsible for attenuating various cardiac complications.
3. **Other important health benefit of Pomegranate:**

- Pomegranate and Its Role in Cancer Chemoprevention.
- Antidiabetic Properties of Pomegranate.
- Hepatoprotective Role of Pomegranate.
- Pomegranate and Brain Health.
- Anti-Inflammatory and Bone Health Promotion Properties.
- Microbial Pathogenesis Inhibitory Role of Pomegranate.
- Gut Health Promotion Properties of Pomegranate.
- Role of Pomegranate in Modulating Renal Disorders.

Clinical trials in human subjects and animal models have demonstrated significant effect of pomegranate consumption in improving the body's inherited defence against various forms of infections, inflammatory, and non-inflammatory disorders. In comparison with the fruits of the same and other classes, pomegranate has shown broader applicability against serious maladies. Unlike synthetic drugs, Pomegranate Bioactive Molecules and Health Benefits 17 heterogeneous biochemical composition of pomegranate and its extracts has ability to manipulate multiple biochemical pathways that can further be exploited for the treatment of various complex disorders. Controlled and clinical trials on pomegranate and its hydro alcoholic extracts have been regarded as safe for human health at orally administrated doses supplying up to 2000 mg polyphenols per day. However, exploitation of pomegranate and derived bioactive compounds as therapeutic agent either alone or in combination calls for careful experimentation to rule out genotoxic response of the plant material.

Chapter 15

Nutritional importance and health benefits of pomegranate in functional foods

Pomegranate is an excellent source of dietary fiber and health-benefiting nutrients, including vitamins (i.e., vitamin C, A, folic acid) and minerals (such as potassium). It is also a rich source of phenolic compounds and some alkaloids, triterpenes and sterols. Pomegranates are also rich in unsaturated fatty acids like the omega 5 punicic acid that constitutes around 70% of pomegranate seed oil. These compounds have been suggested to exert numerous beneficial health activities (beyond their nutritional properties) and are the basis for considering pomegranate as a possible functional food.

The peel represents approximately 50% of the total weight of the pomegranate fruit and contains a much higher number of polyphenols than the edible arils. Ellagitannins (punicalin and two isomers of punicalagin), gallotannins, proanthocyanidins, and ellagic acid derivatives are the primary peel polyphenols. For this reason, the peel is mainly used to obtain food additives or potential functional ingredients. Besides, anthocyanins are minor phenolics present in the outer part of the peel and the arils, and responsible for the characteristic pomegranate colour. The polyphenolic fraction, mainly composed of ellagitannins, has been recognized as the major active component of pomegranate by contributing to the benefits for human health attributed to pomegranate juice and extract. Not only due to the early antioxidant capacity, as previously reported, but also either directly or indirectly through its derivatives produced by the gut microbiota after ingestion. Despite the different proportions and variability described in this fruit, punicalagin and ellagic acid derivatives are the most abundant phenolic compounds (over 60%) and are almost exclusively found in the peel. Therefore, a common industrial strategy to obtain ellagitannin-rich pomegranate juice is to press the entire fruit or add punicalagin-rich pomegranate extract to pomegranate juice, previously obtained from arils. Pomegranate is a ruby-red fruit with juicy seeds called as arils that can be added to salads, cocktails, and meat or rice-based entrees. This versatile fruit provides important vitamins and minerals, such as vitamin C and copper, along with a healthy dose of fiber.

Numerous epidemiological, observational, preclinical, and human intervention studies highlight the inverse correlation between consuming an adequate number of plant-derived foods and the risk of suffering chronic diseases (Yip et al., 2019). In this line, pomegranate has gained attention

primarily due to its possible health benefits beyond basic nutrition (Hou et al., 2019).

Health benefits of pomegranate

- **Free radicals:**

Pomegranates are a rich source of antioxidants that helps to protect our body's cells from free radicals, which cause premature aging. Free radicals are formed due to exposure to the sun and harmful toxins from the environment.

- **Pomegranate is natural blood thinners:**

Prevents blood clots in the heart and arteries, also urinary retention. The seeds prevent your blood platelets from coagulating and forming clots.

