MANUAL ON CITRICULTURE

Compiled by

Dr. B.S. Baghel
DEAN

&

Dr. Rajesh Tiwari
Scientist (Fruit Science)

KNK COLLEGE OF HORTICULTURE, MANDSAUR
JAWAHARLAL NEHRU KRISHI VISHWA VIDYALAYA
<table>
<thead>
<tr>
<th>Particulars</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. History, origin, spread, citrus growing regions, development of citrus</td>
<td>02</td>
</tr>
<tr>
<td>2. Industry, problems of citrus industry and future strategies.</td>
<td>04</td>
</tr>
<tr>
<td>3. Classification and nomenclature of citrus</td>
<td>07</td>
</tr>
<tr>
<td>4. Methods of propagation</td>
<td>10</td>
</tr>
<tr>
<td>5. Root-stock scion relationship</td>
<td>11</td>
</tr>
<tr>
<td>6. Bud variation, bud selection and bud wood certification</td>
<td>14</td>
</tr>
<tr>
<td>7. Major citrus species/varieties of horticultural importance</td>
<td>18</td>
</tr>
<tr>
<td>8. Soil and Climate</td>
<td>21</td>
</tr>
<tr>
<td>9. Training and Pruning</td>
<td>24</td>
</tr>
<tr>
<td>10. Nutrient management</td>
<td>25</td>
</tr>
<tr>
<td>11. Blossom biology</td>
<td>29</td>
</tr>
<tr>
<td>12. Tips for raising of disease free citrus nursery</td>
<td>31</td>
</tr>
<tr>
<td>13. Raising of Nucellar seedlings</td>
<td>33</td>
</tr>
<tr>
<td>14. Method of raising of cross protected plants of lime</td>
<td>34</td>
</tr>
<tr>
<td>15. Causes and control of fruit cracking / splitting of citrus / lemon fruits</td>
<td>34</td>
</tr>
<tr>
<td>16. Use of plant growth regulators / bio-regulators in citrus</td>
<td>35</td>
</tr>
<tr>
<td>17. Replant problem in citrus</td>
<td>36</td>
</tr>
<tr>
<td>18. Crop regulation and Bahar treatment</td>
<td>39</td>
</tr>
<tr>
<td>19. Water management</td>
<td>41</td>
</tr>
<tr>
<td>20. Management of insect-pest and Disease of citrus</td>
<td>46</td>
</tr>
<tr>
<td>31. Causes and control of citrus decline</td>
<td>51</td>
</tr>
<tr>
<td>22. Citrus granulation / crystallization. dry and corky ness</td>
<td>53</td>
</tr>
<tr>
<td>23. Post harvest technology of citrus fruits</td>
<td>57</td>
</tr>
</tbody>
</table>
1. HISTORY, ORIGIN AND SPREAD

- Scanty information has been responsible for poor knowledge about early history and origin of citrus fruits. Tanaka has reported that true citrus fruits appeared on the globe after Australia had been separated from the main continent during the upper Cretaceous period at least 30 million year ago.
- However most of the taxonomists have a general agreement that Himalayan region and South China are the place of origin for most citrus fruits.
- Some of the mandarins have their origin in China
- Lemon is said to be indigenous to India, However Bonavia concludes that Malaya is the home of lemons.
- The sour orange was probably the first to reach Mediterranean although Tolkowsky believes that sour and sweet oranges reached Europe at about the same time i.e. in the first century A.D. it was one of the first emigrants to America in the fifteenth century.
- De candolle thought that the Pummelo originated in the Island east of Malaya Archipelago.
- The Grape fruit has never been found in old world except where it has been introduced. It owes its origin as a seedling or bud mutation from pummelo in west India.
- Genus Poncirus and genus Fortunella are native to China.

**Botany:**

Citrus fruits are members of the Rutaceae family, which contain more than a thousand species mostly found in the tropical region of Africa, South East Asia and Australia.

The basic botanical classification of citrus fruits right from the natural order to genus is as follows:

<table>
<thead>
<tr>
<th>Order</th>
<th>Geraniales (21 families)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sub-order</td>
<td>Garaniinae (12 families)</td>
</tr>
<tr>
<td>Family</td>
<td>Rutaceae (7 sub-families)</td>
</tr>
<tr>
<td>Sub-family</td>
<td>Aurantioideae (2 tribes)</td>
</tr>
<tr>
<td>Tribe</td>
<td>Citrae (3 sub tribes)</td>
</tr>
<tr>
<td>Sub-tribe</td>
<td>Citrinae (3 groups, 13 genera)</td>
</tr>
<tr>
<td>Group C</td>
<td>The citrus fruit trees (6 genera)</td>
</tr>
<tr>
<td>Genus</td>
<td>1. Poncirus (1 species)</td>
</tr>
<tr>
<td></td>
<td>2. Fortunella (4 species)</td>
</tr>
<tr>
<td></td>
<td>3. Citrus (2 sub genera)</td>
</tr>
<tr>
<td></td>
<td>(a) Eucitrus (b) Papeda.</td>
</tr>
</tbody>
</table>
Poncirus
The native home of the trifoliolate orange is Central and northern China, where it is widely distributed, wild or cultivated throughout the country.

Fortunella (Kumquats)
1. *F. margarita* (Nagami Kumquat)
2. *F. japonica* (Marumi Kumquat)
3. *F. crassifolia* (Meiwa Kumquat)
4. *F. hindsi*i (Hong Kong wild Kumquat)

Citrus
These are natives of China, the Malaya Archipelago and adjoining Parts of Asia.

**Major citrus growing countries:**

Citrus growing countries:

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Country</th>
<th>Production (000'Mt.)</th>
<th>Contribution towards world production (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Brazil</td>
<td>17693.0</td>
<td>19.1</td>
</tr>
<tr>
<td>2</td>
<td>USA</td>
<td>16469.3</td>
<td>17.5</td>
</tr>
<tr>
<td>3</td>
<td>China</td>
<td>7909.5</td>
<td>8.8</td>
</tr>
<tr>
<td>4</td>
<td>Spain</td>
<td>5167.7</td>
<td>6.7</td>
</tr>
<tr>
<td>5</td>
<td>Mexico</td>
<td>4458.0</td>
<td>5.7</td>
</tr>
<tr>
<td>6</td>
<td>India</td>
<td>4430.0</td>
<td>4.8</td>
</tr>
</tbody>
</table>

Citrus growing regions of India:

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Region</th>
<th>States</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>North West India</td>
<td>Gujarat, Haryana, Himachal Pradesh, Punjab, Rajasthan</td>
</tr>
<tr>
<td>2</td>
<td>North East India</td>
<td>Arunachal Pradesh, Assam, Manipur, Mizoram, Meghalaya, Nagaland, Sikkim, Tripura, Bihar, Orrisa, Uttar Pradesh</td>
</tr>
<tr>
<td>3</td>
<td>Central India</td>
<td>Madhya Pradesh, Maharashtra</td>
</tr>
<tr>
<td>4</td>
<td>South India</td>
<td>Andhra Pradesh, Karnataka, Tamilnadu</td>
</tr>
</tbody>
</table>

**Points for successful citrus production:**

1. Suitable land
2. Disease free planting material with healthy root system
3. Sufficient number of trees per unit area
4. Good cultural practices
5. Sufficient fertilizer and proper water supply
6. Good plant protection
7. Good post harvest management
8. Development of cooperative marketing system
2. **Development of Citrus industry / Future strategies:**

For increasing the production by minimizing input cost and reduction in post harvest losses to increase the returns to the citrus growers following future strategies should be adopted.

1. **Citrus improvement / Genetic resources:**
   (a) Collection and evaluation of germplasm of Mandarin, Sweet orange, Acid lime, Lemon and rootstock from indigenous and exotic sources for desired horticultural characters and processing qualities.
   (b) Improvement of commercial cultivation of citrus fruits through clonal selection, Nucellar seedlings selection and mutation breeding for desirable horticultural and processing characteristics.
   (c) Improvement of citrus fruits through hybridization for tolerance to salinity, drought, disease and insects.

2. **Development of package and practices (production technology):**
   (a) Nursery management
   (b) INM studies by developing leaf nutrient indices as ready reckoner to diagnose the fertilizer requirement.
   (c) Development of Fertigation techniques for fertilizer use efficiency and better monetary returns.
   (d) IWM studies to workout the water requirement at different stage of growth for optimum utility of water.
   (e) Identification of suitable rootstock for high density planting to increase the productivity per unit area.
   (f) Identification of suitable citrus based inter cropping system.
   (g) Flowering behavior and crop regulation to control irregular crop in commercial citrus cultivars.
   (h) Efficient land use management for citrus.
   (i) Amendment of problematic soil of orchards.
   (j) Methodology of applying ponds water through sprinkler and drip irrigation.
   (k) Development of suitable drainage system.
   (l) Use of water harvesting and moisture conservation techniques under rainfed condition.
   (m) Crop regulation for want of desire crops.
(n) Bahar treatment for maximum flowering and fruiting.
(o) Replant problem and their solution.
(p) Development of production technology for export quality production.
(q) Ideal rootstock-scion combination for different agro climatic regions.
(r) Control of soil erosion and nutrient losses due to runoff water.
(s) Citrus based integrated farming system including bee keeping.
(t) High-density multi species mixed cropping system.
(u) Development of technology for rejuvenation of declined orchards.
(v) Development of IPM for control of insect-pests and diseases.

3. **Plant Protection technology:**

(a) Development of forecasting models for the outbreak of insect-pests and diseases.
(b) Development of location specific integrated management strategies for major insect-pests and diseases, exploitation of biological control, alternative eco-friendly control measures.

4. **Post harvest technology:**

At national level there is an urgent need to develop maturity standards for harvesting of all commercial varieties of citrus, especially for mrig bahar crop of Nagpur / Kinnow and Khashi mandarin, Mosambi and Sathgudi orange. Similarly, standardization of post harvest treatment and storage techniques for control of post harvest disease of citrus. Irradiation processing and controlled atmosphere storage should be also standardizing for increasing the shelf life of citrus fruits.

5. **Citrus processing:**

Feasible and economically viable processing technology should be developed for debittering of Kinnow/ Nagpur mandarin juice without affecting natural qualities. Method for preservation of natural qualities of Nagpur mandarin juice as a viable alternative of synthetic soft drinks as well as technology for extraction of colour pigments and flavonoids from citrus processing waste should be also develops.
Problems of citrus industry:

1. Non-availability of disease free planting material.
2. Irregular bearing.
3. Scarcity of water for irrigation.
4. General neglect.
5. Poor water management practices.
6. Cultivation in unsuitable soils.
7. Wide use of rough lemon as rootstock, which is susceptible to phytophthora and salinity.
8. Improper fertilizer schedule in the absence of information on nutrient constraints existing in the orchards.
9. Incidence of citrus black fly (Kolshi / Sooty mould), Psylla, leaf minor, lemon butterfly / orange dog, mites, bark eating caterpillar, trunk borer, mealy bug and aphids.
10. Heavy infestation of phytophthora, root rot in nursery and grown up orchards, canker and virus diseases.
11. Improper post harvest handling.
3. CLASSIFICATION OF CITRUS FRUITS

Criteria for classification of Citrus:

Taxonomists have employed different criteria for classifying citrus fruits. The important characters, on which classification was based are elucidated below:

1. **Plant characters**: Hardiness to cold, height, habit, mode of branching, foliage, nature of thorns, roundness of branches, pubescence.

2. **Leaf characters**: Shape, size, thickness, apex, margin, colour, vines, wings, articulation, aroma of crushed leaf and pubescence of leaf.

3. **Floral characters**: Sex, solitary or crowded, size of peduncle, pedicel, size of flower, pubescence, colour, shape of calyx, division of sepals, stamens free or united, nature of anthers, ovary size, shape, colour, style size, nature of stigma, fragrance of flowers and nature of inflorescence.

4. **Fruit characters**:
   (a) **External characters**: colour, shape, size, surface, base of calyx, areole, persistency.
   (b) **Internal characteristic**: Nature of rind (thickness, firmness and adherence), density of oil gland, colour of glandular layers, taste of mesocarp, number and size of carpel’s, pulp colour and texture, size and shape of juice vesicles, closely or loosely packed, arising from dorsal or radial side of carpellary wall, presence or absence of acrid oil, axis, hollow or solid, juice taste, quality, amount and flavor, sugar and acid content, seeds-number, size, shape. Colour of cotyledons, colour and nature of embryo whether monoembryonic or polyembryonic, number of embryos.

Classification of Citrus:

Citrus fruits are the members of the Rutaceae family which contain six genus and more than 1000 (thousand) species mostly found in the tropical and sub tropical regions of Africa, South East Asia and Australia.