- **Arthritis prevention:**

Pomegranate can reduce the damage on the cartilage for those hit with arthritis. This fruit has the ability to lessen the inflammation and fights the enzymes that destroy the cartilage.

- **Help in erectile dysfunction:**

Pomegranate juice can improve erectile dysfunction only moderately.

- **Prostrate cancer and heart diseases:**

Two separate studies claim that pomegranate juice helps fight prostate cancer. In one lab experiment, the juices "slowed the growth of the cultured cancer cells and promoted cell death". In the second experiment, pomegranate juice improved the condition of the blood, hence improving the health of individuals down with cardiovascular diseases.

- **Prevention of atherosclerosis:**

Pomegranates prevent the hardening of the artery walls with excess fat, leaving your arteries fat free and pumping with antioxidants. The potent antioxidant properties of the fruit have been attributed to its high content of soluble polyphenols. When tested in vitro on normal and colon-cancer cell lines, the juice was found to have superior antioxidant, antiproliferative, and proapoptotic effects compared with single purified active ingredients, probably the result of synergistic actions among the fruit's multiple compounds. pomegranate juice may be cardioprotective, reducing risk factors (such as cholesterol accumulation, foam-cell formation in macrophages, and oxidized low-density lipoprotein [LDL]) without affecting native LDL. Diabetic patients have shown that supplementing the diet with pomegranate juice had beneficial

antioxidant effects on macrophages, implying that it could reduce the development of atherosclerosis. In Ayurvedic medicine, the astringent properties of pomegranates are linked with bone and cartilage build-up; in the cosmetic arena, fruit-peel extract has been shown to stimulate a type of procollagen synthesis and inhibit a dermal degeneration process.

Pomegranate derivatives in functional foods

Pomegranate juice, in the form of powder, may be used in yogurt production, mainly as a replacer of sucrose content. The addition of pomegranate juice powder (5%) has been shown to lead to a product with an increased total phenolic content, an increased antioxidant activity, and a higher in vitro bio-accessibility. The addition of a pomegranate peel extract is another way to add the beneficial properties of pomegranate to dairy products. This extract is mainly used to increase the antioxidant activity of the products, as well as their storage shelf life. In addition, it has been used in cheese production
and has resulted in improved lipid oxidative stability and storage quality. In general, the pomegranate peel extract may be used as a promising natural preservative in fermented dairy products, though it should be used in low concentrations in order to avoid the adversarial effect on sensory attributes.

Meat products are very susceptible to undesirable alterations during processing and storage, which result in extensive flavor changes, color loss, and protein structure damage, all of which reduce sensory parameters and consumer acceptability. All these undesirable changes are mainly caused by three different biochemical pathways—lipid oxidation, protein decomposition, and microbial contamination—that are more pronounced in minced meats. Therefore, pomegranate has been evaluated as an additive in meat products in order to suppress the development of these effects.

Lyophilized pomegranate peel nanoparticles, which have a high phenolic content and antioxidant capacity, were evaluated as antioxidant and antimicrobial additives (up to 1.5%) in meatballs during storage at 4°C for up to 15 days. The results demonstrated that lyophilized pomegranate peel nanoparticles were more effective in retarding lipid oxidation and improving the microbial quality and cooking characteristics of meatballs compared to samples with 0.01% butylated hydroxytoluene (BHT) and without any treatment. Pomegranate peel extracts could potentially be used as natural antioxidant and antibacterial agents in fish products.

Pomegranate peel extracts, either in crude or encapsulated form, were mixed with

hazelnut paste in order to extend the shelf life of the product through the inhibition of lipid oxidation. An inhibition of lipid oxidation with a reduced formation of peroxides and a limited solubility of the crude extract in the high lipid content matrix of hazelnut paste were reported. In a similar study, pomegranate peel extracts, which were encapsulated by spray-drying when using orange juice industry by-products as wall materials, were used to fortify cookies with an increased phenolic content and oil oxidation stability. The antioxidant activity of the enriched cookies remained at high levels throughout the whole storage time, and they were preferred for their color and odor by the panelists during sensory evaluation. Pomegranate seed powder was incorporated in gluten-free bread in order to increase its total phenolic content and antioxidant activity. The results showed that pomegranate seed powder increased the specific volume and springiness of gluten-free breads, whereas their hardness and chewiness decreased significantly with increasing powder additions.

Studies on pomegranate derivatives in functional foods and its effect

Types of functional food	**Pomegranate derivatives**	**Food product**	**Effect**	**Reference**
Dairy products	Juice	Kefir-Type	↑viscosity; ↑acidity	Dimitreli et al., (2019)
	Juice powder	Yogurt	↑total phenolics; ↑antioxidant activity; ↑solid-like behavior	Pan et al., (2019)
	Peel extract	Cheese	↑lipid oxidative stability; ↑storage quality	Mahajan et al., (2015)
Meat and fish products	Peel powder	Meatballs	↑antioxidant activity; ↓lipid and protein oxidation; ↑microbial quality	Morsy et al., (2018)
	Peel powder	Beef Sausage	quality criteria improvement; improvement of cooking characteristics	El-Nashi et al., (2015)
	Peel extract	Fish Patties	↑shelf-life	Martínez et al., (2019)
Cereal and nut	Peel extract	Hazelnut Paste	↑shelf life; delay oxidation	Kaderides et al., (2015)

products	Peel extract	Cookies	↑shelf life; ↑antioxidant activity; ↑panelist acceptance (odor, color)	Kaderides et al., (2020)
	Seed powder	Gluten-Free Bread	↑specific volume and springiness; ↑antioxidant activity	Bourekoua et al., (2018)
	Seed powder	Gluten-Free Cake	↑antioxidant activity, protein and fiber; ↓peroxide value	Saeidi et al., (2018)

In recent years, the food industry's demand for antioxidants from natural sources has continuously grown, especially now with the increased numbers of adverse toxicological reports on many synthetic compounds. Therefore, pomegranate, which presents extremely high antioxidant and antimicrobial properties, has a great potential for applications in food products. The application of pomegranate and its extracts, mainly as antioxidants and antimicrobials, has been extensively studied in different types of food products and has shown very promising results. In addition, many studies have shown that these additives can positively affect the overall sensory quality, and hence the shelf life, of food products.

Chapter 16

Pomegranate processing and value addition for entrepreneurship developemnt

Pomegranate enjoys the consumer's patronage for its nutritional and medicinal properties. Post harvest management and value addition plays a crucial role to sustain the profitability of pomegranate production with the rapid rate of expansion in pomegranate area and production in India. Research on development of need based and cost-effective post-harvest technologies will go a long way in the expansion of market destination for domestic as well as export trade. Similarly, development of value-added products from pomegranate will facilitate the total utilization of this high value commodity. The processing of pomegranate for value addition requires the separation of arils from the fruits. The process is very tedious and time consuming when done manually. The mechanized machines and hand tools have been developed for the separation of arils from the fruit. The separated arils are then used for further processing in to the various value-added products (Fig. 1).

A. Pomegranate Juice: Pomegranate juice is nutritionally an important beverage. It is consumed frequently for its phenolic compounds. The juice extracted from whole fruits or arils is subjected to following processing operations. The juice is clarified by heating in a flash pasteurizer at 79-82 ^{0}C, cooling, settling for 24 hours racking up and filtering or decanting. The clear juice can be preserved by heat treatment or by using chemicals (1000 ppm sodium benzoate). After heating at 80^{0}C it is filled in to bottles while still hot. The bottles are crown corked and further stored at low temperature for better storability of juice.

I. Ready to Serve (RTS) beverage: RTS beverage is prepared by using 15 % of pomegranate juice and addition of sugar for adjusting TSS to 15 °Brix and citric acid for adjusting acidity to 0.3 %.

II. Carbonated RTS beverage: Carbonated RTS beverage can be prepared with 15 % juice and 12 % sugar and 0.3 % acidity with carbonation at 80 psi of CO_2 pressure.

III. Pomegranate jelly: Pomegranate jelly is prepared from combination of juice sugar 1:1 and citric acid as acidulant for better quality, colour, flavour and acceptance.