Order : Geraniales
Family : Rutaceae
Sub family : Aurantioideae
   (1) Citrus
   (2) Poncirus
   (3) Fortunella
1) **Classification According to Swingle:**

Genus Citrus : 16 species  
Sub genus : (1) Eucitrus (10 species)  
(2) Papeda (6 species)

2) **Classification According to Tanaka:**

Genus citrus : Recognized more than 144 species  
Sub genus : (1) Archi-citrus (98 species)  
(2) Meta citrus (46 species)

3) **Classification According to Hodgson:**

On the basis of critical study of classification made by Swingle and Tanaka, a simple classification of citrus fruit made by Hodgson by grouping the different citrus fruits under four different groups are as follows:

(A) **Acid members Group (9 species):**

1. *C. aurantifolia*  -  Lime  
2. *C. lemon*  -  Lemon  
3. *C. Jambhiri*  -  Rough Lemon  
4. *C. limettoides*  -  Sweet Lime  
5. *C. medica*  -  Citron  
6. *C. limetta*  -  Lemon x Lime  
7. *C. latifolia*  -  Tahiti lime/Persian lime  
8. *C. karna*  -  Karna Khatta  
9. *C. limonia*  -  Rangpur lime (mandarin lime)

(B) **Oranges Group (2 species):**

1. *C. sinensis*  -  Sweet orange  
2. *C. aurantium*  -  Sour orange

(C) **Mandarins Group (4 species):**

1. *C. reticulata* (Mandarin orange, Indo-China origin)  
2. *C. unshiu* (Satsuma mandarin/Japanese origin)  
3. *C. deliciosa* (Mediterranean mandarins)  
4. *C. noblis* (*C. reticulata* x *C. sinensis*)
(D) Pummelos Group (2 species):
1. C. paradisi (Grape fruit)
2. C. maxima / C. grandis (Pummelo/Shaddock)

Other Related Genera of Citrus Fruits:

(E) Poncirus (one species)

Poncirus trifoliata : Trifoliate orange.

This is a distinctive genus with single species. Plant deciduous with trifoliate leaves, highly thorny and fruits inedible. Seeds polyembryonic and the species is principally used as root stock for citrus.

(F) Fortunella (Kumquats: 4 species):

1. F. margarita (Nagmi Kumquat)
2. F. japonica (Marumi Kumquat)
3. F. crassifolia (Meiwa Kumquat)
4. F. hindsii (Hongkong wild Kumquat)

Trees small hubby / bushy with very small oval or round orange coloured fruits. These species of Kumquat are used for candying, ornamental purpose and as dwarfing rootstocks.
4. METHODS OF PROPAGATION

1. By seed (Nucellar seedlings), Cross protected plants
2. By cutting:
3. By layering: Ground and Air layering
5. By budding: Shield, T, Inverted T

Micro Propagation:
1. Tissue culture
   (a) Nucellus culture In vitro
   (b) Ovule culture
   (c) STI
2. Cell culture / Somatic cell
3. Embryo culture
4. Anther culture
5. Endosperm culture (Produce triploid seedless fruits)
6. Chloroplast culture

Citrus fruits and methods of propagation:

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Crop</th>
<th>Commercial method of propagation</th>
<th>Time of propagation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Mandarin,</td>
<td>Shield budding, T budding, Inverted T budding, Some</td>
<td>September-October, February-</td>
</tr>
<tr>
<td></td>
<td>Sweet orange</td>
<td>time Patch, Side, cleft grafting</td>
<td>March</td>
</tr>
<tr>
<td>2</td>
<td>Lime, Lemon</td>
<td>Air layering, STG, Nucellar seedling</td>
<td>July-September</td>
</tr>
</tbody>
</table>
5. **ROOT STOCKS AND SCION RELATIONSHIP**

**Qualities of a good rootstock:**

1. Rootstock must have a high degree of congeniality with the scion variety.
2. It should be well adapted to the agro-climatic conditions of the proposed area.
3. It should be resistant to diseases and pests.
4. It should have favourable influence on the performance, bearing and quality of fruits of scion.
5. It should have other desirable qualities like salt tolerance, drought resistant, frost endurance.
6. It should possess good nursery characters like good germination, high degree of polyembryony, ability to attain grafted size in a short period.

**Rootstock and scion relationship in citrus:**

1. **Effect of root-stock on vigour of scion:**
   
   Rough lemon and tryoer Citrange exhibited vigorous growth with most of the citrus species.
   
   Trifoliate orange, Fortunella species and sweet lime exhibited dwarfing effect on most of the citrus species.

2. **Effect on precocity:**
   
   Rough lemon produces heavy crop at an early stage. Sweet lime induces early when Mosambi budded on it.

3. **Effect on productivity and yield:**
   
   In general, vigorous rootstock like rough lemon produces more crop over a larger period. On the other hand dwarfing rootstock are more fruitful in high density planting.

4. **Effect on fruit size, colour and quality:**
   
   Dwarfing root stock produce larger fruit like trifoliate orange stock with Valencia oranges. While vigorous rootstocks like sweet orange produce the smallest fruits. The sour orange rootstock produces smooth, thin skinned, juicy fruits with excellent quality of sweet orange, mandarin and grape fruit, which store well without deterioration. However, fruits on rough lemon stock are often thick skinned, coarse, inferior in quality and low in sugar, acid and TSS but high in ascorbic acid.

> Trifoliate orange and Cleopatra mandarin stocks produced fruits with juice high in acidity and TSS but low in ascorbic acid.
Fruit borne on trifoliate orange are free from bitterness when canned while, fruits on rough lemon are very bitter when canned.

Vigorous rootstock such as rough lemon produce more granulated fruits.

5. Effect on winter hardiness:
Trifoliate orange and it's hybrids, Kumquat and it's hybrids are seem to be winter hardy. Rangpur lime roots survived much better than those on rough lemon or sour orange.

6. Effect on nutrition:
- Tresses on rough lemon are less susceptible to boron deficiency in the soil than trees budded on sour orange due to more efficient uptake of boron by rough lemon.
- Rough lemon, sour orange and Cleopatra mandarin are associated with high Ca and Mg and low P and K in the leaves.
- Trifoliate orange stock increases the K₂O and Mg contents of leaves of scion.

7. Effect on disease resistant / biotic and abiotic factors:

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Crop</th>
<th>Resistant to</th>
<th>Salt (Biotic)</th>
<th>Drought (Abiotic)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Tristeza</td>
<td>Exocortis</td>
<td></td>
</tr>
<tr>
<td>1.</td>
<td>Rangpur lime</td>
<td>R</td>
<td>S</td>
<td>R</td>
</tr>
<tr>
<td>2.</td>
<td>Rough lemon</td>
<td>R</td>
<td>R</td>
<td>T</td>
</tr>
<tr>
<td>3.</td>
<td>Sour orange</td>
<td>HS</td>
<td>T</td>
<td>T</td>
</tr>
<tr>
<td>4.</td>
<td>Cleopatra mandarin</td>
<td>R</td>
<td>R</td>
<td>MT</td>
</tr>
<tr>
<td>5.</td>
<td>Trifoliate orange</td>
<td>R</td>
<td>HS</td>
<td>HS</td>
</tr>
</tbody>
</table>

R- Resistant  S- Susceptible  T- Tolerant
MT- Moderately tolerant  HS- Highly susceptible
Characteristics of Important citrus root stocks:

1. **Sweet orange (Citrus sinensis Osbeck):** Large vigorous tree, tolerant to quick decline, tolerant to tristeza, susceptible to gummosis, more sensitive to soil salinity.

2. **Sour orange (Citrus aurantium):** Susceptible to quick decline, tolerant to salts, well suited for heavy moist soils, endures drought, severely affected by lime chlorosis.

3. **Trifoliolate orange (Poncirus trifoliata):** Hardest rootstock, not suitable for calcareous soils, resistant to gummosis and nematodes.

4. **Rough lemon (Citrus jambhiri Lush):** Sensitive to cold, good adaptability to light sandy soils, tolerant to salts, endurance to gummosis.

5. **Rangpur line (Citrus limoni Tanaka):** Highly resistant to tristeza, tolerant to salts, susceptible to exocorticis and gummosis.

6. **Troyer citrange (Citrus sinensis x Poncirus trifoliata):** Highly resistant to gummosis, tolerant to quick decline, well suited for cold area.
6. **BUD VARIATION AND BUDWOOD CERTIFICATION**

**Bud Variation:** Abnormal variations, occurring in stems, leaves and fruits that are capable of perpetuation by budding are coined as bud variations. They arise in the somatic cells of the plants and are inheritable. Bud variations also called as bud sports originate by any of the somatic mutations or chromosomal changes.

**Causes of bud variations:** Shamel summarises the probable causes of bud variations in citrus thus:

(i) Abrupt variations in plant food, soil moisture, climatic or other environmental influences during the most active growing periods, which may cause shocks to plant growth.

(ii) The sorting out or the segregation of hybrid characters.

(iii) The mixture in the somatic cells of different kinds of tissues, which develop into mutations commonly, called “chimeras” of either sectorial or the periclinal type or both.

(iv) Mechanical injuries or related influences such as those due to cutting or in some way interfering with or changing the natural growth of the tissues, as in the bending of the plants by the winds in pruning or in other plant disturbances.

(v) The effect of penetrating rays such as X-rays or other waves of energy.

(vi) Place effect or the effect of a decided change in environmental conditions due to location.

**Bud Selection:** Taking of buds for purpose of multiplication form trees selected on the basis of performance records and intimated tree knowledge is referred as bud selection.

The isolation of superior types can be achieved by progeny propagation of desirable variations, spotted on survey of the existing orchards. Elimination of inferior strains may be achieved by (a) Avoiding further propagation of these strains (b) by top working the trees of such strains and (c) by replanting with trees of dependable strains.

**Bud Selection Methods:**

(i) Individual tree performance records

(ii) Selection of parent trees

(iii) Selection of Bud wood

(iv) Progeny propagations
**Citrus bud wood certification:**

Certification programmes have the objectives of producing certified planting material of citrus species which gives guarantee of disease-free and desirable horticultural characters of the plants. Because the plants are the foundation on which an orchard is built. If the plants are reliable and of guaranteed performance, they will be high yielding and will produce quality fruits. Thus bud wood certification programmes ensure sound scientific footing of the citrus industry of any country.

1. **Methods of citrus bud wood certification programme:**
   
   (i) The following steps are involved in bud wood certification programme.
   
   (ii) Selection of local superior mother plants or importing of bud wood of foreign varieties.
   
   (iii) Propagation and virus indexing or therapy / STG.
   
   (iv) Raising of virus-free planting material.
   
   (v) Raising of disease-free planting material in protected foundation block or foundation block at nursery.
   
   (vi) Virus indexing, evaluation and inspection.
   
   (vii) Certification of plants.

   OR

   (i) Raising of desirable rootstocks in insect-free net house.
   
   (ii) Raising of virus-free scion bank/mother plant.
   
   (iii) Massive multiplication of plants under net house.
   
   (iv) Indexing of plants for certification and quarantine programme.
   
   (v) Certified plants for sale.

2. **Method of indexing of virus-free plants:**

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Detection technique</th>
<th>Disease detected</th>
</tr>
</thead>
<tbody>
<tr>
<td>A.</td>
<td>Biological method</td>
<td></td>
</tr>
<tr>
<td>Indicator plant</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(i) Mexican lime</td>
<td>Tristeza virus</td>
<td></td>
</tr>
<tr>
<td>(ii) Pineapple sweet orange</td>
<td>Psorosis, Ring spot, Greening</td>
<td></td>
</tr>
<tr>
<td>(iii) Sweet tangor</td>
<td>Psorosis, Ring spot, Mosaic</td>
<td></td>
</tr>
<tr>
<td>(iv) Etrog citron</td>
<td>Exocortis, Tristeza</td>
<td></td>
</tr>
<tr>
<td>B.</td>
<td>Microscopy method</td>
<td></td>
</tr>
<tr>
<td>(i) Electron</td>
<td>Tristeza, Ring spot, Mosaic and other viruses. Phytoplasma</td>
<td></td>
</tr>
<tr>
<td>(ii) Fluorescence</td>
<td>Phytoplasma</td>
<td></td>
</tr>
<tr>
<td>C.</td>
<td>Molecular and Biotechnological methods</td>
<td></td>
</tr>
<tr>
<td>(i) Electrophoresis</td>
<td>Tristeza</td>
<td></td>
</tr>
<tr>
<td>(ii) RNA / DNA test</td>
<td>Tristeza</td>
<td></td>
</tr>
<tr>
<td>D.</td>
<td>Serological method</td>
<td></td>
</tr>
<tr>
<td>(i) ELISA technique</td>
<td>Tristeza</td>
<td></td>
</tr>
<tr>
<td>(ii) DIBA technique</td>
<td>Tristeza</td>
<td></td>
</tr>
</tbody>
</table>
3. Integrated disease management for bud wood certification:

For successful bud wood certification programme several aspects such as regulation, cultural practices, sanitation, quarantine, vector control, vaccination / cross protection and resistance host must be included for the success of any certification programme.

(i) Regulation:

Regulation is vital part of bud certification scheme which ensure that all bud wood available in the country is virus / disease free. This is the first time of defense against the introduction of viral diseases into a region, which involves mandatory certification of every tree for plantation.

(ii) Quarantine:

The main objective of quarantine is avoiding of introduction of insect-pest and diseases by therapy, which may be carried through the imported planting material.

(iii) Sanitation:

The objective of sanitation programme is to recover healthy plants by selection of mother tree from local cultivars, virus indexing of mother plants, recovery of pathogen free plants by shoot tip grafting (STG), horticultural evaluation of healthy plants and maintenance of healthy plants.

(iv) Cultural practices:

Most of the diseases like ring spot, mosaic and Exocortis are transmitted through field implements during harvesting, pruning and grafting. Hence, tools should be adequately disinfected with 2% sodium hypochlorite or other detergents prior to fruit picking; pruning, grafting and budding to avoid mechanically transmitted diseases.

(v) Vector control:

Most of the virus diseases are transmitted by aphids and psylla. Hence, these insect vectors should be controlled by using biological and non-biological methods in order to stop spread of virus diseases.

(vi) Vaccination / Cross protection:

Cross protection is the phenomenon which occurs when a particular plant is previously inoculated with a mild strain of Citrus Tristeza Virus (CTV), does not display symptoms of more severe strain of CTV in the plant. This technology is being used commercially in many areas for the last four decades. Over 15 million trees are cross
protected against stem pitting of sweet orange and grape fruit is being used on a large scale in Brazil, Africa, Australia and Japan.

(vii) Transfer of resistance gene (Host-resistance):

This technology is being used for evolving of new virus resistant varieties by transfer of virus resistant gene from virus resistant variety. Many CTV tolerant rootstocks have been obtained by using the gene of *Poncirus trifoliata*. Virologists of developed countries have successfully transferred virus resistant gene in plants to produce genetically engineered “Transgenic plants” which exhibit virus resistance. Though these plants are not completely immune to CTV but may prove useful as CTV tolerant.

4. Future thrusts for bud-wood certification:

In India, a sound citrus certification programme is the urgent need, but this may take time due to limited infrastructure and proper trained manpower. The other major drawback towards achieving a successful certification scheme is the lack of participation of the farmers due to lack of awareness.

The presence of diseased in field also hampers the progress of the certification programme as these trees serve as a source of infection to certified trees. Therefore, timely detection of such virus infected plants subsequently their eradication is highly essential. In near future the various disease management strategies must be used in order to protect susceptible cultivars. Some diseases not transmitted through vectors, this may require the application of current existing technologies such as virus free bud wood. For other diseases, it will require better knowledge of host pathogen, vectors interactions involved and innovative use of new approaches. Study of the evaluation of virus suggested that most of citrus diseases have co-evolved with citrus in field conditions in the centre of origin and diversification. Hence, an efficient certifications and quarantine programme may prevent and reduce the possibility of a new disease, but may not prevent them all together. Therefore, pathologist should always be on their toes to identify and control previously unknown diseases before they spread and cause considerable damage.
7. MAJOR CITRUS SPECIES/VARIETIES OF HORTICULTURAL IMPORTANCE

(A) Acid Group:

Botanical Name

1. *C. aurantifolia* - Acid / Sour lime: Kagzi lime, Pramalini, Vikram, Rasraj (IIHR) Sairsharbati (MAU), Jai Devi, Mexican lime, Palmetto, Mexican.

2. *C. lemon* - Lemon

: Eureka and Lisbon (USA), Bernia (Spain) Kagzi Kalan, Italian round, Assam lemon, Nepali oblong, Baramasi Galgal, Pant seedless lemon, Lucknow seedless, Hill malta, Indore seedless

3. *C. jambhiri* - Rough lemon : Jambhiri

4. *C. limettoides* - sweet lime : Mitha nimbu / Sharbati, Palestine sweet.

5. *C. latifolia* - Tahiti lime : Seedless lime (Tahiti), Pond Bearss

6. *C. limonia* - Mandarin lime : Rangpur lime

(B) Orange Group:

1. Sweet orange Group

: Mosambi, Malta Blood Red, Valencia, Pineapple, Washington Navel (USA), Shamouti (Israel) Succar (Egypt), Dobla Fina (Spain) Sathgudi (India), Jaffa, Hamlin, Ruby

(a) Common oranges : Pineapple, Hamlin, Jaffa, Valencia

(b) Acid less group : Mosambi, Succar

(c) Pigmented group : Blood Red, Ruby, Moro, Torócco.

(d) Navel group : Washington Navel, Roberston

2. Sour/Bitter orange group

: Sour orange.
(C) Mandarin Group:
1. Reticulata group: Nagpur or Ponkan, Coorg, Khashi and Ponkan mandarin.
2. Unshiu group: Satsuma (Japan) Owari, Kara, Silver Hill.
3. Noblis group: King (USA), Temple
4. Deliciosa group: Kinnow (king x willow leaf) willking (sister hybrid of kinnow), willow leaf, Emperor Blinda, Algerian selection
5. Tangerine group: Dancy, Beauty (those varieties producing deep orange or scarlet fruits, comes under this group)
6. Other species: Calamondin, Spice mandarin (C. reshni)

(D) Pummelo -Grape Fruit Group:
1. Pummelo group: White fleshed, Red or Pink fleshed, Kao pan, Chakaiya, Nagpur Chakotara
2. Grape fruit group: Faster, Ruby, Marsh seedless, Duncan, Thompson, Saharanpur special

(E) Other Wild Semi-Wild Species:
1. Indian wild orange: C. indica
2. Khasiopapeda: C. latipus
3. Papeda: C. macroptera- Satkara, Hitkara and Tithkara
4. Gajanimma of India: C. pennisiculata, used as a root stock

(F) Some Hybrids of Citrus:
(a) Intra-generic:
1. Tangor: Mandarin x Sweet orange -Temple, Clementine, Momeal. are some important cultivars, mostly monoymbryonic.
2. Tangelo: Mandarin x Grape fruit- Orlando, Sampson, Minneola, Seminole etc.
3. Lemonime: Lemon x Lime -having a cultivar like parrine.
4. Lemonange: Lemon x Orange
5. Lemmandarin: Lemon x Mandarin
(b) Inter-generic:
1. Citrange : *Poncirus trifoliata* x *C. Sinensis* - having cultivars like Troyer, Carrizo, Mortán, Rusk, Coleman etc.

(G) Some Important Species/ Varieties of Citrus used for Root Stock :
1) Rangpur lime
2) Rough lemon/Jambhiri
3) Cleopatra mandarin
4) Trifoliata orange
5) Troyer Citrange
6) Sour orange
7) Karna Khatta
8) Jatti Khatti
9) Carrizo Citrange
10) Severinia
11) Marmalade orange
12) Flying Dragon
13) Calamondin
14) Nasnaran
15) Willow leaf mandarin
16) Rich 16-6
17) X-639
18) Gajanimma
19) Citrumelo
20) Kitchli
21) Kodakithuli
8. **SOIL AND CLIMATE**

Soil is an important natural factor, which determines the success and failure of a crop. Because soil furnishes water and nutrients for its growth and development. For good performance citrus require a deep, well-drained soil, free of excess salt with fair humus content. Though citrus can be grown on all types of soil, However, in view of the high oxygen requirements of its roots, light sandy to medium loam soils are considered best. The following properties of soil should be kept in mind before selecting the soil for citrus cultivation.

1. **Water drainage:**

   Drainage of water is more important than any other factor, because citrus roots have high requirements of oxygen due to lack of root hairs and accumulation of free water in the root zone results in poor aeration which hindering the function of root lets. Under prolonged conditions of poor drainage, progressive injury and death of roots occur. Resistance of the roots to root rot and other soil conditions also gets reduced under poor drainage conditions. On the other hand, the performance of citrus is exceedingly well in sandy soils due to good drainage conditions, which provided sufficient nutrients. Sticky heavy soils through which water does not readily percolate should be avoided.

2. **Depth of soil:**

   2 to 3 meters deep well drained soils without any hard pan in sub soil, allow good depth for root development, producing trees of standard size, heavy yield and long life. Shallow soils with hardpan layers in the sub soils produce sub standard trees with short life span and poor yields.

3. **Nature of sub soil:**

   Nature of the sub soil is more important than that of a surface soil, because it effects the depth, drainage and fertility of the soil and ultimately the performance of orchard trees. Soils with hardpan within 2 meters of the sub soil due to either calcium carbonate (CaCO₃) concentrations or clay should be avoided, as they affect both the permeability and aeration of soils. High proportion of CaCO₃ and presence of hardpan layer are hazardous for successful citrus cultivation. Soils with large amount found toxic and harmful to the citrus especially oranges should be avoided. A high content of CaCO₃ in cirrus soils is important contributing factor for deficiencies of Zinc, Iron and manganese. Therefore, soils containing more than 5 % lime in any of the horizon upto 2 meters depth should not be selected for citrus cultivation.
4. Soil reaction:

pH value of 5.5 to 6.0 is considered to be an optimum for citrus cultivation, as lower levels tend to increase leaching of lime and magnesium and higher levels are likely to reduce the availability of trace elements. Nevertheless, citrus orchards continue to flourish on soils with pH value of 4.0 to 8.5 and even higher. Hass reported that citrus grows better in acid than in alkaline medium.

5. Salt:

Health of citrus trees adversely affected due to excess salt in the soil. Therefore, soils in which the total concentration of salts exceeds 1000 ppm should be discarded for citrus cultivation. Kanwar and Randhawa found that soil salinity is one of the important causes of chlorosis in citrus.

6. Type and fertility of the soil:

Sandy and gravelly soils are suitable in the high rainfall areas like Khashi hills of Assam and projecting for provide good drainage. Well-drained heavy soils may produce good crop but increase the difficulty in cultivation. But still deep black cotton soils of fine texture, which cracks during summer, are not suitable.

Climate:

Climate is a deciding factor about success or failure of a given crop at a given place. Among the climatic factors temperature is most important factor influencing the performance of citrus followed by rainfall, humidity, altitude and winds.

1. Temperature:

The temperature range within which the citrus tree is able to grow, develop and fruit is 14-40 °C. However, the best growth and performance occurs under around 32 °C or within 29-35 °C. Fruit maturation including production of sugar and development of rind colour reach its highest perfection in the lower range of temperature i.e. 29-32 °C.

The maximum temperature that citrus can endure may be about or slightly higher than 50 °C. Sweet oranges are being successfully grown under temperature upto 46 °C in Deccan plateau of India and even upto the temperature of 52 °C in Northern Rajasthan, western U.P. and Punjab. Any temperature below freezing (0 °C) is dangerous for citrus cultivation especially when it persists long enough.
2. Relative humidity:

Atmospheric humidity has a greater role in the performance of citrus. In general, low humidity gives good colour and external appearance, whereas high humidity favours thin skinned juicy fruits, which are smaller in size but high in quality. Disease infection is favoured by high humidity. As such desert areas are remarkably free from disease like gummosis and canker etc. Low humidity promotes transpiration and loss of water resulting in fruit abscission. For the best performance of citrus average relative humidity should be in between 50-55%.

3. Rainfall:

Proper distribution of rainfall is more important than the total rainfall. The annual rainfall of 700 mm is considered adequate to provide it is favorably distributed. While the annual rainfall of 1250 to 1850 mm is generally regarded as sufficient. Best quality fruit grows in semi arid, subtropical regions with less than 500 mm of rains, when orchards are irrigated. Under such conditions, especially with warm days and cool nights, the fruit acquires a good colour even on the tree itself. Whereas, in the humid tropics even ripe fruits remain green. However, heavy rainfall in the two months before harvest influences the quality of citrus fruits by reducing TSS and acidity.

4. Winds:

Exposure of strong winds whether hot or cool is harmful to citrus trees, flowers and young fruits. Therefore, windbreak should be planted in regions where stormy winds are prevalent.

5. Altitude:

The commercial citrus areas of the world are located mainly at moderate elevations ranging from slightly above sea level to 450-750 m. In India, citrus fruits are grown from sea level to an elevation 1500 m, in California 700 m, in Spain upto 250 m, although in South East Asia trees of citrus species flourish at altitude upto 2000 m but the culture becomes hazardous at such higher elevations.
9. TRAINING & PRUNING

Pruning in citrus:

1. Pruning of young and pre bearing plants
2. Pruning of bearing trees
3. Pruning of older trees
4. Pruning of neglected trees
5. Pruning of over grown trees
6. Hedging of trees
7. Root Pruning
8. Pruning for top working

Purpose of pruning:

2. To giving the shape or framework.
3. To control disease and insects.
4. To increase the productivity
5. To increase the productive shoot in unproductive trees.
6. To penetrate the sunlight.
7. To inducing flowering.
8. To check the over growth / vigour.