B. Anardana: Arils of sour type pomegranate are dried to prepare *Anardana***.** *Anardana* is also used in the ayurvedic medicine as digestive and stomachic**.** It is used as acidulent and condiment in Indian culinary or traditional system of medicine**.** The cabinet drying at 55^{0}C for 7 hours of the arils is best for getting quality *anardana***.** New varieties / hybrids with high acidity for production of good quality *anardana* have been identified by NRCP and testing is in progress**.**

C. Minimally processed pomegranate arils

Commercialization of minimally processed and "ready-to-eat" fresh arils is the good alternative. In the minimal processing generally, various means are used to reduce spoilage of freshly extracted arils using low temperature, pH regulation and edible generally recognised as safe (GRAS) chemicals as anti-microbial agents. The minimal processing consists of washing with sanitizing agents to reduce the primary inoculum load, pH modification, use of antioxidant agents, temperature control and others, to control partially the high perishability of the fruits. On the other hand, the selectively permeable polymeric films for packaging of minimally processed

pomegranate arils are used for generation of modified atmosphere, in order to develop a micro controlled environment that reduces the respiratory activity and maintains unfavorable conditions for the action of many contaminating microorganisms. Minimally processed arils can be stored under refrigerated conditions for 15 days.

D. Pomegranate seed oil

Pomegranate is one in about six plant sources known to contain conjugated fatty acids. Conjugated fatty acids are important because they inhibit eicosanoid metabolism at several points in the synthesis of prostaglandins from arachidonic acid. This makes them significant natural anti-inflammatory agents with the richest known plant source of a steroidal estrogen, estrone. Other important compounds found in Pomegranate seed oils include gamma-tocopherol, a rare and potent form of Vitamin E and the phytosterols: beta-sitosterol, stigmasterol and campesterol. It has been linked to improved heart health and also give in protect against cancer and artheroschlerosis.

Juice

RTS

Wine

Seed Oil

Minimally Processed Arils

Anardana

Rind Powder

Fig. 1: Value added products of pomegranate

E. Bio-Colours from Pomegranate: The rind of pomegranate contains a considerable amount of tannin, about 19% with pelletierine. The main coloring agent in the pomegranate peel is granatonine which is present in the alkaloid form N-methyl granatonine. This compound is responsible for biocolour present in pomegranate peel.

F. Pomegranate Wine: The pomegranate wine is prepared by pressing cut fruits without crushing or extraction of juice from arils which gives yield of 76-85 %. Sugar is added to juice to bring TSS to 22-23 °B. Potassium meta-bisulphite is added to restrict the growth of undesirable microorganisms. The juice is fermented with starter wine yeast and the wine is aged and. The wine is flash pasteurized at 60^{0} C, bottled hot and sealed.

Chapter 17

Indian pomegranate export: opprotunities and Challenges

Pomegranate from India and Iran are almost available throughout the year. Spain produces only approx. 10% of the World production but has more than 50%share in world. India Produces almost 50% of the world pomegranate but has mere 10% share in the world.

India's strength

India is the largest producer of Pomegranate in the World With adoption of different "Bahars" India can supply Pomegranate almost throughout the year. Quality of Pomegranate is much superior to Spain & Iran in edible quality and attractiveness. Excellent Export facility centres from Govt. and private sector

State wise Area & Production and Productivity of Pomegranate - 2019-20

State	Area (Ha)	Production (MT)	Share in Area (%)
Maharashtra	128650	1197700	**71**
Karnataka	23230	261820	**13**
Gujrat	14770	171660	**8**
AP	5380	76000	**3**
Other State	8610	82130	**5**
Total	**180640**	**1789310**	

India is major producer of Pomegranate in the world. India is also exporting Pomegranate to Various Countries. Bhagwa and Arakta are the major export varieties. During last 3 years state wise export of pomegranate is as follows.