- An ideal citrus tree should be low headed, with almost globular periphery dome like crown and with foliage extending to the ground.
- Training of plants in the nursery consist of staking the scion shoot in order to get a straight stem of about 75 cm length removal of stock sprouts and side buds on the shoot and finally heading back of the plant at a height of 75 cm from the ground and allowing 3-6 well spaced shoots to develop at 7-10 cm apart on the upper portion of the scion shoot.
- The main object of pruning the bearing trees is to maintain the frame work and to secure higher yields and better grade fruits each year, Pruning of bearing citrus trees, though differ with the variety chiefly consist of removal of dead, dried, disease and broken branches, whose existence on the tree is determinately to the health of the tree, removal of water shoots and suckers is also essential.
- Old trees become unproductive as they fail to put its adequate new growth. Pruning is not generally advocated to stimulate new growth on such trees. Ordinarily good orchard management practices like judicious manuring and irrigation are sufficient to stimulate the new growth on such trees.
- If the neglected trees are young it is usually best to remove them and replant with vigorous new stock. On the other hand if the neglected trees are old they can be brought back into bearing condition by causations pruning.
- Citrus trees may be pruned at any time but it is better to avoid those periods when the trees are in active in growth. The best time for pruning the bearing trees is after the harvest of the fruits during late winter or early spring when they are in dormant stage.
10. NUTRIENT MANAGEMENT

Citrus like other plant also requires a number of mineral nutrients for proper growth and development. The following table given an idea about the general composition of the oranges.

Elements composition of the Vegetative parts of the Citrus plant

<table>
<thead>
<tr>
<th>Part</th>
<th>Percentage dry matter</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
</tr>
<tr>
<td>Leaves</td>
<td>2.22</td>
</tr>
<tr>
<td>Twigs</td>
<td>1.02</td>
</tr>
<tr>
<td>Trunk &amp; main branches</td>
<td>0.40</td>
</tr>
<tr>
<td>Roots</td>
<td>0.82</td>
</tr>
</tbody>
</table>

NITROGEN

Deficiency: General and uniform yellowing of leaves, particularly of the veins is the first symptom of nitrogen deficiency. The intensity of yellowing depends on the magnitude of nitrogen starvation.

Toxicity: Excess nitrogen causes thickening and softening of rind and lowers the resistance power of plants to diseases.

PHOSPHORUS

Deficiency: Phosphorus deficiency causes low assimilation rate, diminishes vegetative growth, causes defective formation of buds, poor fruit setting, bending and discoloration of leaves, which lose their deep green colour and fade to bronze. Lateral shoots are reduced and grow less vigorously. Lateral buds may remain dormant or die. Premature drop of fruits results.

Toxicity: Excessive phosphorus results in the aggravation of mottle leaf (Zinc deficient) and copper deficiency. It reduces the content of solids in fruit juice, inhibits root growth and lowers frost resistance.

POTASSIUM

Deficiency: Potassium deficiency result first in slowing down the growth accompanied by defoliation at flowering time. Growth is retarded especially in the tops of older trees. Weak shoots tend to develop but are shed before hardening. Foliage is sparse, somewhat bronzed and lusterless. With more acute deficiency the leaves crinkle and twist in the form of ‘S’.

Excess potassium tends to limit calcium and magnesium absorption and leads to manganese and zinc deficiencies.
MAGNESIUM

Deficiency: Magnesium deficiency is commonly characterized by bronzing. In India it was reported from Assam and Madras. The deficiency is mostly noticed in highly acidic soil, where it is leached out. Under field conditions, antagonism between the major bases viz; potassium, calcium and magnesium was reported.

ZINC

Deficiency: Zinc deficiency is widespread all over the world. A number of names have been given to zinc deficiency such as “frenching” in Florida, “mottle leaf or little leaf or foliocellosis” in California and India.

Zinc deficiency is next to nitrogen deficiency in citrus. The characteristic symptom of deficiency is the interveinal chlorosis of leaves. While the midribs and veins and tissue along them remain green. The inter spaces become lighter green, greenish yellow or even very pale yellow according to the severity of deficiency. The subsequent flush produces markedly reduced leaves.

COPPER

Deficiency: Excess of nitrogen induces copper deficiency. Indiscriminate use of lime renders both copper and zinc unavailable. Deficiency of copper occurs on leached acid sandy soils or even on those with high organic matter.

Dieback ‘ammoniation’, ‘red-rust’ and ‘exanthema’ are the common names used for copper deficiency, which may be caused by copper deficiency in the plant or unbalanced copper and nitrogen ratio.

Table 1: Nutrient uptake (kg/ha) by various Citrus Spp.

<table>
<thead>
<tr>
<th>Fruit and type</th>
<th>N</th>
<th>P₂O₅</th>
<th>K₂O</th>
<th>CaO</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Oranges</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High yielding</td>
<td>243</td>
<td>54</td>
<td>205</td>
<td>316</td>
</tr>
<tr>
<td>Medium yielding</td>
<td>169</td>
<td>41</td>
<td>146</td>
<td>297</td>
</tr>
<tr>
<td>Poor yielding</td>
<td>36</td>
<td>22</td>
<td>77</td>
<td>206</td>
</tr>
<tr>
<td><strong>Mandarins</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High yielding</td>
<td>182</td>
<td>54</td>
<td>205</td>
<td>273</td>
</tr>
<tr>
<td>Medium yielding</td>
<td>116</td>
<td>36</td>
<td>130</td>
<td>214</td>
</tr>
<tr>
<td>Poor yielding</td>
<td>58</td>
<td>20</td>
<td>64</td>
<td>141</td>
</tr>
<tr>
<td><strong>Lemons</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High yielding</td>
<td>270</td>
<td>54</td>
<td>209</td>
<td>358</td>
</tr>
<tr>
<td>Medium yielding</td>
<td>183</td>
<td>34</td>
<td>140</td>
<td>242</td>
</tr>
<tr>
<td>Poor yielding</td>
<td>94</td>
<td>21</td>
<td>77</td>
<td>193</td>
</tr>
</tbody>
</table>
Table: 2   Fertilizer schedules for oranges and mandarins.

<table>
<thead>
<tr>
<th>Age (Years)</th>
<th>FYM</th>
<th>Oil cake</th>
<th>Ammonium Sulphate</th>
<th>Super phosphate</th>
<th>Bonemeal</th>
<th>Woodash</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>10</td>
<td>1</td>
<td>0.25</td>
<td>0.50</td>
<td>0.50</td>
<td>1.50</td>
</tr>
<tr>
<td>2.</td>
<td>20</td>
<td>2</td>
<td>0.50</td>
<td>1.00</td>
<td>1.00</td>
<td>3.00</td>
</tr>
<tr>
<td>3.</td>
<td>30</td>
<td>3</td>
<td>0.75</td>
<td>1.50</td>
<td>1.50</td>
<td>4.50</td>
</tr>
<tr>
<td>4.</td>
<td>40</td>
<td>4</td>
<td>1.00</td>
<td>2.00</td>
<td>2.00</td>
<td>6.00</td>
</tr>
<tr>
<td>5.</td>
<td>50</td>
<td>5</td>
<td>1.25</td>
<td>2.50</td>
<td>2.50</td>
<td>7.50</td>
</tr>
</tbody>
</table>

Table: 3   Manural schedules for mandarins in Coorg (kg/plant).

<table>
<thead>
<tr>
<th>Age (Year)</th>
<th>FYM</th>
<th>Calcium Ammonium nitrate</th>
<th>Single super Phosphate</th>
<th>Muriate of postsh</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>15</td>
<td>0.6</td>
<td>0.6</td>
<td>0.30</td>
</tr>
<tr>
<td>2</td>
<td>25</td>
<td>105</td>
<td>2.0</td>
<td>0.35</td>
</tr>
<tr>
<td>3</td>
<td>30</td>
<td>3.0</td>
<td>3.8</td>
<td>0.70</td>
</tr>
<tr>
<td>4</td>
<td>40</td>
<td>4.5</td>
<td>4.5</td>
<td>1.00</td>
</tr>
<tr>
<td>5</td>
<td>50</td>
<td>6.5</td>
<td>4.5</td>
<td>2.00</td>
</tr>
<tr>
<td>6</td>
<td>50</td>
<td>6.5</td>
<td>4.5</td>
<td>2.00</td>
</tr>
<tr>
<td>7</td>
<td>100 &amp; Above</td>
<td>7.5</td>
<td>6.5</td>
<td>2.00</td>
</tr>
</tbody>
</table>

Table: 4 Manural schedule for sweet oranges.

<table>
<thead>
<tr>
<th>Age (Years)</th>
<th>F.Y.M. (kg)</th>
<th>Ammonium sulphate (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-3</td>
<td>5-20</td>
<td>0.25-0.75</td>
</tr>
<tr>
<td>4-6</td>
<td>20-50</td>
<td>1.00-1.75</td>
</tr>
<tr>
<td>7-9</td>
<td>65-90</td>
<td>1.50-2.00</td>
</tr>
<tr>
<td>10 &amp; above</td>
<td>100-200</td>
<td>2.25-4.00</td>
</tr>
</tbody>
</table>

The following schedule has been suggested for Nagpur oranges.

| Farm yard Manure          | 61.5 kg/tree |
| Super phosphate           | 4.5 kg/tree  |
| Ammonium sulphate         | 2.5 kg/tree  |
| Potassium sulphate        | 0.5 kg/tree  |
| Lime                      | 1.5 kg/tree  |

**Determination of fertilizer needs:**

1. **Soil fertility analysis:**

   The soil fertility concept implies to nutrient status of the soil but does not give any information about the utilization of these nutrients for optimum growth and productivity.

2. **Tissue analysis:**

   Tissue analysis test is a practical tool in determining fertilizer needs for citrus by developing leaf nutrient indices (critical level) for different elements responsible for growth and productivity. There are two saplings techniques of tissue analysis for determining fertilizer needs.
(a) Leaf sampling techniques:

- 6-8 months old leaves for ambia flush
- 5-7 months old leaf for mrig flush

The leaves can be taken from any position out of 2\textsuperscript{nd}, 3\textsuperscript{rd} and 4\textsuperscript{th} leaf on a shoot at a height of 1.5-1.8 meter from the ground and number of leaves as low as 30 covering 2\% trees in an orchard will be sufficient to represent the nutrient status.

(b) Juice analysis:

The juice analysis is advantageous in terms of providing a rapid mean of assessing the nutrient status, better correlation with fruit quality parameters, earlier collection of fruit samples. However, some disadvantages are also associated such as storage and transport of sample is more of a problem with fruits then with dried leaf samples.

3. Bark analysis:

   Used for identification of species of rootstock:

**Methods of fertilizer application:**

Soil Application:

Soil application of manures and fertilizers is the oldest method. It was based on the fact that the primacy. Function of the roots is to absorb plant nutrients from the soil. Soil application is cheaper, easier and the residual effect is longer as compared to foliar applications.

First of all the trunk should be given a hoeing, then the finely powdered manure is evenly broadcasted and mixed well into the soil by giving a second hoeing. This is followed by a judicious irrigation.

Foliar Application.

The fundamental basis of foliar application of nutrients etc. is the fact that leaves readily absorb the applied chemicals.

The significance of foliar application of nutrients especially trace elements was greatly realized and utilized in case of acute deficiencies.
11. BLOSSOM BIOLOGY OF CITRUS

Blossom biology of citrus varies with spices, variety, place and even within a variety at a given place. Blossom biology constituents, blooming or flowering period, flower bud differentiation, flower bud development, inflorescence, sex ratio, anthesis, dehiscence, pollen fertility and stigma respectability.

1. Blooming period:

Different species and cultivars may normally have different blooming periods, influenced by agro-climatic conditions. The Poncirus and fortunella flowers very late i.e. in June and July while most of the citrus species flower in spring i.e. in March-April. The lateness of flowering in Poncirus and fortunella is generally due to their dormancy in winter and late initiation of growth in spring. According to flowering season, there are generally three type of “Bahar” occurred in Indian conditions.

(i) Mrig bahar – Flowering appear during June-July
(ii) Hast bahar – Flowering appear during September-October
(iii) Ambe bahar – Flowering appear during February-March

2. Flower bud differentiation:

Generally new vegetative growth is pre-requisite for inducing differentiation of flower bud. Induction and differentiation are not seen outside. However, under a microscope differentiation of flower bud can be observed. Generally four stages of development during the process of differentiation are recognized.

Ist Stage - Calyx differentiation
IInd Stage - Corolla differentiation
IIIrd Stage - Stamen primordia differentiation
IVth Stage - Pistil primordia differentiation

3. Flower bud development:

In complete development of flower bud, citrus fruits take about 18 to 47 days. Its differ variety to variety and species to species. Sweet orange takes 18 to 22 days while lemon takes 20 to 32 days and sweet lime takes 20 to 25 days. The development of flower bud in citrus is greatly influenced by the temperature; if the temperature is increases the time taken by a bud to develop is reduced.
4. Inflorescence:

Inflorescence of citrus is “Cymose” type which borne on two types of fruits, one with leaves and the other without leaves. “Leafy inflorescence” is borne on new woods/shoot, while “leafless inflorescence” is borne on old wood. Leafy inflorescences are more productive than leafless inflorescence. Therefore, presence of leaves is essential for increased production.

5. Sex ratio:

Citrus produces two types of flowers which “Staminate” and “Hermaphrodite” on the same tree with varying intensities. The production of staminate and perfect flowers is greatly influenced by species, season and nutrition etc. Low temperature and high humidity seem to be more conducive for the higher production of hermaphrodite flowers. Zinc deficiency results in low percentage of perfect flowers. Judicious application of nitrogen as well as girdling, ringing and defoliation increased the production of perfect flowers. Starch content of the shoots also influenced the percentage of perfect flowers.

6. Anthesis: Ordinarily in citrus the flowers open during the morning time. Many workers have reported that anthesis occurs between 9 A.M. and 12 Noon in citrus. Anthesis is influenced by different factors like temperature, light, position of flower bud, type of inflorescence, aspect of the tree etc.

7. Dehiscence: Dehiscence of anthers in citrus takes place at different times, in some before anthesis and in others after anthesis.

8. Stigma receptivity: In general the stigma receptivity in various citrus varieties starts 2-3 days earlier to anthesis and lasts 4 to 6 days after anthesis with maximum receptivity on the day of anthesis.

9. Pollination and Fecundation: Self pollination and cross pollination seem to be about equally prevalent and also effective to bring about the formation of embryos and seed in citrus. Natural self pollination in citrus is brought about by contact of anthers with the stigma by pollen falling or being blown against the stigma or by transfer of pollen by insects.

10. Fruit Development: Citrus fruits develop very slowly, usually taking 6-13 months to reach proper maturity. The duration from set to maturity varies from species to species, cultivars, influenced by the condition of the tree, availability of moisture, temperature etc.
12. TIPS FOR RAISING OF DISEASE FREE CITRUS NURSERY

Production of disease free planting material is the most important basis of a sound and productive citrus industry. Citrus is highly susceptible to both biotic and abiotic stresses but virus and virus like pathogens are the main biotic agents responsible for poor tree health and reduced yield. Hence, without growing of healthy citrus trees, none of the potential of the improved practices can be fully realized. Therefore, production of disease free planting material is a thrust of bright and healthy future of citrus industry of India. Various aspects to be considered for raising healthy disease free planting material of citrus are as follows:

1) Selection of suitable site for nursery.
2) Development of containerized nurseries.
3) Soil Solarisation.
4) Soil fumigation.
5) Selection of suitable rootstocks.
6) Selection of seeds.
7) Raising of seedlings in primary nursery.
8) Raising of seedlings in secondary nursery.
9) Selection of mother plant and bud wood.
10) Budding and care of budlings.
11) Management of insect pests and diseases of nursery.

Some important tips for raising of disease free planting material of citrus is as below:

1. The location of nursery must be away from the citrus plantation/orchards.
2. Saplings should be raised in plastic trays (60 x 40 x 15 cm in primary nursery) and poly bags (15cm diameter x 25cm deep) in secondary nursery.
3. Sterilized potting mixture (solarized and fumigated with Basamid granules @ 50g/m² or Formaldehyde 5% solution) should be used in primary and secondary nursery.
4. Primary nursery bed should be at least two feet high above the ground level.
5. Seed should be treated with Captan / Thirum @ 2.5g/ kg seed.
6. For better germination seed should be shown just after extraction or as early as possible.
7. Seed should be shown in trays (60 x 40 x 15cm) under shed in primary nursery.
8. Seedlings when reach 10 to 15cm tall having 8 to 10 leaves should be transplanted to poly bag of 15cm diameter and 25cm deep having 3-4 holes at the bottom.
9. Seedlings having bent or twisted tap root system should be avoided for planting in secondary nursery.
10. For maximum survival, seedlings should be transplanted in poly bags during rainy season.
11. To ensure the straight penetration of root in the soil, too long tap root of seedlings should be cut.
12. Seedlings should be treated with Ridomil (@ 2.5-3.0 g/litre of water) solution before transplanting.
13. Hardy rootstock like Rangpur lime and Rough lemon should be used as rootstocks.
14. Known pedigree mother plants free from diseases should be selected for budwood.
15. Bud wood should be selected from fairly well mature non-bearing shoots of current year growth from mother plants.
16. High budding should be done not less than 20cm height above the ground level.
17. Budding knife should be disinfected with alcohol or sodium hypochloride solution.
18. For maximum success, T or shield budding should be performed during September - October and February-March.
19. For better growth of budlings, 5g urea/plant should be applied twice in a month.
20. Follow frequent light irrigation in nursery.
21. Plants are sprayed with Bavistan @ 1 g/litre of water or 1% Bordeaux mixture at monthly interval as a prophylactic measure. If plants affected by Phytophthora spp. remove the affected plants from poly bags and spray Ridomil @ 2.5-3.0g/litre water. For control of leaf miner, leaf eating caterpillar / orange dog / lemon butterfly, citrus psylla and aphid in nursery monocrotrophos or quinalphos or endosulphan @ 1 ml and for mites Dicofol @ 1.5ml/litre water should be sprayed in nursery.
22. At the entrance of the nursery, their should be provision of disinfecting the shoes with either copper oxychloride dust or with 5% Formalin solution (Formalin water ratio 1:20).
13. RAISING OF NUCELLAR SEEDLINGS

Nos of nucellar seedlings / seed:

1. Multiple apogamic:
   When 2 or more seedlings are produced from a single seed and all of them are uniform and vigorous.

2. Simple apogamic:
   When only one seedling per seed is produced, which was vigorous and looked like seed parent.

3. Multiple mixed:
   When 2 seedlings from a single seed are produced out of which one is relatively vigorous and looked like seed parent but the accompanying one is weak and variable.

4. Multiple gametic:
   When 2 or more seedlings arise from a single seed and all are relatively small and variable.

5. Simple gametic:
   When only one seedling develops from a single seed, which is small and weak and variable from the seed parent.

Horticultural significance of nucellar seedlings:

1. True to type seedlings
2. Genetically uniform rootstock
3. More vigorous seedlings
4. Virus free seedlings and bud wood

Neophysis:
Continuous vegetative propagation leads to decline in vigour in citrus. In such cases it can be restored back by using seedlings due to existence of neophysis.

Neophysis is a phenomenon by which we can restored vigour of the citrus by using nucellar seedlings.
14. METHOD OF RAISING OF CROSS PROTECTED PLANTS OF LIME

1. Mild strain of the tristeza virus should be maintained on lime plants in glass house conditions. Monoclonal antibiotics (MCA) is being used to differentiate sever strains and mild strains of CTV. Other molecular and biotechnological techniques are being used to identify the CTV like hybridization, RNA analysis, gene sequencing etc.

2. Raising of lime plants in poly bags under insect proof conditions (6 to 9 month old seedlings).

3. Training of lime plants.

4. Preparation of matrix at the time of vaccination.

5. A narrow rectangular bark piece (0.25 x 0.5 cm) on the stem of the healthy plant is removed and replaced with a similar size bark piece carrying from mild strain inoculated plants.

6. Removal of same size of piece of bark from mild strain inoculated plants.

7. Inserting of mild strain inoculated bud in the cut portion of the plants.

8. Wrapping of bark piece with polythene strip.

9. Removal of poly strips after 15 days of budding. If bark piece on the inoculated plant was found green, it indicated that infection has takes place.

10. Inoculated plants, two to three months after inoculation should be planted in the field.

15. CAUSES AND CONTROL OF FRUIT CRACKING / SPLITTING OF CITRUS / LEMON FRUITS

Causes:

1. Sudden changes in weather conditions.

2. Heavy irrigation or rainfall after a prolonged drought.

3. Infection of bacteria.

4. Hot wind.

5. Potassium (K) deficiency.

Control:

1. Timely and frequently light irrigation during summer.

2. Irrigation after a drought should be light.

3. Application of K also reduces fruit splitting.
16. USE OF PLANT GROWTH REGULATORS/BIO-REGULATORS IN CITRUS

1. Seed germination – GA, NAA
2. Growth of seedlings – IAA, GA
3. For control of fruit drop - 2,4-D @ 20-50 ppm and NAA @ 50-100 ppm
4. Increase the size of fruits – sprays of PGR’s for increasing the size of fruits are referred as “sizing sprays”. Spray of 2,4-D at 6-8 weeks earlier to bloom increases the fruit size. Application of 2,4-D to small fruits increases size at harvesting time.
5. To delayed the maturity – 2,4-D and 2,4,5-T, GA
6. To reduces external decay - 2,4-D and 2,4,5-T
7. Overcoming the alternate bearing tendency – NAA @ 250-350 ppm, GA3 @ 20-25 ppm, Cultar.
8. To induce seedless ness
9. Deblossoming of unwanted bahar
10. Rooting in cutting and layering: 1000-4000 ppm IBA
11. Increasing of fruit set – GA3 @ 2.5-10 ppm
   Self-incompatible clementine and Orlando mandarins increase the fruit set with the application of GA as compare to pollinated flowers.
12. Correction of peel disorders
   Many peel disorders such as soft rind, water spotting, puffiness, pitting, roughness and rind stickiness etc can be reduced or corrected by GA application of 20 ppm or CCC @ 1500 ppm (2 sprays) or 2500 ppm (1 spray).
13. Increase flowering – CCC @ 1000 ppm, NAA, SADH @ 2500 ppm, PP333-
14. Ripening of fruits – Ethephon also known as CEPA (2 Chloroethyl Phosphonic acid) @ 1000 ppm for lemon and 50 ppm for grapefruit.
15. For reducing of fruit removal force before mechanical harvesting eg. 100-1000 ethrel.
16. For weed control - 0.1% 2,4-D
14. REPLANT PROBLEM IN CITRUS

Old citrus soil contains inhibitory compounds of plants or microbial origin like Homovanillic acid, Seselne and Xanthylanine isolated from decomposed citrus fruits. The Homovanillic was the major growth inhibitor, which stopped root cell elongation and caused root tip swelling.

In almost all declined trees, the pathogen Phytophthora citrophthora was found to have advance onto the roots until it reached the crown of the trees. It is observed that a marked decline in number of beneficial fungi such as Trichoderma viridi occurred when soils were cropped to citrus. These fungi are capable of breaking down phenolic compounds in the soil and their absence leads to accommodation of these compounds in soil.

It is rule with few exceptions that when similar crops are repeatedly grown at one site, subsequent crop growth and yield gradually reduces. The cause of reduction of growth and yield of monocultures is very widely such as deterioration of soil fertility, structure, erosion and accumulation of toxic substances and parasites. In case of fruit crops and other woody plants the term replant or replanting is used which indicating the second or following planting of same crop or closely related species of the crop at a given site. Many fruit crops grow poorly when replanted for gap filling of place of died plants of orchard or on land previously occupied by the same or closely related species (declined plants/orchards). Such poor growth disorder is referred as “Replant problem ”or more clearly “Replant discover/disease”.

Symptoms:

The replant disorder /disease has a wide variety of symptoms. The general replant problem may be the result of injury to the root system or shoots and leaves or both. However, it is not uncommon for affected plants to manifest as part of their phyco-pathological syndrome, some type exaggerated growth disorder, leafmal formation, thickening or elongation of plant parts, lack of or excessive branching, stunting growth and disorganized growth characteristics of tumors and galls. According to symptoms replant problem classified as below

1. **Specific replant disorder (SRD):**

The term SRD is used to describe the poor growth of fruit plants when planted on plant previously occupied by the same or closely related species. In this case usually no leaf symptoms are evident, but the roots of affected trees are weak, sparsely branched, discoloured and necrotic. The causes agents of SRD appear to persist in the soil for a number of years.
2. Non specific replant disorder (NSRD)

   In this case, the growth of plants is stunted leaf chlorosis, discolouration and necrosis of feeder roots and in severe case death of the tree within two or three years of planting.

**Causal factors of replant problem:**

   Various physibiochemical, pathogenic and environmental factors alone or in combination are responsible for replant disease of fruit crops.