State wise Export of Pomegranate from India during last 3 Years

State	2018-19		2019-20		2020-21	
	Quantity (MT)	Value (Crs)	Quantity (MT)	Value (Crs)	Quantity (MT)	Value (Crs)
Maharashtra	**51586**	**548**	**65663**	**554**	**55424**	**390**
Gujarat	4980	51	4561	51	6065	76
Karnataka	516	25	497	23	375	17
Terengganu	798	31	565	25	271	11
Other State	1092	34	9263	35	5581	23
Total	**67892**	**689**	**80548**	**688**	**67976**	**517**

Country wise export of Pomegranate during 2020-21 seasons

Country	Export during 2020-21	
	Quantity (MT)	Value (crs)
U ARAB EMTS	12509	162
BANGLADESH PR	36526	159
QATAR	2350	30
NEPAL	6788	27
NETHERLAND	759	26
SAUDI ARAB	1964.	24
OMAN	3175	20
SRI LANKA DSR	568	10
EGYPT A RP	734	10
BAHARAIN IS	571	8
Other Countries	2032	41
Total	**67,976**	**517**

International Market trends

Food safety standards are higher & more complex requirements, demanding regulations, increasing health concerns reflected in food consummations and Pesticide Residue Free are the major market global trends. India, Spain, Iran, Peru, Israel, Pakistan, America are major Pomegranate producing countries and Thailand, Spain, Iran, India Vietnam, Mexico, Israel, Uzbekistan, Turkey in the world. and Gulf Sector: Dubai, Saudi Arabia, Bahrain, Kuwait, Qatar, The Netherlands, England, Germany, France, Switzerland, Belgium are major Pomegranate Importing Countries.

Challenges for pomegranate export

For export of Pomegranate following five major challenges for Export

1. Quality Parameter

2. Pesticide Residues

3. Food safety

4. Quarantine regulation

5.Traceability

To fulfil the requirement Importing countries quarantine requirement, **Pesticide Residues** Remnants of pesticides and toxic metabolites in or on food, This includes odor after the completion of an application. Harmful to our health and environment Detection of pesticide residues in Pomegranate may result ban on its export, Report on residue analysis of 200 pesticides is at present compulsory for issuance of Phytosanitary certificates and promote of Pomegranate export APEDA has taken initiatives for monitoring of traceability system through Anar net in the country

Objective of AnarNet

I. To establish a system for controlling pesticide residues in exportable Pomegranate at the farm and plot level.
II. To monitor pesticide residues in soil and water at Pomegranate farms or plots and pack houses.
III. To establish a surveillance system for controlling pesticide residues recommended by the NRC Pomegranate as well as for traces of other pesticides, which might appear due to previous use on the land.
IV. To establish a system for corrective action in the event of detection of residue levels higher than those established through this RMP.
V. To establish a system for corrective action in the event of issuance of an Internal Alert Information.

VI. To ensure that Pomegranate exported from India to the European Union do not test for pesticide residues in excess of MRLs

Major steps taken under Anar Net for Pomegranate Farm Registration

I. For monitoring the quality assurance being maintained in the supply chain of Pomegranate export, the system has been developed in line with the Grape Net which has been successfully implemented.

II. Registration of Pomegranate Farms by State Horticulture Department

III. Residue Analysis and Agmark Inspection by Laboratories

IV. Consignment Creation, online application for issue of CAG & PSC

V. Certificate of Agmark Grading (CAG) by Regional Agmark Office(s)

VI. Issue of Phytosanitary Certificate by PSC Authorities

VII. Monitoring of Residue Analysis by NRL

VIII. Login as State Admin to View Registration Report

State wise Pomegranate Farms Registered under Anar Net system for 2020-21 seasons as follows

Sr. No.	Name of State	No of Pomegranate farm registered
1	Maharashtra	1518
2	Andhra Pradesh	6
3	Gujarat	1
	Total	1525

During 2021-22 season Pomegranate farm Registration is open for throughout year. Farm Registrations Mobile App is making available for online application for farm registration. Details are available on *WWW.apeda.com*

Integrated Pack House Facility for Pomegranate export from India

With a view to carving out for Indian horticulture produce and for ensuring an appropriate standard in exports, APEDA through a development of integrate facility such as of pack house to intending exporters in super cession of the Horticulture Produce. The objective of this pack house is to encourage exporters of horticultural produce to meet the international standards in terms of quality of produce with quarantine safety. The pack house development as per the requirement for material handling, holding, pre-inspection, shorting, grading, washing, standard treatment, packaging, stacking, pre-cooling, cold storage, quarantine check etc., encouragement to backward linkages, maintain the traceability, export of good quality produce,

promotion and publicity at the international level, encouraging adoption of internationally acceptable standards and practices, up gradation of standards for product quality, hygiene, food safety, and creation of a healthy, competitive environment among exporters.