(I) **Biochemical factors:**

   For a long time phytotoxins have been suspected as factors responsible for the unsatisfactory growth of second and subsequent planting of the same crop on same site. Phytotoxins may cause disease symptoms, by inhibiting or changing membrane permeability, which are characteristics of initial response of plant to any pathogenic or non-pathogenic causal factor. Hydrocyanic acid or hydrogen cyanide produce by soil or root inhibiting fungi is also toxic to plants under most conditions. Similarly toxic chemicals like phlorizin phenolic released from old roots occupy and important position in the list of causal factors of replant problems on old sites.

(II) **Pathogenic factors:**

   Numerous pathogenic factors like Bacteria (Pseudomonas sp.), Fungi (Pythia ceous, cytospora, verticium and phytophthora etc), nematodes (root knot and several species of meloidogyne) and actinomycetes are major contributors in short life and replant disease of fruit crops.

(III) **Environmental factors:**

   The environmental factors like high temperature, water stresses and cold injury are the most serious environmental hazard to the fruit trees.

   Besides these factors imbalance nutrient supply and time and extent of pruning also influence the replant disease.

**Control of replant disease:**

   Proper and complete diagnosis of a replant disease is pre-requisite for working out the suitable control method of the disease. The treatment for controlling of replant disease cannot be the same for all soil, even if it is with respect to a particular fruit species. A treatment that is most beneficial in the particular soil and species may cause severe damage in another.

   Some fertilizers and biocides can cause of severe damage to plants in may soil, if
properly applied or it used at too high dose. For combating the replant disease in different fruit crops, both preventive and curative methods. Should be adopted.

(A) **Preventive methods:**

1. Proper selection of rootstock can help to same extent in avoiding the occurrence of replant disease. Because a deep rooting rootstock is substantially better than shallow rooting for control of nematodes.

2. Heating or sterilization of pits and soil before replanting of plants by fumigation or burning of cow dung cakes, wood, leaves of plants and other variable materials for control of several soil borne problems of fruits crops by eliminating a wide range of microbial species and nematodes.

3. Planting of wind to protection plants/ orchards from sun injury and adverse effect of hot weather as well as for protection from the cold waves during the winter seasons.

(B) **Curative methods.**

1. Drenching / application of biocides like Bordeaux mixture or 0.3% copper oxychloride or phylodon or Bavistin and Thimet 10 G or forget for control of soil borne problem of fruit crops (any copper fungicide + nematicide).

2. Adequate and timely supply of nutrients and proper cultural practices also control or minimize the replant problem of fruit crops.

3. Replant disease of young plants due to hot weather during April to June can be conveniently protected by creating thatches made of rice straw, maize and jwar slacks, sarkanda, khajoor leaves and other waste materials.

4. During cold spell period, as and when frost is threatened, irrigation of field and providing of smoke screens by leaves and grasses at several places of field are useful for protection of plants cold injury.
18. CROP REGULATION AND BAHAR TREATMENT

The main objective of crop regulation is to force the tree for rest and produce profuse blossom and fruit during any one of the two or three flushes. This aims to regulate uniform and good quality fruits and maximize production as well as profit to the grower. Fruit crops like guava, pomegranate and lemons flower and fruit three times in a year. A good harvest is possible only if crop is regulated to single season (bahar). The selection of bahar at a location is mainly determined by availability of water, occurrence of disease and pest and market position. Mango, kinnow and oranges exhibit the problem of irregular or alternate bearing with normal crop in ‘On’ year followed by negligible crop in ‘Off’ year. Crop regulation is achieved through various technique like withholding irrigation, flower bud thinning, shoot pruning and application of different chemicals.

Method of Crop regulations

➤ Withholding irrigation:

In pomegranate the operation withholding irrigation, root exposure, root pruning etc. imposed moisture stress resulting in leaf drop and cessation of growth during the period of unwanted bahar. The bahar treatment is of great significance in southern, central and western India where growth and flowering continue though out the year.

In guava withholding water (irrigation) exposing feeding roots and pruning fibrous ones to force blossom in desired season is practiced in Mumbai and Deccan (western India). Root pruning is not recommended practice in U.P. It is sometimes combined with withholding of irrigation to get better results.

➤ Hand thinning

It is possible to regulate the cropping pattern in guava by hand thinning of flower buds. Hand thinning of the flower/fruits during the month of March-April in Red fleshed, Safeda and Sardar proved to be most effective in reducing the size of the rainy season crop by withholding waters. In mango partial or completed Deblossoming in the ‘On’ year increase flowering during the ‘Off’ year.
Pruning

Annual pruning is used as cheap and effective cultural technique for regulating the cropping pattern, increasing fruiting, yield and fruit quality in guava, citrus, pomegranate, mango and fig. In guava, maximum number of fruits and highest yield of winter crop (fruits per tree) is obtained from trees in which 3/4th shoot length was pruned in the month of May.

Smudging

Smudging or smoking mango trees to induce off-season flowering and fruiting is a unique feature of mango growing in the Philippines.

Chemical methods

In guava, de blossoming with 600ppm NAA to prevent flowering and cropping during rainy season in order to increase cropping in the winter season. It can also be achieved through manual removal of flowers or use of NAA at 50 ppm followed by 2,4-D at 30 ppm; hand de blossoming followed by half shoot pruning. Double spray of NAA 800-1000 ppm at 20 days interval was found better for winter season crop.
19. WATER MANAGEMENT

Irrigation Requirement of Citrus Trees

- Irrigation requirement of citrus trees is generally higher than most of the other subtropical fruits, because of their evergreen nature and active growth and development throughout the year.

- The fine textured deep and well-drained soils generally met with in the Indo-Gangetic plains, which have moisture retentive capacity need comparatively less irrigation, provided the rainfall is normal and well distributed. The amount of water required also depends on drainage conditions and should be based on the amount required to rewet soil in the root zone to field capacity. Wet pit adding excess water to wet the subsoil.

- It is advisable to maintain the soil moisture at 55-65 percent field capacity from bloom until the young fruit exceed 2-5 cm diameter, after which temporary leaf wilt can be used as a guide for irrigation.

- Under dry climate with low humidity and high temperature irrigation is generally required when the interval between rains is longer than 15 days. Citrus cannot be grown even under artificial irrigating if the rainfall is below 500 mm. At least 700 mm of rainfall is necessary for citrus, provided it is favorably distributed.

Time and Frequency of irrigation.

- The frequency of irrigation assumes an important role in maintaining the health and production at higher level. In winter season the interval may be from 10 to 15 days and in summer it is much shorter. During the hot periods, the topsoil dries up quickly and light irrigation between thorough irrigations is advisable. But frequent light irrigations tend to develop superficial root system in the top 25 cm soil and they are liable to damage during cultural operations and cannot stand even short dry spells such as those occur frequently in the arid tracts of Punjab, Rajasthan and Rayalaseema districts of Andhra Pradesh. Bearing trees should be watered at shorter intervals than trees, which are nonbearing. However, irrigation during harvest period should be avoided, because it reduces T.S.S. and acid.
Quality of Irrigation Water:

- Quality of irrigation water assumes importance in the citriculture. Irrigation water may come from canals, wells, lakes or ponds. As such they are liable to contain salts, though in variable quantities. Water containing 2000 ppm salts and above causes injury to citrus roots and even lower concentration may prove dangerous, unless drained away by rain or liberal irrigation.
- Chlorides are said to be more injurious than sulphates, while carbonates are reputed to be the most injurious of all the salts. High moisture content and high water table, especially in the presence of high proportion of calcium may cause chlorotic symptoms in plants.
- If better quality of water is not available, the toxic effects of salts can be minimized by following certain management practices.

Systems of Irrigation:

- An ideal irrigation system should minimize the losses of water through surface run off, deep percolation, surface evaporation and by weeds. Whatever may be the system of irrigation utilized it must wet the entire areas of root spread and penetration so as to enable the roots to draw nutrients from a wider area.

Basin System:

- The most common system of irrigation citrus trees, particularly at the young stage in India, is the basin system. Basins are small enclosures formed around the tree, which cover only a limited area. The shape of basins in generally circular, but often also square or rectangular. The size varies according to the age of the trees. They are about 7-15 cm lower than the ground level and extend 60-150 cm beyond the plant. This system is recommended on light sandy soils and in groves which are very irregular in slope and as on a steep gradient.

Furrow system:

- This system of irrigation is suitable for locations where the flow of water can be regulated so that it could move slowly in furrows. The trees are fed through lateral moment of water. The gradient for furrows should not exceed 2 percent and should preferably be under one percent.
- Furrows are made in between the tree rows at a distance of 120-150 cm. either in one or two directions, so that all of the soil in the alleys is irrigated, but this involves more labour.
Flood irrigation system:

- When the tree is fully-grown and touches each other, basin system is usually replaced by flood system. This would, however, depends on the source of irrigation. If water supply is ample, flood irrigation is preferred. Basins are removed and the entire orchard area is divided into convenient beds, which are flooded at each irrigation. In this system water is allowed over the surface of soil. This system is feasible when ground is level. It is based on the assumption that the root system of fully-grown, bearing trees has spread all over the entire orchard soil. It provides scope for inter-cultivation. However, it is undoubtedly a wasteful system and is inferior to check system is regard to the economy of water.

Check system:

- This system was in vogue in U.S.A. before the switch over to sprinklers. It is practiced in sathgudi and Batavian orchards in South India. It is suitable where vertical percolation in the soil is rapid such as in coarse or porous soils. Ample water is needed as in flood system and costs more.

Sprinkler irrigation:

- In many developed countries like U.S.A., Japan, Italy, Australia, Israel, etc. sprinkler irrigation has become more popular. Most of the citrus orchard in these countries is under sprinkler irrigation. Oppenheimer states that by 1951 sprinklers had been installed in 70% of the orchards. But in India sprinklers are to use in citrus irrigation.

Yield of citrus trees due to various irrigation methods (t-tonnes)

<table>
<thead>
<tr>
<th>Country</th>
<th>Irrigation</th>
<th>Percentage increase by sprinkler compared with</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>None t/acre</td>
<td>Traditional acre t/acre</td>
</tr>
<tr>
<td>Brazil</td>
<td>11.1</td>
<td>-</td>
</tr>
<tr>
<td>Florida</td>
<td>20.0</td>
<td>-</td>
</tr>
<tr>
<td>Greece</td>
<td>-</td>
<td>12.0</td>
</tr>
<tr>
<td>Morocco</td>
<td>-</td>
<td>15.0</td>
</tr>
<tr>
<td>South Africa</td>
<td>-</td>
<td>15.5</td>
</tr>
</tbody>
</table>
Drip or Trickle irrigation:

- Drip irrigation has originated in Israel and has now become internationally accepted and popular as an efficient system of irrigation with maximum water economy.
- The basic principle in this system is thin, non-corrosive perforated plastic tubes are placed in shallow ploughed furrows so that dripping water supplies moisture and plant food direct to the roots. The equipment comprises plastic piping fertilizer tank and pressure apparatus. For about every 2 hectare the system requires a control head consisting of water tap with filter, water meter and fertilizer tank through which the water runs before being fed to the pipes and distributed to the trees.

Pitcher system:

- This is a cured modified method of drip irrigation. Develop at Triupati (Andhra Pradesh, India) in an attempt to find out methods to raise fruit plants with minimum water. This system needs no pipes, filters, pump etc. Earther pots of 20 liters capacity with narrow mouth are buried up to their necks in the basins of citrus plant about 35 cm from the stem after providing a small hole of 0.3 to 0.4 cm at a height of 5 cm from the bottom. The hole faces the trunk. Pots are filled with water. By force of gravity water trickles from the post and the wets the soil at the root zone. By this method about 60 percent of water is saved. This system is suitable for young plants in arid regions where during dry period scarcity of water is experienced.

Irrigation to young and pre-bearing trees:

- The prime object of irrigation in case of young and pre-bearing citrus trees is to encourage repaid and vigorous growth of the tree. This can be achieved by frequent, but light irrigations, as the root spread in the initial years is not very extensive. Thus, the soil has to be wetted to a lesser depth than in the case of bearing trees where root spreads is far and wide in which case more area is required to be wetted to make moisture available to the entire root system. Therefore, the interval of irrigation has to be shorter than that suggested for pre-bearing trees of 2-10 years age. The intensity of irrigation should also be lighter; any amount of moisture away form the periphery of he root system would be a virtual waste.
- In view of the above considerations the newly set citrus trees are irrigated every second or third day for the first 6 months till they have established. Thereafter, the
interval of irrigation as well as the quantum of water applied per irrigation is progressively increased. The irrigation continues to be light and frequent till the trees are 4-5 years old. The interval between irrigations differs with age of the trees, soil, climate etc. For the first six months it should be between 2 and 4 days for the attainment of bearing age, between 7 and 20 days. The interval in light soil should be shorter than that in heavier soils. Likewise during summer the interval should be shorter than that during winter, unless irrigations is specially required for protection against frost.

- Under the existing conditions in India for young trees basin system of irrigations is best.