APEDA recognition:

Pack house is applicable to handling and processing for all horticulture produce viz fresh fruits, vegetables etc. for export. The APEDA Recognition for pack house will be granted for multiple produce for which appropriate facilities and procedural compliances commensurate with matching infrastructure facilities are found to be existing at the Pack house on the basis of inspection-by-Inspection committee.

The various stakeholders are involved and getting the responsibilities for compliance of procedural formalities for quality export as per the importing countries. General Requirements for EU countries: The vegetables & fruits from India can be exported to the European Union countries based on the phytosanitary inspection at the pack houses approved jointly by NPPO/APEDA where adequate facilities for inspection, examination etc. are available and the produce is packed under the supervision of plant quarantine official.

Phytosanitary status of the inspected consignments will be secured by proper storage in demarcated quarantine area at the pack house, transported by clean & disinfested vehicles. Also, loading of the consignment at exit point will be ensured in clean and disinfested cargo containers preventing cross contamination.

Importance of Traceability Net System for Pomegranate Export:

The approved pack houses will be responsible to maintain the backward traceability information for the consignment. Further, the exporters will file the application for PSC through the web-based Plant Quarantine Information System (PQIS) where history of the case is retrievable. A unique registration number generated for each consignment and printed on the PSC will be source of document traceability for the consignment.

Responsibilities of pack house for pomegranate export to EU etc:

a. Design of pack house should be appropriate to handle inflow to outflow of the commodities in a unidirectional manner with no chances of cross infestation/contamination. For example, absolute isolation is required between stacking/holding area; grading, sorting and packing area; PQ inspection area and post inspection storage area. Door should be of sliding type with strip curtain.
b. The procurement of fruits & vegetables should only from the registered formers and the list of such farmers will be maintained for records.
c. Log book should be maintained for general hygiene and cleanliness in Pack House.

d. Pack House should be free from cracks and crevices in floors and walls as also cobwebs etc on walls to avoid shelter to harmful pests.
e. To apply prophylactic treatment in and around the pack house, periodically.
f. Safeguard to prevent infestation/ re-infestation during all steps of the sorting/grading/packing processes.
g. To provide exclusive area for plant quarantine inspection. 8. To provide proper inspection table with sufficient light and magnifier.
h. To possess required equipment's/items as per the listed by NPPO.
i. To provide separate storage area for finally packed and inspected consignments.
j. To install insect proof net/wire mesh on the windows and other opening in the pack house.
k. To install traps for fruit fly, white fly and thrips. All the traps must be numbered and their records to be maintained with periodic observations for insects catch to be recorded in writing. 13.As far as possible, packing boxes shall have insect proof mesh on the aeration holes to prevent cross infestation.

II. The finally packed boxes after inspection shall be pasted with a sticker/stamp "Plant Quarantine Inspected" after the inspection. The pack house will provide such sticker seal and vehicle seal duly numbered to be monitored by PSC issuing authority.
III. To ensure that all the requisite registers viz; Commodity inflow register containing details of source material, preliminary inspection register, insect monitoring/ trap register, general hygiene register, commodity rejection register, consignment sealing register, vehicle cleanliness/seal register, commodity outflow register are maintained.
IV. All the signage/ display material particularly the commodities being handled in the pack house and related pests/ damage signs required for implementation of SOP.
V. To declare in writing the capacity/ quantum of commodity that can be handled through the pack house per working day such as grading, sorting, packing and PQ inspection.
VI. To ensure cleanliness/ general hygiene of the vehicle used for transporting the certified material and maintains records.
VII. To ensure the disposal of infested/infected/left over material after inspection of each consignment/ lot .and a record to be maintained in this regard.
VIII. Must have a master register wherein list of all documentation/registers is mentioned.
IX. All the personals are well informed/ trained about the activities of the pack house and their responsibilities along with maintenance of relevant documentation.
X. The semi-skilled labourers engaged by the pack house in sorting/ grading and packing of the fruits and vegetables will be trained on symptoms/ damage signs of major pests of the commodities processed by the pack house

Responsibilities of State Department of Agriculture/ Horticulture under Anar Net System:

I. To register farmers/farms intended to export fresh vegetables and fruits to EU on the request of the farmer or exporter.
II. The registration of the farm will be for one crop season/one year.

III. To monitor status of pests and diseases in the registered farms on fortnightly basis and ensure that their record is maintained at the registered farm along with the record of the control measures/ plant protection measures
IV. To advise appropriate plant protection measures for control of pests and diseases specially the pests of concerns to EU as referred in EC Directives.
V. To ensure maintenance and monitor the records at farm level on the management practices of the crop from sowing to harvesting.
VI. To organize training of the approved farmers on production of pest free crops especially management of pests concerns to EU. 7. To ensure availability of POP/IPM/GAP inputs (eg. light/sticky/pheromone traps, tricho cards, bio-pesticides, etc.) to the registered farmers.

Responsibilities of Exporters under Anar Net System:

I. To request State Department of Agriculture/Horticulture for registration of a farmer/farm.
II. To provide information to the State Department of Agriculture/Horticulture about the farmers/farms to be registered, crops grown, area/location of the farm and tentative production during the crop season.
III. To procure the fresh fruits and vegetables from the registered farmers only.
IV. To provide technical support to the registered farmers so as to ensure procurement of pest free produce for export.
V. To provide information related to each consignment with registered farm no. to the pack house.
VI. To ensure safe transport of the produce from farm to the pack house without mixing with produce of unregistered farms.

Responsibilities of Farmers under Anar Net System:

I. To request State Department of Agriculture/Horticulture for registration of the farm intending export to EU.
II. To maintain status of pests and diseases in the registered farms on fortnightly basis along with the record of the control measures/ plant protection measures undertaken during the crops season.
III. To maintain the records of each crop in the registered farm on the management practices from sowing to harvesting.
IV. To follow the advice from State Department of Agriculture/Horticulture or technical support from exporter on pest management practices, waiting period for pesticides etc.

Pomegranates-new king of healthy fruits.

Pomegranate is globally recognized as a “Super-food” owing to its nutritious characteristics. Its demand is seeing a world-wide rise, as given the high prices there is a great

interest in growing pomegranates and great competition in the market. The producing countries have reportedly increased the acreage but lack of supply available in the market has led to high prices.

Global consumption of Pomegranates is on rise

The global pomegranate and pomegranate arils market was valued at USD 8.2 billion in 2018 and is expected to reach USD 23.14 Billion by year 2026, at a CAGR of 14.0 percent. Increasing demand for pomegranate products such as pomegranate powder, pomegranate juice, functional beverages, as well as other pomegranate-derived products is major factor projected to drive the global pomegranate market growth during the forecast period.

Growing consumption and demand for processed pomegranate products across the globe, in which juice and cosmetics have become most popular, is a key trend observed in the market and is expected to gain traction, thereby supporting revenue growth of the global market.

Growing initiatives and investments by governments of various countries such as providing subsidies and training for farmers and exporters is a factor expected to create opportunities for the players in the target market. In addition, rising focus on plans to reduce the cost of end product, as the pomegranate and related products cost are higher in North America and Europe region.

This in turn, is a factor expected to create lucrative opportunities for players operating in North America and Europe market. For instance, adoption of automation for growing and harvesting can aid the manufacturers in improving overall processes and reduce manpower and related costs. Among the type segments, the pomegranate powder segment is expected to account for major revenue share and is expected to maintain its dominance over the forecast period.

The pomegranate powder segment is expected to register CAGR of over 4.8%. The pomegranate juice concentrate segment accounts for the second highest share in terms of revenue in the near future. As pomegranate juice concentration is used in cooking both as concentrated syrup and as a fresh juice.

Indian pomegranate season is picking up after slow start

The Indian pomegranate season has been going pretty well so far. Although the sizes are relatively small compared to other origins, demand is growing. Exporters expect about 20 per cent more volume compared to last season, despite there being low volumes available during the early season. The pomegranate season is going on quite well, as expected.