**Irrigation to bearing trees:**

- The principal objective of irrigating bearing trees is to maintaining them healthy and highly productive with better quality produce. As with young trees irrigation for bearing trees must be given judiciously. Over irrigation is an injurious to citrus trees as the under irrigation. Lack of moisture is detrimental prior to and during blooming as it reduces the amount of fruit set be way of shedding flowers and newly set fruits. Any lack of moisture when fruits are on the tree is likely to reduce the rate of growth, resulting in smaller fruits or even cause fruits shedding. A shortage during maturing period may cause the fruit it shrinks as water is withdrawn form the fruits and also drying up of their pulp. Hence watering should be done based on the needs of the bearing plants. Throughout the fruit development period till the fruits are harvested.
20. MANAGEMENT OF INSECT-PEST AND DISEASES OF CITRUS

Among the factors responsible for low productivity and quality of citrus fruits, insect pests and disease are of major concern. About a dozen of insects like citrus black fly, white fly, psylla, leaf minor, lemon butterfly, bark eating caterpillar, fruit sucking moth, scale insects, mealy bugs, aphids, thrips, mites and many disease like Gummosis, Anthracnose, Canker, Tristeza virus, Psorosis, Exocortic and greening are attack citrus trees regularly right from nursery stage to the harvest causing organizable damage. Thereby posing a serious threat to citrus cultivation.

1. Lemon Butterfly or Orange Dog:

Eight species of lemon butterfly have been reported which are feeding on citrus in India. Caterpillar is the damaging stage of the pest, which feeds on foliage causing defoliation. Infestation is more pronounced in nurseries and young plants where the seedlings and new flushes may completely be defoliated. Young larvae are brownish or black in colour with irregular white strips and appears like buds excreta. Total life cycle varies from 18-40 days but in winter it may go upto 145 days and 4-6 overlapping generations have been reported in a year.

Control measures:

- Hand picking of various stages of the pests and their destruction.
- In case of severe infestation, spraying of Monocrotophos / Quinalphos / Endosulphan / Phosfone @ 0.05-0.1% at 10-15 days interval is found more effective.
- Conserve the natural enemies of butterfly by avoiding broad-spectrum insecticides.
- Spray of Dipel (Biological formation of bacteria @ 0.05% against the larval stage).

2. Citrus leaf minor:

It is a serious pest of nurseries and young orchard. Larvae makes serpentine tunnels / mines on tender leaves only. In severe cases of infestation, mine can be also seen on shoot portion of the new twigs. Severe infestation may lead to retarded growth of young plants and die back may also occur. This pest help to development of canker by predisposing of leaves and shelters mealy bugs help to spread of this disease.

Control measures:

1. Spray of Monochrotophos/quinalphos @ 0.1 % at 7-10 days interval found beneficial
2. Spray Metasystox @ 0.1% at regular intervals.

Citrus Psylla (Diaphorina citri Kuwayma): Citrus psylla is a kind of plant lice that sucks sap from young leaves, tender shoots and flower buds. It excretes honeydew on which develops the soory mould fungus. The general vitality of the tree is deteriorated, Young fruits are shed.

Control measures:

1. Soil application of Dimethoate at 10 g. (a.i.)/tree followed by light irrigation.
2. Spray of Dimecron (0.025%) or parathion (0.025) or Malathion (0.05%) checks the pest.
3. Biological control for citrus psylla has been done by Tetriasticus radiusus W, a hymenopterous.
Whiteflies: Among many species, *Dialeurodes citri* Ashme whiteflies and *Aleurocanthus woglumi* Ash, black flies are the most destructive. The former is a minute in size and pale yellow with dark red eyes whereas the adult of later wooly whiteflies is distinctly more yellow than other. They remain hiding on the under surface of the leaves during daytime. Both nymphs and adults suck the sap of leaves and reduce the plant vigour. Severely infested leaves become pale yellow to brown and later they curled and shed. Flowering and fruiting are affected very badly. Whiteflies may encourage the incidence of red scale and which collect under the wool of the whiteflies to avoid light.

**Control measures:**

1. Spray lime sulphur before anthesis in the spring, which removes white mealy powder on the nymphs and kills them by contact action.
2. Spray malathion (0.05 %) or formothion (Anthio) at 0.15 percent.

As such control of whiteflies is very difficult. However, in nature, ladybird beetle (*Branus naturalis*) feeds on eggs and larva of citrus whiteflies. Mealy bugs (*Pseudococcus spp.*) are polyphagous pest. In citrus species, especially limes, lemons and sweet oranges are main target. Besides, they feed on cactus and begonia. They are most serious pest in many parts of India. The adult female is wingless with a flattened body, having short waxy filaments, while the male is winged with no mouthparts and long antennae and is rarely seen. The nymphs are also covered with white waxy coatings and are amber coloured. The nymphs and adult females suck the sap from the underside of the leaves and at the base of the fruit near the stalk-end. The plant growth is arrested, leaves, flowers and newly set fruits are shed. Ants aid in the spread of the mealy bugs, which are attracted by the honeydew secreted by mealy bugs. The sooty mould develops on honeydew, which adversely affects photosynthesis.

**Control measures**

1. Dust the lime sulphur.
2. Spray parathion at 0.04 per cent at 2 or 3 weeks intervals.
3. Lady bird beetle (*Cryptolaemus montrouzieri*) is a very affective predator of mealy bugs. Fungi (*Entomophthora fumosa*) has been reported to parasitize on the mealy bugs and to destroy them.

Aphids: Very common species of aphids which attack citrus crops in India are *Aphis citricidus* Kirk., *Toxoptera citricidus* (Kirk), *Myzus persicae* Sulzer (peach green aphid), *Toxoptera aurantii* Fonscolombe (Citrus black aphid) and *T.citrinola* (Citrus brown aphid), *Aphis gossypii* (Cotton aphid), *Aphidula poni* de Greer (apple green aphid).

Aphids are found in clusters, over the tender parts of the plant (leaves, new shoots, flower buds). The incidence of aphids is highest in winter and rainy season. They suck the sap.
from tender parts, which fade and become blighted. They also secrete a sweet honey-like substance, which attracts the ants and develops sooty mould on it. Aphids also act as a vector of virus disease.

**Control measures:**

Spray the trees with Malathion (0.05%) or phosphamidon (0.025%) or Katin (0.1 %) or Rogor (0.3%).

There is no insecticide, which can control aphids as vectors of Tristeza virus, because aphids transmit the virus in much shorter time than any insecticide could kill them. They are also migratory in habit and hence defy chemical control.

**Fruits flies (Dacus spp.)**

In India, several species of fruit flies are found damaging Citrus fruits. But Dacus diversus (guava fruit fly) occasionally becomes serious pest. Besides, it also attacks on banana, jamun, loquat, mango, melons, citrus etc. Dacus dorsalis (Orient fruit fly) a major pest of mango, has been found on citron, pommpelo, mandarin, sour orange, sweet orange, sweet lime etc. Mature fruits are subjected to the attack of these flies.

Similar preventive measures as far citrus sucking moth may be adopted to reduce the population of flies.

**Diseases of citrus fruits:**

Citrus crops are subjected to many diseases but only important ones, which are commonly seen, are discussed here.

**Gummosis (Phytophthora spp, Diplodia natalensis Pole Evans).** Affected plant parts, particularly trunk, branches exude gum through cracks on bark which turns brown to black on drying. Causal fungi live in the soil and spread by air, rains, insects and contacts.

**Control measures:**

1. Remove carefully affected portion with sharp knife along with some portion of healthy bark from all the sides. Thereafter washing out portion properly with disinfectant like mercuric chloride (1:1000) solution followed by application of Bordeaux paste on complete cut portion.
2. Make provision of good drainage and avoid excess irrigation
3. Use only healthy planting material from reliable nursery
4. Use resistant rootstock.
5. Avoid deep planting of bud grafts i.e. portion of bud union remain fairly above the ground level.

**Anthracnose (Colletotrichum gloeosporioides and Glueosporium kimthicolum Clausen).** Pathogen cause shedding of leaves and dies back of twigs. Necrotic spots are seen on leaves and...
dry twigs. Infected buds fail to develop and affected fruits drop off. The tree vigour is reduced. The disease is serious on limes, lemons and citrons.

**Control measures:**
1. Follows scientific management practices like manuring, irrigation etc.
2. Remove affected portion of plants and paste cut ends with Bordeaux paste.
3. Spray with Bordeaux mixture at 1 per cent in February, March and September.

**Citrus canker (Xanthomonas citri Dowsan)**
The bacterium is highly infectious and gets entry through stomata and wounds. Leaves attacked by citrus leaf miner give easy entry to canker pathogen. Canker affects all plant parts. Canker is seen in the form of tiny, circular, brown crater like eruptions on leaves, stems and fruits. The lesions on the fruits remain conformed to the rind only. The canker is carried over from season to season mainly from the cankerous lesions on twigs and branches. Incidence of canker is comparatively more in the high rainfall areas than in the dry areas. Further a mild temperature and wet weather are favorable conditions for canker spread. Kajzi lime is the most affected whereas mandarins and lemons are the least while sweet oranges are only partial resistant.

**Control measures:**
1. Prune affected twigs before and after monsoon and burn them.
2. Spray with Bordeaux mixture or Blitox at 1 per cent: Sprays should be repeated as and when new growth is seen.
3. Spray streptomycin sulphate at 500 to 1000 ppm at 20-25 days intervals.
4. Control the leaf miner by spraying metasystox at 0.1 per cent at regular intervals.
5. Plant wind breaks around citrus orchards and nurseries to prevent dissemination of bacterium by wind.

**Tristeza virus disease (Corium vialonis):**
Infected tree lacks a new growth during normal flush period. The tree look chlorotic and sick leaves drop off and twig dieback. Affected trees usually blossom heavily. The fruit size is reduced. Tristeza virus is both vector and bud transmissible but not through seed. The main insect vectors are tropical citrus aphid (Aphids citricidus Kirk) Taxoptera citricidus. Myzus persicae.

**Control measures:**
1. Raise citrus on tristeza tolerant rootstocks: Jattia khatti, sweet lime, Karna khatta, Rangpur lime, Sathgudi.
2. Use virus free buds for budding.
**Xyloporosis:** It is also known as little leaf disease of citrus. Below bud union, small, round, ovoid, depression occurs. Pits and pegs are developing on wood and inner bark. Severely affected trees bark turns brown, rots and splits. The virus is bud transmissible.

**Control measures:**
1. Use only virus-free bud wood or use nucellar bud wood.
2. Avoid the use of rootstocks of such as sweet lime and Orlando tangelo, which are susceptible.

**Psorosis.** It is incited by *citrivir psorasis* Faw. It is spread mainly by infested buds, leaves and bark tissues, occasionally by root grafting in the soil

**Control measures:**
1. Remove all affected twigs.
2. Replant with stock budded from virus-free trees.

**Exocortis or scaly butt.** It is caused by viroid. Affected trees show stunting. The entire rootstock portion of trunk results in scaling of bark. Chlorotic blotches are seen on bark.

**Control measures:**
1. Remove severely affected trees.
2. Use nucellar sweet orange and sandra budwood.
3. Use virus-free budwood.

**Citrus greening:** This disease was first discovered by Fraser and Singh in India. Causal pathogen is reported to be the Rickettsia-like organisms (RLO). Citrus plants of all ages are affected. The leaves of spring growth flush, after reaching maturity develop striking chlorotic patterns, resembling those of zinc deficiency. On leaves, green dots or islands appear against yellow background. Twigs show multiple bud formation and off-season blooming and later dieback symptoms are seen. Affected fruits develop orange colour first at the button-end, instead of at the styral-end (as in the normal sequence). Seed abortion, with formation of gum pockets has been reported.

Citrus greening can be transmitted by grafting and through insects like citrus psylla. Sweet oranges, mandarins, acid limes and grapefruits are susceptible to citrus greening. Whereas sweet lime and pummelo are tolerant.

**Control measures**
1. Apply tetracycline hydrochloride through injections (6-10g per mature tree).
2. Prune affected portion.
3. Spray with Rogor (0.03%) or apply Rogor granules (10g/ tree) in the soil around the trunk to control citrus psylla.
21. CITRUS / MANDARIN DECLINE

Citrus decline is not a specific disease but is an asymptotic expression of many disorders in the plant. It is also named as dieback, trenching and chlorosis.

SYMPTOMS:

In the initial stages, symptoms are restricted to a few limbs but eventually whole tree is affected and following symptoms are occurred:

(i) The leaves may be small with light green interveinal areas with midribs and lateral veins remaining dark green.

(ii) The new flush on the affected twigs may be smaller in size.

(iii) In advance stages, chlorotic areas gradually increase. In some leaves only the basal portion of the midrib of leaves is green, while other spots yellow or pale green are present between the lateral veins.

(iv) In acute causes, the growth is usually checked and entire canopy of tree bears short twigs and narrow small leaves on their lower portion, while distal portion of twigs are devoid of leaves.