During the early season there will be lower volumes available, thanks to a slower start. However, the pace of shipments has been increasing recently. The ‘Bhagwa’ variety of pomegranates is grown and it is expected that a 20 per cent increase in terms of volume that is being exported, compared to last season.,

Global impact of Corona virus on fresh produce markets

The recent pomegranate season ended in India with lower volumes. However, for the next season, which starts in June, a great yield (+30%) is expected thanks to the monsoon. The main market for the pomegranate seeds is Western Europe.

Due to the corona virus, Indians expect a greater demand for pomegranate seeds, since they are rich in antioxidants. However, the logistics is becoming a major challenge, because air freight is hardly possible. This could have effects on the logistics chain in India

New facility for Indian pomegranate aril exporter is 100% self-sufficient

A third pomegranate arils processing facility at Nashik, India has been inaugurated for the export of fresh pomegranate arils from India. Spread over 45,000 SFT, their new processing facility is located at the heart of the pomegranate growing region in India. With the addition of this facility, Sam Agri has increased its pomegranate processing capacity to over 6,000 MT per annum.

Over the last few years, Sam Agri has been working closely with small farmers and farmer producer organizations in Nashik and other regions of Maharashtra to enable them to comply to Global Gap standards and produce residue-free pomegranate fruit suitable for exports to EU, UK, and other developed markets.

Ready-to-eat Pomegranate Arils continues to be the most important product of Sam Agri and over the years the company has added other value-added pomegranate products to its portfolio, including dried pomegranate arils, chocolate coated dried arils, IQF arils and fresh cold pressed pomegranate juice. Other small export facilities can take help and guidance in order to gain grounds in jaggery exports.

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India's Growth Story & Projected Opportunities

The Indian pomegranate production is growing by 20 to 25% every year.ϖ Demand is on the rise, both at domestic level and in the export market.ϖ The best-known variety in India, Bhagwa, a huge sweet variety of really good quality. India is a growing player to destinations in Europe, the Middle East and Asia. The country is alsoϖ expecting to enter the U.S. market. India competes with various players in the world, but it manages to stand out with unique varieties.ϖ The trend in India is convenience; pomegranates are widely appreciated and the seeds are reallyϖ popular amongst consumers.

Market opportunities for indian pomegranate

UNITED ARAB EMIRATES UAE is the major importing country of Indian pomegranates, accounting to nearly 32% of Indian global exports. Indian pomegranates trade at 0% MFN, with very low non-tariff barriers.

Some characteristics of Indian Pomegranates in UAE Market: India's pomegranate account to 46.8% of UAE's imports.ϖ Indian sizes are smaller compared to those from othersϖ but have thicker arils & softer seeds Indian Bhagwa Red variety is highly preferred in UAEϖ Pack size = 12 pcs/ cartonϖ Low Price (Dhs) = 22; High Price (Dhs) = 26ϖ Popularity of Pomegranate has increased due to greater interest in UAE consumers in consumingϖ healthy & nutritious products "UAE population Fruits Consumption has grown by 4.7% "ϖ "Health beverage industry is booming in Dubai, with increasing consumption of fruit juices,ϖ particularly influenced due to the arid geographyand hot summers. The market of concentrated pomegranate juice is evergreen in UAE. India being its all-season supplier has high trade opportunities "During Ramadan, Pomegranate is highly consumed - as people prefer quality over priceϖ

Exploring Health Benefits of Indian Pomegranate

Pomegranates have two unique plant compounds that are very beneficial to one's health: Punicalagins: It is a very powerful antioxidant which is contained in the seeds as well as peel of the pomegranate. It has an anti-oxidant activity of nearly 3 times more than red wine or green tea Punicid Acids: Called pomegranate seed oil, or fatty acid that has potent biological effects". Indian Pomegranate has 30% punicalagins in their seeds/ arils extract" Eating Pomegranates can thus reduce Atherosclerosis by removing any fat and reducing the hardening of artery walls

New Market and Opportunities for Pomegranate Export

I. New Market (Russia, Thailand, Malaysia, Singapore, China and USA)
II. Establishment of INDIA One Brand for Export
III. Domestic market (Delhi, Hyderabad, Chennai. Kolkatta, Mumbai)

IV. Introduction new verities
V. Introduction of corrugated box packing in domestic market
VI. Scope for Quality, Residue free and proper grading and packing for export as well as

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