(v) The shoots have tendency to die from growing points to downwards. In a few years flushes are reduces and network of veins becomes prominent.

(vi) Either only few trees or entire orchard may be affected.

(vii) Sometimes excessive flowering is occurred but fruits are not carried to maturity.

(viii) The feeder root system becomes depleted and turns black.

(ix) In severe cases, the young and old leaves may become very pale. The colour of veins gradually fades until only a very pale midrib remains.

(x) The yield and quality of affected trees deteriorated.

(xi) Size of fruits reduced and shining of rind of fruits also deteriorated.

(xii) Reduction in juice.

(xiii) Increasing of roughness.
CAUSES:

The some causes of decline in one locality may not necessarily be the same in another locality. Most of the factors singly or jointly may be responsible for decline.

(i) Non-availability of disease free planting material.
(ii) Incompatibility between rootstock and scion.
(iii) Decline varies variety to variety and species to species.
(iv) Presence of excessive free lime or impregmented layers of CaCO₃ in the soil.
(v) High soil pH (>7.5).
(vi) Low soil pH (< 5.5).
(vii) Excess salt (>1000 ppm).
(viii) Excessive potassium.
(ix) Defective soil erosion.
(x) Poor soil structure.
(xi) Bad drainage.
(xii) Malnutrition (Deficiency of NPK, Zn, Cu, Mg and B).
(xiii) Excess of Iron and high uptake of Mn.
(xiv) Improper amount and frequency of irrigation (Avoid moisture deficiency during fruit set, excess water, saline water, water contact with the trunk and water stagnation).
(xv) Deep ploughing.
(xvi) Excessive and indiscriminate inter cropping (decline may be due to incompatible irrigation, insect pest and disease of inter crops, exhaustion of nutrients, deterioration in physical properties of soil).
(xvii) Incidence of Nematodes (Citrus nematode and burrowing nematode).
(xviii) Insect pest
(xix) Non-cleaning of dried shoot.
(xx) Imposing of wrong bahar treatment.
(xxi) Replant problem.

CONTROL:

(i) Planting of disease free elite planting material.
(ii) Use of hardy disease resistant rootstocks.
(iii) Adoption of proper cultural practices.
(iv) Proper soil, nutrient, weed, irrigation, insect pest and disease management.
22. CITRUS GRANULATION / CRYSTALLIZATION, DRY AND CORKYNESS

Citrus granulation is a physiological disorder of the juice sacs of citrus fruits, wherein; they become comparatively hard, dry and greyish colour. Such fruits become unmarketable, as a result of which, the growers suffer heavy losses. It was first time reported during 1934 but till today, specific causes and control of this disorder are still observe, yet several factors have been found to be associated with it.

A. Climatic factors:
1. Temperature: High temperatures in spring favour the granulation.
2. Light: Those fruits borne inside the canopy found free from the granulation. This shows that high light intensity is responsible for this disorder.
3. Humidity: Incidence of granulation was found more in humid region of citrus as compared to dry region. On the other hand high relative humidity decreases the granulation in Punjab.
4. Seasonal influences (Frost): incidence of granulation raisee from 6% in October to over 50% in January.

B. Locality specification:
Granulation might be a result of an interaction between the cultivars and locality.

C. Tree characteristics:
1. Tree age and its health: The incidence of the granulation is higher in young trees than the older trees. The extent of the granulation was found higher in declining trees in comparison to the healthy ones.
2. Tree vigour: Conditions favouring a luxuriant growth have been found to be associated with the granulation.
3. Tree aspect: Fruits on the southern side of a tree have higher incidence and degree of the granulation than other side of the fruits.
4. Tree variation: Some trees within a orchard produces more granulated fruits while other produces healthy fruits. This may be due to inherent factors of a tree.

D. Fruit size:
Larger fruits were more affected by granulation.
E. Harvesting date and storage:

Generally the fruits harvested late in the season tend to show more granulation. The incidence of the granulation usually appears during later period of the fruit maturity.

F. Crop load:

Higher incidence of granulation was recorded in trees having a heavy crop load

G. Species and the cultivars:

Sweet oranges are more prone to the granulation than the mandarins, tangelos and grapefruit.

H. Root-stock:

Rough lemon and trifoliate orange rootstocks produced the maximum granulated fruits. Whereas, grapefruit rootstock produced least granulated fruits.

I. Nutrition:

Low levels of the Ca, Zn and Bo in the leafs and fruit pulps are associated with the higher incidence of the granulation.

J. Physiological factor:

Increased level of the ABA and ethylene are related to the granulation during storage period upto three months. Higher level of the auxins, kinins and ABA and low gibberellins are also associated with granulation.

K. Bio-chemical factors:

Higher concentrations of the pectin’s and hemicellulose are associated with granulation.

L. Enzymatic activities:

Low activities of diastase and pectineseterase in the juice are are associated with granulation.

**Control measures to reduce the granulation**

Citrus granulation is a complex problem. Till today these is no conclusive information is available on the causes and complete control of this disorder. However some reports suggested certain measures to reduce the incidence as well as intensity of granulation.

1. Use of the rootstocks:

Trees budded on the most vigorous rootstock favours the granulation and less vigorous tree not severely affected by the granulation. Sweet orange on the Cleopatra mandarin rootstock produced fewer granulated fruits than those budded on the Jambhiri.
2. Frequency of irrigation:

Reduced amount of the water and frequency of the irrigation reduced the granulation. Citrus orchard receiving 10-15 irrigation per year produced lowest incidence of the granulation. Further more the irrigation at 60% available water in comparison to 40% available water resulted in the lowest incidence and extent of the granulation.

3. Use of lime and calcium compound:

Two percent lime reduced the granulation about 50% in orange. Spray of 2% Ca (OH)₂ reduced the incidence of granulation by 28%. Two spray of 0.5% Ca(NO₃)₂, 1% Bordeaux mixture also reduced the granulation.

4. Use of potassium nitrate:

Few spray of potassium nitrate @ 1% reduced granulation by 42%. Potassium and its uptake by different species in reducing the granulation had been well established.

5. Use of magnesium nitrate:

The spray of 1% magnesium nitrate at monthly interval reduced the granulation by 7-18% only.

6. Use of Zinc and copper:

Zinc and copper are important micronutrient for the over all health and productivity of a plant. Two spray of ZnSO₄ @ 0.5% reduced the incidence of granulation by 40 %. Combined spray of ZnSO₄ and CuSO₄ @ 0.5% each is more effective than alone spray for reducing the granulation.

7. Use of Iron and Mangnese:

Spray of Ferrous sulphate and Mangnese sulphate @ 0.4% each reduced the incidence of granulation.

8. Use of Boron:

Two spray of Boron @ 0.5% and four spray of 25 ppm boric acid are reduced the intensity of granulation.

9. Use of the Lead arsenate:

Five spray of Lead arsenate @ 500 ppm reduced the intensity of granulation. Although it is not advisable to use the compounds of the arsenate because they are bound to create health hazards to the consumers.
10. Use of growth regulators:

- GA₃ @ 10 ppm between August to November at 10 days interval reduced the granulation by 71%.
- GA₃ @ 15 ppm in combination with 250 ppm ethrel or with 300 ppm Planofix (NAA) or both reduced the incidence of granulation by 60%.
- Three spray of the Planofix @ 300 ppm during August, September and October decrease the incidence and degree of granulation by 57-66 %.
- NAA @ 200 ppm three times at monthly interval.
- NAA @ 300 ppm with GA₃ @ 15 ppm.
- Ethrel @ 250 ppm
- Spray of Ethrel @ 250 ppm with 15 ppm GA₃ or 300 ppm NAA decrease the incidence of granulation by 60 %.
- Kinetin
- Spray of 2,4-D @ 12 ppm – 15 ppm reduced the incidence of granulation by 75%.
- 2,4-D @ 12 ppm with ZnSO₄ @ 0.5%.
- 2,4-D @ 30 ppm or 2,4,5-T @ 20 ppm reduced the granulation and increased the fruit weight and juice percentage.
- PP₃₃₃
- Dipping of fruits in sodium benzoate preservative and wrapping with thin film of polythene.

11. Harvesting and the storage at room temperature:

Delayed harvesting as well as storage accelerated the granulation.

12. Adoption of some precautionary measures:

Planting of the selected plant material of low granulation history has been recommended. Vigorous rootstock, frequent irrigation and heavy application of the nitrogen encourage the development of the granulation. Therefore, it is imperative to keep the plant growth in control by judicious use of the nitrogen, irrigation, very light or no pruning is recommended.
23. POST HARVEST TECHNOLOGY OF CITRUS FRUITS

Causes of deterioration of citrus fruits:
1. Harvesting condition:
   Causes – harvested during wet weather or early morning, a mature or over mature fruits, harvesting by pulling.
   Control – Harvesting of fruits by keeping stem on the fruits.
2. Loss of moisture:
   Causes – respiration and transpiration processes resulting in loss of freshness. The immature fruits loss moisture more rapidly compared to mature ones.
3. Post harvest decay:
   Causes – harvesting and handling injuries, wind scars, pest damage, twig blight and poor sanitary conditions.
4. Pre harvest factor:
   Cultural practices, wet and dry weather and tree condition influence the fruits potential for storage by modifying physiology, chemical composition and morphology of fruits. GA sprays (10 ppm) delay colour development; maintain firmness and extended harvesting about a month beyond normal harvest time. Higher doses on N increases losses whereas, K extended shelf life (best doses 600-200-100 NPK)

Post harvest handling:
1. Maturity standards:
   ➢ Minimum sugar acid ratio 14:1 for ambe bahar.
   ➢ Minimum sugar acid ratio 18:1 or 20:1 for mirg bahar.
   ➢ Mandarin takes 240-280 days to mature from the date of fruit set.
   ➢ Lime takes 160-190 days to mature from the date of fruit set.
2. Harvesting:
   Fruits should be harvested by keeping stem on the fruits to minimize buttonholes.
3. Degreening (Removal of chlorophyll from the peel):
   ➢ Post harvest spray of Ethephon @ 2000-4000 ppm.
   ➢ Pre harvest spray of Ethephon @ 150-250 ppm at colour break stage.
   ➢ Favourable temperature – 29° C. RH 90-95%.
4. Sorting, Washing and Waxing:
   Sorting based on fruit soundness, size, shape, colour and freedom from diseases and damage.
5. Grading:
   Culling grading and packing are done on a scientific basis in advanced countries. This is not in vogue in India. At present most of the citrus crop is marketed without paying any attention to the grading of fruit. The marketing Co-operative societies can play an important role in improving the marketing of citrus fruits by proper grading. Naik and
Sugurappa reported that the Kodur Fruits Growers Co-operative Society Limited has introduced a cheap, simple and satisfactory hand-grading machine.

6. Packaging:

Package protects the fruits from physical, physiological and pathological deterioration during handling.

- Transport losses under traditional method – 20-25%
- The corrugated fibreboard boxes (CFB) found best as compared to other packaging material.
- Wrapping fruits with tissue paper and newspaper.
- Polyethylene liner in the box has been found very good water vapour barrier while handling fruits.

7. Shrink-wrapping:

Heat shrinkable polythene films are used to wrap the individual fruits and over wrapping of trays. This techniques extend the shelf life of fruits upto 3 weeks at ambient conditions.

8. Pre cooling:

The aim of pre cooling is to slow down enzymatic and respiratory activities, minimize susceptibility to microorganisms and reduced water loss. The forced air-cooling of packed fruits invented corrugated boxes before refrigerated storage or transport was found best as compared to vacuum cooling and hydro cooling.

9. Storage:

At present refrigeration is the only efficient method of prolonging shelf life of citrus fruits at commercial stage.

Optimum storage conditions and storage life of citrus fruits:

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Commodity</th>
<th>Temperature (°C)</th>
<th>Relative Humidity (%)</th>
<th>Storage life (Weeks)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Mandarin</td>
<td>4-6</td>
<td>90-95</td>
<td>8-12</td>
</tr>
<tr>
<td>2.</td>
<td>Sweet orange</td>
<td>5</td>
<td>90-95</td>
<td>10-12</td>
</tr>
<tr>
<td>3.</td>
<td>Lime</td>
<td>10</td>
<td>90-95</td>
<td>10-12</td>
</tr>
<tr>
<td>4.</td>
<td>Lemon</td>
<td>8</td>
<td>90-95</td>
<td>8-10</td>
</tr>
<tr>
<td>5.</td>
<td>Grapefruit</td>
<td>10</td>
<td>90-95</td>
<td>16-20</td>
</tr>
</tbody>
</table>

10. Evaporative cool chamber:

For short duration storage life of fruits as small scale Evaporative cool chamber (ECC) having drip system for watering and fan for air movement was found best for extending the shelf life of fruits upto 25 days.